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report
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Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory: Autecology

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This report should be cited as follows:

> KA Bishop, SA Allen, DA Pollard & MG Cook 2001. *Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory: Autecology*. Supervising Scientist Report 145, Supervising Scientist, Darwin.

This report is the third and final volume of *Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory.* The first two volumes were published as **Research Report 4** Volume I and II in 1986 and 1990 respectively, and should be cited as follows:

> Bishop KA, Allen SA, Pollard DA & Cook MG 1986. *Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory. Volume I Outline of the study, summary, conclusions and recommendations*. Research report 4 (i), Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.
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> Bishop KA, Allen SA, Pollard DA & Cook MG 1990. *Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory. Volume II Synecology*. Research report 4 (ii), Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

The Supervising Scientist is part of Environment Australia, the environmental program of the Commonwealth Department of Environment and Heritage.

Supervising Scientist
Environment Australia
GPO Box 461, Darwin NT 0801 Australia

ISSN 1325-1554

ISBN 0 642 24348 4

e-mail: publications@eriss.erin.gov.au

Internet: http://www.ea.gov.au/ssd/index.html

Printed in Darwin by NTUniprint

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Acknowledgments

The authors would like to thank the following people and institutions for identifying specimens: Dr G Allen (Melanotaeniidae), Ms M Feinberg (Plotosidae), Dr D Hoese (Eleotrididae and Gobiidae), Ms P Kailola (Ariidae), Dr L Cannon (fish parasites), Mr G Crook (anuran larvae), Dr R Marchant (aquatic macroinvertebrates), and Dr D Thomas, Dr H Ling and Ms J Kessell (algae). Dr D Hoese and Ms S Reader of the Australian Museum, Sydney, helped with fish taxonomy.

For occasional assistance in the field we thank Mr M Alderson, Mr J and Ms P Bell, Mr W and Ms E Bishop, Ms J Burchmore, Mr S Clark, Mr M Giles, Mr R Goldberg, Dr J Harvey, Dr N Mackay, Mr J and Ms M Middleton, Mr P and Ms G Parker, Dr B and Ms E Pease and Mr F Reynolds. For help with preparing the report we would particularly like to thank Mr A Collins (computing and analyses), Ms L Staessens (histological sectioning of fish tissues), Mr D Rodgers (specimen photography), Ms H Waddell (drafting of figures) and Mr D Ormsby (preparation of data from stomach contents analysis).

We would like to thank Drs G Allen, D Hoese, W Ivantsoff, S Kessell, L Llewellyn, J Merrick, S Morton, J Paxton and J Pepperell and Ms M Middleton, who read and discussed sections of the report, and made helpful suggestions for its improvement. Drs H Larson, B Russell and R Pidgeon helped update species and family names. We gratefully acknowledge Ms A Webb, Ms J Taylor, Mr D Walden and Dr V Mawson for valuable editorial and formatting work. Dr L Gyurasits, Ms B Purse and Ms S Jones are thanked for their editorial work on this voluminous report early in its long gestation. We also thank Ms G Barrowcliff for extensive wordprocessing work on various drafts of the report. Working from the original hardcopies, Mr B Green and Mr A Wilkes created digital files for the figures. Mr D Walden also helped with locating, identifying and scanning many of the original plates and drawings.

Thanks are also due for assistance offered and data supplied by Ranger Uranium Mines Pty Ltd, Pancontinental Mining Ltd, Queensland Mines Ltd, Noranda Australia Ltd and the Northern Territory Water and Sewerage Division. Mr H Midgley supplied much unpublished information on the reproductive biology of the fishes of the region.

Explanatory notes

This volume outlines the autecology of the fishes of the Alligator Rivers Region. It is designed to be read in conjunction with the other volumes in the series: Volume 1, *Outline of the study, summary, conclusions and recommendations*; and Volume 2, *Synecology*.

Nomenclature changes

Since this manuscript was first completed (September 1980), the names of some fish species and billabongs have been revised. These changes have been incorporated into the text, appendixes, figures and tables of this volume.

Fish genus and species names

Osteoglossidae	*Scleropages jardini* → *S. jardinii*
Ariidae	*Hexanematichthys* → *Arius*
	H. australis → *A. graeffei*
Plotosidae	*Tandanus ater* → *Neosilurus ater*
Belonidae	*Strongylura kreffti* → *S. krefftii*
Melanotaeniidae	*Melanotaenia maculata* → *M. splendida inornata*
	Melanotaenia australis → *M. splendida australis*
Atherinidae	*Craterocephalus marjoriae* → *C. marianae*
Teraponidae = Terapontidae	*Pingalla* sp. → *Pingalla midgleyi*
Mugilidae	*Liza diadema* → *L. alata*
	Liza dussumieri → *L. parmata*
	Squalomugil nasutus → *Rhinomugil nasutus*
Eleotridae = Eleotrididae	*Hypseleotris compressus* → *H. compressa*
	Oxyeleotris lineolatus → *O. lineolata*

Fish family names

Pseudomugilidae replaces Atherinidae for *Pseudomugil tenellus*.
Ambassidae replaces Centropomidae for *Ambassis* spp. and *Denariusa bandata*.
Terapontidae replaces Teraponidae for all five species of this family discussed.
Eleotrididae replaces Eleotridae for all three species of this family discussed.

Place names

Baroalba crossing (coded BX) → Malabanbandju Billabong
Nourlangie Rock (NR) → Umbungbung → Anbangbang Billabong
Skull Rock (SR) → Long Harry → Namandi Garrigorry → Noarlanga
Magela bore pool (II) → Surshar Billabong

Names of animals and plants

Scientific and common names of fishes follow the recommendations of the Australian Museum, Sydney (but see above). Those of plants follow the recommendations of the Royal Botanic Gardens, Sydney (made in 1979/80).

Abbreviations

ARR	Alligator Rivers Region	LFM	length at first maturity
DO	dissolved oxygen	RM	Ranger Mine
GMSI	gonad maturity stage index	RUM	Ranger Uranium Mine
GSI	gonadosomatic index	RUPA	Ranger Uranium Project Area
LCF	length to caudal fork	TL	total length

Sampling method and site abbreviations are found in section 2: Materials and Methods.

Aquatic seasons

The system of seasons used in this report takes into account the main changes in aquatic habitats resulting from the Wet–Dry monsoonal climate. Five seasons are recognised, but they do not have clear time boundaries because of the variability in the starting and ending times of the 'the Wet'. Spatial variability of rainfall may also create a situation where separate catchments experience different seasons. Descriptions of the five seasons are given below, together with the equivalent Aboriginal names in Gundjehmi (Mayali) language in parentheses.

Late-dry (*Gurrung* to early *Gunumeleng*) Usually September to October; sometimes begins in August or ends in November or December. Waterbodies are isolated and have contracted greatly, owing to extensive evaporation. Many waterbodies disappear altogether, but the ones with considerable depth that persist and remain deep are important refuges for aquatic animals. Temperatures and turbidities rise to high levels in the shallower waterbodies. Water persists on the floodplain only in channel waterholes.

Early-wet (*Gunumeleng*) Usually November to December; sometimes begins in October or ends in January. Waterbodies receive first rains and surface inflows. Littoral grasses begin to grow. Temperatures in the littoral zone of the waterbodies are very high. Towards the end of this season, creek channels begin to flow, connecting the already replenished waterbodies, and the floodplains start to fill. Animals in the waterbodies can now move throughout the catchments.

Mid-wet (*Gudjewg*) Usually January to March; sometimes begins in December or ends in April. Heavy rains induce strong flows in the channels and flooding of the surrounding forest. Waterbodies are deepest at this time of year, large expanses of water cover the floodplain and, in the upper reaches, water levels may drop and rise rapidly. There are extensive connections between fresh and estuarine waters.

Late-wet–Early dry (*Bang-gereng* and *Yegge*) Usually April to early June; sometimes begins in May and continues to the end of June. Rainfall slackens and water levels begin to drop in channels and waterbodies. Dissolved oxygen levels drop in waterbodies as flow-induced mixing slows and organic matter decays. By the end of this season, channel flow has reduced considerably, making it difficult for larger aquatic animals to move between waterbodies, and considerable water level draw-down occurs on the floodplain, which becomes isolated from the estuary.

Mid-dry (*Wurrgeng*) Usually late June to August; can be early June to mid-August or mid-September. Rainfall stops completely and temperatures are at their lowest. 'Trickle' flows enable small animals to move to more secure (deeper) waterbodies, but these flows usually stop in the middle of this season and the waterbodies then become isolated. Draw-down continues on the floodplain as parts become very shallow.

Abstract

The essential objective of the study was to identify the locations and timings of activities critical in the life cycles of each of the fish species considered. By cross-relating such knowledge to information on the location and timing of potential mining-induced physical and chemical (abiotic) impacts, the life-cycle components of species most at risk can be identified – an important task in impact risk assessment.

Primary biological/ecological information was obtained and analysed for each of the 37 freshwater fish taxa found in the Alligator Rivers Region in relation to the following generic species-account structure: size composition, environmental associations, reproduction and feeding habits. Each of these components revealed complementary information on the locations and timing of activities critical in the life cycles of the fish taxa considered.

Size composition. Smaller juveniles of the largest number fish species were found in lowland backflow billabongs and floodplain billabongs. These two habitats therefore appear to be particularly important as nursery areas. Larger species tended to have recruitment limited to a single season, primarily either the Early-wet or Mid-wet seasons. Smaller fish species tended to have continuous recruitments with a few peaks occuring during the year. The primary recruitment peaks of such species typically occurred in the Mid-wet season.

Environmental associations. Useful information indicative of the environmental associations of 32 fish species was obtained. Three main groups of species were distinguished by characteristic combinations of associated environmental factors. Escarpment-associated species are potentially the most vulnerable component of the fish fauna to mining induced abiotic impacts. They were usually associated with low temperature, high DO concentration, low conductivity, low turbidity and coarse substrate. These species therefore display a general 'clean water' association. Accordingly, they are at risk when they make incursions to the lowlands near mining areas in the Wet season, or are trapped therein throughout the Dry season. They are therefore likely to be the most useful candidates for monitoring and biological testing.

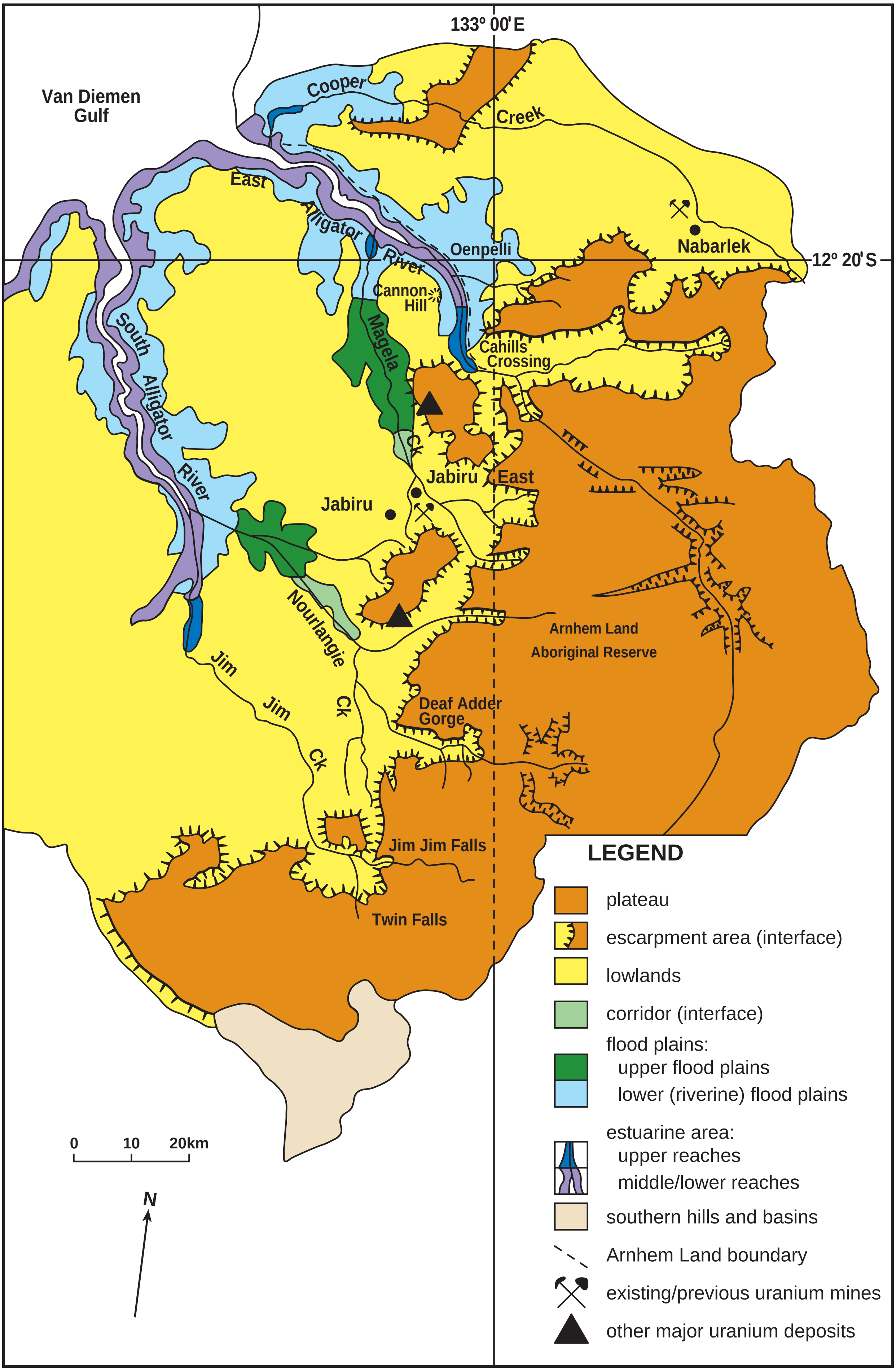
Reproduction. Six breeding strategies were exhibited by the fishes studied. Species which lay demersal eggs are most prone to impacts associated with siltation, and/or the release of toxic materials from sediments when anoxic conditions develop at depth within waterbodies. Accordingly, such species are therefore likely to be the most useful candidates for monitoring and biological testing. The most important spawning habitat was the lowland backflow billabongs, where 19 species showed evidence of spawning. Most fish species (25) bred around the onset of the Wet season. This is the time when initial flooding hugely increases the area and diversity of aquatic habitats available as well as initiating major increases in plankton and other foods.

Feeding habits. Nine feeding guilds were identified. If biomagnification effects are the focus of future investigations then the peak carnivores are the most suitable candidates for monitoring. Similarly, if exposure to disturbed contaminated sediments is a key factor, then the herbivore/detritivores, omnivores and/or benthic carnivores are the most suitable candidates. Downstream of the Ranger Uranium Mine (RUM) the highest feeding activity was recorded in lowland backflow billabongs followed by floodplain billabongs. Upstream of RUM the highest feeding activity was recorded in escarpment mainchannel waterbodies followed by lowland billabongs. The season of greatest feeding activity was, as other researchers in tropical seasonal rivers have found, the Wet season. Feeding activity thus increased most dramatically between the Late-dry season and the Early-wet season. By the

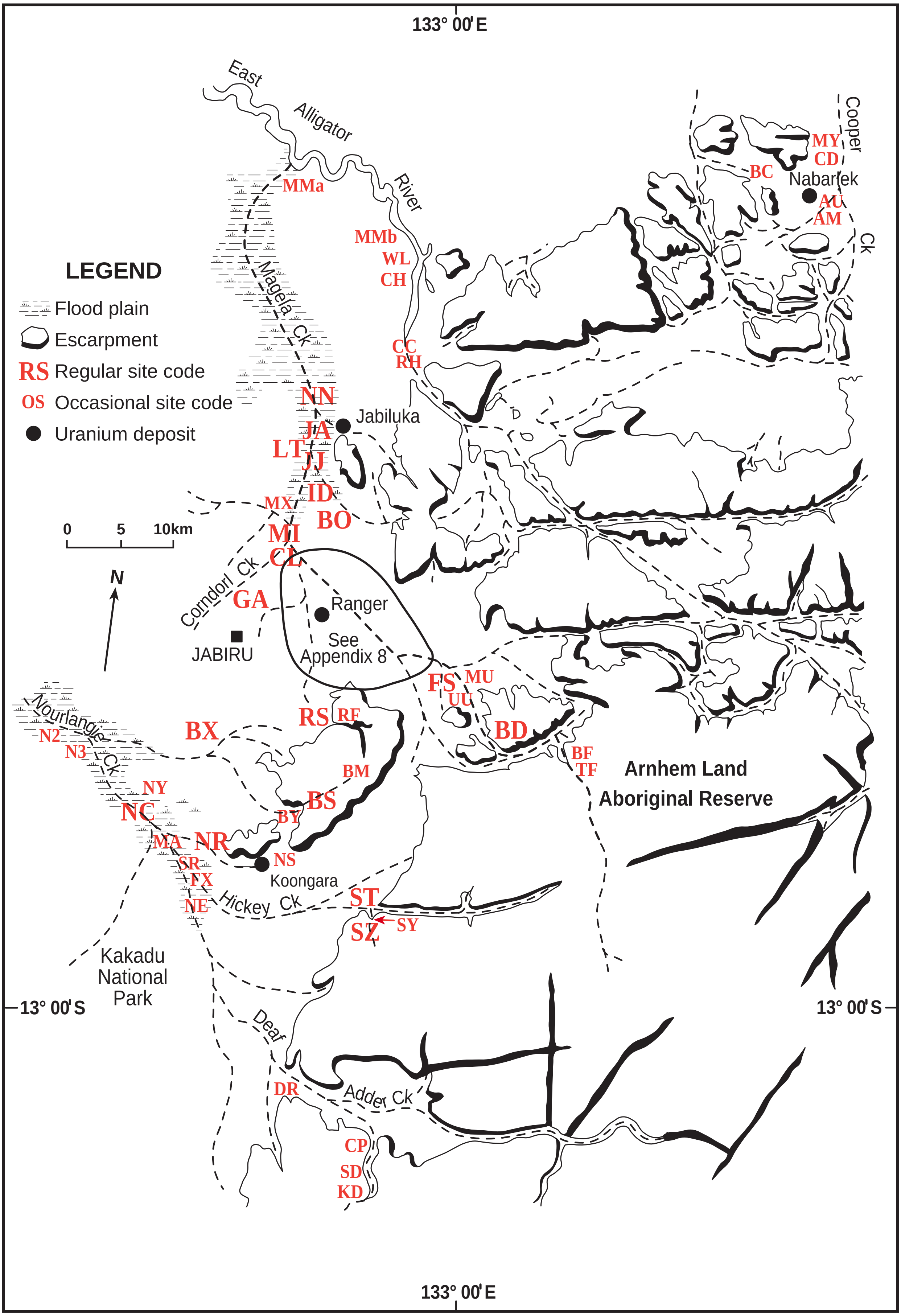
Mid-wet season feeding activity had peaked, and then decreased slightly by the Late-wet–Early-dry season. An examination of variations in body condition indicated that most species obtained their best condition from the Mid-wet to the Mid-dry season, with a peak in the Late-wet–Early-dry season.

A key finding from the study is the crucial importance of lowland backflow billabongs to the ecology of the majority of the freshwater fish fauna.

The detailed information presented in this report constitutes a major contribution to the autecological knowledge of the freshwater fish fauna of the Alligator Rivers Region. Because many of the species have a wide distribution, the information will be valuable to researchers across Australia, especially those working in the Timor Sea, Gulf of Carpentaria and north-east coast drainage divisions, and within Papua New Guinea and Irian Jaya. Insights gained into the processes ‘driving’ the ecology of this tropical riverine fish fauna also have world-wide application. Importantly, the information arising from the present study will have considerable application when assessing the nature and magnitude of impacts arising from a range of freshwater-associated developments, and particularly those in the mining arena.



Map 1 Major catchments and zones examined in the Alligator Rivers Region



Map 2 Location of regular and occasional sampling sites. Sites JD and TW are further south than the coverage of this map. Sites CA, C1, C2, C3, C4, DA, GD, GL, GN, GU, IF, II, IM, LC, MD, MG, MJ, RO, RT, TD and ZZ are shown in appendix 8.

1 Introduction

1.1 Preamble

Ecological studies on the freshwater fishes of the Alligator Rivers Region (maps 1 & 2) were carried out from August 1978 to December 1979 for the Office of the Supervising Scientist. The results of these studies are presented in three volumes.

Volume 1 (Research Report 4, Volume I) contains the overall introduction to these studies, a description of the physiography of the region, a brief description of the aquatic habitats and climate cycle, a summary of the results, and general conclusions and recommendations.

Volume 2 (Research Report 4, Volume II) considers the synecology of the freshwater fishes of the region. 'Synecology' is the study of the ecological relationships of particular communities or assemblages of organisms, in this case fish communities, with their environment.

This volume (SSR145) discusses the autecology of the fish species of the region. 'Autecology' is the study of the ecology of particular individuals, populations or single species.

1.2 Objectives of the autecological studies

Prior to the Ranger Uranium Environmental Inquiry (Fox et al 1977), the existing information on freshwater fishes of the Alligator Rivers Region (ARR) was primarily on taxonomy and distribution (Taylor 1964, Midgley 1973, Pollard 1974). Accordingly, the inquiry emphasised that existing biological and ecological information on the freshwater fishes of the Alligator Rivers Region was inadequate to predict either the effects of uranium mining and processing on the fish fauna or any long-term effects on the aquatic ecosystems. It was recognised that further research was required to provide basic background information on the environmental requirements, life histories and general biology of the freshwater fishes of the area.

The objectives of the ecological studies of the freshwater fishes of the ARR that are relevant to the autecological studies are:

1 (*Background information*) to collect and interpret basic biological and autecological data on the freshwater fishes of the ARR for use in evaluating the effects of possible changes associated with future uranium mining and processing in the area;

2 (*Detection methodologies*) to attempt to delineate those biological and ecological features of the fish fauna and variables of the aquatic environment that are most sensitive to these human-induced changes and that are likely to prove of greatest value in a continuing monitoring program, and to indicate how they can be most reliably sampled and usefully measured;

3 (*Prediction*) to gather more detailed biological and ecological data on selected fish species for use in the interpretation of data from future waste water toxicity studies.

In essence, the information in volume 3 is centred on identifying the location and timing of activities critical in the life cycle of the fish species considered. By relating this knowledge to information on the location and timing of mining-induced physical and chemical impacts, species most at risk can be identified – an important task in impact assessment.

Examination of the size composition of populations across habitats and seasons reveals, for example, where the nurseries are and when they are used. Similarly, examination of stomach fullness and reproductive condition reveals, respectively, the main feeding and spawning areas and times. Not all fish species exposed to the impacts from mines are likely to be equally affected; information on feeding habits and reproductive strategies will help to identify those species. Knowledge of the environmental requirements of these species may also reveal their sensitivity to certain water-quality changes, or indicate that certain physical features, which may be prone to mining impacts, are important to a species' survival.

Knowledge of critical nursery, feeding and spawning areas and times, as well as, for example, feeding habits and reproductive strategies, is fundamental to the design of monitoring systems that aim to detect impacts, and toxicity studies that aim to predict wastewater impacts. To provide an early warning of impacts, monitoring systems and toxicity studies need to focus on sensitive features of the target fauna. Early life-history stages are usually most sensitive to water-quality changes, so where impacts coincide with nursery and spawning areas and times, such stages of the exposed fish species should be targeted. The feeding habits of particular species may also render them sensitive to water-quality changes by, for example, biomagnification effects in the case of peak carnivores, or exposure to disturbed contaminated sediments in the case of detritivores. Similarly, then, where water-quality impacts coincide with feeding areas and times, species representing a range of feeding habits should clearly be targeted.

1.3 The fauna

In 1980, a total of 59 fish taxa had been collected from the region; they are listed in phylogenetic order in volume 1 (table 1, pp 3–4). Fifty of these taxa are known from freshwater habitats.

During this study, 166 standard samples were taken from freshwaters, yielding 29 254 fish of 37 taxa in 18 families (The majority of the taxa were identified to the species level, however, two were subspecies of *Melanotaenia splendida*). In addition 39 sets of underwater observations were made in escarpment area sites, in which 6276 fish of 28 taxa yielded additional information.

The number of taxa per family from freshwaters was as follows:

Five taxa: Terapontidae[1]

Four taxa: Plotosidae

Three taxa: Ariidae,[2] Melanotaeniidae,[3] Ambassidae, Eleotrididae[4]

Two taxa: Atherinidae, Toxotidae, Gobiidae

One taxa: Carcharhinidae,[5] Megalopidae, Clupeidae, Osteoglossidae, Belonidae, Pseudomugilidae,[6] Synbranchidae, Centropomidae, Apogonidae, Mugilidae

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[1] An additional terapontid species, the coal grunter (*Hephaestus carbo*), was recorded in the study area in 1988.

[2] An additional ariid catfish species, the shovel-nosed catfish (*Arius midgleyi*), was recorded in the study area in May 1988.

[3] An additional melanotaeniid species, the banded rainbow fish (*Melanotaenia trifasciata*), was recorded in the study area in 1988. The exquisite rainbowfish (*M. exquisita*) was also recorded in the upper South Alligator River system in the late 1980s.

[4] Two additional eleotrid taxa, the poreless gudgeon (*Oxyeleotris nullipora*) and black-banded or giant gudgeon (*O. selheimi*), have subsequently been recorded.

There was some confusion between the various plotosid catfishes identified in the early stages of the study. The difficulties in identifying catfish species from the family Plotosidae are detailed in this volume.

Autecological data are presented on the 37 taxa in the 18 families listed above. Data on a single carcharhinid shark species, collected to date only from tidal freshwaters in the region, are also included. The quality of information presented on each species obviously varies with the number of specimens collected and the degree of representation across habitats and seasons. Table 1 (next page) gives an indication of this quality by listing, per taxa, the number of specimens examined for basic biological data.

Australia is the only scientifically developed nation with a marked lack of financial support for fundamental studies on its freshwater systems, despite the importance to the country of water as a basic and relatively scarce resource (Williams 1971). Certainly, very little work has been published on the ecology of our freshwater systems, and Lake (1971), in his book on the freshwater fishes and rivers of Australia, highlighted how little was known about our rivers and their fauna. The tropical freshwaters of Australia have been investigated in even less detail than the temperate freshwaters.[7] A summary of ichthyological studies of the freshwaters of the Australian tropical zoogeographic region is given in a previous volume (vol 1, p 2).

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[5] Three additional carcharhinid taxa, pigeye shark (*Carcharhinus amboinengis*), Bizant River shark (*Glyphis* sp. A) and the Northern Speartooth shark (*Glyphis* sp. C), have subsequently been recorded in the study area in the late 1990s.

[6] An additional pseudomugilid taxa, the spotted blue-eye (*Pseudomugil gertrudae*), was recorded in the study area in the early 1980s.

Accordingly, the revised number of taxa per family from freshwaters is as follows:

Six taxa: Terapontidae

Five taxa: Melanotaeniidae, Eleotrididae

Four taxa: Carcharinidae, Ariidae, Plotosidae

Three taxa: Ambassidae

Two taxa: Atherinidae, Pseudomugilidae, Toxotidae, Gobiidae

One taxa: Megalopidae, Clupeidae, Osteoglossidae, Belonidae, Synbranchidae, Centropomidae, Apogonidae, Mugilidae

[7] A detailed survey of the freshwater fishes of Cape York Peninsula (Queensland) was undertaken in 1992–94 and later published by Herbert et al (1995). Cape York is primarily within the wet-dry tropics as is the Alligator Rivers Region. In 1993 freshwater fish surveying was undertaken in the wet tropics region of Queensland (Cooktown to Cardwell) and reported by Pusey and Kennard (1996) and Pusey et al (1995a). These Queensland surveys primarily had a synecological focus, although some autecological information did arise from the wet tropics investigation (ie a paper on feeding ecology — see Pusey et al 1995b).

Table 1 List of fish taxa ranked by the number of specimens examined for basic biological information

Fish species	Number of specimens	Rank no	Quartile	Report section
Melanotaenia splendida australis	2	1	Lower	3.15
Toxotes lorentzi	2	1	Lower	3.30
Ophisternon gutturale	2	2	Lower	3.19
Carcharhinus leucas	7	3	Lower	3.1
Arius proximus	9	4	Lower	3.6
Scleropages jardinii	16	5	Lower	3.4
Anodontiglanis dahli	31	6	Lower	3.8
Arius graeffei	41	7	Lower	3.7
Neosilurus colour-type 'B'	42	8	Lower	3.10
Syncomistes butleri	43	9	Lower	3.27
Glossogobius aureus	53	10	Lower middle	3.34
Hephaestus fuliginosus	54	11	Lower middle	3.25
Lates calcarifer	62	12	Lower middle	3.20
Hypseleotris compressa	70	13	Lower middle	3.35
Pingalla midgleyi	85	14	Lower middle	3.28
Neosilurus ater	106	15	Lower middle	3.9
Neosilurus hyrtlii	125	16	Lower middle	3.10
Oxyeleotris lineolata	134	17	Lower middle	3.37
Neosilurus colour-type 'C'	147	18	Lower middle	3.11
Megalops cyprinoides	155	19	Lower middle	3.2
Liza alata	211	20	Upper middle	3.32
Neosilurus colour-type 'A'	224	21	Upper middle	3.9
Strongylura krefftii	224	22	Upper middle	3.12
Pseudomugil tenellus	232	23	Upper middle	3.16
Mogurnda mogurnda	263	24	Upper middle	3.36
Glossogobius giuris	278	25	Upper middle	3.33
Toxotes chatareus	290	26	Upper middle	3.31
Porochilus rendahli	328	27	Upper middle	3.11
Leiopotherapon unicolor	439	28	Upper middle	3.26
Melanotaenia nigrans	579	29	Upper middle	3.13
Amniataba percoides	581	30	Upper	3.24
Arius leptaspis	740	31	Upper	3.5
Nematalosa erebi	845	32	Upper	3.3
Glossamia aprion	1020	33	Upper	3.29
Denariusa bandata	1340	34	Upper	3.23
Craterocephalus marianae	1730	35	Upper	3.17
Craterocephalus stercusmuscarum	1976	36	Upper	3.18
Ambassis macleayi	2028	37	Upper	3.22
Ambassis agrammus	3381	38	Upper	3.21
Melanotaenia splendida inornata	3636	39	Upper	3.14

A few specimens of *Melanotaenia splendida australis* (section 3.15) were collected in the South Alligator River system but none were examined for basic biological information.

2 Materials and methods

2.1 Sampling design

Seasons

From August 1978 to December 1979, fish were collected during the following eight sampling periods:

Mid-dry 1978
Late-dry 1978
Early-wet 1978–79
Mid-wet 1978–79
Mid-dry 1979
Late-dry 1979
Early-wet 1979–80
Late-wet–Early-dry 1979

Sampling was least extensive during the first (pilot survey; Pollard & Bishop 1978) and last periods. In the intervening periods a large set of *regular* sites was consistently sampled, and some sites were sampled *occasionally* to augment information on fish distributions. Sampling was timed to coincide with the periods of greatest biological activity, based on the Wet-Dry seasonal cycle of events (see 'Aquatic seasons' in Explanatory notes) rather than on fixed time intervals. The relationships between sampling period, the Wet-Dry seasonal cycle, water flow and date are given in volume 1 (table 3, p 15).

The sampling regime provided a base for examining the gathered biological and autecological data to identify the timing of activities critical in the life cycle of the fish species.

Sites and habitats

The ecological effects of any controlled or uncontrolled releases of wastes from the Ranger Uranium Mines Pty Ltd development near Jabiru would be expected to become apparent first in Coonjimba, Gulungul, Georgetown and Djalkmara Creeks and their associated waterbodies in the Magela Creek system. An intensive program to regularly sample the freshwater fishes in these areas was thus undertaken as a part of a monitoring program for the whole Magela Creek system. Upstream 'control' sites representative of habitats downstream of the Ranger site were also sampled regularly as were out-of-catchment 'control' sites in the Nourlangie Creek system (this system drains into the South Alligator while Magela Creek drains into the East Alligator River; Bishop et al (1990) showed that differences exist between the fish faunas in these systems). The fish faunas of sites adjacent to the other three major uranium deposits (Jabiluka, Koongarra and Nabarlek) were sampled occasionally, as were other sites outside the Magela catchment, to provide additional information on fish distributions.

A summary table of regular and occasional sampling sites, grouped according to drainage systems, geographical zones and habitat types is also given in volume 1 (table 5, p 19). The sites, site codes, grid references, and latitude and longitude are listed in volume 1 (table 4, pp 16–18). Appendix 1 (this volume) details the sites alphabetically by site code. Map 1 in this volume shows the major drainage systems and geographic zones examined. Map 2 and appendix 8 illustrate site locations with respect to the drainage systems and the mining operations in the Alligator Rivers Region.

The sampling sites were selected to represent the following ten freshwater habitats:

- plateau area habitat (two sites sampled occasionally);

- escarpment area habitats, consisting of mainchannel area habitats (two sites sampled regularly and six sites occasionally), seasonal feeder streams (one site sampled regularly and three sites occasionally) and perennial streams (two sites sampled regularly and one site occasionally);
- lowland habitats, containing sandy creek beds with pools or channels (three sites sampled regularly and eight sites occasionally) and backflow billabongs (ten sites sampled regularly and ten sites occasionally);
- corridor habitat (three sites sampled regularly and seven sites occasionally);
- upper floodplain billabong habitat (four sites sampled regularly);
- lower (riverine) floodplain billabong habitat (two sites sampled occasionally); and
- artificial habitat (five sites sampled occasionally).

A detailed description of these habitats is given in volume 2 (section 2.2, pp 5–14) and illustrated in plates 1–6 of the same volume.

For habitats represented by regular sampling sites, this habitat classification system provided a base for examining the gathered biological and autecological data to identify the location of activities critical in the life cycle of the fish species. Depending on the study objectives, and the availability of specimens for particular laboratory examinations, the habitat classification system included finer divisions, such as position upstream or downstream of the Ranger mine, or types of lowland backflow billabongs.

2.2 Recording of environmental data

Habitat–structural, physico–chemical and general habitat variables (relating to the whole waterbody, rather than the immediate fishing area) were collected for each site sampled during the study period. The recording methods are described in detail in volume 1 (section 3.2, pp 15–20; data cards A and E are given in appendixes 1 and 2 of that volume).

2.3 Collection and observation of fishes

The techniques used to obtain a representative fish community sample at each site are described in detail in volume 1 (section 3.3, pp 20–21). Two standard (regular and repeatable) collecting methods were used: gillnetting with multiple-mesh-sized monofilament nets (gn) and seine netting (sa). In escarpment sites where these methods would be likely to create an undesirable fishing pressure, underwater observations were substituted. Other collecting and observation methods were used occasionally: spears, lines, castnets, dipnets, poisoning and natural fish kills.

2.4 Field procedures

These procedures are described in detail in volume 1 (section 3.4, p 21). Information on fish catches and fish species found at the sampling sites were listed by species name and number on data card B (see this volume, appendix 2; species names are updated) in the field.

Each card line in appendix 1 contained the sample reference number corresponding to that on the environmental card A (see volume 1, appendix 1, pp 39–40) and the general habitat card E (volume 1, appendix 2).

Small fish (less than about 60 mm in length) collected with seine nets and by other methods were preserved intact in 10% (v/v) formalin; larger fish (over 60 mm in length) first had their body cavities slit to help preserve the stomach contents. Where practical, samples of larger fish collected with gillnets were deep-frozen overnight and processed later in the laboratory (see next section) after thawing – usually the following day. Those that could not be deep-frozen (eg on extended field trips) were preserved in 10% formalin.

2.5 Laboratory and data analysis procedures

The fish samples were either rinsed to remove formalin or thawed, and the following details were recorded: length in millimetres (length to caudal fork [LCF] for fish with forked tails, or total length [TL] for fish with rounded tails); weight (to the nearest 1 g, or 0.1 g for small fish); gonad weight (0.01 g, or 0.001 g for small fish); gonad stage on a seven-point scale after Pollard (1972) (variations from this method are noted in the text); stomach fullness (details given later in 'Feeding habits'); and an identification number for each fish. Each detail was recorded on a separate card line on data card C (see this volume, appendix 3). This card line also contained the reference number of the sample and the species name and code, so that biological information from a given fish could be related to the species and environmental data. The above data were summarised for each species on card B, where the total number of fish caught, their total weight (g), and maximum and minimum lengths (mm LCF or TL) were recorded.

Size composition

Length frequency

The length increments used in the length–frequency distribution (either 10, 5 or 2 mm LCF or TL) were decided on for each species according to the mean length of specimens captured during the study. The increments used for each species are apparent on the respective length-frequency distribution figures.

Where sample sizes permitted, three length-frequency distributions per species are examined: overall (all sites and seasons combined), seasonal changes (1978 Late-dry to 1979 Late-dry) and habitat differences per catchment. For the Magela Creek catchment, a detailed habitat breakup is presented, resulting in the following separations: lowland sandy creek upstream of the Ranger Mine (RM), lowland sandy creek downstream of the RM, lowland shallow backflow billabongs upstream of the RM, lowland shallow backflow billabongs downstream of the RM, lowland channel backflow billabongs (all downstream of the RM), sandy corridor waterbodies, muddy anabranch corridor waterbodies, and floodplain billabongs. The corridor billabong ID, being transitional in character with floodplain billabongs, was grouped with the latter habitats. These separations, corresponding site allocations, and the shading key for the figures are given in appendix 5.

Condition factor

Relative condition factors (K) were calculated for seasonal collections of fish using the equation:

$$K = W_s / aL_s^{\,b}$$

where W_s and L_s are the mean weights and lengths (geometric means were used as log-normality was assumed), respectively, for season *s*; *a* is a constant and *b* is the exponent in the overall length-weight relationship.

Environmental associations

Environmental features commonly associated with particular fish species were taken as an initial indication of the environmental requirements of the species. Definitions and analytical origins of the terms used are given below:

Quarters

For each environmental variable (eg pH, temperature, DO), the mean value associated with each fish species (or colour form in the case of the plotosid catfishes) was calculated. The 36 species studied were then ranked for that environmental variable in ascending order of these means. After ranking they were divided into four quarters: species with ranks 1–9 (the lowest mean values) constituted the lower quarter; species with ranks 10–18 formed the lower-middle quarter; those with ranks 19–27 the upper-middle quarter; and those with ranks 28–36 the upper quarter. If data were not available for all 36 species, these numbers changed accordingly.

Aquatic vegetation dominance

The amount of cover provided by four defined types of vegetation was estimated by a rank number, from 0 to 6 (see volume 1, appendix 1). A further rank number (7) was given to submerged terrestrial vegetation.

The total dominance of each vegetation type was calculated by using equation:

$$TD_j = \sum_{i=0}^{5} N_{ij}\, x_i,$$

where TD_j = total dominance for fish species j,

N_{ij} = frequency of occurrence of rank i for fish species j, and

x_i = rank number (0 to 5 only).

This total dominance score was converted to a percentage of the sum of the total dominance scores for all four vegetation types for a particular fish species j, ie percentage dominance (PD) of vegetation type k is given by:

$$PD = TD_{jk} \text{ x } 100/\sum_{k=1}^{4} TD_{jk}\ ,$$

The accuracy of this percentage dominance score decreases as sample size decreases.

Vegetation-occurrence index

This index was obtained by dividing the number of times there was vegetation in association with a particular species found at a sample site, by the total number of times the cover of aquatic vegetation was estimated at all sample sites associated with that species. Thus, the vegetation-occurrence index effectively estimated the frequency (expressed as a percentage) at which the fish species was found in waters with vegetation. The accuracy of this index decreases with smaller sample size.

Substrate dominance

As defined in volume 1 (appendix 1), dominant and subdominant substrates were noted for the species found at each site sampled. Seven types of substrates were listed. Each time a substrate was considered dominant it was given a rank of 2, and each time a substrate was subdominant it was ranked 1. These values were summed for each substrate type to give a final weighted score of total substrate dominance. This dominance total was converted into a percentage dominance figure by dividing it by the sum of total dominance for all substrate types.

Reproduction

Estimation of gonad maturity stages

When a fish was first captured, gentle pressure was applied to its abdominal area to see whether milt or eggs were extruded. At dissection, the gonads were observed by cutting away the abdominal wall. A seven-stage system adapted from Pollard (1972) was used: maturity stages were subjectively assigned according to the appearance and size of the gonads in the body cavity. As a number of unrelated species were examined, a generalised staging system was developed. Any features differing from the general system are outlined in the section on that particular species.

The changes in macroscopic appearance of the gonads are:

Stage I (immature virgin)

Gonads thin and threadlike, translucent and colourless; sexes usually indistinguishable.

Stage II (developing virgin/recovering spent)

Testes: thin and straplike, translucent and greyish. Ovaries: more rounded, usually translucent and colourless; eggs not visible to the naked eye.

Stage III (developing)

Testes: thickening opaque and greyish white. Ovaries: thickening, opaque; small, pale yellowish eggs may be visible to the naked eye.

Stage IV (maturing)

Testes: swollen, elongated, often extend ¾ of the way along length of body cavity. Ovaries: swollen, rounded, extend ¾ way along length of body cavity; larger, opaque, yellow eggs clearly visible.

Stage V (mature)

Testes: may extend length of body cavity; opaque white, generally with a smooth creamy texture. Ovaries: may fill body cavity and distend abdominal wall; large yellow eggs often translucent.

Stage VI (ripe)

Testes: as in V; milt may be extruded from fresh specimens by pressure on abdominal wall. Ovaries: as in V; eggs translucent yellow, free of ovarian connective tissue; may be extruded by pressure on the abdominal wall in fresh specimens.

Stage VII (spent)

Testes: thin, flaccid, straplike; blood vessels and ‘bruising’ evident; may contain white areas of residual sperm. Ovaries: hollow, thin and flaccid; sac-like; may contain both residual and undeveloped eggs; blood vessels and ‘bruising’ evident.

As ‘bruising’ subsides and residual eggs and sperm are resorbed, stage VII gonads became stage II and the maturation cycle may begin anew.

Slides of histological sections of gonad tissue stained with eosin and haematoxylin were prepared where determination of the gonad stage of small fishes proved difficult. Gonad staging was then confirmed or reassessed after the sections were examined under a high-power microscope.

Length at first maturity

The method for estimating the length at which fish first become sexually mature was adapted from State Pollution Control Commission (1981). Fish recorded with gonad stages later than III were considered capable of spawning during the forthcoming reproductive season. The length at first maturity (LFM) was therefore considered to be the length at which 50% of the fish examined had a gonadal maturity stage later than stage III, using the following method:

The highest percentage of fish with gonads at stages later than III in any two-monthly sample was plotted against fish length. A line of best fit was plotted by eye through the scatter points in the length range from where the percentage of stage IV–VII gonads was first greater than zero to where it consistently equalled 100%. A horizontal line was drawn from the 50% maturity level on the y-axis to intersect the line of best fit. The x coordinate of the intersection point was taken to give the estimated LFM.

This method was used because it avoids basing the LFM on a few isolated, sexually precocious individuals. Any problems arising from this method were generally due to small sample sizes; small samples of fish captured mainly outside their breeding season may result in a biased estimate of LFM. In these cases, the position of the line of best fit was allowed to be influenced more by the scatter points for mature fish collected in the breeding season than by the scatter points for those collected outside the breeding season. Species that are aseasonal spawners would not be expected to have 100% mature individuals in any given sample; in such cases the position of the upper end of the line of best fit was determined by the percentage of scatter points much lower than the 100% level.

Fish smaller than the LFM of the particular species are termed ‘juvenile’, and fish equal to or greater than the LFM are termed ‘adult’. Any fish – juvenile or adult – with a gonad stage less than IV is termed ‘immature’; it may be either an immature virgin or an adult outside the breeding season with regressed gonads.

Gonadosomatic and gonad maturity stage indices

Both fish and gonad weights were used to calculate the gonadosomatic index (GSI), using the formula:

GSI = gonad weight (g) / total fish weight (g) x 100

The gonad maturity stage index (GMSI) was calculated as the mean gonad maturity stage of all adult fish (ie those of length greater than or equal to the LFM). In calculating the mean, stage VII gonads (ie spent) were assigned the same value as stage II.

Reproductive development was assumed to be accurately delineated by changes in the mean GSI of adult fish calculated for each season. The use of GMSI to determine accurately the reproductive development period was also assumed to be valid, as discussed by State Pollution Control Commission (1981).

Estimation of reproductive development and spawning periods

Reproductive development was assessed by plotting mean GSI and GMSI (for adult fish) against sampling season. The period of reproductive development was arbitrarily defined as the period of time encompassed by obvious peaks that rise from and return to the resting level on the GMSI and GSI plots. The spawning period was defined as the range of seasons during which fish were found with gonads at maturity stage VI (ripe), or the seasons including or just before the capture of stage VII (spent) individuals. The data on reproductive biology are, where sufficient, summarised in a composite figure for each species.

Spawning sites

The spawning sites of each species were assumed to be the habitats from which fish with gonads at maturity stages VI (ripe) and VII (spent), or small juvenile fish, were collected.

Sex ratio

The numbers of identifiable males and females captured over each sampling period, and the numbers of adults of each sex (ie with lengths equal to or greater than their respective LFM), were noted for each species. The sex ratios for both the total catches of a species and the adults only were calculated and compared with expected values using a chi-square test (Zar 1974). Differences between these two values were examined for changes in sex ratio within each season.

Fecundity and oocyte diameter

Ovaries from stage V (mature) females were preserved for two weeks in 10% formalin and then transferred to 75% alcohol. Each preserved ovary was weighed and dissected; where the two lobes of the ovary were nearly the same size, only one lobe was dissected. Often eggs of several size-classes were present, representing different stages of oocyte development. Only the largest size-class of eggs was counted for the fecundity estimate. Either total counts were made by teasing the eggs away from the ovary tissue, or a smaller section of ovary was removed and weighed, the eggs in the subsample were counted, and the total fecundity was estimated by multiplying back to the original weight of the gonad.

For each ovary, the diameters of ten oocytes from the largest size-class were measured, and either the range or the mean and standard deviation, or both, were calculated. The mean oocyte diameter for the species was the average of the individual means if more than one ovary was dissected.

Feeding habits

Stomach fullness

Stomach fullness was recorded on a five-point scale after Ball (1961). Details of this are given in the data card C (appendix 3, column 77). Fullness was examined to give an indication of important feeding sites and times. A detailed habitat break-up is presented and this follows the separations used to examine habitat differences in length-frequency distributions.

Stomach contents data

The stomach contents of each fish were analysed under a dissecting microscope by the points (estimated volumetric) and occurrence methods (Pollard 1973). The percentage volume of each food type in the stomach contents was recorded to the nearest 5% on card lines in data card D (see appendix 4). Card D also contained the sample reference number, the fish species code, and the individual fish's number so that stomach contents data for a given fish could be related to the biological and environmental data. The data are presented to show seasonal and habitat differences in feeding habits.

Grouping of stomach contents data

The diet of each species was the mean of the sub-means of the stomach contents in all habitats and seasons. These sub-means were rounded off to the nearest 1%, which sometimes generated an error of up to ± 2%; in these instances only the unidentified organic material component was adjusted (to minimise distortion of the identifiable diet components) to absorb the ± 2% rounding-off error and make the diet total for each species 100%; this made the sub-means more useful as relative abundance data. Bait material and alimentary tract parasites were excluded from this examination and therefore the sub-means were corrected by a factor of 100/(100 – n), where n = % parasites and/or bait material (and sub-means were again corrected to add up to 100%).

Some of the rarer food items were then grouped on a taxonomic basis (though not at any particular phylogenetic level), leaving a total of 60 food groups. Emphasis in these selective groupings was given to relatively widespread occurrence of a food item amongst the different species and to items represented in high proportions in the diets of individual species. These data were then analysed to compare different species' diets, using the CSIRO TAXON library programs CANMAR/MULCLAS, GROUPER, GOWER and GOWECOR.

The 60 food items were further grouped to 27 items (again on a taxonomic basis at various phylogenetic levels). These groupings were used in pie diagrams showing the main components of the diets of each species, which also illustrated the main differences in the diet. As a consequence the invertebrate food items are revealed in more detail than the plant or vertebrate food components (the invertebrates tended to be more varied and specialised and to reflect a more distinct partitioning of resources, whereas the various vertebrate and plant components tended to be less specific in stratifying the feeding preferences of the different species). In the diagrams, the aquatic and terrestrial components of the diet are separated and the outer circles are used to group the food items (again taxonomically) for broader comparisons.

Macroscopic parasites, predators, movements and mortality

Parasites on fish were noted during the study. The information (including the position of the parasite in or on the body of the fish) was recorded so it could be related to the rest of the data.

An examination of the incidence of parasite infestations across habitats and seasons helps identify sites and times when fish are likely to be naturally stressed. The information obtained is presented in the Discussion section.

Information on predators, movements and mortality, most of which is derived from published literature, is also presented in the Discussion.

3 Autecology of the fishes

The extent of biological information gathered varied considerably between taxa, mainly due to their relative abundances in the Region. A list of fish taxa ranked by the numbers of specimens examined for basic biological information is shown in table 1.

Information on fish distributions beyond the Alligator Rivers Region is given in the introductory section for each taxa. This is facilitated by the provision of a map showing Australian drainage divisions (map 3).

A key to length-frequency distribution figures showing habitat preferences of the fishes studied is given in appendix 5.

Map 3 Australian drainage divisions (adapted from Lake 1978)

1 North-east coast

2 South-east coast

3 Tasmanian

4 Murray-Darling

5 South Australian Gulf

6 South-west coast

7 Indian Ocean

8 Timor Sea

9 Gulf of Carpentaria

10 Lake Eyre

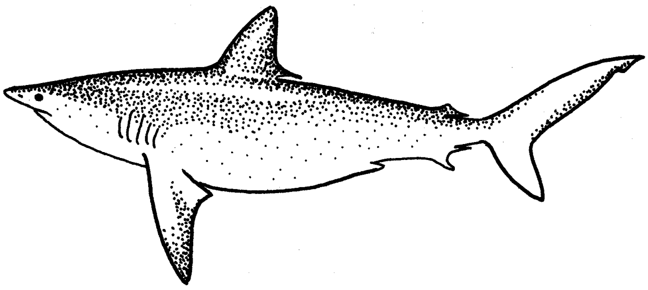
11 Bulloo-Bancannia

12 Western Plateau

Family CARCHARHINIDAE

3.1 *Carcharhinus leucas* (Muller & Henle)

Carcharhinus leucas, commonly known as the river whaler shark or bull shark is a euryhaline marine/freshwater carcharhinid with a worldwide distribution in tropical and warm temperate waters; it has been found in North and South America, Africa, South-East Asia, Papua New Guinea and Australia. In Australia it is found in the north-east, south-east, south-west, Indian Ocean, Timor Sea and Gulf of Carpentaria drainage divisions (see map 3).



Carcharhinus leucas

In South Africa and Central America, *C. leucas* is often found far upstream in freshwaters; in Australia it has been reported as far as 320 km upstream in the Fitzroy River in the Kimberley Region of Western Australia (Chubb et al 1979).[8]

Pollard (1974) found that river whaler sharks, which he identified as *C. mckaili* (syn. *C. leucas*; Chubb et al 1979), were common in tidal waterbodies of the East Alligator River system;[9] Taylor (1964) identified the head of a single specimen collected by R. Miller in the East Alligator River as being from *C. mckaili*. There are unconfirmed reports (M. Alderson, pers comm) of river whaler sharks in Yellow Water Billabong in the Jim Jim Creek drainage of the South Alligator River system.

Size composition

The lengths and weights of 10 specimens, all taken with 150 mm mesh multi-filament gillnets from tidal waterbodies of the East Alligator River, were measured.

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[8] In Papua New Guinea, bull sharks have been recorded in the Sepik River 70 km upstream from the river mouth (Kan & Taniuchi 1991). They are also reported to be very common in Lake Jamur, some 130 km inland from the Arafura Sea (Allen 1991). Herbert and Peeters (1995) indicated that bull sharks are distributed throughout all coastal streams of Cape York Peninsula and are known to penetrate great distances into freshwaters.

[9] Larson (2000) indicated that *C. amboinensis* and two potential species of rare speartooth (whaler) sharks, *Glyphis* sp. A (Bizant River shark) and *Glyphis* sp. C (Northern Speartooth Shark), have recently been identified from the Alligator Rivers Region. Their specific identity could not be determined as the taxonomy and relationships of these freshwater sharks within the genus *Glyphis* are still currently being investigated. Following Last and Stevens (1994), *Glyphis* sp. A (GS) varies from *C. leucas* (CL) in the following features:

- lower teeth — CL serrated; GS not serrated, and first few anterior teeth with cutting edges confined to slightly expanded spear-like tips.
- height of the 2nd dorsal relative to the first dorsal — CL 32%; GS 60%.
- toothcount — CL 25-27/25; GS 33/32.

Length–weight relationship

As only 10 specimens were caught, an expression for the length–weight relationship was not derived.[10] Specimens ranged in weight from 4.0 to 6.8 kg (mean = 5.3 kg) (table 2).

Table 2 Length, weight and reproductive condition of *C. leucas*

Sampling period	LCF (mm)	TL (mm)	Wt (kg)	Gonad stage	Gonad wt (g)	GSI
Females						
Mid-dry 1978	670	825	5.0	II	15	0.30
	670	845	4.6	II	14	0.30
	730	910	6.2	II	36	0.53
Males						
Mid-dry 1978	680	850	4.9	II	18	0.36
	710	880	4.8	II	24	0.5
	710	880	5.4	II	20	0.37
	710	900	5.3	II	24	0.45
Mid-wet 1978–79	800	995	6.8	II	15	0.22
	820	1025	6.3	II	21	0.33
Museum specimen: preserved whole						
Mid-dry 1978	640	805	4.0			

Length-frequency distribution

The specimens of *C. leucas* ranged in length from 640 to 820 mm LCF (825–1025 mm TL) (table 2). The mean length was 714 mm LCF.

Specimens caught during the 1978 Mid-dry season (pilot survey) were smaller (640–730 mm LCF) than those caught in the 1978–79 Mid-wet season (800–820 mm LCF).

Bigelow and Schroeder (1948) reported that this species is 650–700 mm TL at birth.[11] Springer (1960) noted that embryos ranged in size from 680 to 700 mm TL. The specimens caught in this study are therefore probably small juveniles.[12] Thorson et al (1966) reported that this species grows up to 2060 mm TL in freshwater and 2590 mm TL in brackish

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[10] The length-weight relationship given by Snelson et al (1984) for a population in mesohaline lagoons along the central east coast of Florida, USA, was:

$\log_{10}WT = -0.270 + (0.011)(TL); r = 0.98; P(F) < 0.0001$

where WT is weight in kg, and TL is total length in cm.

[11] In Florida, USA, *C. leucas* are born at a size of 600–800 mm TL, with an average of about 750 mm (Snelson et al 1984).

[12] From the examination of rings on vertebral centra, Tanaka (1991) indicated that 785 to 888 mm TL bull sharks collected from Northern Australia and Papua New Guinea seemed to be in their first year. In the Lake Nicaragua–Rio San Juan system of Nicaragua and Costa Rica, Thorson and Lacy (1982) found the growth rate of bull sharks to be relatively rapid in the first two years (180 and 160 mm per year), then gradually slows to 120 to 110 mm per year, and appears to remain at 90 to 100 mm per year for the later years of life. Females reached a maximum size of 2500 mm TL in 16 years while male reached 2140 mm TL maximum size in 12 years. In marine environments from the northern Gulf of Mexico, Branstetter and Stiles (1987) found lengths at age for males and females were similar except that males did not attain as great a length/age as females. Growth was slow and varied among individuals, but in general, was estimated to be 150–200 mm per year for the first five years, 100 mm per year for years 6–10, 50–70 mm per year for years 11–16, and less than 40–50 mm per year thereafter. Males matured at 2100–2200 mm TL or 14–15 yr of age; females matured at >2250 mm TL or 18+ yr of age. The largest male (2450 mm TL) was 21.3 yr old; the largest female (2680 mm TL) was 24.2 yr old.

waters.[13] Haines (1979) reported *C. leucas* ranging in length from 1110 to 1380 mm in the Purari River, Papua New Guinea.

Environmental associations

During this study, *C. leucas* was captured only in deep tidal waterbodies with sandy substrates, bordered by bedrock outcrops.

Studies from other areas indicate that *C. leucas* moves back and forth between fresh and salt water (Thorson 1971) and can readily tolerate both (Thorson & Gerst 1972). Osmoregulatory adaptations of this species have been examined by Oguri (1964) and Gerzeli et al (1969).

Carcharhinus leucas was observed in a fish kill that occurred during March 1978 in the Belmore River (Macleay River system, northern New South Wales) during rapid de-oxygenation of floodwaters (Richardson 1979, pers comm). Most specimens died when dissolved oxygen levels dropped below 20% saturation at temperatures ranging between 22° and 25°C.

Carcharhinus leucas can readily inhabit and navigate through areas of torrential flow. Thorson et al (1966) noted that, in Nicaragua, *C. leucas* have been observed both below and above three large rapids in the Rio San Juan, as well as actually in the rapids, mainly heading upstream into Lake Nicaragua.[14]

Reproduction

The reproductive condition of *C. leucas* captured in this study is shown in table 2.

Like most other sharks, *C. leucas* is ovoviviparous. Studies from other areas indicate that the young are born at 600–750 mm TL, in litters of between 5 and 13 embryos (Bigelow & Schroeder 1948; Springer 1960; Clark & von Schmidt 1965; Bass et al 1973). The young are probably born during summer after a gestation period of 10–11 months (Bass et al 1973).

There is no conclusive evidence that *C. leucas* breeds in freshwater. It is believed that the young are born in estuarine areas and stay there during the early part of their lives. In South Africa the larger sharks tend to move into lake systems and then out to sea as they mature (Bass et al 1973). Bass et al (1973) found a preponderance of young male sharks in estuarine and lower river areas; in the present study, most of the specimens captured in tidal waterbodies were juvenile males (table 2).

Feeding habits

The stomachs of nine specimens were examined; eight contained food (fig 1). The main dietary component was teleosts (85%); the remainder (15%) was unidentified organic material, most probably partially digested fish flesh. *Toxotes chatareus* (a 250 mm specimen bitten cleanly in half) was the only identifiable teleost species found in the stomachs.

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[13] Snelson et al (1984) indicated that maturing and adult *C. leucas* apparently reside primarily in deeper marine waters off the coast of central Florida. Females 2400–2650 mm TL, most carrying near-term embryos, begin to appear in shallow inshore marine water during Spring, and enter coastal lagoons to give birth in late-Spring to early-Summer.

[14] The voluntary swimming speeds of bull sharks in aquarium conditions was determined by Weihs (1981) to average 0.62 m/s (SE = 0.04 m/s) for a 2 m TL individual, and 0.72 m/s (SE = 0.06 m/s) for a 2.3 m TL individual.

C. leucas can therefore be classified as a macrophagous piscivore. Haines (1979) also classified *C. leucas* as a piscivore in the freshwater delta of the Purari River system, Papua New Guinea.[15]

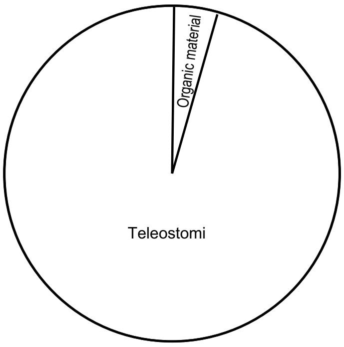

Figure 1 The main components of the diet of *C. leucas*

Larger *C. leucas* can be aggressive and dangerous to humans: they have attacked and killed bathers off the beaches in Lake Nicaragua, Central America (Thorson et al 1966).[16] Lack of food appears to be primarily responsible for such attacks (Blegvad & Loppenthin 1944).

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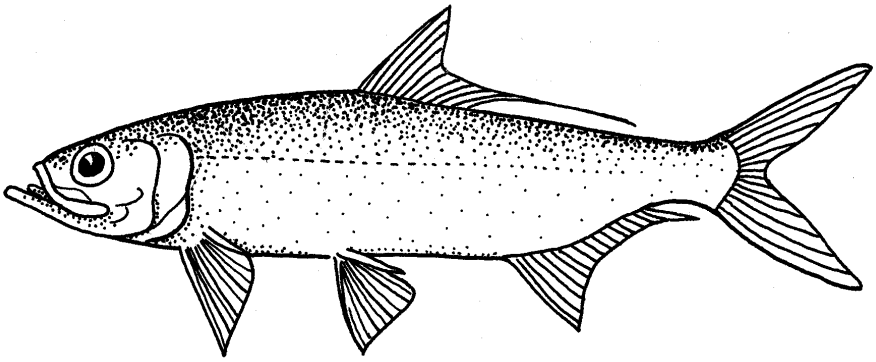
[15] Juvenile bull sharks in coastal lagoons within the central coast of Florida, USA, were found by Snelson et al (1984) to feed primarily on stingrays and marine catfishes.

[16] Bull sharks have been implicated in 34 unprovoked attacks (17 fatal) within freshwaters of Southern Iran from 1953 to 1985 (Coad & Papahn 1988).

Family MEGALOPIDAE

3.2 *Megalops cyprinoides* (Broussonet)

Megalops cyprinoides, commonly known as the tarpon or ox-eye herring, is widespread in the tropics, from East Africa across the Indian Ocean to South-East Asia, Papua New Guinea and Tahiti. It is also found in temperate seas as far north as Japan. In Australian seas, it is found as far south as the coasts of northern New South Wales and south-western Western Australia. Pollard (1974) found this species in floodplain and sandy corridor waterbodies of the Magela Creek system.[17] Miller (cited in Taylor 1964) found it in billabongs and creeks of the Oenpelli area.[18]



Megalops cyprinoides

It is essentially a marine species, though smaller specimens inhabit estuaries and are regularly found in freshwater rivers and creeks well above tidal influence. In Australia, it is likely to be commonly found in freshwaters only in far northern Australia.[19]

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found to be common in all floodplain and corridor waterbodies and backflow billabongs downstream of RUPA, and was occasionally found in some lowland sandy creekbeds. It was also found in escarpment habitats in the Nourlangie Creek system and lower riverine floodplain billabongs of the East Alligator River. It was most widely distributed during the Late-wet–Early-dry season (mainly in floodplain, corridor and backflow billabongs); it was found in fewest sites in the Late-dry season (mainly in floodplain billabongs).

Size composition

The lengths and weights of all 155 specimens, which were captured in multiple-mesh gillnets, were determined. Some of the largest specimens observed in the 150 mm mesh of the gillnets at the beginning of sets during the 1978–79 Mid-wet season had struggled free by the time

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[17] Herbert and Peeters (1995) indicated that tarpon are a common species in all rivers of northern Queensland. Large pools and lagoons are their preferred habitats.

[18] In the Sepik River catchment of northern Papua New Guinea, Coates (1987) recorded *M. cyprinoides* in high-order rivers, ox-bow lakes and other areas of permanent water and also on the floodplain, although the latter was not a preferred habitat.

[19] Allen (1991) indicated that *M. cyprinoides* penetrates at least 900 km upstream the Fly River system in Papua New Guinea.

the nets were collected an hour later, so the number of larger specimens is underestimated. Additionally, length-frequency distributions may have been affected by mesh selectivity.

Length–weight relationship

The length–weight relationship is described by the expression:[20]

$W = 2.42 \times 10^{-2} L^{2.83}$ $r = 0.84$ (length in cm, weight in g)

Seasonal changes in mean length, weight and condition factor are shown in table 3. The condition factor was lowest during the 1978 Late-dry season and increased markedly by the 1978–79 Early-wet season. Condition remained stable (near unity) through the Mid-wet and Late-wet–Early-dry seasons, peaked during the 1979 Mid-dry season, and then fell in the Late-dry season.[21]

Table 3 Mean length, mean weight and condition factor of *M. cyprinoides*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	13	297.4	326.6	0.91
Early-wet (1978–79)	4	295.0	354.8	1.01
Mid-wet (1978–79)	28	266.7	255.2	1.00
Late-wet–Early-dry (1979)	19	233.5	182.6	1.01
Mid-dry	20	247.4	222.5	1.05
Late-dry	71	234.1	177.8	0.98
Overall	155	246.2	209.9	1.00

Length-frequency distribution

The specimens captured ranged in length from 137 to 410 mm LCF (fig 2); the large minimum size is consistent with the observation that this species does not breed in freshwaters (Wade 1962).[22] The LFM was estimated to be 300 mm, which indicates that most of the specimens captured were large juveniles. Pollard (1974) suggested that this species may possibly grow to at least 1000 mm.

The mean and modal lengths of specimens captured were 246 and 250 mm LCF respectively. Approximately 80% of the total number of fish captured were between 170 and 300 mm LCF. Pollard (1974) mentioned that small specimens (usually between 200 and 500 mm in length) inhabit estuaries in northern Australia and are regularly found in freshwater rivers and creeks well above tidal influence. Haines (1979) found *M. cyprinoides* between 290 and 470 mm in length in the Purari River, Papua New Guinea.

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[20] The length-weight relationship given by Coates (1987) for *M. cyprinoides* from the Sepik River catchment of northern Papua New Guinea was:

$W = 9.96 \times 10^{-6} L^{3.1}$, $r^2 = 0.95$

where L is total length in mm, W is total weight in g.

[21] In the Sepik River catchment of northern Papua New Guinea, Coates (1987) found the condition of *M. cyprinoides* to be slightly, but significantly, lower during the dry season. A fat deposit index also followed this pattern, however, this index was low for the whole population indicated that surplus energy was directed to growth and not stored.

[22] The size range of *M. cyprinoides* recorded in the Sepik River catchment of PNG by Coates (1987) was 103–440 mm standard length, all classed as immature stages.

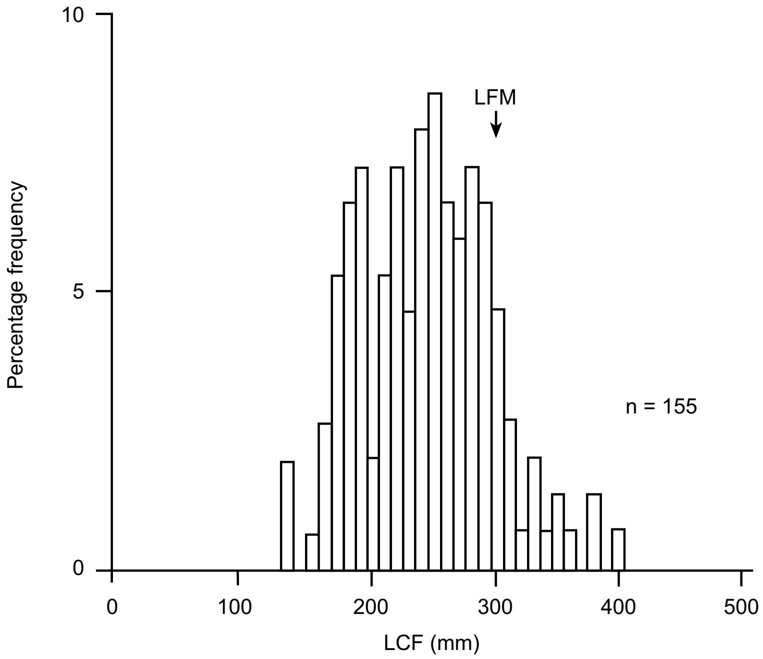

Figure 2 Length-frequency distribution of all *M. cyprinoides* captured

Seasonal changes in distribution

The smallest specimens were captured during the 1978–79 Mid-wet and 1979 Mid-dry seasons; the largest specimens were captured in the Mid-wet season (fig 3). The juveniles therefore recruited to the catchments during the Mid-wet season when connection was made with the estuaries. Small juveniles were present in the Nourlangie Creek catchment into the Mid-dry season and persisted in the escarpment perennial streams to the 1979 Late-dry season.

The seasonal changes in length-frequency distribution are shown in figure 3. The mean lengths (table 3) of the fish were consistently high during the 1978 Late-dry and 1978–79 Early-wet seasons and then began to decrease during the Mid-wet season as juvenile recruits became more common in the populations.[23] The mean lengths were further reduced during the Late-wet–Early-dry season and remained low until the 1979 Late-dry season. Juvenile recruitment in the catchments may, therefore, have been greater in the 1978–79 Wet season than in the 1977–78 Wet season.

Growth rate

The growth rates could not be estimated from data gathered in the present study, as the size distribution of recruits was not well defined. If the growth rate of *M. cyprinoides* captured in this study is comparable with that of larvae reared in freshwater by Alikunhi and Rao (1951) (31.4 mm/month), then the largest specimens examined would be less than a year old, indicating that the fish may mature within their first year of life.[24]

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[23] In contrast, the smallest juvenile *M. cyprinoides* entered the Sepik River of PNG in April to July, ie a period equivalent to the Early- to Mid-dry season in the Alligator Rivers Region. Russell and Garrett (1983) have recorded very small (22–25 mm) individuals in the Norman River estuary, northern Queensland, during December which is equivalent to the Early-wet season.

[24] The oldest *M. cyprinoides* recorded were at least 52 years of age (Kulkarni 1992). The specimens arose from releases of fingerling tarpon made in July 1939 into an isolated freshwater lake near Bombay, India. Stunted growth was apparent as specimens averaged only 670 mm in length and weighed 3 kg. Crabtree et al (1995) indicated the closely related *M. atlanticus* has a maximum age of at least 55 years in South Florida waters, USA. Growth of *M. atlanticus* was rapid to the age of twelve years (fork lengths 1200 mm for males, and 1435 mm for females), then slowed considerably.

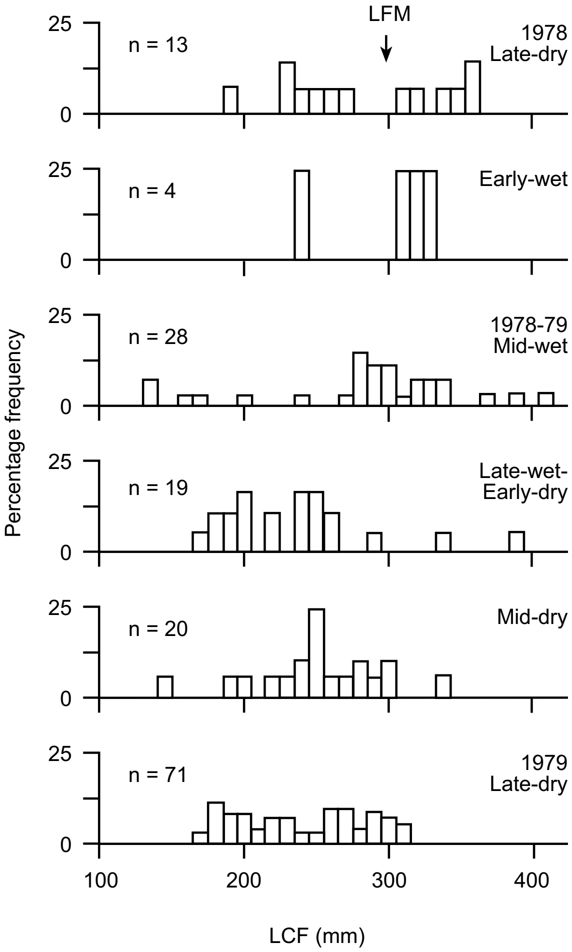

Figure 3 Seasonal length-frequency distribution of all *M. cyprinoides* captured

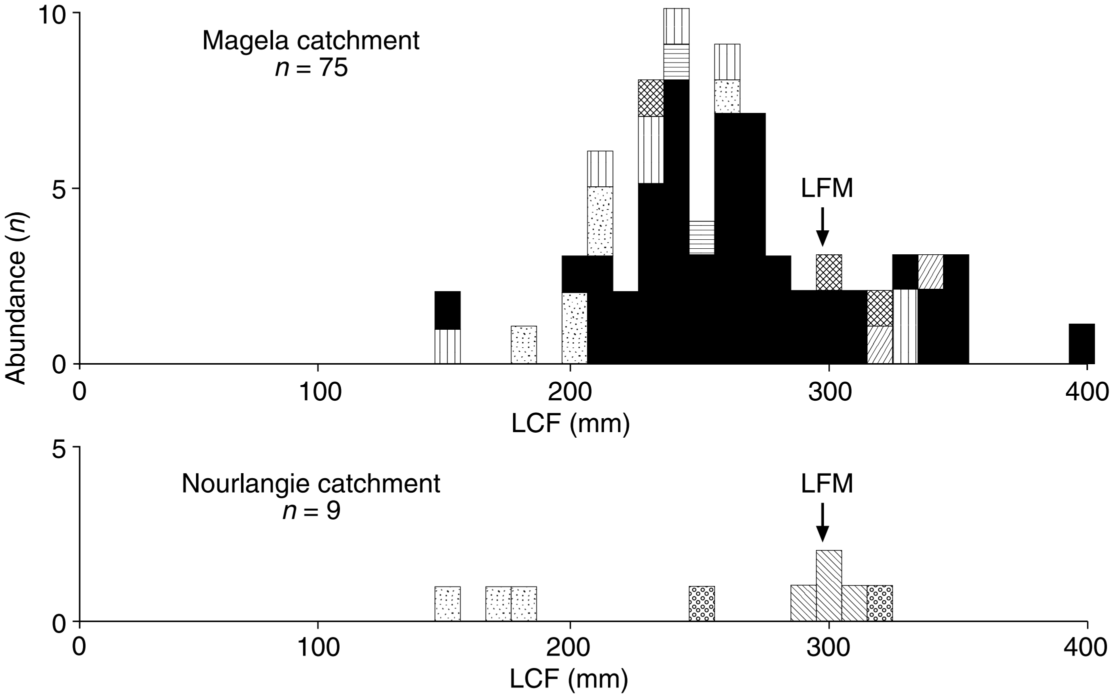

Figure 4 Length-frequency distributions and habitat preferences of *M. cyprinoides* captured at regular sampling sites (see appendix 5 for key to the habitats)

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *M. cyprinoides* captured in regular sampling sites in the Magela and Nourlangie creek catchments are given in figure 4.

Magela catchment

The smallest juveniles were captured in floodplain billabongs and in shallow and channel backflow billabongs. The larger juveniles were captured mainly in the floodplain billabongs, with fewer in the backflow billabongs and corridor waterbodies. No juveniles were found upstream of RUPA.

Most of the specimens, including the largest adult (Jabiluka Billabong), were netted in floodplain billabongs. Smaller numbers of adults were found in corridor waterbodies and lowland sandy creekbeds and shallow backflow billabongs. No adults were found upstream from RUPA.

Nourlangie catchment

The few small juveniles that were captured were found in a channel backflow billabong (Baroalba Crossing) during the Mid-wet season. Small juveniles also appeared in the headwaters of Baroalba Creek during the Mid-wet season and remained there until the 1979 Late-dry season. Some larger juveniles were found in shallow backflow billabongs.

The few adults captured in this catchment were found in escarpment mainchannel waterbodies and shallow backflow billabongs. Both adults and juveniles were seen in the lower reaches of an escarpment perennial stream during the 1979 Mid-dry season. No floodplain billabongs were sampled in the Nourlangie catchment.

Environmental associations

Rank numbers for *M. cyprinoides* for the various physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables[25]

Temperature

This species was captured in waters with surface temperatures from 23° to 34°C (mean = 29.8°C); bottom waters had the same range (mean = 28.0°C). *Megalops cyprinoides* was therefore found at some of the lowest temperatures recorded in the region. It was ranked in the lower-middle quarter for surface and bottom water temperature based on mean temperatures (see fig 170 in chapter 4).

Dissolved oxygen

Dissolved oxygen concentrations in waters in which this species was captured ranged from 1.9 to 9.7 mg/L (mean = 6.2) in surface waters and from 0.2 to 7.4 mg/L in bottom waters (mean = 2.8). *M. cyprinoides* was ranked in the upper-middle quarter for surface DO and at the base of the lowest quarter for bottom DO (see fig 171 in chapter 4).

Although *M. cyprinoides* was known from previous sampling to occur in the area, it was not found in a large fish kill, caused by de-oxygenation of the water (Bishop 1980), in Leichhardt Billabong during the 1978–79 Early-wet season. The closely related Atlantic tarpon *Megalops atlanticus* was not reported in a large fish kill caused by oxygen depletion in North Florida Bay during 1960 (Tabb & Jones 1962). *Megalops atlanticus* is an obligate air breather (Schlaifer

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[25] Chaverri (1994) found the juveniles of the closely related *M. atlanticus* to be associated with low levels of dissolved oxygen, H_2S occurrence, high turbidity, and variable salinities and temperature in lagoons and creeks in the coast of Costa Rica.

1941), a characteristic that may be associated with its 'rolling' behaviour (Wade 1962). Schools of *M. cyprinoides* exhibit similar 'rolling' behaviour and are also air breathers, and thus able to survive the de-oxygenation of a billabong (Merrick & Schmida 1984, Wells et al 1997).[26] The surface rolling behaviour of *M. cyprinoides* was more noticeable in the more anoxic billabongs of the region.

Visibility

Secchi depths recorded at sites in which this species was captured ranged from 4 to 270 cm (mean = 86 cm). *Megalops cyprinoides* was ranked at the top of the upper-middle quarter, based on the mean Secchi depth of waters in which it was captured (see fig 172 in chapter 4).

pH

Surface water pH ranged from 5.3 to 9.1 (mean = 6.5) and bottom pH ranged from 5.2 to 7.1 (mean = 6.0). This species was ranked towards the top of the highest quarter of pH for surface waters and in the upper-middle quarter for bottom waters (see fig 173 in chapter 4).

Conductivity

The conductivity of surface waters varied between 2 and 200 µS/cm; the conductivity of bottom waters varied between 4 and 280 µS/cm.

Habitat–structural variables

Substrate

The substrates over which *M. cyprinoides* was captured were mainly mud and clay, and to a lesser extent sand. Only a few specimens were captured over other substrates. The ranked positions for mud, clay and sand substrates were upper-middle, upper (near maximum) and lower-middle quarters, respectively (see fig 174 in chapter 4).

Hydrophytes

Megalops cyprinoides was typically found in vegetated waters (vegetation-occurrence index 78.5%). The dominant hydrophyte types were submergent (percentage dominance = 50.0%), floating-attached (23.6%) and emergent forms (20.9%).

Reproduction

Over 95% of *M. cyprinoides* captured were immature, with the sexes being indistinguishable. Seven males (186–360 mm LCF) were captured during the 1978 Late-dry season, mostly in Western Red Lily Billabong on the East Alligator flood plain. Two females were captured at Magela Crossing during the 1978–79 Mid-wet season. The length, weight and reproductive condition of the males and females are given in table 4.

Length at first maturity

As only a few sexually distinguishable fish were captured, the LFM had to be estimated: 300 mm LCF for both males and females.

Sex ratio

Too few (nine) sexually distinguishable fish were captured to test the sex ratio (7:2) statistically. However, all the fish captured on the East Alligator flood plain during the 1978 Late-dry season were males and all those captured at Magela Crossing during the 1978–79 Mid-wet season were females.

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[26] Wells et al (1997) stated, without citations, that *M. cyprinoides* are facultative air breathers that use a well-vascularised swim bladder for oxygen uptake. Wells et al showed that tarpon had a high blood-oxygen carrying capacity.

Table 4 Length, weight and reproductive condition of sexually distinguishable *M. cyprinoides*

LCF (mm)	Weight (g)	Gonad stage	Gonad wt (g)	GSI
Females				
390	1000	VII	1.8	1.80
410	1150	VII	2.1	1.83
Males				
186	100	II	0.1	0.10
225	152	II	1.0	0.66
235	170	II	0.4	0.25
245	275	III	0.4	0.15
270	325	III	0.7	0.22
353	725	V	2.4	0.34
360	775	V	1.5	1.19

Breeding season

Sexually distinguishable fish were captured during only two sampling periods. Male fish showed reproductive development at the end of the Dry season and spent females were captured as they moved back upstream in the Mid-wet season, supporting previous reports (Lake 1971; Pollard 1980) that *M. cyprinoides* spawns in the summer. Wade (1962), however, cites evidence that *M. cyprinoides* breeds throughout the year.[27]

Site of spawning

Spawning sites could not be determined from the data collected in the present study. However, *M. cyprinoides* has been reported to breed in estuarine or shallow inshore waters (Lake 1971; Pollard 1980) and in deeper offshore waters (Wade 1962).[28]

Fecundity

No mature ovaries were collected. The fecundity of *M. cyprinoides* is most likely high, with small pelagic eggs being produced (Breder & Rosen 1966). The larvae are of the leptocephalus type: colourless, elongate, ribbon-like and translucent, with a very small head and small undeveloped fins. Although the larva takes only seven weeks to metamorphose, it does not fully attain the adult appearance until around 300 mm TL, which takes about nine months (Wade 1962).

Summary

Published information suggests that, during the Early-wet season, *M. cyprinoides* migrates downstream to coastal or possibly offshore areas to spawn, and lays numerous small pelagic eggs. The larvae move shoreward, metamorphosing in coastal and estuarine areas, and juveniles are found in shallow coastal waters and in adjacent brackish and freshwater pools and rivers (Wade & Robins 1962, Wade 1962).

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[27] Crabtree (1995) indicated that spawning of the closely related *M. atlanticus* occurs in late-Spring to early-Summer in marine waters off the Florida coast, USA. The spawning activity appeared to be associated with the lunar phase (peak hatching activity occurred 6–7 days after the full moon and 3–8 days after the new moon).

[28] Spawning of *M. atlanticus* occurs in marine waters 65–511 m deep off the Florida coast, USA (Crabtree (1995). Smallest larvae were captured in surface waters over a bottom depth of 240 m.

Feeding habits

Overall diet

The stomachs of 151 specimens were examined; 79 contained food. The overall diet is summarised in fig 5; the dietary components are listed in table 5. The main dietary components were aquatic insects (42%) and teleosts (31%). Most of the aquatic insects were libellulid larvae, chironomid pupae, coleopterans and naucorid bugs. The identifiable teleosts were mainly *Ambassis* spp. and *M. splendida inornata,* and less abundant species were *Neosilurus* spp., *P. tenellus, D. bandata* and *H. compressa*. Macrocrustaceans (6%, only *Macrobrachium*) were also found in the stomachs, as were microcrustaceans (3%, *Cyzicus* and *Diaphanosoma*) and terrestrial insects (2%). There were also traces of terrestrial plant material, inorganic material and unidentified organic material. *Megalops cyprinoides* can be classified as a macrophagous carnivore/piscivore that feeds predominantly in surface and mid-waters.[29]

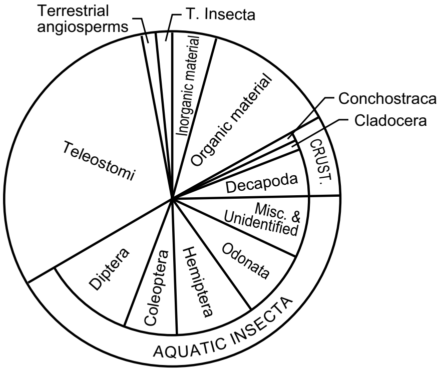

Figure 5 The main components of the diet of *M. cyprinoides*

Pollard (1980) reported that *M. cyprinoides* adults feed on crustaceans and smaller fish, and that the young will eat insects at the water's surface, while the larvae will eat plankton. Haines (1979) classified this species as a prawn eater in coastal areas near the mouth of the Purari River, Papua New Guinea. Wade (1962) noted that information on feeding habits was scarce, but that larvae acclimatised to freshwater ate freshwater plankton, insects and young forage fish.

Adults of the closely related *M. atlanticus* are carnivorous and prey upon fish (including mullet and long toms) and crustaceans (Wade 1962). The food of larval and young *M. atlanticus* included cyclopoid copepods, fishes, shrimps and *Aedes* mosquito larvae.

Seasonal changes

During sampling periods 1–6, respectively, 151 stomachs of *M. cyprinoides* were examined (all habitats combined): 11 (27% empty), 4 (0% empty), 27 (18% empty), 18 (28% empty), 20 (65% empty) and 71 (65% empty).

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[29] Based on data from the present study, Bishop and Forbes (1991) classified *M. cyprinoides* as a piscivore which uses ambush tactics, particularly in the lowland sandy creekbed habitat. In the Sepik River catchment of PNG, Coates (1987) found *M. cyprinoides* to be a meso-predator, feeding mainly on small prawns, aquatic and terrestrial insects and small fish. Catano and Garzon-Ferreira (1994) found the closely related *M. atlanticus* to consume gastropods, shrimps, insects, fishes and plant remains in an estuarine-deltaic system in the Caribbean coast of Colombia.

Table 5 Dietary composition of *M. cyprinoides*

	Habitat				Season							
	Magela system			Nourlangie system	1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Bb	Cb	Fb	Bb	Late-dry	Early-wet	Mid-wet	Late-wet– Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Aquatic animals												
Microcrustacea												2.5
Conchostraca												
Cyzicus	–	–	–	19.0	–	23.8	–	–	–	–	1.2	
Cladocera												
Diaphanosoma	7.7	–	–	–	–	–	–	–	14.3	–	1.3	
Macrocrustacea												5.8
Macrobrachium	13.9	–	1.3	–	–	–	2.5	6.2	–	13.0	5.8	
Insecta												42.1
Fragmented	–	–	8.7	–	25.0	–	1.4	–	–	12.4	6.8	
Ephemeroptera												
Baetidae	–	–	–	–	–	–	–	–	7.1	–	0.6	
Odonata												
Libellulidae	1.5	–	–	–	–	–	1.8	1.5	–	21.6	7.6	
Hemiptera												
Naucoridae	–	–	6.7	–	–	–	8.0	–	14.3	5.2	5.1	
Gerridae	–	16.7	–	–	–	–	–	7.7	–	–	1.3	
Anisops	–	–	–	–	–	–	–	–	–	1.2	0.4	
Corixidae	–	20.0	–	1.0	–	1.3	–	–	2.9	8.0	2.9	
Coleoptera												
Fragmented	8.8	20.0	–	–	–	–	9.8	7.7	2.9	4.0	6.0	
Diptera												
Chaoborinae	13.9	–	–	–	–	–	–	13.9	–	–	2.3	
Chironomidae (larvae)	–	–	13.0	–	–	–	–	–	35.7	–	3.2	
Chironomidae (pupae)	–	26.7	0.3	–	37.5	–	–	–	22.9	0.2	5.9	

Table 5 continued

	Habitat				Season							
	Magela system			Nourlangie system	1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Bb	Cb	Fb	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Teleostomi												31.1
Fragmented	–	–	6.7	20.0	–	25.0	4.3	7.7	–	6.4	5.8	
Neosilurus spp.	–	–	–	–	–	–	–	–	–	4.0	1.3	
M. splendida inornata	12.3	–	26.3	–	12.5	–	20.7	7.7	–	–	8.3	
P. tenellus	–	–	5.3	–	–	–	–	–	–	3.2	1.0	
Ambassis spp.	18.5		18.7	–	–	25.0	10.9	36.9	–	–	10.4	
D. bandata	–	–	–	40.0	–	–	9.1	–	–	–	2.5	
H. compressa	–	–	–	–	–	–	4.6	–	–	1.6	1.8	
Terrestrial plants												
Angiospermae												0.9
Fragmented	–	–	1.3	–	–	–	–	1.5	–	2.0	0.9	
Terrestrial animals												
Insecta												2.4
Fragmented	–	16.7	0.3	–	–	–	4.8	–	–	–	1.3	
Orthoptera												
Fragmented	–	–	–	–	–	–	4.1	–	–	–	1.1	
Parasites												
Nematoda	0.8	–	–	–	–	–	0.5	–	–	–	0.1	0.1
Inorganic material	–	–	–	–	–	–	–	–	–	11.8	3.7	3.7
Organic material	22.7	–	11.0	20.0	25.0	25.0	17.3	9.2	–	5.4	12.0	12.0
Number of empty fish	2	19	14	–	3	–	5	5	13	46	72	72
Number of fish with food	13	6	15	5	8	4	22	13	7	25	79	79

Figures represent the mean percentage volume determined by the estimated volumetric method.

Bb = lowland backflow billabong Cb = corridor billabong; Fb = floodplain billabong

The highest proportion of specimens with empty stomachs was during the 1979 Mid-dry and 1979 Late-dry seasons; the lowest in the 1978–79 Early-wet season.[30]

In the 1978 Late-dry season, mainly aquatic insects and smaller amounts of *M. splendida inornata* were eaten. In the 1978–79 Early-wet season the few specimens examined had eaten primarily teleosts (mainly *Ambassis* spp.) followed by conchostracans (*Cyzicus*). In the Mid-wet season the diet consisted mainly of teleosts (*M. splendida inornata*, *Ambassis* spp., *D. bandata* and *H. compressa*), with some aquatic (coleopterans and naucorids) and terrestrial insects. By the Late-wet–Early-dry season the teleost component of the diet (mainly *Ambassis* spp. and *M. splendida inornata*, which were migrating in this season) was still large, though aquatic insects (chaoborids, coleopterans and gerrids) were of increasing importance. During the 1979 Mid-dry season, teleosts were no longer found in the stomachs. They were replaced by aquatic insects and cladocerans (mainly chironomid larvae and pupae, and naucorids). By the 1979 Late-dry season, small quantities of teleosts (plotosids and *P. tenellus*) had reappeared, although the aquatic insects (mainly libellulid larvae and corixids) still dominated the diet, with an additional *Macrobrachium* component.

Habitat differences

Magela catchment

A total of 60 stomachs of *M. cyprinoides* were examined (all seasons combined): 15 (13% empty) from backflow billabongs, 25 (24% empty) from corridor waterbodies and 29 (48% empty) from floodplain billabongs.

The diet in the backflow billabongs consisted mainly of teleosts (*Ambassis* spp. and *M. splendida inornata*), aquatic insects (chaoborids and coleopterans) and *Macrobrachium*, with smaller portions of cladocerans. During the Mid-wet season, schools of 10–20 *M. cyprinoides* established feeding stations in the Magela system sandy creekbeds, at sites where migrating *M. splendida inornata* were congregating in large numbers (within hydrophytes, which covered the upstream ends of creek islands). The specimens of *M. cyprinoides* from these areas had stomachs full of *M. splendida inornata*.

In the corridor waterbodies *M. cyprinoides* was feeding only on aquatic insects (mainly chironomid pupae, corixids, coleopterans and gerrids). On the floodplain, it was eating mainly teleosts (*M. splendida inornata*, *Ambassis* spp. and *P. tenellus*) and, to a lesser extent, aquatic insects.[31]

Nourlangie catchment

The stomach contents of five specimens from backflow billabongs were examined. All had teleost fish (mainly *D. bandata*) in their stomachs, with only traces of aquatic insects.

Fullness

Mean fullness indices of *M. cyprinoides* are summarised in table 6. These data are presented on the assumption that feeding times within the day do not vary with habitat or season.

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[30] Coates (1987) found no major seasonal changes in the diet of *M. cyprinoides* from the Sepik River catchment of PNG. Catano and Garzon-Ferreira (1994) found the diet of the closely related *M. atlanticus* to vary considerably with the seasons, particularly in relation to the availability of juvenile mullet which entered the studied estuarine-deltaic system in mass migrations in March to July. Larger *M. atlanticus* were more piscivorous.

[31] Catano and Garzon-Ferreira (1994) found the diet of the closely related *M. atlanticus* to vary considerably between habitats, particularly in relation to both the greater diversity and insect-component of the diet in swamps as opposed to river mouths where environmental changes were stronger and more frequent.

Table 6 Mean fullness indices of *M. cyprinoides* in different sampling periods and habitats

Habitat	Sampling period						Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	
Magela Creek catchment (regular sites only)							
Downstream of RUPA:							
Lowland sandy creekbed	n/s	1.0 (1)	1.0 (1)	n/s	n/s	n/s	1.0 (2)
Lowland channel backflow billabong	n/s	n/s	n/s	1.2 (5)	n/s	1.0 (1)	1.2 (6)
Lowland shallow backflow billabong	n/s	1.0 (1)	1.5 (2)	0.8 (4)	1.0 (2)	n/s	1.0 (9)
Corridor sandy billabong	n/s	n/s	n/s	0 (1)	n/s	0 (2)	0 (3)
Corridor anabranch billabong	n/s	n/s	n/s	1.0 (1)	n/s	1.0 (1)	1.0 (2)
Floodplain billabong	3.0 (2)	n/s	1.3 (6)	1.3 (7)	0.5 (15)	0.2 (20)	0.7 (50)
Nourlangie Creek catchment (regular sites only)							
Escarpment main-channel waterbody	n/s	n/s	0 (1)	n/s	0.3 (3)	n/s	0.2 (4)
Lowland channel backflow billabong	n/s	n/s	1.7 (3)	n/s	n/s	n/s	1.7 (3)
Lowland shallow backflow billabong	n/s	2.5 (2)	n/s	n/s	n/s	n/s	2.5 (2)
Seasonal mean (all sites)	2.5	2.0	2.7	1.1	0.6	0.5	

Numbers examined are given in parentheses; n/s = not sampled in the habitat

Seasonal changes

The mean seasonal fullness index (all habitats combined) fell during the 1978–79 Early-wet season and then rose to a peak in the Mid-wet season. The index decreased suddenly to the Late-wet–Early-dry season and remained low for the remainder of the Dry season.

Habitat differences

In the Magela catchment, *M. cyprinoides* was found only downstream of RUPA. The mean fullness indices were highest in the lowland and corridor anabranch habitats, and lowest in the sandy corridor habitats.

In the Nourlangie catchment, the mean fullness indices were highest in the lowland habitats, but sample sizes were very small.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- floodplain billabong; 1978 Late-dry, 1978–79 Mid-wet and 1979 Late-wet–Early-dry seasons
- lowland shallow backflow billabong; 1978–79 Mid-wet season

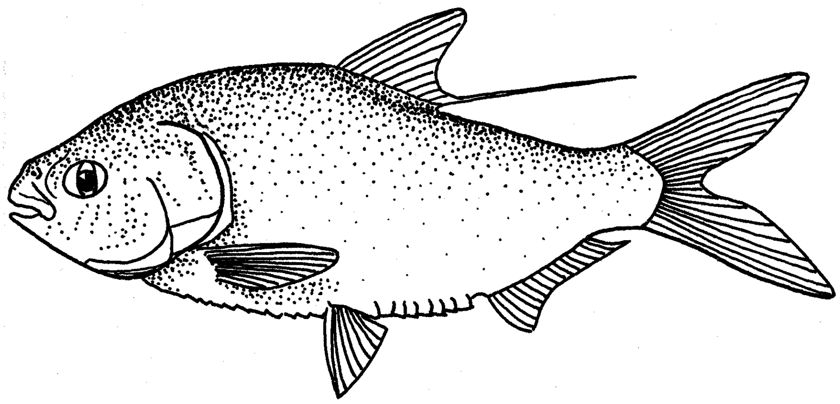
Nourlangie catchment

- lowland shallow backflow billabong; 1978–79 Early-wet season
- lowland channel backflow billabong; 1978–79 Mid-wet season

Family CLUPEIDAE

3.3 *Nematalosa erebi* (Gunther)

Nematalosa erebi is commonly known as the bony bream or freshwater herring. It is found in the Indian Ocean, Timor Sea and Gulf of Carpentaria drainage divisions; in Papua New Guinea, and throughout the Murray–Darling River, Lake Eyre and Bulloo drainage divisions (map 3). Pollard (1974) found this species to be common in a variety of habitats in the Magela Creek system. Miller (cited in Taylor 1964) captured this species in billabongs in the Oenpelli area and on the riverine flood plains of the East Alligator River. Other members of the genus *Nematalosa* generally occur in estuarine or marine environments.



Nematalosa erebi

P. Kailola identified *Hilsa kelee* (Cuvier) (syn. *Macrura brevis* Bleeker) from samples collected during extensive fish sampling by R. Tait (pers comm) in Magela Creek floodplain billabongs; on closer examination of these specimens the authors found them to be juvenile *Nematolosa* rather than *Hilsa.*

Detailed information on catches at each site and in each season is given in volume 2. In summary, *N. erebi* was found commonly in all floodplain, corridor and escarpment mainchannel waterbodies and in some lowland sandy creekbeds; it was also moderately abundant in most backflow billabongs. In the Late-dry season it was found mainly in escarpment mainchannel and in some backflow billabongs; during the Mid-wet and Late-wet–Early-dry seasons it was found mainly in backflow billabongs.

Size composition

The lengths and weights of 677 specimens were determined; only the lengths of a further 168 specimens were determined. The smallest *N. erebi* were caught with 10 mm mesh seine nets and the largest with monofilament gillnets of multiple-sized mesh. All sizes of fish appeared to be effectively sampled; however, the number of large adults may be underestimated, as some specimens were observed to struggle free from the gillnets. Some of the smallest juveniles captured in the seine nets were caught because hydrophytes clogged the net, effectively reducing the mesh size.

Length–weight relationship

The length–weight relationship is described by the expression:

$$W = 1.22 \times 10^{-2} L^{3.12} \qquad r = 1.00 \text{ (length in cm, weight in g)}$$

Seasonal mean length, weight and condition factor are shown in table 7. The condition factor was high during the 1978 Late-dry season, then fell dramatically during the 1978–79 Early-wet season, probably because of spawning activity. It then improved through the Mid-wet season to peak by the Late-wet–Early-dry season; this corresponds to the period of highest estimated rate of growth. The condition factor fell markedly during the Mid-dry season and remained at a stable low level for the remainder of the study. Condition in the 1979 Late-dry season was poorer than that recorded in the 1978 Late-dry season, indicating a difference in the environmental conditions.

Table 7 Mean length, mean weight and condition factor of *N. erebi*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	88	139.9	49.1	1.06
Early-wet (1978–79)	154	110.3	20.4	0.93
Mid-wet	114	76.4	7.0	1.00
Late-wet–Early-dry (1979)	147	124.9	34.7	1.09
Mid-dry	93	144.2	49.8	0.98
Late-dry	73	167.2	77.6	0.96
Early-wet (1979–80)	8	216.6	173.2	0.96
Overall	677	120.2	28.7	1.00

Length-frequency distribution

Specimens ranged in length from 16 mm to 340 mm LCF (fig 6). *N. erebi* is reputed to grow to 400 mm (Pollard 1974). The LFM was estimated to lie between 130 and 140 mm; the overall mean length at capture was 120 mm, indicating that more juveniles than adults were captured. Large numbers of very small juveniles were captured. Peaks in abundance of larger specimens (between 110–160 mm and 240–270 mm) may be due to mesh-size selectivity.

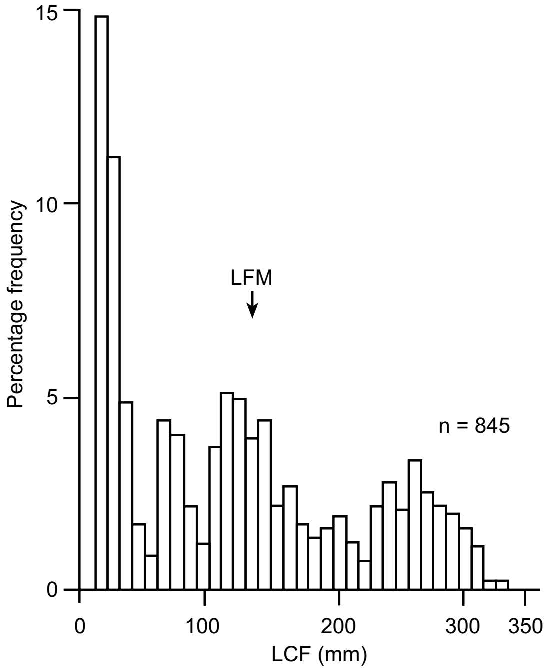


Figure 6 Length-frequency distribution of all *N. erebi* captured

Seasonal changes in distribution

Seasonal length-frequency distributions of all *N. erebi* captured are given in fig 7. The largest number of small juveniles was captured during the 1978–79 Early-wet season, and the second largest in the Mid-wet season. Small numbers were present during the other seasons, except for the 1979–80 Early-wet season when the sample size was small. There were more small juveniles in the 1978 Late-dry than the 1979 Late-dry season. Large adults were caught every season, with the largest being caught in the 1979 Late-dry and 1979–80 Early-wet seasons.

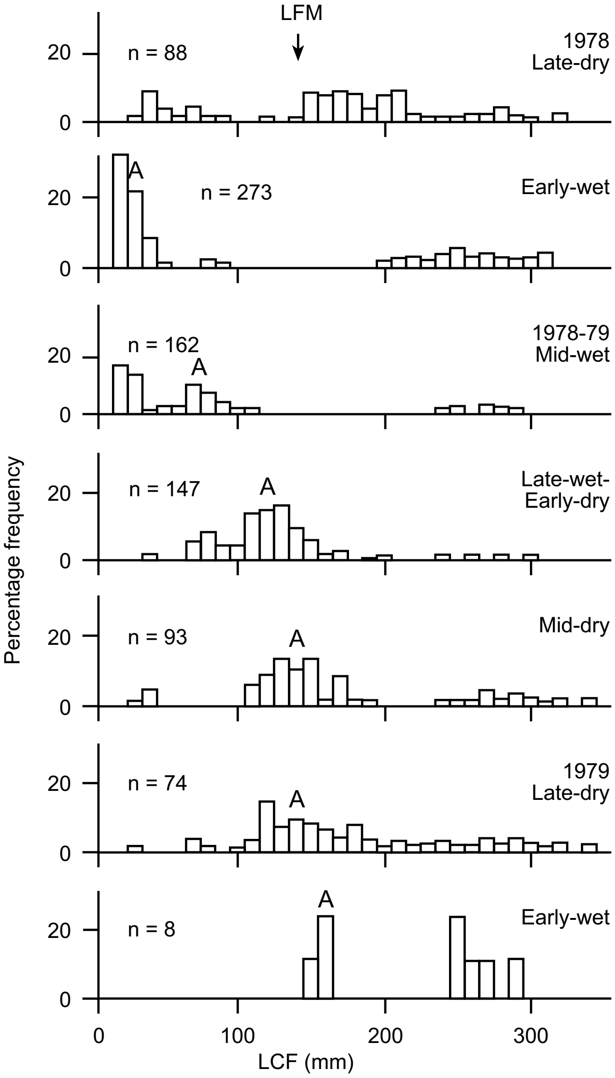


Figure 7 Seasonal length-frequency distribution of all *N. erebi* captured

The seasonal changes in the mean lengths of specimens that were both weighed and measured are shown in table 7. Mean length fell to its lowest between the 1978 Late-dry and the 1978–79 Mid-wet season, when large numbers of juveniles recruited to the populations. After recruitment had eased, mean lengths increased throughout the remainder of the study. The mean length achieved by the 1979 Late-dry and 1979–80 Early-wet seasons was much greater than the previous year, as few juvenile recruits appeared in the population (possibly due to the extreme nature of the 1979 Dry season).

Specimens captured during the 1978 Late-dry season had a nearly continuous size range, with peaks in the numbers of small adults and small juveniles. By the Early-wet season small adults had virtually disappeared, while the number of small juveniles and large adults had increased. The length-frequency distribution in the Mid-wet season was similar to that of the previous season, the only differences being there were fewer large adults and more larger juveniles. By the Late-wet–Early-dry season the number of large juveniles peaked, corresponding to the loss of the small-juvenile component; the large-adult component remained stable. During the 1979 Mid-dry season the large-juvenile component consolidated and remained strong and the large-adult component remained stable; some small juveniles appeared in the population during this season, giving evidence of some breeding activity in the billabongs.

During the 1979 Late-dry season a near-continuous size range of specimens was captured, with a distribution similar to that of the 1978 Late-dry season; however, fewer small juveniles, and more large juveniles than small adults, were captured during the 1979 Late-dry season. In the 1979–80 Early-wet season only eight specimens (small and large adults) were captured.

Growth rate

The growth rate of small juveniles spawned in the 1978–79 Early-wet season can be tentatively followed by examining the progression of this size group (A on fig 7) during the study. They appeared to grow fastest over the Wet season, and some attained 100–130 mm LCF by the Late-wet–Early-dry season (ie in about six months). Growth appeared to slow down in the Dry season, as only a further 30–50 mm increase in length was noted up to the 1979–80 Early-wet season. Yearly growth appeared to be around 140–170 mm LCF, indicating that *N. erebi* may reach sexual maturity in the region during its first year.

Ruello (1976) noted a 40 mm shift (130 to 170 mm) in modal size of this species over two months in Lake Eyre, South Australia.[32]

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *N. erebi* captured in regular sampling sites of the Magela and Nourlangie creek catchments are shown in figure 8.

Magela catchment

The smallest juveniles were most frequently caught in sandy corridor waterbodies, channel backflow billabongs and, less often, in floodplain and corridor anabranch billabongs and sandy creekbeds. Larger juveniles appeared to be dispersed in the lowlands and were most frequently caught in channel and shallow backflow billabongs and sandy creekbeds. Very few juveniles were found upstream of RUPA.

Adults were found in a wide variety of habitats: the smaller ones most often in channel and shallow backflow billabongs and sandy creekbeds and to a lesser extent in sandy corridor waterbodies, and the larger most often in corridor and floodplain billabongs as well as backflow billabongs. Few adults were found upstream of RUPA; only larger specimens were found in escarpment mainchannel waterbodies, and no specimens were seen in, or collected from, escarpment seasonal or perennial streams.

Nourlangie catchment

Length-frequency distributions in the Nourlangie and Magela catchments were markedly different (fig 8); few juveniles and very few small adults were caught in the former.

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[32] Data from Puckeridge and Walker (1990) on the growth of *N. erebi* in the River Murray, South Australia, indicate that total lengths at ages 1, 2 and 3 were ~110, 170 and 265 mm respectively. Median lengths at first maturity were given as 159 and 180 mm respectively for males and females respectively, indicating that the species matures in its second or third year, considerably later than that apparent in the Alligator Rivers Region.

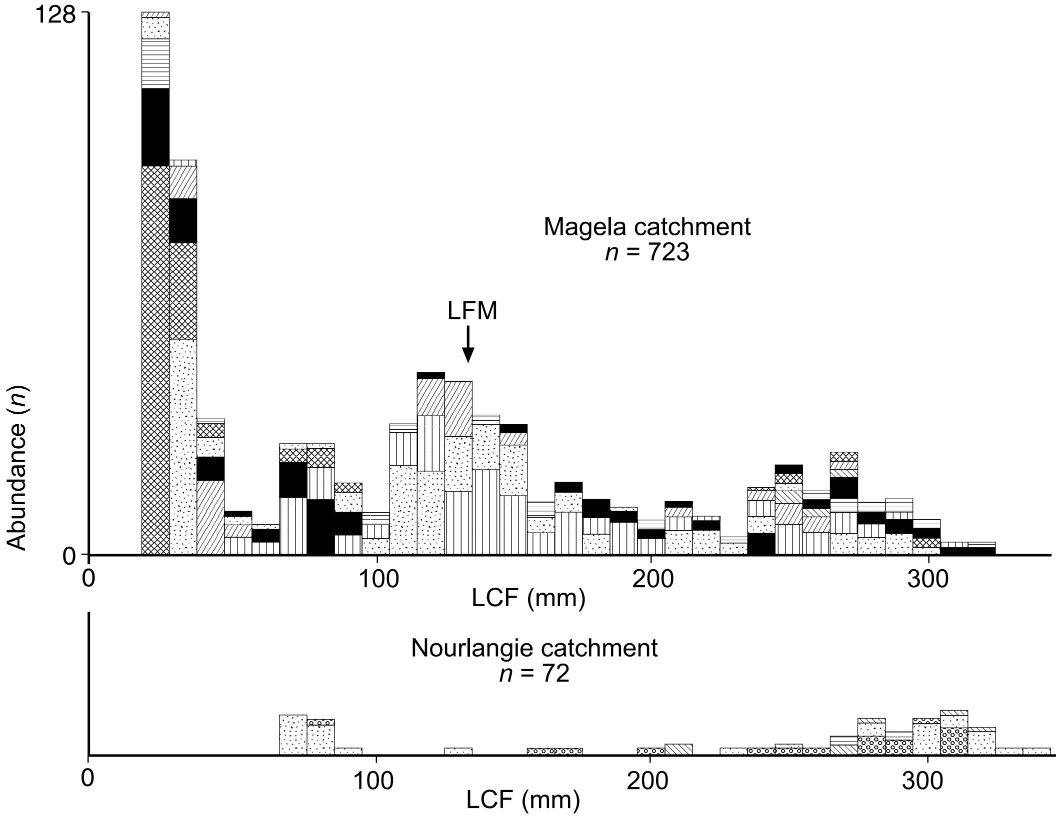

Figure 8 Length-frequency distributions and habitat preferences of *N. erebi* captured at regular sampling sites (see appendix 5 for key to the habitats)

The few juveniles that were caught were found mainly in channel and shallow backflow billabongs; none were found in escarpment habitats.

Small adults were caught mainly in backflow billabongs, while the larger adults were caught mainly in channel backflow and in shallow backflow billabongs. A few large adults were found in escarpment mainchannel waterbodies.

Environmental associations

Rank numbers for *N. erebi* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

The surface temperature range was 23–38°C (mean = 31.0°C); the bottom temperature range was 23–35°C (mean = 28.8°C). Although this species was found at some of the lowest temperatures recorded in the region, it was ranked in the highest and lower-middle quarters for mean surface and bottom temperatures respectively (see fig 170).

Nematalosa erebi is also found in the cooler temperate freshwaters of Australia; however, Lake (1971) noted that rapid drops in water temperature during winter in New South Wales frequently resulted in kills. The species is now rare in the Murrumbidgee and Murray rivers for several hundred kilometres below Burrinjuck and Hume dams, probably because cold hypolimnetic discharges reduce average summer water temperatures (22–24°C) by approximately 6°C.[33]

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[33] Puckeridge and Walker (1990) indicated that *N. erebi* in the River Murray, South Australia, spawn at temperatures 21–23°C, independently of flooding.

Dissolved oxygen

Dissolved oxygen concentrations ranged from 2.7 to 9.7 mg/L (mean = 6.3) in surface waters and from 0.2 to 9.5 mg/L (mean = 3.9) in bottom waters. *Nematalosa erebi* was ranked in the highest and lower-middle quarters for surface and bottom mean DO levels, respectively (see fig 171).

Small numbers of *N. erebi* were observed in a fish kill at Leichhardt Billabong during the 1978–79 Early-wet season when surface DO levels dropped below 0.1 mg/L.[34]

Visibility

Secchi depths ranged from 1 to 360 cm, with a mean of 65 cm (ie this species was found in both the clearest and most turbid waters in the region). *Nematalosa erebi* was ranked in the upper-middle quarter based on mean Secchi depths (see fig 172).

pH

Surface water pH ranged from 5.1 to 8.6 (mean = 6.2) and bottom pH ranged from 4.8 to 6.8 (mean = 5.9) at the capture sites, which placed it into the upper-middle and lower-middle quarters respectively (see fig 173).

Conductivity

Surface and bottom conductivities ranged between 2 and 498 µS/cm and between 6 and 478 µS/cm respectively. Ruello (1976) recorded a large kill of *N. erebi* in Lake Eyre during 1976, which he attributed to high salinity (50–300 ppt); he found *N. erebi* surviving in 39 ppt salinity.

Habitat–structural variables

Substrate

The main substrates over which *N. erebi* was captured were mud and clay, followed by sand. Specimens were also found over gravel and leaf litter substrates, but rarely over rocks and boulders. The ranked positions for mud, clay and sand substrates were upper-middle, highest and lower-middle quarters respectively (see fig 174).

Hydrophytes

Nematalosa erebi was typically found in vegetated waters (vegetation-occurrence index 73.9%). The hydrophyte types amongst which *N. erebi* was captured were submergent (45.4%), floating-attached (25.6%) and emergent forms (24.6%).

Reproduction

The gonads of 565 *N. erebi* were examined: 241 fish were sexually indistinguishable, 167 were females and 157 males.

Length at first maturity

Males and females reached LFM at 130 and 140 mm respectively (fig 9). Briggs (1980) suggests that *N. erebi* probably reaches maturity at about 80 mm LCF, but mature individuals below 130 mm were not found in the present study.

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[34] Herbert and Peeters (1995) noted that *N. erebi* is highly susceptible to low oxygen levels, and is one of the first species to show distress when oxygen levels are reduced. Mortalities in *Nematalosa* have been recorded at the following DO concentrations: 0.2 mg/L (Hogan & Graham 1994), 0.5 mg/L (Townsend et al 1992) and 0.74 mg/L (Bishop 1994).

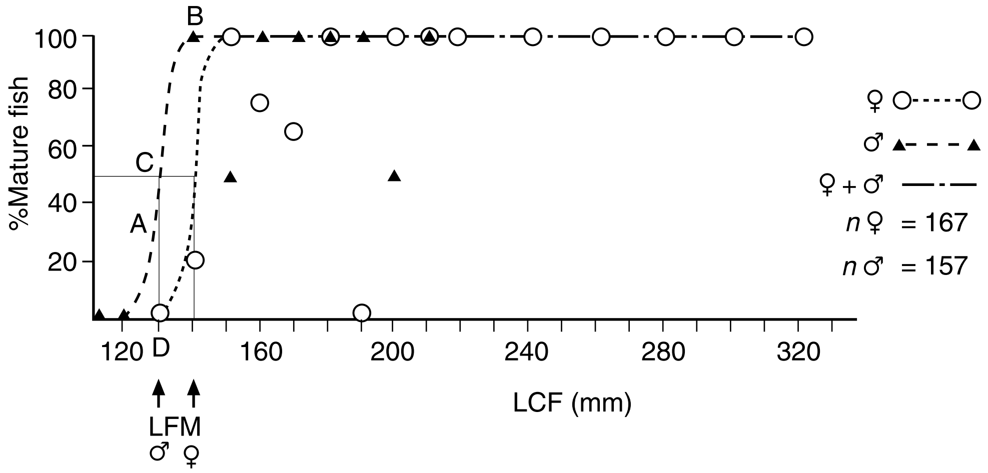

Figure 9 Estimated length at first maturity (LFM) of male and female *N. erebi*

Sex ratio

The sex ratio was 157 males to 167 females, and of these 154 males and 150 females were adults. A chi-squared test was carried out to test the sex ratio at each season on both the entire sample and the adult portion of the sample only (table 8); these ratios were not significantly different from 1:1 in any season.[35]

Breeding season

Nematalosa erebi maintained a relatively high GSI and GMSI throughout the year, with minor and major peaks around the Early-wet seasons of 1978 and 1979 (fig 10; table 8). An analysis of the percentage frequency of occurrence of gonad stages V, VI and VII indicated that some fish were maturing in the 1978 Late-dry season. More ripe fish, together with some spent specimens, were found during the 1978–79 Early-wet season. By the Mid-wet season most of the fish were spent. By the 1979 Mid-dry season both males and females were maturing and 4% of the male fish captured were running-ripe. Spent males were captured in the following Late-dry. Spent females were captured during the 1979 Mid-dry season, although no running ripe females were identified at any time after the 1978–79 Early-wet season. The data indicate that there was no reproductive activity at all in the 1979–80 Early-wet season (although this may have been an artefact of small sample size).

Small juveniles were captured in large numbers only during the 1978–79 Early-wet and 1978–79 Mid-wet seasons. The one juvenile in the 1979 Late-dry season sample was possibly the progeny from some Mid-dry season breeding (table 9).

It appears that *N. erebi* may have reproduced throughout the year but had a peak in reproductive activity during the 1978–79 Early-wet season. *Nematalosa erebi* are aseasonal spawners in Papua New Guinea (Roberts 1978) and the same species breeds in spring–early summer in the Murray–Darling system (Lake 1978; Briggs 1980). These variations may be due to the differences in environmental and physico–chemical conditions.[36]

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[35] This was in contrast to the finding of Puckeridge and Walker (1990) for *N. erebi* in the River Murray, South Australia, that the male:female sex ratio there was 0.86:1.

[36] Herbert and Peeters (1995) indicated that bony bream breed in October to December in the middle of Cape York Peninsula, but stated it is possible that they could breed all year round where temperatures are high enough.

Site of spawning

The habitats in which fish with gonads at stages V to VII (table 10) were captured, and those in which the smallest juveniles were captured (table 9), suggest that *N. erebi* was breeding in the corridor backflow billabongs — this species can breed in still waters such as dams and other isolated waterbodies (Midgley, pers comm; Lake 1978).

Spent fish and juveniles were also caught in corridor waterbodies; however, no ripe fish were caught at these sites. Juvenile fish were also collected in the Magela Creek near Gulungul Billabong in the 1978–79 Early-wet season.

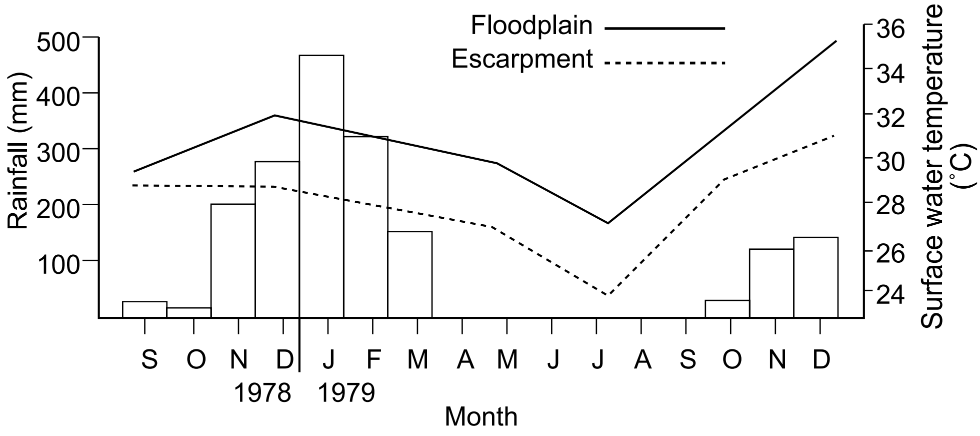
Table 8 Seasonal changes over all habitats in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI), and the percentage frequency of *N. erebi* captured with gonad stages V–VII

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	32	45	8	24	32	23	4
adults	M	*n*	35	41	15	21	24	17	4
		χ^2	0.24	0.19	2.13	0.2	1.4	0.9	0
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	30	45	8	18	28	17	4
	M	*n*	35	41	15	21	23	15	4
		χ^2	0.38	0.19	2.13	0.23	0.49	0.13	0
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	3.1	3.6	1.4	1.7	1.7	1.9	5.4
		s.d.	1.3	2.6	1.0	1.3	1.2	1.2	1.6
	M	mean	1.1	1.8	0.9	0.4	1.9	1.3	3.7
		s.d.	0.9	1.3	0.9	0.3	1.0	0.9	1.9
	F+M	mean	2.1	2.8	1.1	1.1	1.8	1.6	4.6
		s.d.	1.4	1.3	1.0	1.1	1.1	1.1	1.9
GMSI									
Adults only	F	mean	4.3	4.1	2.7	2.8	3.0	2.9	4.0
		s.d.	0.5	0.5	1.3	0.6	0.9	1.1	0.0
	M	mean	4.1	4.5	2.5	2.2	4.0	3.9	4.0
		s.d.	0.7	0.6	0.7	0.8	0.7	1.5	0.0
	F+M	mean	4.2	4.3	2.6	2.5	3.5	3.4	4.0
		s.d	0.6	0.6	0.9	0.7	1.0	1.3	0.0
Gonad stage									
Mature, V	F	%	31	31	13	0	13	9	0
Ripe, VI		%	3	4	0	0	0	0	0
Spent, VII		%	0	7	75	4	3	0	0
		Total *n*	32	45	8	24	32	23	4
Mature, V	M	%	26	32	7	0	42	41	0
Ripe, VI		%	6	10	7	0	4	0	0
Spent, VII		%	0	0	60	10	0	6	0
		Total *n*	35	41	15	21	24	17	4

n = number; χ^2 = Chi-squared value; n.s. = not significant ($P > 0.05$); s.d. = standard deviation.

Table 9 Abundance (*n*) of juvenile *N. erebi* (< 30 mm)

	Sampling period		
Habitat	Early-wet	Mid-wet	Late-dry
20–29 mm juveniles			
Lowland sandy creekbed	6	1	–
Upper floodplain billabong	19	–	–
Corridor billabong	66	42	–
Backflow billabong	21	17	1
10–19 mm juveniles			
Corridor billabong	11	2	–



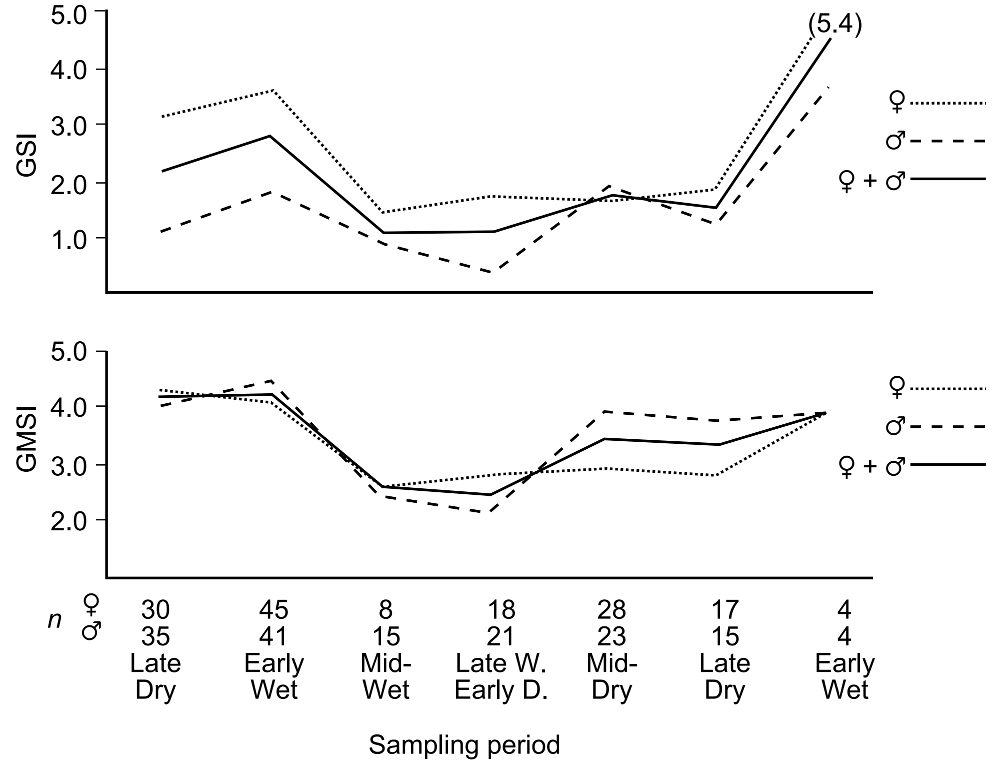


Figure 10 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *N. erebi*

Table 10 Possible sites of spawning of *N. erebi* as indicated by the abundance (*n*) of mature, ripe and spent fish

	Gonad stage					
	Mature (V)		Ripe (VI)		Spent (VII)	
Habitat	F	M	F	M	F	M
Escarpment						
Mainchannel waterbody	3	1	–	–	–	–
Lowlands						
Sandy creekbed	2	1	–	–	–	–
Backflow billabong	20	29	3	6	9	11
Corridor	2	6	–	–	2	3
Floodplain billabong						
Upper	1	2	2	–	–	–
Artificial	3	–	–	–	–	–

Fecundity

Examination of three ovaries of *N. erebi* indicated fecundities of 80 000, 85 500 and 230 000 (mean = 132 000).[37] Mean diameters of oocytes in two ovaries were 0.43 ± 0.04 mm and 0.41 ± 0.05 mm. These results confirm an observation (Briggs 1980) that *N. erebi* had a very high fecundity and very small eggs.

Summary

Nematalosa erebi first matures around 130–140 mm, possibly at one year old, and shows a peak of reproductive development around the Early-wet season. The sex ratio was 1:1 throughout all seasons. The fish spawns many thousands of tiny eggs, probably in backflow billabongs and possibly also in corridor waterbodies. Many species of Clupeidae spawn in large aggregations (Lake 1971).

Feeding habits

Overall diet

The stomach contents of 493 specimens were examined; 471 stomachs contained food. The diet of *N. erebi* is summarised in figure 11; the dietary components are listed in table 11. The main dietary components were algae (37%), detritus (38%) and microcrustaceans (4%).[38] The identifiable algal component consisted mainly of planktonic-sized taxa such as Desmidaceae and Dinophyceae. Microcrustaceans (mainly cladocerans) were frequently eaten by juvenile *N. erebi*. Aquatic insects, inorganic material and traces of *Hydracarina* and terrestrial plant material were also found in the stomachs of various-sized specimens. *Nematalosa erebi* can therefore be classified as a microphagic omnivore. The smaller fish were the most omnivorous, while the larger fish were mainly detritivorous and planktivorous (mainly phytoplankton).

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[37] Puckeridge and Walker (1990) presented a range of relationships between fecundity and body-size variables for *N. erebi* in the River Murray, South Australia. They indicated that fecundity ranged from 33 000 for a fish of 199 mm TL (body weight 88.9 g) to 880 000 for a fish of 403 mm TL (595.4 g). Puckeridge and Walker also described egg and larval development.

[38] Pusey et al (1995b) found *N. erebi* to primarily consume detritus in two rivers of the Australian wet tropics, northeastern Queensland. Smith (1998) indicated that the two closely-related species *N. papuensis* and *N. flyensis* in the Fly River system of Papua New Guinea appear to be largely planktonivorous, never grazing over bottom substrates. Hydro-acoustic sampling had demonstrated that these species form large schools that are present throughout the water column at all times of the day.

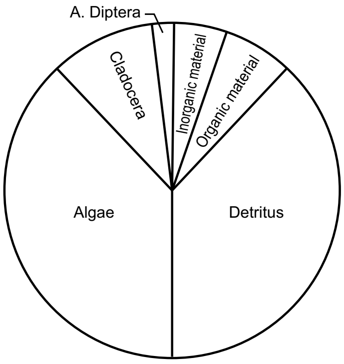


Figure 11 The main components of the diet of *N. erebi*

From the few specimens he examined, Pollard (1974) noted that *N. erebi* ate predominantly detritus and mud (ie it was iliophagous). It was also known to eat algae, other aquatic plants and sometimes small insects. The diet of specimens collected during the present study appeared to have a larger algal component than that noted by Pollard.

Seasonal changes

In sampling periods 1–7 respectively, 80 (0% empty), 100 (13% empty), 82 (4% empty), 93 (0% empty), 73 (5% empty), 57 (4% empty) and 8 (0% empty) stomachs of *N. erebi* were examined (all habitats combined). The proportion of specimens with empty stomachs was generally low—the highest proportion was in the 1978–79 Early-wet season.

The diet in the 1978 Late-dry season was based primarily on detritus with a large, unidentified component of organic material. A large microcrustacean component appeared in the diet during the 1978–79 Early-wet season when many small fish were captured. This component was very small for the remainder of the study, except in the 1979 Mid-dry season, because *N. erebi* was feeding extensively on other planktonic forms.

The algal component of the diet increased in importance from the 1978–79 Mid-wet. During the Late-wet–Early-dry season, it peaked and then gradually decreased to its lowest point in the few specimens examined in the 1979–80 Early-wet season. The levels of algae recorded in the stomach contents during the 1979 Late-dry and 1979–80 Early-wet seasons were much higher than in the previous year.

The detrital component of the diet was large throughout most of the study. However, during the Late-wet–Early-dry it dropped dramatically and remained at a low level, increasing after the 1979 Mid-dry. The decrease in the detrital component may have resulted from anoxic conditions at the bottom, ie *N. erebi* filter-fed on phytoplankton from the mid-water zone of the billabongs rather than entering anoxic bottom waters to feed on the substrate.

Habitat differences

Magela catchment

The totals of stomachs of *N. erebi* examined (all seasons combined) were: 7 (0% empty) from the Magela Creek catchment escarpment mainchannel waterbodies; 32 (0% empty) from lowland sandy creekbeds; 239 (5% empty) from backflow billabongs; 91 (7% empty) from corridor waterbodies and 51 (2% empty) from floodplain billabongs. Generally, few specimens had empty stomachs; however, slightly more fish with empty stomachs were found in corridor and backflow billabongs.

Table 11 Dietary composition of *N. erebi*

	Habitat							Season								
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																
Algae																36.5
Miscellaneous	71.4	22.2	23.2	12.7	6.4	24.0	60.7	3.0	–	–	28.0	58.8	45.5	37.5	20.6	
Desmidaceae	–	–	8.3	17.5	4.0	–	–	–	2.3	19.0	18.2	4.6	–	–	7.9	
Dinophyceae	–	2.8	14.3	–	2.0	–	3.6	–	–	–	35.1	3.9	–	–	7.5	
Conjugatophyta																
Mougeotia	–	–	+	2.8	–	–	–	–	1.2	1.8	–	–	–	–	0.5	
Aquatic animals																
Arachnida																0.2
Hydracarina	–	–	–	1.2	–	–	–	–	–	1.3	–	–	–	–	0.2	
Microcrustacea																11.0
Fragmented	–	–	0.4	–	–	–	–	–	1.2	–	–	–	–	–	0.2	
Conchostraca																
Cyzicus	–	–		0.7	–	–	–	–	–	0.8	–	–	–	–	0.1	
Cladocera																
Miscellaneous	–	–	3.2	0.9	0.4	–	–	1.3	0.9	–	1.1	9.0	0.4	–	2.0	
Diaphanosoma	–	37.5	2.8	17.9	11.9	–	–	–	45.3	–	–	–	–	–	8.4	
Ostracoda	–	0.9	–	1.1	–	–	–	–	–	1.5	–	–	–	–	0.3	
Copepoda																
Cyclops	–	–	–	0.2	–	–	–	–	0.1	–	–	–	–	–	+	

Table 11 continued

	Habitat							Season								
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Insecta																2.2
Ephemeroptera																
Baetidae	–	–	–	–	0.8	–	–	–	0.3	–	–	–	0.7	–	0.2	
Hemiptera																
Corixidae	–	–	0.1	–	–	–	–	0.3	–	–	–	–	–	–	+	
Diptera																
Chironomidae (larvae)	–	2.2	0.9	5.5	–	–	–	–	5.3	3.0	–	0.3	1.8	–	1.7	
Ceratopogonidae (larvae)	–	–	–	1.7	–	–	–	–	–	1.8	–	–	–	–	0.3	
Terrestrial plants																+
Miscellaneous seeds	–	–	+	–	–	–	–	–	0.1	–	–	–	–	–	+	
Parasites																
Nematoda	–	–	+	3.8	0.1	–	–	–	3.6	0.3	–	–	–	–	0.7	0.7
Detrital material	17.9	18.9	37.7	23.9	49.9	15.0	32.1	63.5	28.5	63.8	14.5	11.3	44.6	59.4	37.5	37.5
Inorganic material	10.7	15.2	3.2	2.8	0.9	60.0	–	11.0	1.2	2.5	3.3	3.0	7.1	3.1	4.5	4.5
Organic material	–	–	5.4	5.9	23.4	–	3.6	21.0	10.1	2.5	–	9.1	–	–	7.2	7.2
Number of empty fish	–	–	12	6	1	–	3	–	13	3	–	4	2		22	22
Number of fish with food	7	32	227	85	50	5	28	80	87	79	93	69	55	8	471	471

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creekbed; Bb = lowland backflow billabong; Cb = corridor billabong; Fb = floodplain billabong

In escarpment mainchannel waterbodies, the fish ate mainly algae, together with detritus and incidental organic material. The algae contained large numbers of diatoms (mainly *Melesira granulata*, *Pinnularia* and *Eunotia* [D. Thomas, pers comm]), which were possibly present as a sludge over sandy substrates in these habitats. *N. erebi* was frequently observed 'pecking' at the sand substrate and then spitting out the sand it had incidentally ingested.

The diet in the lowland sandy creekbeds consisted of smaller proportions of algae and detritus and a large component of microcrustaceans (mainly the cladoceran *Diaphanosoma*). This finding reflected the high proportion of juvenile fish, which frequently ate microcrustaceans, collected at this habitat. In the backflow billabongs fairly equal proportions of algae and detritus were eaten, and only a few cladocerans. The algae were mainly desmids (genera included *Micrasterias, Xanthidium, Staurastrum, Phymatodocis* and *Cosmarium*). One specimen captured in Gulungul Billabong in the Mid-wet season had 90 different forms of desmids in its stomach (H. Ling, pers comm), including dinoflagellates (mainly *Peridinium*), euglenophytes (*Euglena, Trachelomonas* and *Phacus*), chrysophytes (*Volvox, Dimorphococcus lunatis*), and cyanophytes (*Spirulina* and *Microcystis*).

In the corridor waterbodies there was a larger cladoceran component in the diet which, however, still had algal and detrital components. The algal component was mainly made up of desmids (*Staurastrum*) and diatoms (mainly *Melosira, Eunotia, Pinnularia, Cymbella* and *Cyclotella* [D. Thomas, pers comm]), and traces of dinoflagellates (*Peridinium*), chlorophytes (*Tetraedrom, Scenedesmus, Mougetia*) and euglenophytes (*Trachelomonas* and *Phacus*).

The diets in the floodplain billabongs and in the lowland backflow billabongs were similar: large quantities of algae (mainly phytoplankton) and detritus.

Nourlangie catchment

Totals of 5 (0% empty) and 31 (10% empty) stomachs of *N. erebi* were examined (all seasons combined) from escarpment mainchannel waterbodies and backflow billabongs, respectively, in the Nourlangie Creek catchment.

The diet in the escarpment mainchannel waterbodies consisted of algae (mainly diatoms) and detritus, with a large inorganic material component. In the backflow billabongs the diet was primarily algae and, to a lesser extent, detritus. The algae included dinoflagellates (*Peridinium*), desmids (*Closterium, Desmidium swartzi* and *Phymatodocis*) and euglenophytes (*Trachelomonas oblongata* var. *australica*). The diet in the backflow billabongs was thus similar to that observed in the equivalent habitats of the Magela catchment.

Fullness

Mean fullness indices of *N. erebi* for different sampling periods and habitat types are shown in table 12. The data are presented on the assumption that feeding times within the day do not vary with habitat or season.

Seasonal changes

The mean fullness indices (all habitats combined) peaked in the 1978–79 Mid-wet season and then fell to lower levels in all subsequent seasons.

Habitat differences

In the Magela catchment the highest mean fullness indices were recorded in habitats with sandy substrates — escarpment mainchannel waterbodies, corridor waterbodies and lowland sandy creekbeds. The lowest indices were recorded in the shallow backflow billabongs and the floodplain billabongs.

In the Nourlangie catchment, specimens from escarpment mainchannel waterbodies had the highest fullness indices.

Table 12 Mean fullness indices of *N. erebi* in different sampling periods and habitats

	Sampling period							
Habitat	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	4 (1)	n/s	n/s	n/s	n/s	3.5 (2)	4.0 (4)	3.9 (7)
Downstream of RUPA:								
Lowland sandy creekbeds	n/s	2.8 (16)	1.0 (1)	3.5 (4)	3.6 (9)	3.0 (3)	n/s	3.0 (33)
Lowland channel backflow billabong	3.3 (8)	2.1 (13)	2.8 (20)	2.6 (27)	2.8 (19)	1.6 (12)	1.0 (1)	2.5 (100)
Lowland shallow backflow billabong	2.4 (14)	1.7 (12)	2.6 (24)	2.3 (46)	2.0 (29)	1.2 (14)	n/s	2.1 (139)
Corridor sandy billabong	n/s	2.5 (28)	2.5 (16)	3.6 (2)	3.3 (3)	2.5 (2)	n/s	3.6 (51)
Corridor anabranch billabong	4 (1)	0 (1)	n/s	3.3 (3)	3.0 (2)	3.2 (5)	n/s	3.0 (12)
Floodplain billabong	1.9 (13)	1.7 (26)	3.1 (17)	4 (1)	1.4 (8)	2.4 (14)	n/s	2.1 (79)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	3.2 (5)	n/s	n/s	n/s	n/s	n/s	n/s	3.2 (5)
Lowland channel backflow billabong	1.5 (4)	n/s	1.5 (2)	1.6 (11)	0.7 (3)	2.2 (5)	n/s	1.6 (25)
Lowland shallow backflow billabong	3.5 (2)	2.7 (3)	n/s	3 (1)	n/s	n/s	n/s	3.1 (6)
Seasonal mean (all sites)	2.5	2.2	2.7	2.4	2.4	2.0	2.0	

Numbers examined are given in parentheses; n/s = not sampled in the habitat

Summary

The habitats and periods of greatest apparent feeding activity where more than one fish was captured were:

Magela catchment

- escarpment mainchannel waterbody; 1979–80 Early-wet season
- lowland sandy creekbeds; 1979 Mid-dry season
- corridor sandy billabong; 1979 Late-wet–Early-dry season

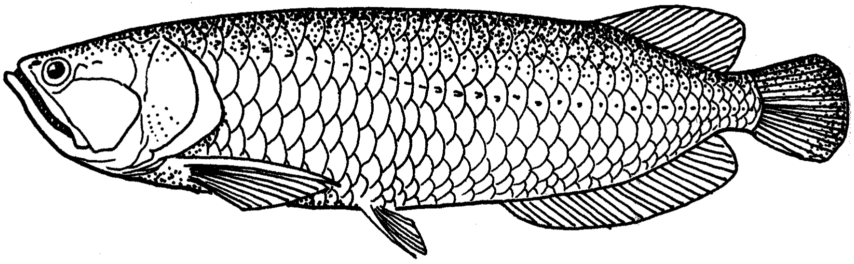
Nourlangie catchment

- lowland shallow backflow billabong; 1978 Late-dry season
- escarpment mainchannel waterbody; 1978 Late-dry season

Family OSTEOGLOSSIDAE

3.4 *Scleropages jardinii* (Saville-Kent)

Scleropages jardinii, commonly known as the northern spotted barramundi or saratoga, is a primary division or true freshwater fish (Darlington 1957) belonging to a family that dates back to Eocene times (50 million years BP). Several genera of this group occur in the Indo-Malayan area, Brazil and in the Nile. It had previously been regarded as a subspecies of *S. leichardti* (Castelnau) which is found in the Fitzroy River system in eastern Queensland.



Scleropages jardinii

Scleropages jardinii is found in the Gulf of Carpentaria and Timor Sea drainage divisions (see map 3).[39] Pollard (1974) found this species in still-water billabongs and larger waterholes, and occasionally in the main channels of rivers in the Alligator Rivers Region. It appeared to be more plentiful in upstream areas of clean water in escarpment country bordering the Arnhem Land Plateau, where it lurks by day under overhanging vegetation and other cover. This species was not captured during Miller's survey in the Oenpelli area (Taylor 1964). It is also found in some southward-flowing rivers in Papua New Guinea.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was collected (but rarely) in all escarpment perennial streams and mainchannel waterbodies, corridor waterbodies, some floodplain billabongs, backflow billabongs and lowland sandy creekbeds.

Size composition

Length–weight relationship

The lengths and weights of 16 specimens were determined. The length–weight relationship was described by the expression:[40]

$$W = 0.21 \times 10^{-2} L^{3.40} \qquad r = 0.99 \text{ (length in cm, weight in g)}$$

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[39] Herbert and Peeters (1995) and Herbert et al (1995) indicated they are also found within some eastern-flowing Cape York Peninsula streams (Olive River and Harmer Creek) within the north-east coastal division.

[40] Length-weight relationships given by Merrick et al (1983) for *S. jardinii* and the closely related *S. leichardti* were as follows (W= weight in g; L= total length in mm):

S. jardinii:

Females: $W = 3.357 \times 10^{-6} \times L^{3.175}$

Males: $W = 3.133 \times 10^{-6} \times L^{3.175}$

S. leichardti:

Females: $W = 5.649 \times 10^{-7} \times L^{3.432}$

Males: $W = 5.272 \times 10^{-6} \times L^{3.432}$

Seasonal mean lengths, weights and condition factors are shown in table 13. As the sample size was small, little can be said about seasonal changes in condition factors other than that the highest was recorded late in the 1978 Late-dry season and the lowest in the 1979–80 Early-wet season. (See table 14 for data on individual fish.)

Table 13 Mean length, mean weight and condition factor of *S. jardinii*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	6	507.0	1382.2	1.08
Mid-wet (1978–79)	1	380.9	429.8	0.89
Late-wet–Early-dry (1979)	2	323.9	283.8	1.02
Mid-dry	4	444.1	772.3	0.95
Late-dry	2	485.0	1096.5	1.00
Early-wet (1979–80)	1	515.2	1164.9	0.86
Overall	16	453.5	876.2	1.00

Length-frequency distribution

Specimens ranged in length from 198 mm to 690 mm TL (fig 12). Lake (1971) reported that both *S. jardinii* and the closely related *S. leichardti* grow to around 900 mm.

The smallest specimen was captured by seine net in the Late-wet–Early-dry season. The largest specimens were captured by gillnet (150 mm mesh) in the Mid-dry. Specimens up to 800 mm in length were observed in escarpment mainchannel waterbodies and perennial streams; such specimens may have struggled free from enmeshing gillnets in the lower reaches.

Most fish captured were either 420 to 440 mm or 500 to 530 mm in length. If *S. jardinii* matures sexually at around the same size as *S. leichardti* (ie 560 mm, Lake & Midgley 1970b), then most of the specimens captured in the study were large juveniles.

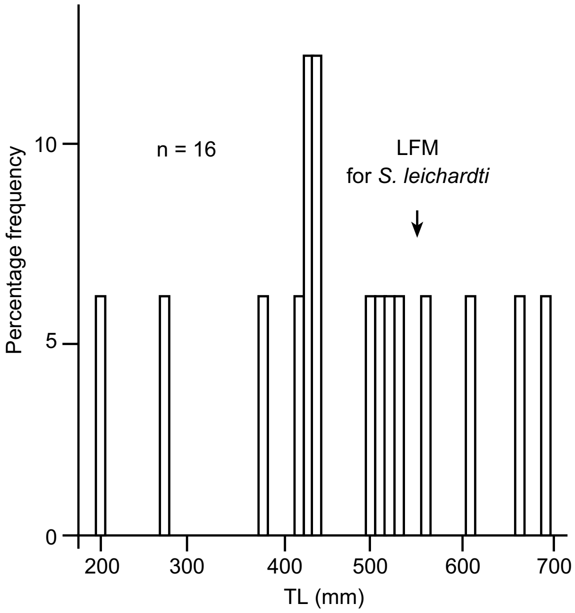

Figure 12 Length-frequency distribution of all *S. jardinii* captured

Seasonal changes in distribution

The smallest specimen was captured in the Late-wet–Early-dry season; the second smallest specimen and the largest specimen were both captured in the Mid-dry season.

Growth rate

No estimate of the growth rate of *S. jardinii* could be made, as only 16 fish were captured during the study. There is no published information on its growth rate, but the closely related *S. leichardti* grows to 270, 430 and 560 mm TL at one, two and three years old respectively (Lake & Midgley 1970a).

Habitat differences in distribution

In the Magela catchment the few small juveniles captured were found in lowland shallow billabongs. Larger juveniles were found in escarpment mainchannel waterbodies and perennial streams, and corridor and floodplain billabongs. Adults were captured only in floodplain billabongs but were observed in escarpment mainchannel waterbodies and perennial streams.

In the Nourlangie catchment the few specimens that were captured were in escarpment habitats. Juveniles and adults of all sizes were frequently seen in escarpment mainchannel waterbodies.

Environmental associations

Rank numbers for *S. jardinii* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

This species was captured in waters with surface temperatures from 23° to 33°C (mean = 28.2°C) and bottom temperatures from 23° to 31°C (mean = 27.3°C). It was placed at the base of the lowest quarter for both surface and bottom temperatures (see fig 170).

Scleropages jardinii is reported to require temperatures above 15°C for survival, and temperature may be a limiting factor in its distribution (Pollard 1974). *Scleropages leichardti* tolerates lower temperatures (range 7–40°C, Lake 1971).[41]

Scleropages leichardti spawns only above 23°C (Lake & Midgley 1970b). As this was the lowest temperature recorded in the Alligator Rivers Region, the temperature at which *S. jardinii* spawns may be somewhat higher.

Dissolved oxygen

Dissolved oxygen concentrations in waters in which this species was captured ranged from 3.0 to 6.8 mg/L (mean = 5.8) for surface waters and from 1.7 to 6.8 mg/L (mean = 3.8) for bottom waters. *Scleropages jardinii* was placed in the lower-middle quarter for both means (see fig 171).[42]

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[41] Merrick and Green (1982) indicated that as surface water temperatures reach 31°C, *S. leichardti* cease cruising on the surface and remain in deeper cooler areas.

[42] Merrick and Schmida (1984) indicated that *S. jardinii* was a suspected facultative air breather. However, Wells et al (1997) stated, without citations, that *S. jardinii* is not an air breather. Wells et al showed that the saratoga has fewer erythrocytes, lower haemoglobin concentration and hence lower oxygen carrying capacity, and higher blood oxygen affinity than either the facultative air breathing tarpon, or the obligate water breathing silver barramundi (*Lates calcarifer*). Herbert and Peeters (1995) indicated that northern saratoga are tolerant of low oxygen levels and are suspected to use their swim bladders as auxiliary lungs.

Lake and Midgley (1970b) noted that, under conditions of thermal stratification and oxygen depletion in the Dawson River, Queensland, *S. leichardti* remained in the top one metre of water and could be seen just under or breaking the surface to obtain oxygen.

Visibility

Secchi depths recorded at sites in which this species was captured ranged from 4 to 360 cm (mean = 130 cm). *Scleropages jardinii* was therefore ranked in the highest (greatest visibility) quarter (see fig 172). Lake (1971) noted that the closely related *S. leichardti* can also tolerate highly turbid waters with Secchi depths as low as 3.8 cm.[43]

pH

At sites where *S. jardinii* were observed or collected, the pH of surface waters ranged from 4.1 to 6.8 (mean = 5.9), and that of bottom waters from 4.5 to 6.5 (mean = 5.8). The species was placed in the lowest quarter for both waters (see fig 173).

Conductivity

Conductivities at sites where *S. jardinii* were captured were generally very low: from 6 to 80 µS/cm for surface waters and from 6 to 58 µS/cm for bottom waters.

Scleropages jardinii is a primary division freshwater fish. It has not been tested for salinity tolerance. The only osteoglossid that has been tested is the South-East Asian species *Scleropages formosus* (Muller & Schlegel); Roberts (1978) concluded that it may be more tolerant of salinity than might be expected for a primary division freshwater fish.

Habitat–structural variables

Substrate

Scleropages jardinii was found most frequently over sandy substrates, followed by boulders/bedrock, rocks, clay and mud. The ranked positions for this species for sand, boulders and rocks were the highest quarters; for clay the lower-middle; for mud the lowest quarter (see fig 174). Lake (1971) reported that *S. jardinii* was frequently captured over clay substrates.

Hydrophytes

Scleropages jardinii was typically found in vegetated habitats (vegetation-occurrence index 62.2%).[44] The main hydrophyte types were submergent (44.7%) and floating-attached forms (28.9%). Lake (1971) records that this species was most frequently caught in billabongs with abundant water lilies.

Reproduction

Of the 16 fish captured, one (265 mm TL) was not dissected. Of the others, 7 were female (420–560 mm TL), 3 were male (440–660 mm TL) and 5 were sexually indistinguishable (198–690 mm TL). Table 14 gives the site and season of capture, and the length, weight and reproductive condition of these 16 fish.

Length at first maturity

The small number of fish captured did not provide enough information to estimate the LFM; however, the smallest maturing fish captured was 435 mm TL. *Scleropages leichardti* can spawn at three years of age (about 560 mm) in the Fitzroy River system, but most do not spawn until four years old (Lake & Midgley 1970b).

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[43] Higher turbidity for *S. leichardti* was considered desirable by Merrick and Green (1982) as it was considered to enable individuals to move into preferred cooler areas at depths unlikely to become deficient in oxygen.

[44] Allen (1991) indicated that *S. jardinii* is frequently seen near the surface or near shore among aquatic vegetation in Papua New Guinea.

Table 14 Site and season of capture, and length, weight and reproductive condition of *S. jardinii*

Sampling period	Site	TL (mm)	Wt (g)	Gonad stage	Gonad wt (g)	GSI
Females						
Late-dry 1978	Corridor billabong	435	785	IV	–	–
"	Corridor billabong	510	1550	V	46.6	2.98
Mid-wet 1978–79	Sandy creekbed	515	1165	III	9.0	0.78
Late-wet 1978–79	Corridor billabong	530	1550	IV	10.8	0.70
Mid-dry 1979	Floodplain billabong	495	1130	III	5.2	0.46
Late-dry 1979	Mainchannel waterbody	420	633	III	3.8	0.61
"	Floodplain billabong	560	1900	IV	70.3	3.70
Males						
Late-dry 1978	Corridor billabong	610	2100	II	0.8	0.04
"	Mainchannel waterbody	440	800	IV	10.1	1.26
"	Perennial stream	660	3900	II	0.9	0.02
Reference collection						
Mid-dry 1979	Backflow billabong	265	140			
Juveniles						
Late-dry 1978	Perennial stream	432	875	I	0.5	0.6
Mid-wet 1978–79	Mainchannel waterbody	381	430	I	–	–
Late-wet 1978–79	Backflow billabong	198	52	I	0.001	0.02
Mid-dry 1979	Corridor billabong	430	750	I	0.14	0.19
"	Corridor billabong	690	3000	I	0.4	0.13

Sex ratio

Seven females were captured from seven sites over five seasons, while three males were captured from three sites in one season (1978 Late-dry). There may be more females present in the population in all seasons; however, the sample is too small to draw conclusions.

Breeding season

Sexually maturing fish were captured during the 1978 and 1979 Late-dry and the 1979 Late-wet–Early-dry seasons. The GSI values suggested an error in the gonad staging of the Late-wet–Early-dry season specimen. Although the data are sparse, they indicate that spawning may have occurred during the Early-wet season (when no fish were captured).

Midgley (pers comm) states that *S. jardinii* breeds from October to November.[45] *Scleropages leichardti* breeds in spring when temperatures rise above 23°C (Lake & Midgley 1970b; Lake 1971).

Site of spawning

As no ripe or spent fish, or females incubating eggs in their mouths, were captured, no spawning site could be identified; however, maturing fish were found in corridor and floodplain billabongs and in an escarpment mainchannel waterbody. Lake and Midgley (1970b) found that *S. leichardti* can breed in small, shallow, turbid pools as well as in rivers.

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[45] Herbert and Peeters (1995) indicated the breeding season extends from September to November.

Fecundity

Scleropages jardinii has a single, naked ovary with eggs generally developing on the left side of the body cavity. A preserved ovary examined contained two size-classes of eggs with mean diameters of 8.4 ± 0.3 mm ($n = 90$) and 1.7 ± 0.78 mm ($n = 10$). Ten eggs from a fresh ovary were measured; the mean diameter was 10.5 mm. The mature ova of *S. leichardti* have a similar mean diameter (10 mm) and fecundity (range 75 to 173) (Lake & Midgley 1970b).[46]

Summary

The data, although sparse, indicate that *S. jardinii* and *S. leichardti* have similar reproductive strategies. *Scleropages jardinii* may spawn in the Early-wet season, most likely in corridor and floodplain billabongs and escarpment mainchannel waterbodies. A small number of large eggs develop in the single, naked ovary and the female carries the eggs and larvae in her mouth until absorption of the yolk sac (Sanderson, pers comm). The eggs of *S. leichardti* take an estimated 10–14 days to hatch at water temperatures between 23 and 30°C; the larvae are well developed at hatching and average 36 mm total length. No external sexual dimorphism is evident, although mature males have been found with fine scratch marks over the operculars and along the sides of the body. Lake and Midgley (1970b) suggested that these scratches were inflicted by teeth during the spawning period; scratches have been observed around the vent area of the body of females (about two years old) .

Feeding habits

The stomach contents of 14 specimens were examined; all stomachs contained food. A summary of the overall diet of *S. jardinii* is given in fig 13; the components are detailed in table 15.

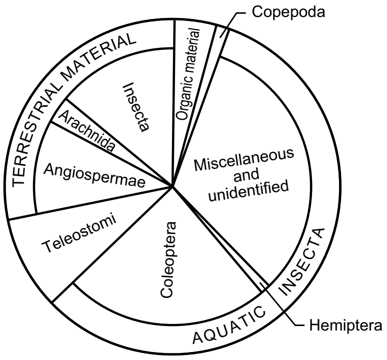

Figure 13 The main components of the diet of *S. jardinii*

The main dietary items were aquatic insects (54%), terrestrial insects (12%), terrestrial plant material (10%) and teleosts (9%).[47] The identifiable aquatic insects were mainly *Macrogyrus* coleopteran adults. The identifiable terrestrial insects also were mainly coleopterans, with traces of zygopteran adults. The terrestrial plant material may have been eaten incidentally when *S. jardinii* was preying upon forage species. The main identifiable teleost was

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[46] Herbert and Peeters (1995) indicated that female *S. jardinii* incubate 30–130 fertilised eggs in their mouths for one to two weeks. Newly hatched larvae continue to reside in or around the mouth for a further four to five weeks.

[47] Smith (1998) indicated that in the Fly River system of Papua New Guinea, *S. jardinii* primarily consumed terrestrial insects, fish, aquatic insects, detritus/mud, and crustaceans in that order. Other vertebrates, aquatic and terrestrial plants and worms were also consumed.

N. hyrtlii. Traces of *Macrobrachium* and terrestrial arachnids were also found in the stomachs. *Scleropages jardinii* can therefore be classified as a macrophagous carnivore/insectivore that feeds opportunistically in mid- and surface waters.

Pollard (1974) noted that this species was predatory, mainly feeding on crustaceans, smaller fishes and frogs, but also to some extent on insects; he appears to have underestimated the importance of insects in the diet. Lake (1978) considered this species ate more fish and crustaceans than the spotted barramundi (*S. leichardti*) of eastern Queensland.

Table 15 Dietary composition of *S. jardinii*

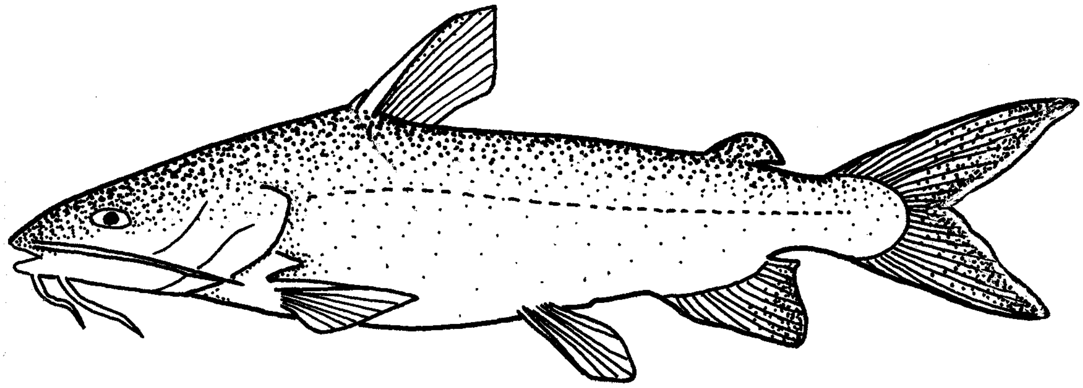
Stomach contents	% Composition	
	Sub-mean	Main-mean
Aquatic animals		
Macrocrustacea		1.4
Macrobrachium	1.4	
Insecta		53.5
Fragmented	30.0	
Hemiptera		
Naucoridae	1.4	
Coleoptera		
Fragmented	2.1	
Macrogyrus	20.0	
Teleostomi		8.9
Fragmented	1.4	
Fish scales	0.4	
N. hyrtlii	7.1	
Terrestrial plants		
Angiospermae		9.7
Fragmented	9.7	
Terrestrial animals		
Arachnida		2.9
Fragmented	2.9	
Insecta		11.7
Fragmented	7.1	
Odonata		
Zygopteran (adults)	+	
Coleoptera		
Fragmented	4.6	
Parasites		
Nematoda	8.2	8.2
Organic material	3.6	3.6
Number of empty fish	–	–
Number of fish with food	14	14

Figures represent the mean percentage volume determined by the estimated volumetric method

Family ARIIDAE[48]

3.5 *Arius leptaspis* (Bleeker)

Arius leptaspis is commonly known as the lesser salmon catfish or fork-tailed catfish. It (or closely related species) is found in coastal drainages of northern Australia from northern New South Wales through Queensland and the Northern Territory to the far west of Western Australia. Pollard (1974) found this species in floodplain and channel backflow billabongs of the Alligator Rivers Region. It is also found in Papua New Guinea.



Arius leptaspis

Arius leptaspis belongs to a predominantly marine family of catfishes, members of which are often caught in brackish waters, especially in river estuaries.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was common to moderately abundant in all floodplain and corridor waterbodies and in most backflow billabongs; it was found only occasionally in escarpment mainchannel waterbodies and lowland sandy creekbeds. It was found in the greatest number of sites in the 1978 Late-dry season (mainly floodplain and corridor waterbodies and escarpment mainchannel billabongs), and was found least often in the Mid-wet (lowland sandy creekbeds and backflow billabongs) and the Late-wet–Early-dry seasons.

Size composition

The lengths and weights of 740 specimens were determined. Most specimens were captured in gillnets, so the number of adults may be underestimated, as larger specimens could have struggled free of the nets. Some of the peaks in the length-frequency distribution may be due to mesh selectivity.

Length–weight relationship

The length–weight relationship was described by the expression:

$W = 1.46 \times 10^{-2} L^{3.1}$ $r = 0.98$ (length in cm, weight in g)

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[48] An additional species of ariid catfish, the shovel-nosed catfish (*Arius midgleyi*), was recorded in the region in May 1988.

Tait (1979) found that the length–weight equations for males and females captured in Magela Creek floodplain habitats were not significantly different.

Seasonal mean lengths, weights and condition factors are shown in table 16. Condition went down after the 1978 Late-dry season to reach a low during the 1978–79 Early-wet season; this change may have been a result of spawning activity in the former season and buccal incubation of eggs by males during the latter season. During the Mid-wet season, condition improved to reach a peak by the 1979 Mid-dry season. The condition factor then fell to a level close to that of the same season in 1978. During the 1979–80 Early-wet season, condition fell to its lowest level, possibly as a result of spawning or the severe 1979 Dry season, or both.

Table 16 Mean length, mean weight and condition factor of *A. leptaspis*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	129	328.7	754.9	1.04
Early-wet (1978–79)	211	336.6	704.5	0.91
Mid-wet	66	362.5	975.8	1.00
Late-wet–Early-dry (1979)	78	253.0	335.0	1.04
Mid-dry	139	281.2	492.4	1.10
Late-dry	89	325.6	711.9	1.02
Early-wet (1979–80)	12	317.6	532.8	0.82
Overall	724	314.5	631.0	1.00

Length-frequency distribution

The smallest specimen captured was 108 mm LCF; the largest was 600 mm LCF (fig 14). This (or a closely related) species is reputed to grow to a length of 1000 mm and weight of over 10 kg (Pollard 1974).

The mean length of all specimens was 314 mm LCF and the modal length was 330 mm LCF. The length at first sexual maturity (LFM) was 270 mm for males and 300 mm for females, so most of the fish captured were adults. Few juveniles were sampled, possibly due to mesh, site or time selectivity — or all three. Specimens up to 60 mm LCF have been found in the mouths of adult males. Most of the specimens captured were small adults (the main peak had a modal value of 330 mm).

Seasonal changes in distribution

A few small juveniles (less than 130 mm LCF) first appeared in the samples during the Mid-wet season. They increased in number during the following Late-wet–Early-dry and Mid-dry seasons (fig 15).

During the Early-wet seasons the smallest fish captured were about 200 mm LCF. The largest fish were captured during the Early-wet seasons and the 1978 Late-dry season.

The seasonal mean lengths of all specimens captured are shown in table 16.

The mean lengths gradually increased from the 1978 Late-dry season to peak in the 1978–79 Mid-wet season. The mean lengths then fell to their lowest during the Late-wet–Early-dry season when juveniles were recruited into the populations. They gradually increased again until the 1979 Late-dry season and then fell slightly in the 1979–80 Early-wet season (in contrast to the same season the previous year).

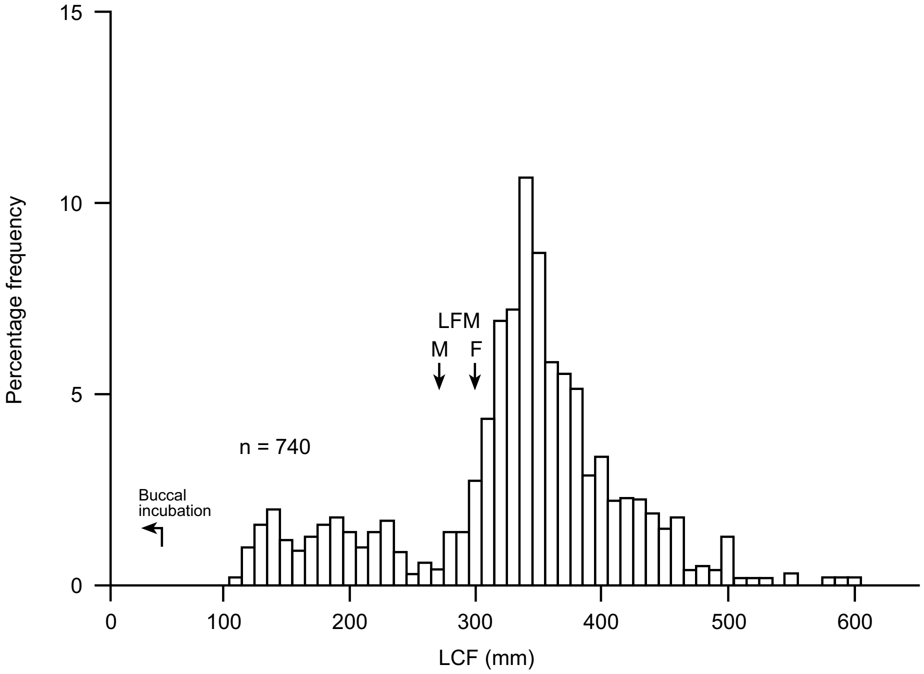

Figure 14 Length-frequency distribution of all *A. leptaspis* captured

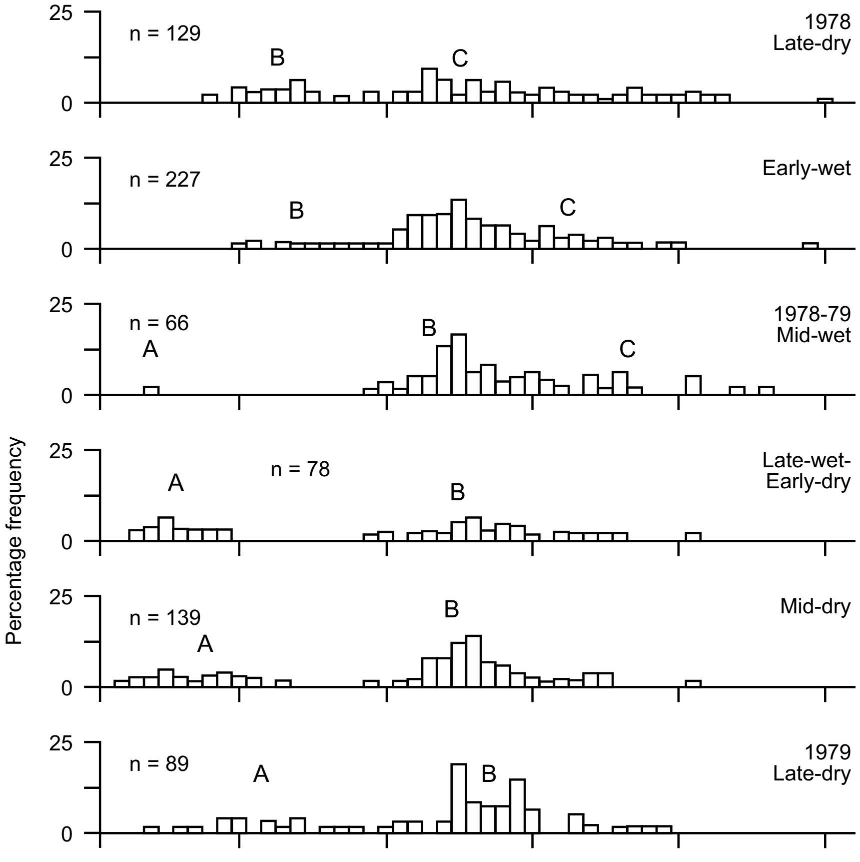

Figure 15 Seasonal length-frequency distribution of all *A. leptaspis* captured

A near-continuous size-range of specimens was captured during the 1978 Late-dry season, with peaks in the numbers of larger juveniles and small adults; there were few specimens with lengths around the LFM in the population. During the 1978–79 Early-wet season the length-frequency distribution was similar, though with fewer of the larger juveniles. Very few large adults were found in these seasons.

By the Mid-wet season there were virtually no large juveniles in the population, which consisted mainly of smaller adults. Growth was also apparent in larger adults, and the first juvenile recruits appeared during this season. The small juvenile component increased by the Late-wet–Early-dry season while the length-frequency of adults remained essentially unchanged. By the 1979 Mid-dry season the juvenile component was reinforced by larger-sized specimens; small adults dominated the population and only a few large adults were present. The gap between the juveniles spawned in the 1978–79 Early-wet season and the small adults closed during the 1979 Late-dry season (as in the 1978 season) as a nearly continuous size-range of specimens was captured; small to medium-sized adults dominated the population. Juveniles appeared to be more common during the 1979 Late-dry season than the 1978 Late-dry season. In the small sample captured in the 1979–80 Early-wet season, most were small adults; only a few were juveniles.

Growth rate

There is no published information on the growth of *A. leptaspis*. Tait (1979) distinguished five age classes in samples collected from the Magela Creek flood plain during June 1979. Estimation of growth rates from the seasonal length-frequency distributions is difficult due to mesh selectivity, the times at which the juveniles were recruited, and the variety of habitats examined.

The growth rate of small juveniles spawned in the 1978–79 Early-wet season can be tentatively followed by examining the progression of this size group (A in fig 15). The same may apply for juveniles spawned in the 1977–78 and 1976–77 Early-wet seasons (B and C, respectively, in fig 15). The growth rate appeared to be fastest over the Wet season and specimens had attained 120–190 mm LCF by the Late-wet–Early-dry season (about 5 months later). By the 1979 Late-dry season most specimens could be considered to be large juveniles (190–250 mm LCF) and a few specimens may have attained the LFM. Most recruits may be ready to spawn by the end of their second year.

Habitat differences in distribution

Magela catchment

Length-frequency distributions showing habitat preferences of *A. leptaspis* captured in regular sampling sites in the Magela Creek catchment are shown in fig 16.

The smallest juveniles were found in backflow billabongs. The medium-sized juveniles were found most often in floodplain billabongs and, to a lesser extent, in backflow billabongs. The larger juveniles were found more often in corridor and backflow billabongs than in the floodplain billabongs.

The smaller adults were found mainly in floodplain billabongs and, to a lesser extent, in corridor and backflow billabongs. Only a few small adults were found in escarpment mainchannel waterbodies and lowland sandy creekbeds. The largest adults were found in floodplain and channel backflow billabongs. The presence of the smallest adults in corridor waterbodies indicates that these billabongs are used as migration routes before the spawning season.

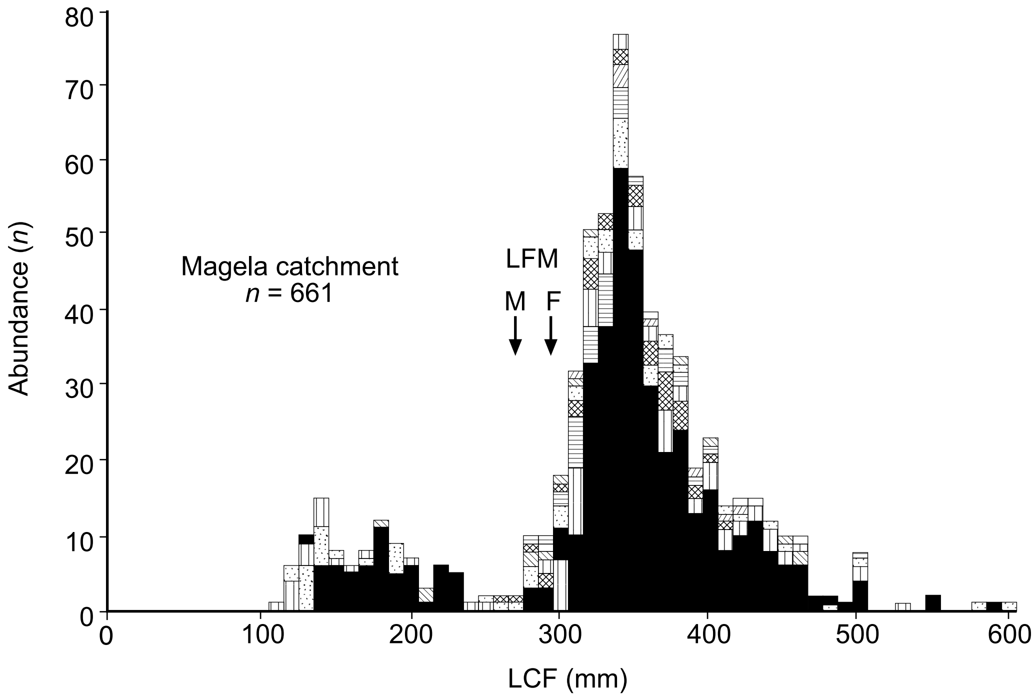

Figure 16 Length-frequency distributions and habitat preferences of *A. leptaspis* captured at regular sampling sites in the Magela catchment (see appendix 5 for key to the habitats)

Nourlangie catchment

Few specimens were found in the Nourlangie catchment. Adults were found in escarpment mainchannel waterbodies and perennial streams as well as in lowland habitats in this system.

Environmental associations

Rank numbers for *A. leptaspis* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

This species was captured at water temperatures ranging on the surface from 26° to 34°C (mean = 30.3°C) and on the bottom from 23° to 32°C (mean = 28.3°C). *Arius leptaspis* was placed in the lower-middle quarters for both waters (see fig 170).

This (or a closely related) species is found in cool temperate waters as far south as the Hunter River in New South Wales.

Dissolved oxygen

Dissolved oxygen concentrations in waters in which this species was captured ranged from 0.1 to 9.7 mg/L (mean = 5.8) for surface waters and from 0.2 to 7.4 mg/L (mean = 2.9) for bottom waters. Specimens captured in almost anoxic waters were usually very inactive when handled and had apparently not been feeding. *Arius leptaspis* was ranked in the lower-middle and lowest quarters for surface and bottom waters respectively (see fig 171).

This species was present in a fish kill in Leichhardt Billabong when surface DO levels fell to 0.1 mg/L during the 1978–79 Early-wet season (Bishop 1980).

Visibility

Secchi depths recorded at sites in which this species was captured ranged from 1 to 360 cm; ie from the clearest to the most turbid waters. The mean Secchi depth was 76 cm, and *A. leptaspis* was ranked in the upper-middle quarter (see fig 172).

pH

The pH of surface waters ranged from 4.8 to 9.1 (mean = 6.1) and of bottom waters from 4.3 to 7.1, (mean = 5.8). *Arius leptaspis* ranked in the lower-middle and lowest quarters for this parameter (see fig 173).

Conductivity

Surface and bottom conductivities ranged from 2 to 750 µS/cm and from 4 to 478 µS/cm respectively.

Pollard (1974) noted that this fish belongs to a predominantly marine family and it and its close relatives are often captured in brackish or marine (35 ppt salinity) waters.

Habitat–structural variables

Substrate

Arius leptaspis was found most often over mud and clay substrates, and next often over sand. Only a few specimens were found over other substrates. The ranked positions for mud, clay and sand substrates were in the highest, highest and lowest quarters respectively (see fig 174).

Hydrophytes

Arius leptaspis was typically found in moderately vegetated waters (vegetation-occurrence index 79.5%). The main hydrophyte types were submergent (44.6%), floating-attached (25.3%) and emergent (24%) forms.

Reproduction

The gonads of 721 specimens were examined, resulting in the identification of 364 females (length range 190–600 mm LCF) and 273 males (length range 118–460 mm LCF), with 84 fish being sexually indistinguishable. Males were generally smaller than females.

Length at first maturity

The LFM (fig 17) was 270 mm LCF for males and 300 mm for females; however, a few precocious males (240 and 187 mm LCF) and females (270 and 290 mm LCF) were also maturing.

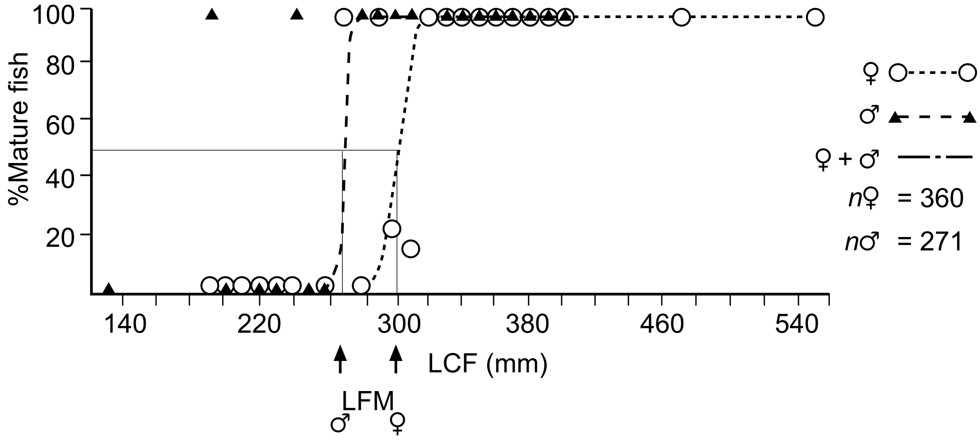

Figure 17 Estimated length at first maturity (LFM) of male and female *A. leptaspis*

Sex ratio

There were significantly ($P < 0.001$) more females in both the entire sample and among the adult fish during the 1978 Late-dry season (table 17). This may reflect our initial difficulty in differentiating between immature and male gonads even in the larger fish, thus reducing the number of males recorded in this season. The sex ratio of adult fish was 1:1 during all other seasons; however, in total samples there were significantly ($P < 0.05$) more females during the 1978–79 Mid-wet season and significantly ($P < 0.05$) more males during the 1979 Mid-dry season. This could reflect a true situation (due to movement or behaviour), a sampling bias, or a bias in sexual determination.

Table 17 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI), over all habitats and the percentage frequency of spent (stage VII) *A. leptaspis* captured

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet– Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	91	111	41	28	42	44	7
adults	M	*n*	21	92	24	19	72	40	5
		χ^2	43.75	1.78	4.45	1.72	7.89	0.19	0.33
		P	***	n.s.	*	n.s.	**	n.s.	n.s.
Adults only	F	*n*	74	105	40	27	42	41	7
	M	*n*	15	86	24	19	57	30	4
		χ^2	39.11	1.89	2.0	1.39	2.0	2.05	0.82
		P	***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	1.9	3.0	0.3	0.3	0.5	4.3	1.3
		s.d.	2.7	2.0	0.1	0.1	0.07	2.6	0.9
	M	mean	0.06	0.08	0.01	0.01	0.001	0.01	0.01
		s.d.	0.05	0.04	0.03	0.04	0.04	0.1	0.0
	F+M	mean	1.4	1.6	0.2	0.2	0.2	2.4	0.9
		s.d.	2.4	2.0	0.2	0.2	0.3	2.9	1.1
GMSI									
Adults only	F	mean	2.90	3.0	2.0	2.0	2.7	3.9	2.5
		s.d.	1.24	0.82	0.0	0.1	0.3	0.8	1.0
	M	mean	2.00	3.9	2.0	1.9	2.1	4.0	2.3
		s.d.	0.9	0.8	0.0	0.2	0.7	1.0	0.6
	F+M	mean	2.7	3.4	2.0	2.0	2.4	3.9	2.4
		s.d	1.2	0.9	0.0	0.2	0.6	0.9	0.8
Spent fish	F	%	8	38	98	52	2	2	86
(stage VII)	M	%	0	67	83	68	2	3	50

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.01$; *** = $P < 0.001$; s.d. = standard deviation.

Breeding season

Seasonal GSI (fig 18) indicated that reproductive activity peaked during the 1978–79 Early-wet and 1979 Late-dry seasons. While females showed significant changes in GSI at the peaks, the GSI of the males hardly varied throughout the year. The testes were elongated, roundish straps and, apart from a slightly swollen appearance and the presence of liquid internally, their appearance did not change appreciably throughout the year.

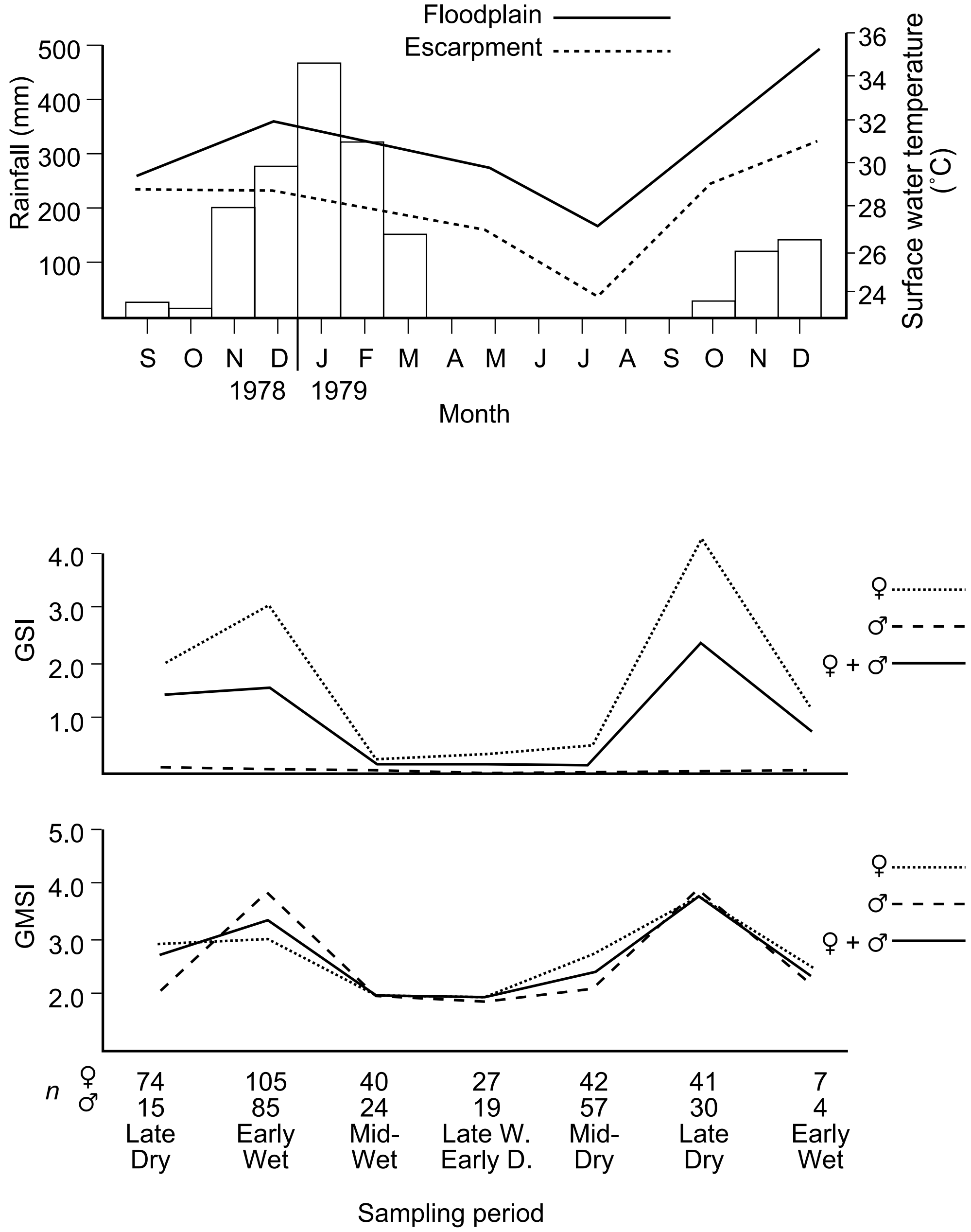

Figure 18 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *A. leptaspis*

Adult male fish were found incubating eggs in their mouths during the 1978–79 Early-wet (27 fish, 31%), 1979 Late-wet–Early-dry (1 fish, 2%), and the 1979–80 Early-wet (1 fish, 25%) seasons. Therefore the fish probably spawn during the Early-wet. Although the GSI was high during the 1979 Late-dry season, no eggs and only a few spent fish were found, which indicates that spawning was limited.

The single record of eggs being incubated during the 1979 Late-wet–Early-dry season may have been a result of a late spawning — the embryos were at the free-swimming/yolk-sac resorption stage.

Arius leptaspis exhibits seasonal reproduction (as also recorded by Roberts 1978), spawning around the Early-wet season (table 17) before the main floods. The spawning period may be quite extended and the spent gonads may have a long recovery period; thus, spent fish were present throughout the year (table 17).

Lake (1978) found *A. leptaspis* breeding when water temperatures were over 26°C.

Site of spawning

Mature, ripe or spent fish, or fish buccally incubating eggs, were found in almost all habitats where *A. leptaspis* was caught in the Magela Creek system (table 18). Although the main concentration of apparently spawning fish was in floodplain billabongs, corridor waterbodies and backflow billabongs (where the highest catches of *A. leptaspis* were recorded), spawning may also have taken place in the higher reaches of the river system where few fish were captured. Spent fish were present in an escarpment mainchannel waterbody (Sawcut Gorge) in the South Alligator system, and in a sandy creekbed in the escarpment area of Magela Creek.

Although sampled infrequently, the East Alligator lower floodplain billabongs also appeared to be spawning areas for this species; both spent fish, and fish incubating eggs, were captured in Cannon Hill Billabong.

Table 18 Possible sites of spawning of *A. leptaspis,* as indicated by the abundance of mature, ripe and spent fish and fish incubating eggs

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Incubating eggs
Habitat	F	M	F	M	F	M	M
Escarpment							
Mainchannel waterbody	2	–	–	–	1	–	–
Lowlands							
Sandy creekbed	1	–	–	–	–	3	–
Backflow billabong	2	2	1	–	37	13	6
Corridor	11	20	–	–	16	9	3
Floodplain billabong							
Upper	9	30	–	1	48	21	20

Fecundity

Egg counts of 20 ovaries gave a fecundity range of 26–70 large yolky eggs, with an average of 42 eggs per ovary. The oocyte diameters ranged from 11.9 to 15.7 mm with a mean of 13.8 mm (n = 200).[49] A large number of medium-sized eggs (4 mm diam.) were not included in the fecundity estimates, as they were most likely eggs developing for the next breeding season.

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[49] Data from Coates (1988) suggest that mature egg size is positively correlated to female parent length in five species of ariid catfish studied in the Sepik River of Papua New Guinea.

Eggs found in the buccal cavities of male catfish and eggs swallowed in the stress of capture were also counted, although it was impossible to estimate how many eggs were lost into the water when the parent fish was captured. The number of eggs in the mouths of incubating fish ranged from 1 to 62, although the smallest numbers were obviously remnants of larger clutches. The mean number of eggs was 28 (standard deviation = 17) for 29 clutches. Lake and Midgley (1970a) recorded a 55 cm, 8 kg *A. leptaspis* from the Dawson River, Queensland, carrying in its mouth 123 well-developed eggs with an average oocyte diameter of 14 mm. In the Alligator Rivers Region, the largest fishes carrying eggs were four males measuring 420 mm LCF and weighing between 1.4 and 1.5 kg; they carried between 44 and 62 eggs each. Although the diameters of the fresh eggs were not measured, the preserved oocyte diameter was 14 mm, which is comparable with the Dawson River specimens.

Summary

Arius leptaspis exhibited external sexual dimorphism. The most obvious differences were the pelvic fins of mature females — which were large and fleshy, particularly in the breeding season — and the generally larger size of the females. Only the males incubated the large yolky eggs in their mouths. *Arius leptaspis* began breeding when the temperatures increased before the onset of the Wet season. They bred mainly in floodplain billabongs, corridor waterbodies and backflow billabongs, where the fish were caught in the greatest numbers.

Well-developed prolarvae hatched after about four weeks' incubation in the buccal cavity of the male; the male holds them either in his mouth or close by until their yolk sacs are resorbed, which takes a further four weeks (Midgley 1980). Plate 1 shows the stages of egg, embryonic and prolarvae development of *A. leptaspis*.[50]

Feeding habits

Overall diet

The stomach contents of 706 specimens were examined; 633 contained food. The overall diet is summarised in fig 19; the components are listed in table 19.

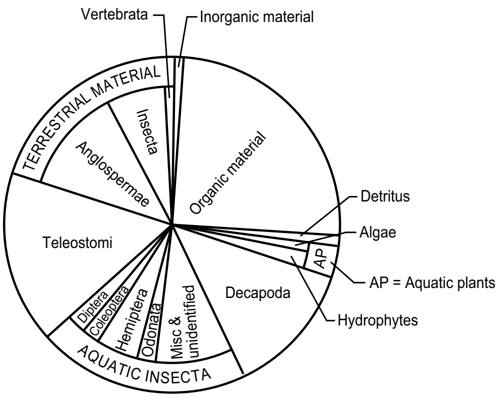

Figure 19 The main components of the diet of *A. leptaspis*

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[50] Data from Coates (1988) suggest that embryo size is positively correlated with the length of the male mouth brooding parent in four species of ariid catfish studied in the Sepik River of Papua New Guinea.

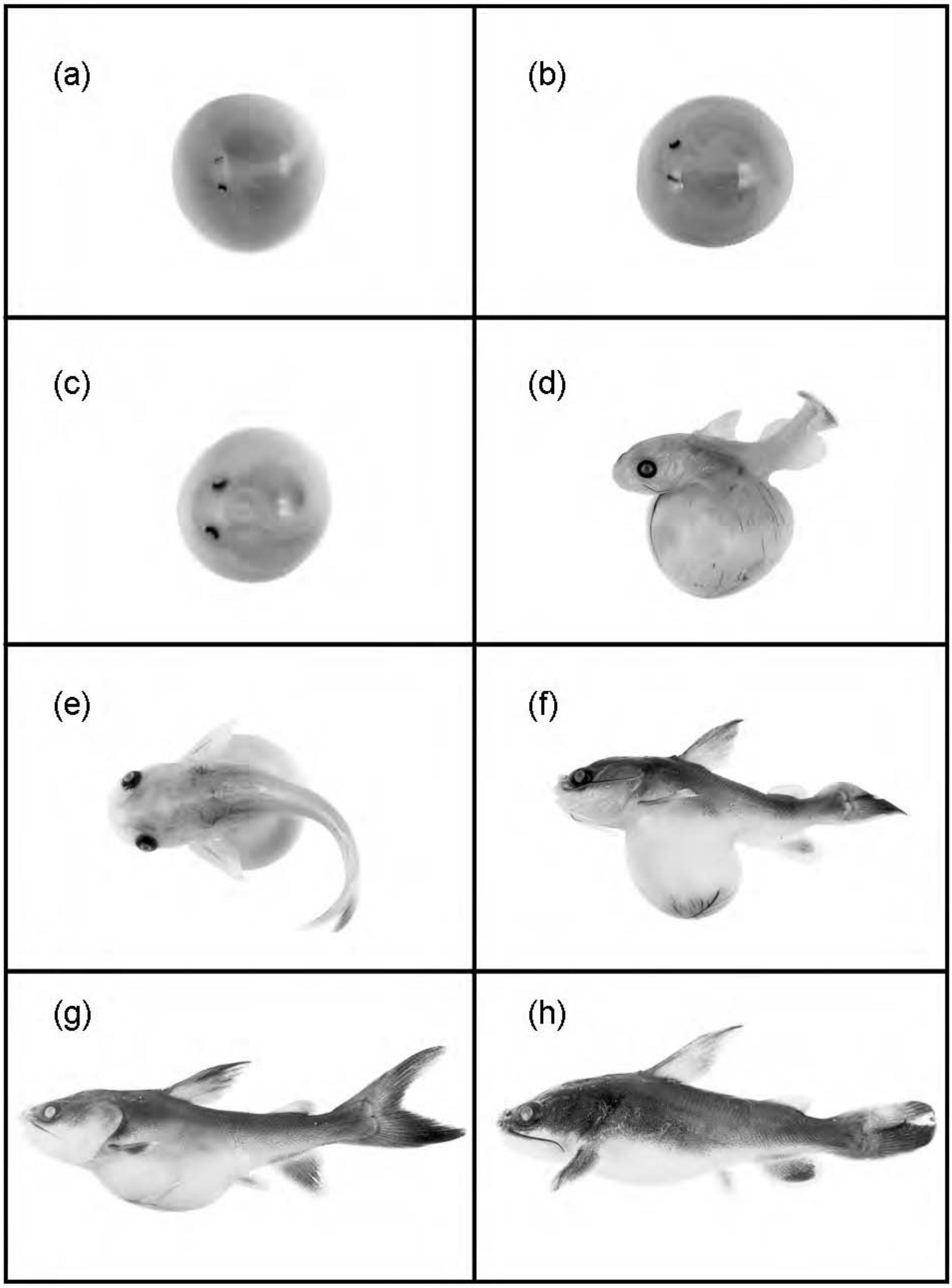

Plate 1 Stages of egg, embryonic and prolarval development of *A. leptaspis*: (a) Egg from mouth (1.2 cm diam.); (b) 11 days after removal (a.r.) (1.3 cm diam.); (c) 17 days a.r. (1.4 cm diam., 2.4 cm LCF); (d) 23 days a.r. (1.5 cm diam., 2.4 cm LCF; (e) 28 days a.r. (1.5 cm diam., 2.4 cm LCF); (f) 38 days a.r. (4.0 cm LCF); (g) 49 days a.r.(egg sac absorbing, 5.0 cm LCF); (h) 62 days a.r. (6.0 cm LCF)

Table 19 Dietary composition of *A. leptaspis*

	Habitat							Season								
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																
Algae																
Conjugatophyta																1.0
Miscellaneous	2.0	–	0.4	1.7	0.8	–	–	3.7	0.1	–	–	0.2	1.6	–	1.0	
Hydrophytes																2.4
Hymenachne	–	–	–	–	0.6	–	–	–	–	–	–	1.1	–	–	0.2	
Najas	–	–	–	–	0.4	–	–	–	–	–	–	0.8	–	–	0.2	
Pseudoraphis	–	–	4.4	0.2	2.2	–	2.0	–	1.3	14.8	–	0.9	–	–	1.9	
Vallisneria	–	–	–	–	–	–	–	0.7	–	–	–	–	–	–	0.1	
Aquatic animals																
Bivalvia																0.4
V. angasi	–	–	1.8	–	–	–	–	–	–	–	–	–	2.7	–	0.4	
Microcrustacea																0.2
Cladocera	–	–	0.2	–	–	–	–	0.3	–	–	–	–	–	–	0.1	
Isopoda	–	–	0.2	–	–	–	–	0.3	–	–	–	–	–	–	0.1	
Macrocrustacea																13.2
Macrobrachium adults	42.0	–	9.5	12.5	8.3	–	1.0	11.9	5.2	9.6	22.1	11.5	8.4	–	10.2	
Macrobrachium (juveniles)	–	–	–	0.6	–	–	–	0.7	–	–	–	–	–	–	0.1	
Parastacidae																
Fragmented	–	–	–	0.1	–	–	–	0.7	0.1	–	–	–	–	–	0.2	
Euastacoides	–	–	0.2	–	–	–	–	–	0.1	0.1	–	–	–	–	+	
Hymenosomatidae																
P. transversa	–	16.9	11.3	–	0.4	–	–	–	3.7	10.5	8.1	0.1	–	–	2.7	
Insecta																19.9
Fragmented	11.0	21.3	9.8	10.2	6.7	4.0	22.0	3.5	12.1	6.9	11.3	8.3	4.8	7.3	8.0	
Miscellaneous	2.0	–	–	0.1	+	–	–	3.7	–	–	–	–	–	–	0.7	
Ephemeroptera																
Baetidae	–	–	0.1	–	–	–	–	–	–	–	–	0.1	–	–	+	
Atalophlebia	–	–	0.1	–	–	–	–	–	0.1	–	–	–	–	–	+	
Odonata																
I. heterosticta	–	–	–	–	0.1	–	–	–	–	–	–	0.2	–	–	+	
Libellulidae	–	–	1.1	1.0	3.0	–	–	–	–	5.5	1.4	4.8	0.1	2.7	1.7	
Aeshnidae	–	–	–	0.4	0.1	–	–	–	–	0.3	0.9	–	–	–	0.1	

Table 19 continued

	Habitat							Season								
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Hemiptera																
Miscellaneous	–	–	0.6	–	–	–	–	–	0.1	–	–	0.4	–	–	1.0	
Naucoridae	–	–	3.5	5.0	4.0	–	10.0	1.5	3.3	0.7	6.9	9.3	0.6	9.1	4.1	
Gerridae	–	–	–	0.2	–	–	–	–	–	–	0.3	1.0	–	–	0.1	
Veliidae	1.0	–	–	–	–	–	–	0.1	–	–	–	–	–	–	+	
Hydrometridae	–	–	0.1	–	+	–	–	0.4	0.1	–	–	–	–	–	0.1	
Anisops	–	–	0.1	–	+	–	–	–	–	–	–	–	0.1	–	0.1	
Coleoptera																
Miscellaneous (adults)	1.0	–	0.8	1.0	0.7	–	2.0	0.1	2.1	0.4	–	0.4	0.4	1.8	0.7	
Miscellaneous (larvae)	–	–	0.2	–	–	–	–	–	–	0.5	–	–	–	–	0.1	
Dytiscidae (adults)	–	–	+	–	–	–	–	–	–	0.1	–	–	0.1	–	+	
Dytiscidae (larvae)	–	–	–	–	0.4	–	–	–	–	1.7	–	–	–	–	0.2	
Macrogyrus	–	–	0.9	–	0.7	0.6	–	0.9	0.6	1.1	1.6	0.9	–	–	0.8	
Diptera																
Miscellaneous (adults)	–	–	–	–	0.1	–	–	0.2	0.2	–	–	–	–	–	0.1	
Miscellaneous (larvae)	–	–	1.0	+	0.2	–	–	–	0.3	0.5	1.6	–	–	–	0.3	
Chaoborinae	–	–	0.7	–	0.9	–	–	–	–	–	–	1.2	2.1	–	0.5	
Chironomidae (larvae)	3.0	–	0.4	0.6	0.8	–	–	1.1	0.2	–	0.2	0.9	1.9	–	0.7	
Chironomidae (pupae)	–	–	–	0.1	–	–	–	0.1	–	–	–	0.1	0.2	–	0.1	
Ceratopogonidae	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	
Tabanidae	–	–	–	–	–	–	–	–	–	–	–	+	–	–	+	
Trichoptera																
Egg case	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	+	
Leptoceridae	–	–	–	0.3	+	–	–	0.2	0.3	–	–	–	–	–	0.1	
Teleostomi																14.7
Fragmented	–	10.0	6.8	3.6	4.8	34.0	6.0	5.6	4.3	6.8	7.9	8.2	1.0	–	5.4	
Fish scales	1.0	–	4.1	9.5	3.4	16.0	4.0	9.9	10.6	0.9	–	0.5	3.6	10.9	5.4	
N. erebi	–	–	0.7	–	–	–	–	–	0.6	–	–	–	–	–	0.2	
S. jardinii	–	–	–	0.7	–	–	–	–	–	–	1.6	–	–	–	0.2	
A. leptaspis	–	–	–	0.7	–	–	–	–	–	1.6	–	–	–	–	0.2	
Neosilurus spp.	–	12.5	1.5	–	0.4	–	–	–	0.6	1.1	1.4	1.0	–	–	0.6	
P. rendahli	–	–	–	–	0.3	–	–	–	–	–	–	0.6	–	–	0.1	
N. ater	–	–	–	–	0.4	–	–	–	–	–	–	0.8	–	–	0.2	

Table 19 continued

	Habitat							Season								
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
M. spendida inornata	–	–	0.5	–	0.2	–	–	–	–	1.0	0.2	0.2	–	–	0.2	
Ambassis spp.	–	–	–	1.3	0.4	–	12.0	–	–	1.0	3.0	0.8	–	–	0.6	
L. unicolor	–	–	–	–	0.3	–	–	–	–	1.4	–	–	–	–	0.1	
T. chatareus	–	–	–	1.3	–	–	–	–	–	–	3.1	–	–	–	0.3	
G. giuris	–	–	0.4	1.0	–	–	–	–	–	0.9	3.4	–	–	–	0.4	
H. compressa	–	–	–	–	–	–	–	1.2	–	–	–	–	–	–	0.2	
O. lineolata	–	–	0.2	–	1.1	–	–	–	–	2.5	–	1.2	–	–	0.5	
S. krefftii	9.0	–	–	–	–	–	–	0.8	–	–	–	–	–	–	0.1	
Egg material																
Miscellaneous	–	–	+	0.5	1.0	–	–	0.6	0.9	–	0.2	–	1.3	–	0.5	
A. leptaspis	–	–	0.8	2.7	2.3	–	–	1.7	5.5	–	–	0.3	2.2	–	2.1	
Leptodactylidae	–	–	–	–	+	–	–	–	0.1	–	–	–	–	–	+	
Terrestrial plants																
Angiospermae																12.1
Miscellaneous	1.0	–	3.4	8.8	5.0	–	4	20.3	9.4	5.3	9.2	16.1	4.5	–	11.6	
Miscellaneous seeds	–	–	–	–	0.4	–	–	–	–	1.5	–	0.1	–	–	0.2	
Pandanus seeds	–	–	–	0.9	0.1	–	–	0.4	0.3	–	–	0.5	–	–	0.3	
Terrestrial animals																
Arachnida																0.1
Fragmented	–	–	–	–	0.2	–	–	–	–	–	0.8	–	–	–	0.1	
Insecta																5.8
Fragmented	–	0.6	0.3	2.9	0.9	–	–	0.2	3.7	0.9	–	–	0.6	–	1.1	
Odonata																
Zypopteran (adults)	–	–	0.2	–	0.4	–	1	+	+	0.7	–	0.3	0.5	–	0.2	
Anisopteran (adults)	–	–	0.6	–	–	–	–	–	–	1.2	1.6	–	–	–	0.3	
Orthoptera																
Miscellaneous	–	25.0	5.3	2.1	2.4	–	–	–	8.1	4.2	3.3	0.6	–	–	2.9	
Egg material	–	–	–	–	+	–	–	–	–	–	0.1	–	–	–	+	
Hemiptera	–	–	0.2	–	0.6	–	–	–	–	3.3	–	–	–	–	0.3	
Coleoptera																
Miscellaneous	–	3.8	0.2	0.6	0.1	26.0	20.0	0.1	1.9	0.4	–	–	0.9	–	0.7	
Diptera																
Larvae	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	

Table 19 continued

	Habitat							Season								
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Lepidoptera																
Larvae	–	–	0.2	–	–	–	–	–	–	–	–	0.5	–	–	0.1	
Adults	–	–	–	0.5	–	–	–	–	0.2	–	–	–	–	–	0.1	
Hymenoptera																
Oecophylla	–	–	–	–	0.3	–	–	–	–	1.2	–	–	–	–	0.1	
Scolopendromorpha	–	–	–	–	–	12	–	–	0.4	–	–	–	–	–	0.1	0.1
Vertebrata																1.3
Fragmented	10.0	–	0.4	0.8	–	–	14.0	1.7	0.8	–	–	–	–	–	0.5	
Reptillia																
Skin (*Acrocaudis*)	–	–	0.5	–	0.3	–	–	0.7	0.9	–	–	–	–	–	0.4	
Scincidae	–	–	–	–	–	4.0	–	–	0.1	–	–	–	–	–	+	
Aves																
Feathers	–	–	–	1.0	0.2	–	–	1.5	–	–	–	–	0.2	–	0.3	
Mammalia																
Fragmented	–	–	0.2	–	+	–	–	–	0.2	–	0.2	–	–	–	0.1	
Parasites																1.6
Cestoda	–	–	–	–	+	–	–	–	–	1.7	–	0.8	–	–	0.3	
Nematoda	3.0	–	0.2	1.3	1.6	–	2.0	2.5	0.9	0.7	3.4	2.1	–	–	1.3	
Detrital material	3.5	–	–	2.0	0.6	–	–	2.6	1.4	–	–	–	0.4	–	0.9	0.9
Inorganic material	1.5	–	0.5	1.0	5.0	–	–	0.3	0.8	1.7	–	0.2	1.2	–	0.9	0.9
Organic material	9.0	10.0	22.9	20.3	35.4	4.0	–	18.4	19.7	5.4	5.9	22.4	61.2	68.2	24.9	24.9
Number of empty fish	–	–	11	26	28	1	0	5	47	6	11	3	–	1	73	
Number of fish with food	10	8	131	147	272	5	5	117	161	59	64	134	87	11	633	

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creekbed; Bb = lowland backflow billabong; Cb = corridor billabongs; Fb = flood plain billabongs

The main components of the diet were aquatic insects (20%), teleosts (15%), macrocrustaceans (13%), terrestrial plant material (12%) and terrestrial insects (6%). Large quantities of unidentified organic material (25%) were also found in the stomachs. The identifiable portion of the aquatic insects consisted mainly of naucorids and libellulid larvae. Fish scales were common. The identifiable teleosts were *N. erebi, A. leptaspis, Neosilurus* sp., *P. rendahli, N. ater, M. splendida inornata, Ambassis* spp., *L. unicolor, T. chatareus, G. giuris, H. compressa, O. lineolata* and *S. krefftii*. The macrocrustaceans were *Macrobrachium* and *Paratelphusa transversa*. Most of the terrestrial plant material consisted of leaves, twigs, bark and grass. The main terrestrial insects were orthopterans and coleopterans. Traces of green filamentous algae, hydrophytes, bivalves, microcrustaceans, terrestrial arachnids, scolopendromorphs, unidentified vertebrates, and detritus were also found in the stomachs. *Arius leptaspis* can therefore be classified as an opportunistic macrophagous omnivore.

Little published information on the diet of this species was found. Haines (1979) considered it to be an omnivore in the Purari River catchment.[51] Pollard (1974) noted that the stomachs of specimens caught in billabongs of the Magela Creek system in 1972 contained the remains of plotosid catfishes.

During the Dry season in the Magela flood plain *A. leptaspis*'s diet was restricted to items obtained by scavenging around the bottom and edges of the billabong—mainly terrestrial plant material, bird bones and feathers and fish scales. Tait (1979) noted that, in the Wet season, after breeding, the catfish can move over the flood plain and seek out fish and macroinvertebrates as food.

Seasonal changes

In sampling periods 1–7 respectively, 122 (4% empty), 208 (23% empty), 65 (9% empty), 75 (15% empty), 137 (2% empty), 87 (0% empty) and 12 (8% empty) stomachs of *A. leptaspis* were examined (all habitats combined). The highest proportions of specimens with empty stomachs were found in the 1978–79 Early-wet and Late-wet–Early-dry seasons.

The diet in the 1978 Late-dry season was based mainly on terrestrial plant material and teleosts (mainly scales), followed by macrocrustaceans and aquatic insects. During the 1978–79 Early-wet season the terrestrial insects increased in the diet and terrestrial plants decreased, while the teleost component (again mainly fish scales) and aquatic insects remained much the same.

During the 1978–79 Mid-wet season, hydrophytes (mainly *Pseudoraphis*) and macrocrustaceans (*Macrobrachium* and *P. transversa*) became more important in the diet. Aquatic insects were still common (libellulid larvae displaced naucorids in importance), as were the teleosts, though in greater variety (*A. leptaspis*, plotosids, *M. splendida inornata, Ambassis* spp., *L. unicolor, G. giuris* and *O. lineolata*). Fish scales were much less important, but terrestrial insects remained important.

By the Late-wet–Early-dry season, hydrophytes had disappeared from the diet and there was a large macrocrustacean component (*Macrobrachium* and *P. transversa*). Aquatic insects (mainly naucorids) and teleosts (mainly *Ambassis* spp., *T. chatareus, G. giuris*, with a few plotosids and *M. splendida inornata*) remained important. Terrestrial plant material and insects decreased in importance.

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[51] Rimmer and Midgley (1985) indicated that larvae which had almost completed yolk absorption showed feeding habits similar to those of adults, which are opportunistic omnivores. Coates (1991) found all 5 species of ariid catfish studied in the Sepik River in Papua New Guinea to be omnivorous, but diets varied according to morphology and habitat preferences.

Aquatic insects (mainly naucorids and libellulids) and terrestrial plant material increased in importance in the diet during the 1979 Mid-dry season, and all other components became less common; terrestrial insects almost disappeared. During the 1979 Late-dry season there was a very large unidentified organic material component (this component was lowest in the Wet season and increased through the Dry season to peak in the Late-dry and Early-wet seasons). Macrocrustaceans (mainly *Macrobrachium*), aquatic insects, and to a lesser extent naucorids and terrestrial plant material, were also important. The few specimens examined in the 1979–80 Early-wet season had eaten mainly aquatic insects (naucorids and libellulid larvae) and fish scales. The fish scale component of the diet appeared to be lowest in the Wet season and gradually increased into the Dry season (large numbers of dead fish, mainly *L. calcarifer*, were found around the edges of the billabongs towards the end of the Dry seasons).

Habitat differences

Magela catchment

The totals of stomachs of *A. leptaspis* examined (all seasons combined) were: 10 (0% empty) from escarpment mainchannel waterbodies; 8 (0% empty) from lowland sandy creekbeds; 142 (8% empty) from backflow billabongs; 173 (15% empty) from corridor billabongs, and 300 (9% empty) from floodplain billabongs.

The diet in the escarpment mainchannel waterbodies consisted mainly of *Macrobrachium*, with aquatic insects and miscellaneous vertebrates of lesser importance. In the lowland creekbeds the diet was mainly of terrestrial orthopterans, miscellaneous aquatic insects, fish (mainly *Neosilurus* sp.), macrocrustaceans (*P. transversa*), and terrestrial coleopterans.

In the backflow billabongs, the fish had eaten mainly macrocrustaceans (*Macrobrachium* and *P. transversa*), aquatic insects, teleosts (including *N. erebi*, plotosids, *M. splendida inornata, G. giuris* and *O. lineolata*), fish scales, and traces of hydrophytes and terrestrial plant material. Large quantities of unidentified organic material were found in the stomachs in this habitat; this material was thought to be mainly fish flesh.

In the corridor waterbodies, macrocrustaceans (mainly *Macrobrachium*), aquatic insects, teleosts (including *A. leptaspis, Ambassis* spp., *T. chatareus* and *G. giuris*), fish scales and terrestrial plant material, featured in the diet. Partly digested *A. leptaspis* eggs, which were presumably accidentally swallowed during buccal incubation, were present in some of the stomachs from corridor and floodplain billabongs. In the floodplain billabongs *A. leptaspis* had eaten a variety of food items, including macrocrustaceans, aquatic insects, teleosts (including fish scales; the identifiable species were *Neosilurus* sp., *P. rendahli*, *N. ater*, *M. splendida inornata*, *Ambassis* spp., *L. unicolor* and *O. lineolata*) and terrestrial plant material.

Nourlangie catchment

Six (17% empty) stomachs of *A. leptaspis* were examined (all seasons combined) from Nourlangie Creek escarpment mainchannel waterbodies and five (0% empty) from backflow billabongs. Generally, higher proportions of specimens in this catchment had empty stomachs.

In the escarpment mainchannel habitat, the diet was different from that recorded in the equivalent Magela Creek habitat: here it was mainly teleosts and terrestrial animals (especially coleopterans and scolopendromorphs), with only a trace of aquatic insects. In the backflow billabongs, the fish ate mainly aquatic insects (naucorids were the main identifiable component); however, teleosts (mainly *Ambassis* spp.) and terrestrial vertebrates and insects (mainly coleopterans) were also part of the diet.

Fullness

A summary of mean fullness indices of *A. leptaspis* at different sampling periods and habitats in the Magela Creek and Nourlangie Creek catchments is given in table 20. It is assumed that feeding times do not vary with habitat or season.

Table 20 Mean fullness indices of *A. leptaspis* in different sampling periods and habitats

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	1.9 (9)	n/s	n/s	n/s	n/s	0 (1)	n/s	1.7 (10)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	3.7 (3)	3.4 (5)	n/s	n/s	n/s	n/s	3.5 (8)
Lowland channel backflow billabong	3.6 (5)	n/s	3.3 (6)	2.3 (9)	3.3 (11)	2.2 (19)	1 (10)	3.4 (60)
Lowland shallow backflow billabong	n/s	2.6 (47)	2.3 (18)	2.3 (6)	3.5 (12)	n/s	n/s	2.6 (83)
Corridor sandy billabong	1.3 (4)	1.5 (25)	1 (1)	1.3 (6)	10.0 (2)	n/s	n/s	1.5 (38)
Corridor anabranch billabong	2.9 (9)	1.9 (23)	n/s	2.0 (4)	n/s	n/s	n/s	2.2 (36)
Floodplain billabong	2.6 (36)	1.8 (106)	2.0 (38)	2.5 (47)	2.2 (114)	1.7 (69)	n/s	2.1 (410)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	1 (2)	1.8 (4)	n/s	n/s	n/s	n/s	n/s	1.5 (6)
Lowland channel backflow billabong	4 (1)	3 (1)	5 (1)	n/s	n/s	n/s	n/s	4 (3)
Lowland shallow backflow billabong	n/s	4 (1)	n/s	3 (1)	n/s	n/s	n/s	3.5 (2)
Seasonal mean (all sites)	2.5	2.0	2.3	2.3	2.4	1.8	0.96	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Seasonal changes

The mean seasonal fullness index (all habitats combined) decreased during the 1978–79 Early-wet season, which possibly corresponded to an increased number of males buccally incubating eggs. The index increased during the Mid-wet season and remained at a higher level till the 1979 Mid-dry season. The index then decreased during the 1979 Late-dry season and reached its lowest during the 1979–80 Early-wet season.

Habitat differences

In the Magela catchment the mean fullness indices of *A. leptaspis* were lowest in corridor sandy billabongs and escarpment mainchannel waterbodies, and highest in the lowland sandy creekbeds and channel backflow billabongs.

In the Nourlangie catchment the specimens examined in the escarpment mainchannel waterbodies and lowland habitats had fullness indices comparable with specimens in the equivalent Magela Creek habitat.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland sandy creekbeds; 1978–79 Early-wet and Mid-wet seasons
- lowland shallow backflow billabong; 1979 Mid-dry season
- lowland channel backflow billabong; 1978 Late-dry season, 1978–79 Mid-wet season and 1979 Mid-dry season

Nourlangie catchment

- lowland channel backflow billabong; 1978–79 Mid-wet season

Family ARIIDAE

3.6 *Arius proximus* (Ogilby)

Arius proximus (identified by P Kailola[52]) is commonly known as the grey catfish. It belongs to a predominantly marine family. It has been collected near Darwin and in the waters of the Arafura Sea around Aru, Pellew and Melville islands. Pollard (1974) tentatively identified this species from tidal waters of the East Alligator River. It has also been tentatively identified by Haines (1979) in the Purari-Kikori delta in Papua New Guinea, where it was found in very brackish and marine waters of the lower estuary and coastal zones.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found (but only rarely) in backflow billabongs and corridor waterbodies of the Nourlangie Creek system.

Size composition

Length–weight relationship

The lengths and weights of nine specimens were determined. The length–weight relationship was described by the expression:

$W = 6.25 \times 10^{-3} L^{3.33}$ $r = 1.00$ (length in cm, weight in g)

The mean weight of specimens captured was 450 g.

Length-frequency distribution

The length-frequency distribution is shown in fig 20. The smallest specimen (captured during the Mid-wet season) was 85 mm LCF and the largest specimen (captured during the 1978 Late-dry season) was 400 mm LCF. The mean length of all specimens captured was 289 mm LCF.

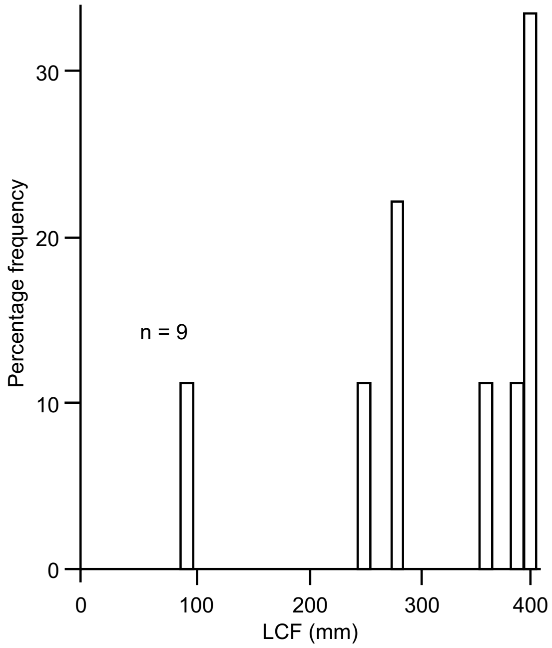

Figure 20 Length-frequency distribution of all *A. proximus* captured

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[52] In Kailola's PhD thesis (Kailola 1990) it is stated that a sample of distinct specimens of an 'Arius', identified in the late 1970s as *A. proximus*, is suspected in hindsight to be *A. graeffei*.

Environmental associations

Rank numbers for *A. proximus* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Arius proximus was captured in waters with surface temperatures from 29° to 34°C (mean = 30.0°C), and with bottom temperatures from 26° to 31°C (mean = 26.7°C). These means were placed in the lower-middle and lower quarters respectively (see fig 170). This range of water temperatures is quite wide despite the small number (*n* = 7) of temperature readings taken.

Dissolved oxygen

Dissolved oxygen concentrations in waters in which *A. proximus* was captured ranged from 5.3 to 7.8 mg/L (mean = 6.7) on the surface, and from 2.0 to 4.9 mg/L (mean = 3.5) on the bottom. The means ranked in the upper and lower quarters respectively (see fig 171). The narrow ranges and large differences between mean concentrations are probably artefacts of the small number of readings taken.

Visibility

Secchi depths recorded at sites in which *A. proximus* was captured ranged from 90 to 210 cm (mean = 130 cm) (fig 172). This mean depth ranked in the upper quarter, indicating an apparent preference for clearer waters, although the small number of readings must be taken into account.

pH

The pH of waters from which *A. proximus* was captured ranged from 5.7 to 6.3 (mean = 6.2) on the surface and from 5.2 to 5.9 (mean = 5.7) on the bottom. These means were ranked in the lower-middle and lower quarters respectively (see fig 173).

Conductivity

Surface-water conductivities at sites where *A. proximus* was found ranged from 10 to 70 µS/cm; corresponding bottom-water conductivities ranged from 10 to 58 µS/cm. *Arius proximus* is reputedly found in estuarine waters (Pollard 1974), so its presence in waters of such low conductivities is of interest.

Habitat–structural variables

Substrate

Arius proximus was captured only over mud and clay substrates. The percentage dominance means for mud and clay substrates thus ranked high in the upper quarter.

Hydrophytes

Arius proximus was found exclusively in vegetated waters (vegetation-occurrence index 100%). The main vegetation type was submergent (60.7%), followed by floating attached (21.4%).

Reproduction

Of the nine specimens captured, two were not examined for reproductive condition and one (85 mm LCF) was sexually indistinguishable. The remainder were four females (length range 360–400 mm LCF) and two males (245–395 mm LCF).

All fish were immature, except for one female (400 mm LCF), which had spent gonads. Two of the large females from a corridor waterbody had eggs at a very early stage of development.

Haines (1979) found breeding individuals only in lower estuarine and coastal zones.

Feeding habits

The stomach contents of nine specimens were examined; eight contained food. A summary of the diet of *A. proximus* is given in fig 21; details of the components are given in table 21.

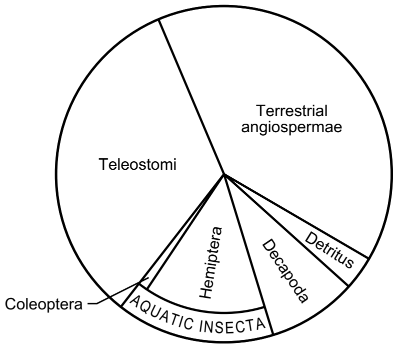


Figure 21 The main components of the diet of *A. proximus*

Table 21 Dietary composition of *A. proximus*

	% composition	
Stomach contents	Sub-mean	Main-mean
Aquatic animals		
Macrocrustacea		9.4
Macrobrachium	9.4	
Insecta		16.2
Fragmented	14.4	
Hemiptera		
Naucoridae	0.6	
Coleoptera		
Macrogyrus	1.2	
Teleostomi		35.0
Scales	35.0	
Terrestrial plants		
Angiospermae		36.3
Fragmented	34.4	
Pandanus (seed)	1.9	
Terrestrial animals		
Insecta		+
Coleoptera	+	
Parasite		
Nematoda	0.6	0.6
Detrital material	2.5	2.5
Number of empty fish	1	1
Number of fish with food	8	8

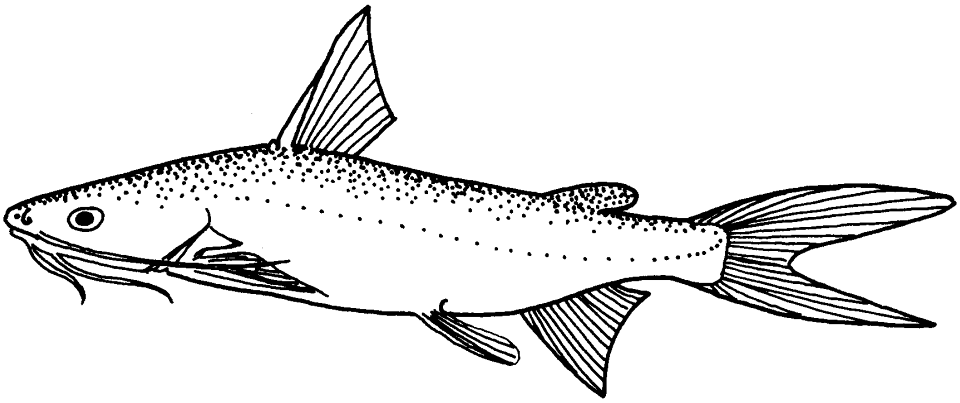
The main components of the diet were terrestrial plant material (36%), teleost scales (35%), aquatic insects (16%) and macrocrustaceans (*Macrobrachium*) (9%). As most of the specimens were captured in the 1979 Late-dry season, it is not known whether there are habitat differences and seasonal changes in the diet. The high proportion of fish scales (mainly from *L. calcarifer*) in the diet is notable. *Arius proximus* can be tentatively classified as a macrophagous omnivore.

Little published information on the diet of this species was found; Haines (1979), however, noted that this species is partly omnivorous in the estuarine waters of the Purari-Kikori delta, where it feeds mainly on prawns and crabs.

Family ARIIDAE

3.7 *Arius graeffei* (Kner & Steindacher)

Arius graeffei is commonly known as the blue catfish, ridged-back catfish, shark catfish and occasionally also as the forktailed catfish. It is mainly found in tropical waters (Haines 1979). In Australia it is found in the Gulf of Carpentaria, Timor Sea, Indian Ocean and the south-east and north-east coast drainage divisions (see map 3). Miller (cited in Taylor 1964) collected *A. graeffei* from billabongs in the Oenpelli area and in the East Alligator River near Cahills Crossing. It has also been found in the coastal zone off the Purari River delta.



Arius graeffei

Arius graeffei belongs to a predominantly marine family and is very common in estuaries and rivers, ascending above the tidal limit into freshwater.

Information on catches at each site and in each season is presented in volume 2. In summary, this species was found only in occasionally sampled sites (backflow billabongs and corridor waterbodies) in the Nourlangie Creek system.

Size composition

Length–weight relationship

The lengths and weights of 41 specimens were determined. The length–weight relationship was described by the expression:[53]

$$W = 9.21 \times 10^{-3} L^{3.19} \qquad r = 0.99 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 22. The condition factors during the 1978 Late-dry and 1979 Late-wet–Early-dry seasons were almost identical.[54]

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[53] The length-weight relationship given by Rimmer (1985a) for *A. graeffei* from the Clarence River upper estuary in north-eastern NSW was:

Females: $W = 1.515 \times 10^{-6} L^{3.45}$, $r^2 = 0.97$

Males: $W = 2.761 \times 10^{-6} L^{3.34}$, $r^2 = 0.95$

where L is standard length in mm, W is total weight in g.

[54] Rimmer (1985a) indicated that the relative condition of *A. graeffei* decreased in winter when water temperatures dropped to a minimum in the upper estuary of the Clarence River.

Table 22 Mean length, mean weight and condition factor of *A. graeffei*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	21	237.0	223.4	1.00
Late-wet–Early-dry (1979)	20	291.2	426.5	0.99
Overall	41	262.0	306.2	1.00

Length-frequency distribution

Lengths ranged from 113 mm to 395 mm LCF (fig 22);[55] the mean length was 262 mm LCF. There are two distinct peaks in the length-frequency distribution, with modes at 180 and 260 mm LCF. They can be attributed to the mesh selectivity of the gillnets used to collect specimens. As this species was not sampled continuously, there are discontinuities in the distribution.

Both the smallest and largest specimens were captured in the Late-wet–Early-dry season.

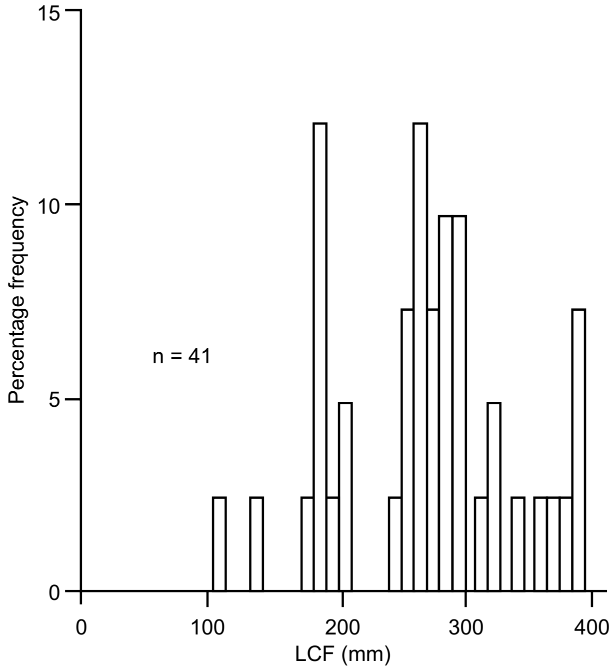

Figure 22 Length-frequency distribution of all *A. graeffei* captured

Environmental associations

Rank numbers for *A. graeffei* for the physico–chemical and habitat–structural variables recorded during the study are shown in table 155.

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[55] The largest specimens of *A. graeffei* collected by Rimmer (1985a) from the Clarence River upper estuary in north-eastern NSW were 494 mm standard length (SL) and 2900 g weight for females, and 453 mm standard length (SL) and 2250 g weight for males.

Physico–chemical variables

Temperature

Arius graeffei was captured in waters with surface temperatures ranging from 28° to 31°C (mean = 29.3°) and bottom temperatures ranging from 27° to 31°C (mean = 28.7°C). These means ranked in the lower and lower-middle quarters, respectively (see fig 170).[56]

Dissolved oxygen

Dissolved oxygen concentrations in waters from which *A. graeffei* was captured ranged from 4.4 to 6.5 mg/L (mean = 5.6) on the surface, and from 0.6 to 4.9 mg/L (mean = 3.2) on the bottom. These means ranked in the lower quarter (see fig 171). A tolerance of low DO concentrations on the bottom is indicated, although the small number of readings must be taken into account.

Visibility

Secchi depths in waters from which this species was captured ranged from 15 to 190 cm, with a mean depth of 117 cm. This mean ranked in the upper-middle quarter (see fig 172).

pH

Both surface and bottom water pH levels ranged from 6.1 to 7.0 (mean = 6.6), (see fig 173).

Conductivity

Conductivity ranged from 10 to 160 µS/cm for both surface and bottom waters.

Habitat–structural variables

Substrate

Arius graeffei was predominantly found over sandy substrates (upper quarter), followed by clay, then mud. No specimens were captured over other substrates.

Hydrophytes

Arius graeffei was infrequently found in vegetated waters (vegetation-occurrence index 20%). Submergent hydrophytes (42.9%) were most often associated with this species, followed by emergent hydrophytes (28.5%) and floating vegetation (28.6%).

Reproduction

In all, 27 sexually distinguishable fish were caught, in the 1978 Late-dry and 1979 Late-wet–Early-dry seasons. The sex ratio was 10 males (191–395 mm LCF) to 17 females (186–395 mm LCF). The LFM could not be calculated due to the small sample size; however, the smallest maturing specimens were a 270 mm LCF female and a 285 mm LCF male.[57]

During the Late-dry season five females were captured. Two (186 and 257 mm LCF) were immature, two (265 and 365 mm LCF) had developing eggs, and one (270 mm) had well-developed ovaries. All females caught during the Late-wet–Early-dry season had either spent or recovering-spent gonads. They had probably spawned some time between the Late-dry and the end of the Wet season.

All six males caught during the 1978 Late-dry season were recorded as immature; however, at that time maturing male gonads were not documented, and the gonads may have actually

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[56] Rimmer (1985b) indicated that *A. graeffei* breed in the upper estuary of the Clarence River in NSW when water temperatures reach 26°C.

[57] Rimmer (1985a) indicated that both males and female *A. graeffei* from the upper estuary of the Clarence River in NSW began to mature at ~250 mm standard length and 250 g weight; all were mature by 350 mm (females) and 325 mm (males) and 1000g.

been developing. In the 1979 Late-wet–Early-dry season, one spent and three recovering-spent or immature males were caught. These data also suggest breeding had occurred some time between the Late-dry and the end of the Wet season.

Although all spent and mature fish were caught in corridor waterbodies in the Nourlangie Creek system, there is not enough information to be sure where they spawn.

Most members of the family Ariidae are buccal incubators; however, Semon & Wiedersheim (quoted in Breder & Rosen 1966) maintained that *A. graeffei* made a nest in the form of a circular depression in the gravel of rapidly flowing streams, and that the eggs (about 2.5 mm in diameter) were buried after spawning. In contrast, Bancroft (1923) described a specimen of this species with eggs in its mouth. Furthermore, Semon & Weidersheim recorded significantly smaller egg diameters than the 14 mm generally quoted for ariids; theirs more closely resemble plotosid egg diameters. Possibly Semon & Weidersheim had found a plotosid nest and wrongly attributed it to *A. graeffei*. Unfortunately, no ovaries were collected from *A. graeffei* during the present study, so egg diameters and fecundities could not be studied.[58]

Feeding habits

Overall diet

The stomach contents of 48 specimens were examined; 38 contained food. A summary of the diet of *A. graeffei* is given in fig 23; details of the components are given in table 23.

The main components of the diet were teleosts (23%), terrestrial plant material (22%), macrocrustaceans (19%) and aquatic insects (9%). The teleosts were mainly scales from *L. calcarifer* and *S. jardinii,* with traces of *M. splendida inornata* and *G. giuris*. The macrocrustaceans consisted mainly of *Macrobrachium* and *Paratelphusa transversa*.

Terrestrial insects (5%) were also found in the stomachs, as well as traces of bivalves, detritus and inorganic material. Large quantities of unidentified organic material (16%) were also found, as well as nematode and microcrustacean parasites. *Arius graeffei* can therefore be classified as a macrophagous omnivore.[59]

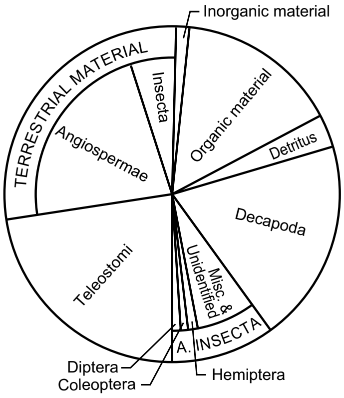

Figure 23 The main components of the diet of *A. graeffei*

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[58] Rimmer (1985b) has subsequently examined the reproductive cycle of *A. graeffei* from the upper estuary of the Clarence River in NSW: gonadal cycle, secondary sex characters, spawning stimuli, egg size, fecundity and sex ratio. Rimmer (1985c) examined early development and buccal incubation from the same population.

[59] Rimmer and Midgley (1985) indicated that larvae which had almost completed yolk absorption showed feeding habits similar to those of adults, which are opportunistic omnivores. Rimmer (1985a) indicated that the stomach fullness of *A. graeffei* from the Clarence River upper estuary in NSW was at a maximum during late-autumn to early-winter, and at a minimum during the breeding season in late-spring to summer.

Table 23 Dietary composition of *A. graeffei*

	Seasons			
	1978	1979	Overall	
Stomach contents	Late-dry	Late-wet–Early-dry	Sub-mean	Main-mean
Aquatic animals				
Bivalvia				0.3
Velesunio	0.6	–	0.3	
Macrocrustacea				19.2
Macrobrachium	2.2	31.3	17.5	
P. transversa	–	3.3	1.7	
Insecta				9.2
Fragmented	12.5	1.0	6.5	
Hemiptera				
Naucoridae	0.6	0.5	0.5	
Coleoptera				
Miscellaneous	–	2.5	1.3	
Diptera				
Chironomidae (larvae)	0.6	0.3	0.4	
Chironomidae (pupae)	1.1	–	0.5	
Teleostomi				22.6
Fragmented	0.6	–	0.3	
Scale	35.6	2.8	18.3	
S. jardinii (scale)	–	1.0	0.5	
M. splendida inornata	–	0.5	0.3	
G. giuris	–	2.0	1.1	
Egg material	5.3	–	2.5	
Terrestrial plants				
Angiospermae				
Fragmented	–	19.5	10.3	21.5
Miscellaneous	11.9	10.0	10.9	
Pandanus (seed)	–	0.5	0.3	
Terrestrial animals				
Insecta				5.4
Fragmented	–	10.3	5.4	
Parasites				
Nematoda	2.2	0.5	1.3	1.3
Microcrustacea				1.6
Argulus	3.3	–	1.6	
Detrital material	7.2	–	3.4	3.4
Inorganic material	1.9	0.3	1.1	1.1
Organic material	17.2	14.0	15.5	15.5
Number of empty fish	5	5	10	10
Number of fish with food	18	20	38	38

Seasonal changes

The stomachs of 48 *A. graeffei* were examined (all habitats combined): 23 (22% empty) from the 1978 Late-dry and 25 (20% empty) from the Late-wet–Early-dry seasons. Fish scales, aquatic insects and terrestrial plant material were the main items eaten in the 1978 Late-dry season. Large portions of *Macrobrachium*, terrestrial plant material and insects were eaten in the Late-wet–Early-dry season.

Family PLOTOSIDAE

The Plotosidae is a predominantly freshwater family of fish with several marine and estuarine representatives, but almost nothing is known about the habits or biology of its tropical Australian members.[60]

Many of the eleven species of freshwater plotosid catfishes listed by Lake (1978) are reputedly common where they occur, but there is considerable confusion as to their identification. Lake (1978) found it impossible to allocate specific names, as he found the original descriptions inadequate. *Anodontiglanis dahli*, however, is easily identified amongst the species found in the Alligator Rivers Region.

Although the colour of a fish is often a poor diagnostic character, Lake found little trouble in separating several of these fishes by their common names, which are based on their colour when alive. Pollard (1974) referred to the plotosid catfishes he collected as 'yellow-finned' and 'black-finned' species. In the present study we initially used a similar colour-based system (for all except *A. dahli*): *Neosilurus* sp. A = 'yellow-bellied'; *Neosilurus* sp. B = 'black-blotched' (fins and body), and *Neosilurus* sp. C = 'yellow-finned'. However, specimens kept in aquaria could change colour with stress or changes in lighting, eg *Neosilurus* sp. A (and sometimes *Neosilurus* sp. C) could appear to turn into *Neosilurus* sp. B with reduction in light intensity. Morphometric characters such as dorsal head profile, snout length and distance to dorsal fin origin appeared to vary within each of the colour-types.

A key to the plotosid catfishes by Feinberg and Nelson became available from the Australian Museum after the Mid-wet season sampling.[61] This key, which distinguished three species on the basis of morphometric characters, was adopted for subsequent samples. These specimens are cross-referenced with the colour-types.

The species composition of the colour-type classification used in the first three sampling periods was:

	Colour-type					
	A		B		C	
	n	%	*n*	%	*n*	%
N. ater	79	82.3	24	72.7	3	0.7
N. hyrtlii	10	10.4	6	18.2	105	24.7
P. rendahli	7	7.3	3	9.1	318	74.6
Total	96	100.0	33	100.0	426	100.0

Each colour-type contained specimens from all three identified species: *Neosilurus* sp. A contained mainly *N. ater* with less than 20% contamination from *N. hyrtlii* and *P. rendahli; Neosilurus* sp. B contained mainly *N. ater* with less than 30% contamination from *N. hyrtlii*;

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[60] The reproduction and development of *N. ater* and *N. hyrtlii* from Queensland has since been described by Orr and Milward (1984). Reproduction and development of *Neosilurus ater* (Perugia) and *Neosilurus hyrtlii* (Steindachner) (Teleostei: Plotosidae) in a tropical Queensland stream, *Australian Journal of Marine and Freshwater Research* 35, 187–195.

[61] Feinberg and Nelson's key was never published. A field guide to Australia's freshwater fishes, including plotosid catfish, is at present being prepared by Dr GR Allen. The names used in this section follow the *Zoological Catalogue of Australia* vol 7, 1989 (AGPS, Canberra).

and *Neosilurus* sp. C contained mainly *P. rendahli* with less than 30% contamination from *N. hyrtlii* and only traces of *N. ater*.

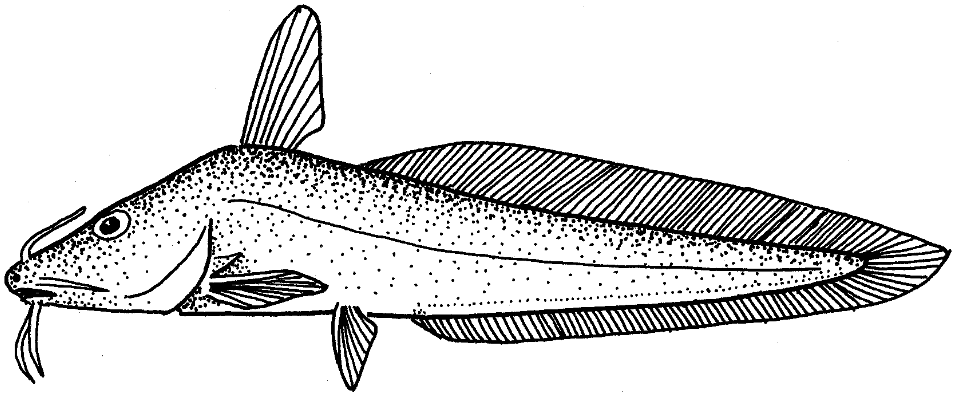
Therefore, as *Neosilurus* sp. A mainly comprises *N. ater*, results on these two are presented together. Similarly, results on *Neosilurus* sp. C are presented with *P. rendahli*.

To allow a condensed presentation, results on *Neosilurus* sp. B are presented with *N. hyrtlii*. The high proportion of *N. ater* in the *Neosilurus* sp. B samples is recognised and identified where appropriate. Escarpment mainchannel waterbodies were the main sites where *N. ater* dominated *Neosilurus* sp. B captures.

Family PLOTOSIDAE

3.8 *Anodontiglanis dahli* (Rendahl)

Anodontiglanis dahli is commonly known as the toothless catfish. It is endemic to Australia and is found in the Timor Sea and Gulf of Carpentaria drainage divisions (see map 3). Midgley (1973) collected this species from Coopers Creek, Deaf Adder Creek and Baroalba Creek in the Alligator Rivers Region.



Anodontiglanis dahli

Information on catches at each site and in each season is given in volume 2. In summary, this species was found, but only rarely, in an escarpment mainchannel waterbody, a backflow billabong and a corridor waterbody in the Nourlangie Creek catchment. One specimen was captured in the Cooper Creek system.

Size composition

Length–weight relationship

The lengths and weights of 31 specimens were determined. The length–weight relationship was described by the expression:

$$W = 0.17 \times 10^{-2} L^{3.43} \qquad r = 0.98 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 24. The condition factors in the 1978 Late-dry and the 1979 Late-wet–Early-dry seasons were similar; the few specimens captured in the 1978–79 Early-wet and Mid-wet seasons had higher factors.

Table 24 Mean length, mean weight and condition factor of *A. dahli*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	23	385.9	452.0	1.00
Early-wet (1978–79)	2	384.9	463.8	1.04
Mid-wet	1	185.0	39.6	1.08
Late-wet–Early-dry (1979)	5	420.8	587.0	0.97
Overall	31	382.1	436.7	1.00

Length-frequency distribution

The lengths of specimens ranged from 185 mm to 490 mm TL (mean = 382 mm, modal = 390 mm TL) (fig 24). Lake (1971) had suggested the maximum length of *A. dahli* was 400 mm TL. Only a few specimens were less than 360 mm TL; most were between 360 and 420 mm TL. It is not known why so few smaller specimens were captured, as small specimens of other species of plotosid catfishes were frequently captured in gillnets. It is most likely that small *A. dahli* were present in unsampled habitats.

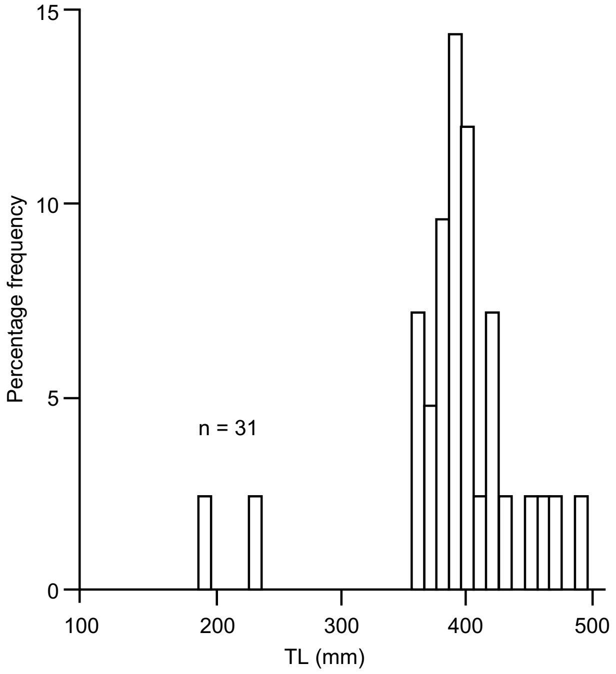


Figure 24 Length-frequency distribution of all *A. dahli* captured

Seasonal changes in distribution

The smallest specimen (185 mm TL) was captured during the 1978–79 Mid-wet season. The largest specimen (490 mm TL) and the second smallest specimen (220 mm TL) were captured during the 1978 Late-dry season.

Habitat differences in distribution

All specimens were captured in the Nourlangie Creek catchment, mainly in escarpment mainchannel waterbodies and to a lesser extent in sandy corridor waterbodies. The smaller specimens were captured in a channel backflow billabong.

Environmental associations

Rank numbers for *A. dahli* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Anodontiglanis dahli was captured in waters with surface temperatures ranging from 27 to 33°C (mean = 30.2°C), and bottom temperatures from 26 to 32°C (mean = 28.6°C). Both means were ranked in the lower-middle quarter (fig 170). *Anodontiglanis dahli* was mainly captured in cooler, escarpment mainchannel habitats.

Dissolved oxygen

Dissolved oxygen concentrations in surface water ranged from 4.4 to 7.4 mg/L (mean = 5.8), and in bottom water from 0.6 to 6.8 mg/L (mean = 4.5). Both means were ranked in the lower-middle quarter (see fig 171). Low bottom-water DO concentrations appear to be characteristic of the habitats of bottom-dwelling plotosid catfishes.

Visibility

Secchi depths ranged from 3 to 210 cm (see fig 172). The mean of 136 cm was placed in the upper quarter, as might be expected for a species that was typically captured in clear escarpment waters.

PH

Surface water pH ranged from 5.4 to 7.0 (mean = 6.2), and bottom water pH from 5.1 to 7.0 (mean = 6.1). These means were placed in the lower and upper-middle quarters, respectively (see fig 173).

Conductivity

Surface-water conductivity ranged from 6 to 24 µS/cm and bottom water from 6 to 47 µS/cm. These conductivities are exceptionally low and the range narrow; this species was mostly captured in habitats with permanent flow or seepage from sandy aquifers and only a few conductivity readings were taken.

Habitat–structural variables

Substrate

The main substrate over which *A. dahli* was captured was sand (upper quarter), followed distantly by mud, then clay. A few specimens were captured in channels with rocky substrates.

Hydrophytes

Anodontiglanis dahli was infrequently found in waters with vegetation (vegetation-occurrence index 21.1%). Of this limited vegetation, submergent hydrophytes were dominant (63.6%), followed by floating-attached hydrophytes (27.3%). Emergent vegetation was notably sparse.

Reproduction

Of the 31 *A. dahli* captured, 30 were examined for reproductive condition: 15 males (length range 226–400 mm TL), 14 females (380–490 mm TL) and one sexually indistinguishable (185 mm).

The gonad maturity stages differ macroscopically from the generalised description given in volume 1. A more accurate description of each stage is given in Davis (1977b).

Length at first maturity

Although the sample size was small, the LFM was estimated as 370 mm TL for males and 400 mm TL for females (fig 25).

The LFM was estimated from 10-mm-length groups. No maturing fish were found below the LFM. Males were generally smaller and matured at a smaller size than females.

Sex ratio

The sex ratios were not significantly different from 1:1 during any sampling period.

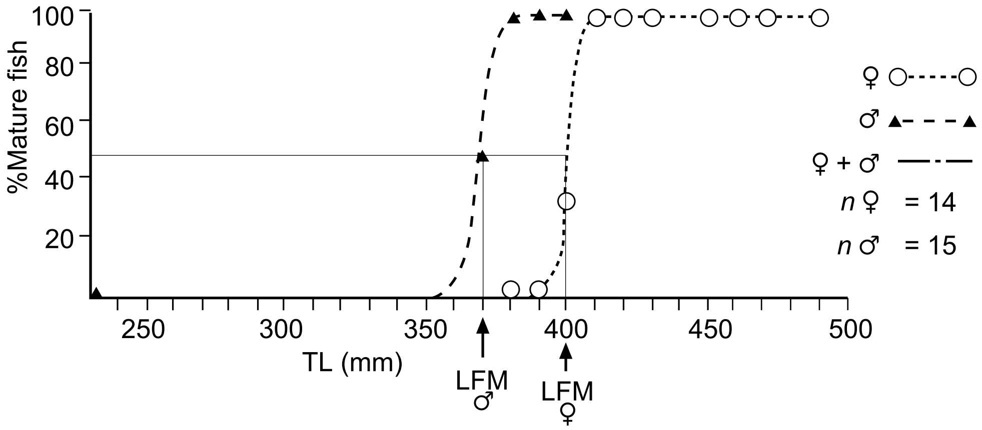


Figure 25 Estimated length at first maturity (LFM) of male and female *A. dahli*

Breeding season

Insufficient data were available to determine the breeding season; however, higher GSI and GMSI (table 25 and fig 26) were recorded in the 1978 Late-dry season than in the 1979 Late-wet–Early-dry. The presence of mature and ripe fish in the former season and spent fish in the latter indicates that spawning most likely occurred during the Wet season.

Table 25 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *A. dahli* over all habitats

Parameter	Sex	Statistic	Sampling period Late-dry 1978	 Early-wet 1978–79	 Late-wet–Early-dry 1979
Sex ratio					
Juveniles	F	*n*	11	–	3
+ adults	M	*n*	11	2	2
		χ^2	0	2.0	0.2
		P	n.s.	n.s.	n.s.
Adults only	F	*n*	8	–	3
	M	*n*	6	2	2
		χ^2	0.3	2.0	0.2
		P	n.s.	n.s.	n.s.
GSI					
Adults only	F	mean	1.9	–	0.5
		s.d.	1.4	–	0.1
	M	mean	0.3	0.4	0.2
		s.d.	0.3	0.3	0.1
	F+M	mean	1.2	–	0.4
		s.d.	1.3	–	0.2
GMSI					
Adults only	F	mean	4.4	–	2.0
		s.d.	1.4	–	0.0
	M	mean	3.8	3.0	2.0
		s.d.	0.8	1.4	0.0
	F+M	mean	4.1	–	2.0
		s.d	1.2	–	0.0

n = number; χ^2 = Chi-squared value; n.s. = not significant (P > 0.05); s.d. = standard deviation

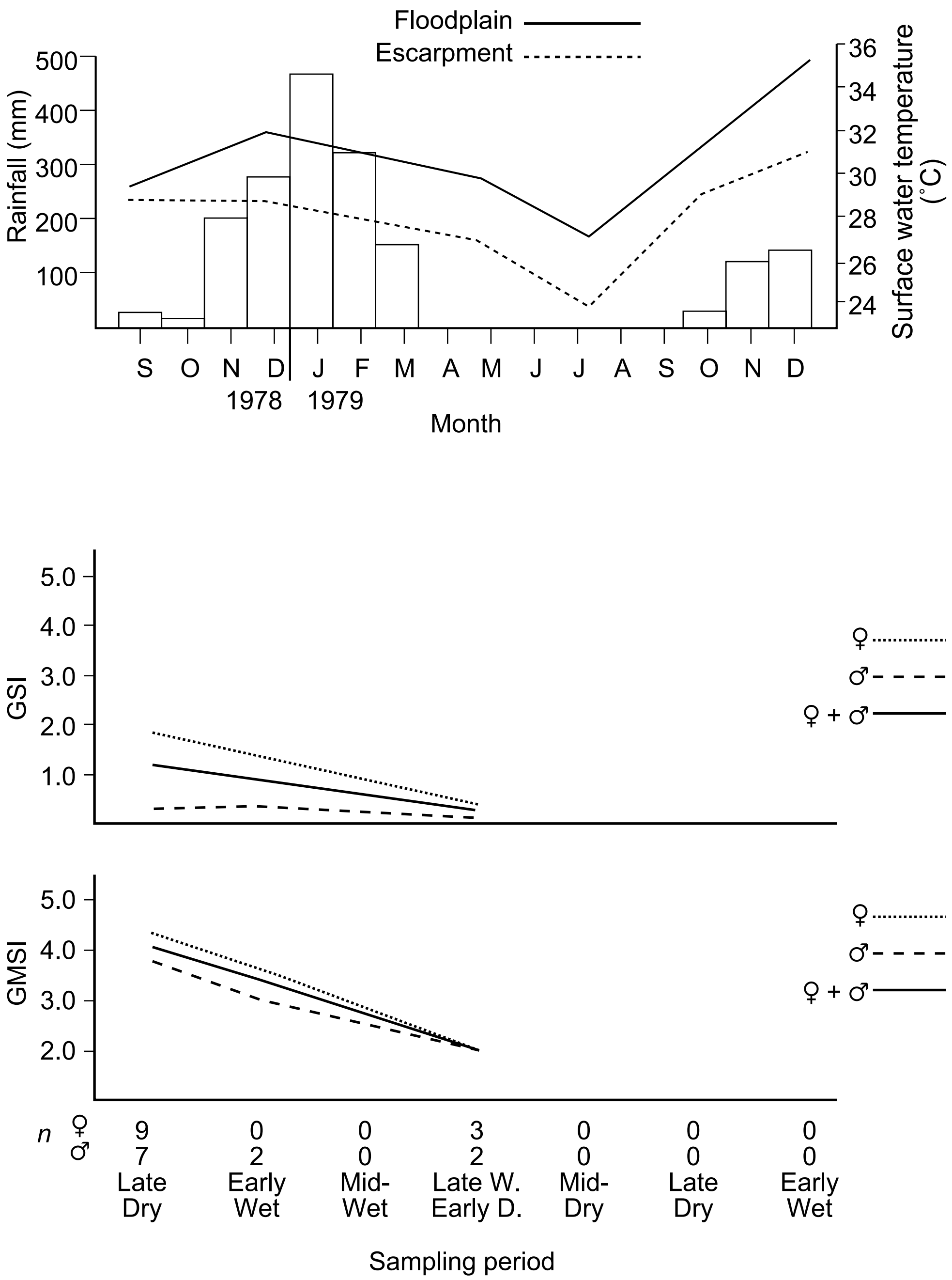


Figure 26 Seasonal fluctuations in gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *A. dahli*

Site of spawning

Anodontiglanis dahli was mainly captured in the Nourlangie Creek system (one spent female was collected in the Nabarlek Dam on Cooper Creek). Mature, ripe and spent fish were collected from an escarpment mainchannel waterbody (Camp 1, Deaf Adder Creek); two deep corridor waterbodies (Nourlangie East and Skull Rock); and a channel backflow billabong (Baroalba Crossing) (table 26) in the Nourlangie Creek system. Spawning thus appears to be widespread through the Nourlangie system.

Table 26 Possible sites of spawning of *A. dahli,* as indicated by the abundance (*n*) of mature, ripe and spent fish

	Gonad stage					
	Mature (V)		Ripe (VI)		Spent (VII)	
Habitat	F	M	F	M	F	M
Escarpment						
Mainchannel waterbody	1	–	–	–	–	–
Lowlands						
Backflow billabong	–	–	–	–	–	1
Corridor	1	1	2	–	3	2

Feeding habits

Overall diet

The stomach contents of 27 specimens were examined; all stomachs contained food. The diet of *A. dahli* is summarised in fig 27; details of the components are given in table 27. The main components of the diet were aquatic insects (37%) and incidental inorganic material (14%). Large quantities of unidentified organic material (20%) and trematode parasites (15%) were also found in the stomachs together with traces of algae, microcrustaceans, terrestrial plant material and detrital material. *Anodontiglanis dahli* can therefore be classified as a meiophagous benthic carnivore. This species has no teeth in its mouth, only in its gullet, and was frequently observed grazing on aquatic organisms over sandy substrates in escarpment mainchannel waterbodies and sandy corridor waterbodies.

No description of the feeding habits of this species could be found, though many of the plotosids are considered to be essentially carnivorous (Lake 1978).

Seasonal changes

A total of 22 specimens of *A. dahli* (all habitats combined) were examined in the 1978 Late-dry season, and 5 in the 1978–79 Late-wet–Early-dry. All the fish had food in their stomachs.

The diet in the 1978 Late-dry season consisted of a wide variety of aquatic insects (mainly chironomids), together with terrestrial plant and detrital material and traces of algae; many trematodes were found in the stomachs along with large quantities of unidentified organic material. The few specimens captured in the Late-wet–Early-dry season were eating only chironomid larvae.

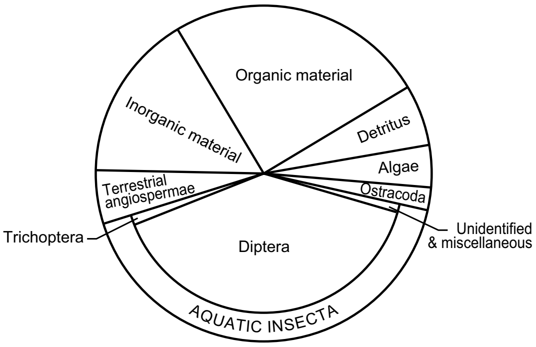


Figure 27 The main components of the diet of *A. dahli*

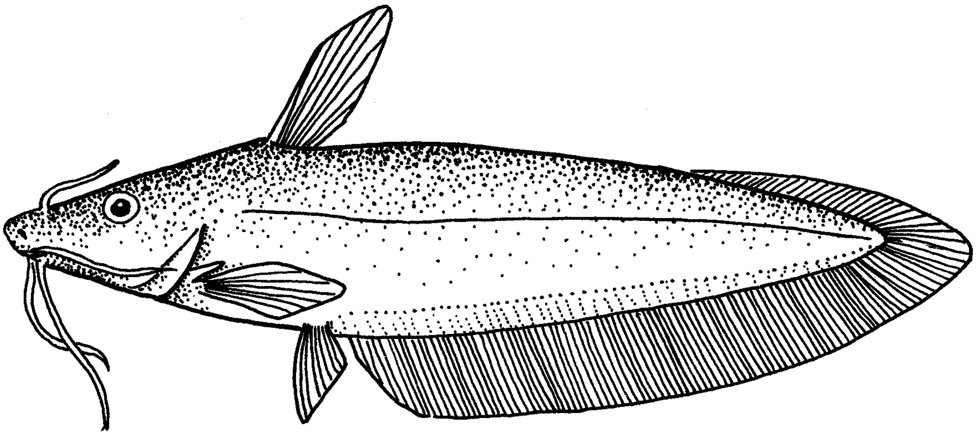
Table 27 Dietary composition of *A. dahli*

Stomach contents	Season 1978 Late-dry	Season 1979 Late-wet–Early-dry	Overall Sub-mean	Overall Main-mean
Aquatic plants				
Algae				2.5
Conjugatophyta	3.2	–	2.5	
Aquatic animals				
Microcrustacea				2.1
Ostracoda	–	–	2.1	
Insecta				36.8
Fragmented	0.9	–	0.7	
Ephemeroptera				
Baetidae	0.5	–	0.4	
Diptera				
Culicidae	0.5	–	0.4	
Chaoborinae	2.7	–		
Chironomidae (larvae)	17.3	96.0	30.7	
Chironomidae (pupae)	2.3	–	1.8	
Trichoptera				
Leptoceridae	0.9	–	0.7	
Terrestrial plants				
Angiospermae				3.8
Miscellaneous	8.6	–	3.8	
Parasites				
Trematoda	19.6	–	15.4	15.4
Detrital Material	6.4	–	5.0	5.0
Inorganic Material	16.4	4.0	13.6	13.6
Organic Material	23.2	–	19.6	19.6
Number of empty fish	–	–	–	–
Number of fish with food	22	5	27	27

Family PLOTOSIDAE

3.9 *Neosilurus ater* (Perugia)

Neosilurus ater is commonly known as the narrow-fronted tandan, butter jew or black catfish. Data on *N. ater* will be presented together with that for the colour-type *Neosilurus* sp. A. This species is found in the Timor Sea and Gulf of Carpentaria drainage divisions (see map 3) and Papua New Guinea.[62] Miller (in Taylor 1964) found it in large billabongs and creeks in the Oenpelli area, and in lower riverine floodplain billabongs.



Neosilurus ater

Detailed information on catches at each site and in each season is given in volume 2. In summary, *Neosilurus* sp. A / *N. ater* were found commonly in all floodplain billabongs, corridor waterbodies, escarpment mainchannel waterbodies and perennial streams, and in most backflow billabongs and sandy creekbed habitats. In the Late-dry season it was found mainly in escarpment mainchannel and corridor waterbodies; in the Mid-wet season mainly in lowland habitats and flood plains; and in the Late-wet–Early-dry season in escarpment mainchannel and corridor waterbodies, when large numbers moved upstream into escarpment perennial streams from lowland habitats.

Size composition

The lengths and weights of 224 specimens of *Neosilurus* sp. A and 106 specimens of *N. ater* were determined.

Seasonal length-frequency distributions and condition factors are based on the *Neosilurus* sp. A colour-type until the Late-wet–Early-dry season and on *N. ater* from then to the end of the study.

Most specimens were captured by gillnet, though some of the small juveniles were captured by seine net. The narrow peaks in the length-frequency distributions were probably partly caused by the mesh selectivity of the gillnets.

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[62] Recent surveys over Cape York Peninsula by Herbert et al (1995) indicated that *N. ater* are found in most streams along the east coast of the Cape. That is, their distribution extends to the north-east coast drainage division.

Length–weight relationship

The length–weight relationships for *Neosilurus* sp. A and *N. ater* were described respectively by the expressions:

$W = 0.29 \times 10^{-2} L^{3.30}$ r = 0.97 (length in cm, weight in g)

$W = 0.73 \times 10^{-2} L^{3.04}$ r = 0.97 (length in cm, weight in g)

The difference in the length–weight relationship between the classification types may have been caused by seasonal changes in condition (see later). In the closely related *T. tandanus*, there is little difference between sexes and some differences between size groups (Davis 1977*a*).

Seasonal mean lengths, weights and condition factors for *Neosilurus* sp. A and *N. ater* are shown in table 28. Seasonal condition fell dramatically from the 1978 Late-dry season to the 1978–79 Early-wet season; it was possibly caused by spawning activity. Davis (1977*a*) noted that the condition of both sexes of *T. tandanus* was highest in the summer months before breeding, and that a drop in condition due to reduction in gonad weight was expected. By the Mid-wet season the condition factor reached its peak. The apparent drop in condition in the Late-wet–Early-dry season was probably a result of 'unfavourable' environmental conditions caused by anoxic benthic waters, which were frequently recorded in backflow billabongs during this season. After the Mid-dry season the condition factor decreased through the Late-dry season to reach a minimum in the Early-wet season similar to that recorded in the 1978–79 Early-wet season. Body condition was much lower in the 1979 Late-dry season than in the 1978 season.

Table 28 Mean length, mean weight and condition factor of *Neosilurus* sp. A and *N. ater*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Neosilurus sp. A				
Late-dry (1978)	68	358.0	424.1	1.08
Early-wet (1978–79)	80	338.5	291.4	0.89
Mid-wet	24	260.3	155.7	1.13
Late-wet–Early-dry (1979)	33	334.9	326.6	1.03
All seasons combined	205	336.8	312.3	1.00
N. ater				
Mid-dry 1979	41	320.0	305.4	1.09
Late-dry	26	360.0	389.5	0.97
Early-wet 1979–80	8	334.4	273.9	0.86
All seasons combined	75	317.0	272.0	1.00

Length-frequency distribution

The lengths of *Neosilurus* sp. A ranged from 22 to 508 mm TL, and of *N. ater* from 72 to 460 mm TL (fig 28). Differences in the lower range are attributable to the presence of small juveniles of *Neosilurus* sp. A in the 1978–79 Early-wet and Mid-wet seasons and the absence of *N. ater* juveniles in the corresponding 1979–80 seasons. Lake (1971) recorded that *N. ater* grows to 400 mm TL. The closely related *T. tandanus* was found to grow to 596 mm TL in the Gwydir River, New South Wales (Davis 1977*a*); however, Lake (1971) reported it can grow to 900 mm TL.

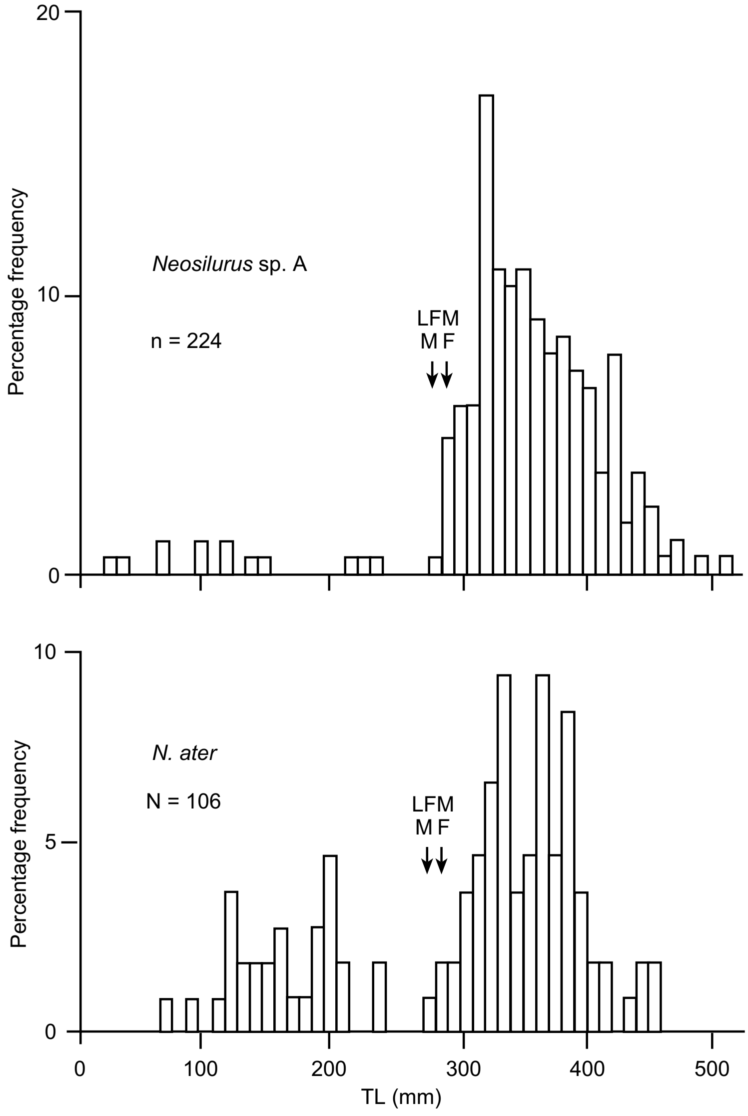

Figure 28 Length-frequency distribution of all *Neosilurus* sp. A and *N. ater* captured

The mean lengths of *Neosilurus* sp. A and *N. ater* were similar: 337 and 317 mm TL, respectively. More adults than juveniles were collected: the LFM for both *Neosilurus* sp. A and *N. ater* was 255 mm TL for males and 275 mm TL for females. Most specimens were between 300 and 400 mm TL.

Seasonal changes in distribution

The smallest specimens of *Neosilurus* sp. A were found in the 1978–79 Early-wet and Mid-wet seasons, and of *N. ater* in the Mid-dry season; this difference between classification types can be readily explained by seasonal growth of juveniles (ie juveniles are smaller earlier in the respective sampling periods). The smallest specimens of *Neosilurus* sp. A captured during the 1978 Late-dry season and of *N. ater* in the 1979–80 Early-wet season were much larger than the smallest specimens captured in other seasons. The largest specimens (*Neosilurus* sp. A) were captured in the 1978–79 Early-wet and Mid-wet seasons.

Only adult *Neosilurus* sp. A were captured in the 1978 Late-dry season, and only adult *N. ater* in the 1979–80 Early-wet season (fig 29). In all other seasons, both adults and juveniles were captured. The length-frequency distribution in the 1978 Late-dry season was similar to that in 1979 except that there were fewer juveniles in 1979.

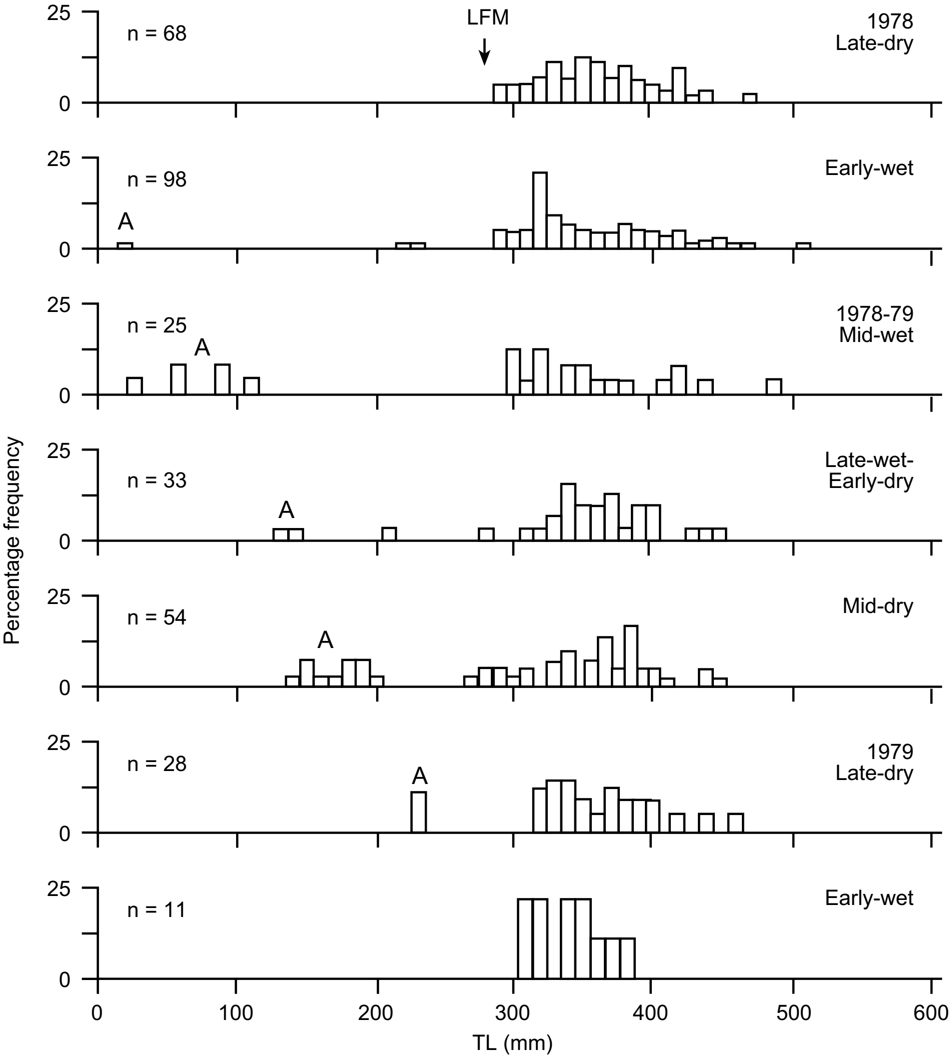

Figure 29 Seasonal length-frequency distribution of all *Neosilurus* sp. A and *N. ater* captured

During the 1978–79 Early-wet season, the adult component of the distribution remained similar in form to the previous season's peak; however, a few juveniles had appeared.

During the Mid-wet season the adult peak persisted while the small juvenile peak strengthened and the animals were slightly larger. By the Late-wet–Early-dry season the juvenile peak had progressed further and the gap to the strong adult peak had narrowed; these changes continued through the 1979 Mid- and Late-dry seasons until the juveniles that had been spawned in the 1978–79 Early-wet season merged with the persistent adult peak by the 1979–80 Early-wet season (however, sample sizes were small in this season).

Juvenile recruitment appeared to be strongest in the 1978–79 Early-wet and Mid-wet seasons. No juveniles were found in the 1979–80 Early-wet season; the absence of strong flow and the extreme conditions in the Late-dry season may have been unfavourable for spawning.

Growth rate

No published information on the growth of *N. ater* was found; however, the closely related *T. tandanus* attains 200 mm TL by year two and 450 mm TL by year five (Davis 1977*a*) .

The pattern of early growth of *Neosilurus* sp. A / *N. ater* can be interpreted from the seasonal length-frequency distributions by following the progression of juveniles (modal length at 20 mm TL; A on fig 29) from the 1978–79 Early-wet season to the 1979 Late-dry season (modal length at 230 mm TL). Growth appears to be very fast: about twice that recorded for *T. tandanus* by Davis (1977a); if true, then *N. ater* could attain the LFM in one year.

Habitat differences in distribution

Length-frequency distributions showing habitat preferences for *Neosilurus* sp. A and *N. ater* caught at regular sampling sites in the Magela Creek catchment are given in fig 30.

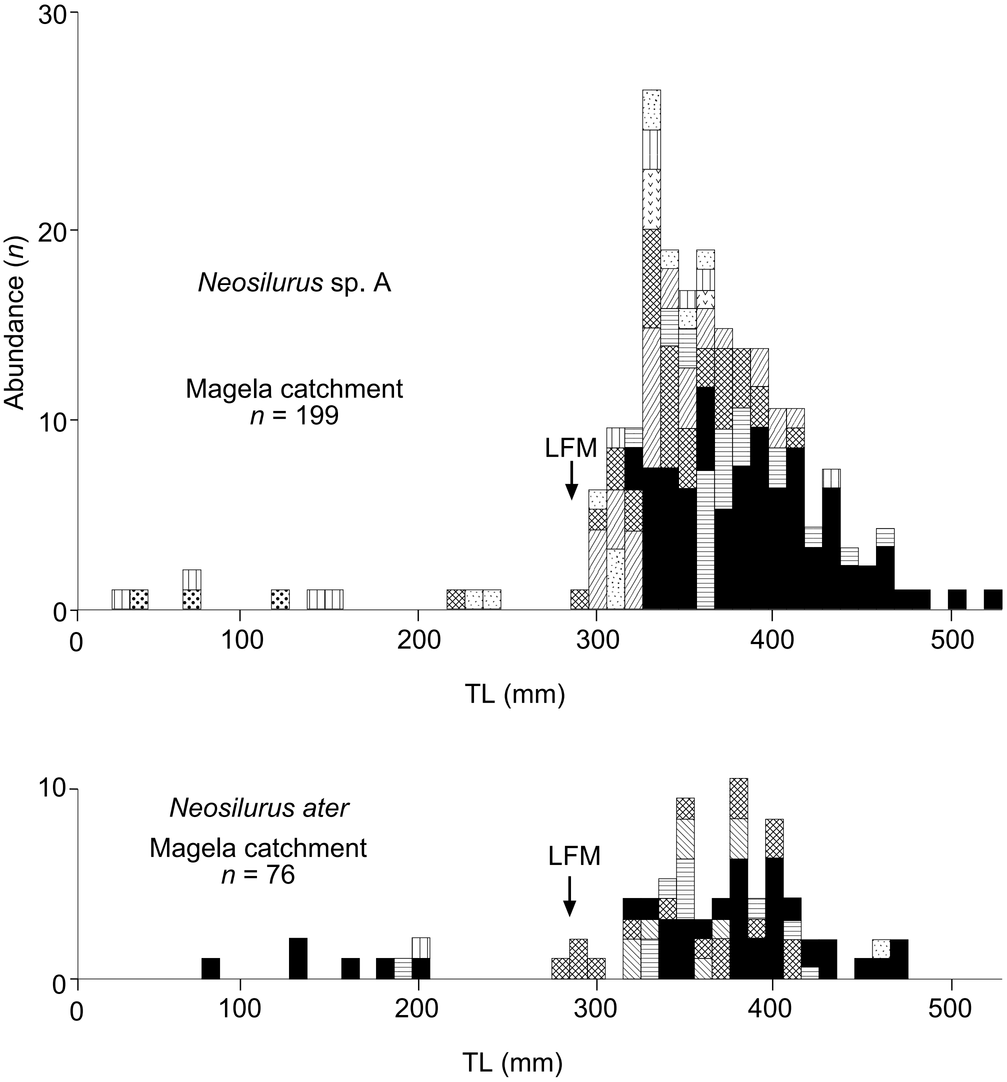

Figure 30 Length-frequency distributions and habitat preferences of *Neosilurus* sp. A and *N. ater* captured at regular sampling sites in the Magela catchment (see appendix 5 for key to the habitats)

Magela catchment

Smaller juveniles of *Neosilurus* sp. A were found in shallow backflow billabongs both up- and downstream of RUPA, while smaller juveniles of *N. ater* were found in floodplain billabongs; this could be a seasonal effect (ie the juveniles migrated from the lowlands to the floodplains) or an effect of contamination by other plotosid species of the *Neosilurus* sp. A sample. Larger juveniles of both classification types appeared to be more abundant in sandy corridor waterbodies. Juvenile *N. ater* were observed in escarpment perennial streams in the Late-wet–Early-dry and 1979 Late-dry seasons.

Smaller adult *Neosilurus* sp. A were found mainly in lowland sandy creekbeds and sandy corridor waterbodies, while small adult *N. ater* were most frequently found in the latter habitat. Overall, the adults of both *Neosilurus* sp. A and *N. ater* were mainly found in floodplain and corridor (usually sandy-bottomed) billabongs; the main differences were that *Neosilurus* sp. A was more abundant in lowland sandy creekbeds and backflow billabongs (this might be an effect of contamination by other plotosid species, especially in the backflow billabongs), and *N. ater* included representatives from escarpment mainchannel waterbodies. It was apparent that specimens classified as *Neosilurus* sp. B in escarpment mainchannel waterbodies were in fact *N. ater.* The largest adults of *Neosilurus* sp. A and *N. ater* were found in floodplain billabongs.

Nourlangie catchment

In the Nourlangie system, small adult *N. ater* and *Neosilurus* sp. A were found in escarpment mainchannel waterbodies and perennial streams (in the 1979–80 Early-wet season), and shallow backflow billabongs. Large adults were often observed in escarpment perennial streams. Juveniles of *N. ater* were observed in lowland-sandy creeks in the Late-wet–Early-dry and 1979 Late-dry seasons.

Environmental associations

Rank numbers for *N. ater* and *Neosilurus* sp. A for the physico-chemical and habitat-structural variables are shown in table 155.

Physico–chemical variables

Temperature

Neosilurus sp. A was found in waters with surface temperatures between 27° and 35°C (mean = 31.3°C), and bottom temperatures between 25° and 34°C (mean = 29.4°C) (see fig 170). Both means ranked in the upper quarter, indicating a tendency for these fish to live in warmer waters (although this may be a seasonal effect, highlighted by the change in classification system). *Neosilurus ater* was found in waters with surface temperatures from 23° to 33°C (mean = 28.5°C), and bottom temperatures from 23° to 32°C (mean = 27.3°C). Both means were ranked at the base of the lower quarter, indicating an apparent preference for cooler benthic waters (similar to those preferred by *P. rendahli* and *N. hyrtlii*).

Dissolved oxygen

Dissolved oxygen concentrations in waters inhabited by *Neosilurus* sp. A ranged from 0.1 to 8.8 mg/L (mean = 5.8) on the surface, and from 0.4 to 6.8 mg/L (mean = 3.5) on the bottom. Both means were ranked at the base of the lower quarter. *Neosilurus ater* favoured a similar range of DO concentrations (2.7–8.2 mg/L at the surface, and 0.6–6.2 mg/L on the bottom), and mean DO concentrations associated with it (5.5 mg/L and 3.4 mg/L) also ranked in the lower quarter (see fig 171). *Neosilurus ater* was amongst the fish killed at Leichhardt Billabong (Bishop 1980) when surface DO concentrations fell to 0.1 mg/L.

Visibility

Secchi depths of waters in which *Neosilurus* sp. A was found ranged from 1 to 270 cm. The mean depth of 93 cm was ranked in the upper quarter; this species was typically captured in the clearer corridor and escarpment waterbodies. *Neosilurus ater* was found in waters with Secchi depths between 2 and 360 cm, with a mean of 95 cm; this mean also ranked in the upper quarter (see fig 172).

pH

Neosilurus sp. A was captured in waters with surface pH ranging from 4.8 to 8.1 (mean = 5.9) and bottom pH ranging from 4.5 to 6.8 (mean 5.7). The pH of waters in which *N. ater* was found ranged from 4.0 to 7.2 (mean = 6.1) on the surface, and from 5.3 to 7.0 (mean = 5.9) on the bottom. The means ranked in the lower and lower-middle quarter respectively (see fig 173).

Conductivity

The waters in which *Neosilurus* sp. A was captured had conductivity readings from 2 to 160 µS/cm on the surface, and from 4 to 234 µS/cm on the bottom. *Neosilurus ater* was found in waters with conductivities from 2 to 120 µS/cm on the surface and from 2 to 70 µS/cm on the bottom. These ranges are both narrow and low, indicating a tendency for *Neosilurus* sp. A / *N. ater* to be found in waters with low concentrations of dissolved solids.

Habitat–structural variables

Substrate

Neosilurus sp. A was associated with a wide range of substrates: sand (upper-middle quarter), mud (upper-middle quarter), then clay, leaves, gravel, boulders and rocks. The substrate most commonly associated with *N. ater* was clay (upper quarter), followed by sand (lower-middle quarter) then mud, rocks, leaves and gravel. This wide range of substrates can be expected of such a widely distributed species. The predominance of clay and sand substrates would correspond to the clearness of waters in which this species was typically captured.

Hydrophytes

Neosilurus sp. A was typically found in vegetated waters (vegetation-occurrence index 70.8%) with submergent (42.3%), emergent (35%) and floating-attached (18.7%) hydrophytes. The order of dominance for *N. ater* was: submergent (41.5%), floating-attached hydrophytes (26.2%) and emergent (24.6%) hydrophytes (vegetation-occurrence index 65%).

Reproduction

Of the 353 *N. ater* and *Neosilurus* sp. A (referred to in this section as *N. ater*) examined for reproductive condition, 214 were females (length range 120–508 mm TL), 119 were males (110–420 mm) and 20 were sexually indistinguishable. The gonad maturity stages differ macroscopically from the generalised description given in volume 1; a more accurate description of each stage is given in Davis (1977b).

Length at first maturity

The LFM was estimated to be 255 TL for males and 275 mm for females (all calculations based on 10-mm-length groups); the smallest maturing male was 260 mm and the smallest maturing female was 220 mm (fig 31). Davis (1977b) found male and female *T. tandanus* maturing at the same age and weight.

Sex ratio

In the entire sample, significantly more females than males were identified in the 1978 Late-dry, 1979 Mid-dry ($P < 0.001$) and the 1979 Late-wet–Early-dry ($0.001 < P < 0.01$) seasons, and in the adult sample in the 1978 Late-dry ($P < 0.001$) and 1979 Mid- and Late-dry ($0.001 < P < 0.01$) seasons (table 29).

Higher proportions of adult females were found in the seasons just before the breeding period (Early-wet season); equal ratios of males and females were found in the 1978–79 and 1979–80 Early-wet and 1978–79 Mid-wet seasons.[63] However, more research is required to determine the sex ratio of this species, as misidentification of immature fish and behavioural differences in the sexes are two likely causes of the unequal sex ratios found in this study.

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[63] A sample of spawning *N. ater* taken during the Mid-wet season from the Ross River in northern Queensland had a sex ratio not significantly different from 1:1 (Orr & Milward 1984).

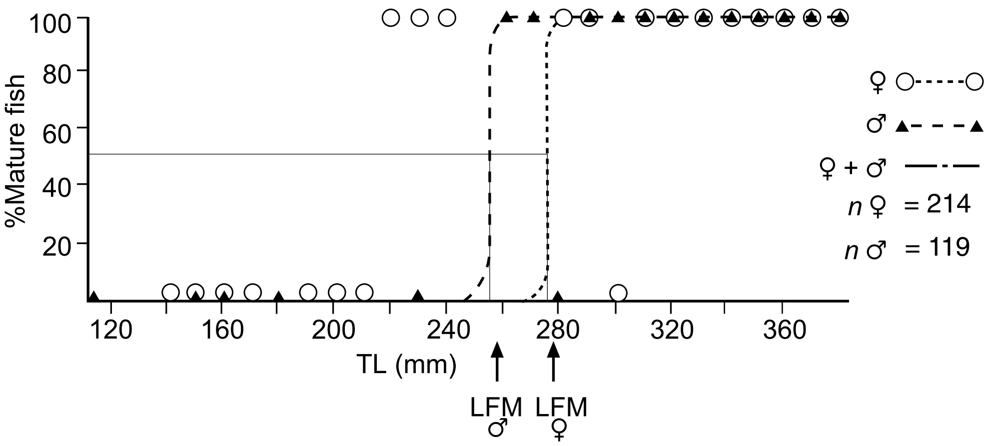

Figure 31 Estimated length at first maturity (LFM) of male and female *N. ater*

Table 29 Seasonal changes in sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *N. ater* over all habitats

Parameter	Sex	Statistic	Sampling period						
			Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	74	40	10	29	37	18	6
adults	M	*n*	27	44	10	11	12	10	5
		χ^2	21.9	0.2	0	8.1	12.8	2.3	0.1
		P	***	n.s.	n.s.	**	***	n.s.	n.s.
Adults only	F	*n*	71	38	10	20	30	17	6
	M	*n*	25	44	9	10	10	4	5
		χ^2	22	0.4	0.1	3.3	10	8	0.1
		P	***	n.s.	n.s.	n.s.	**	**	n.s.
GSI									
Adults only	F	mean	1.0	6.0	0.4	0.3	0.5	1.8	5.3
		s.d.	0.9	2.5	0.3	0.1	0.3	1.1	1.0
	M	mean	0.4	1.7	0.2	0.3	0.2	1.3	1.3
		s.d.	0.2	0.9	0.2	0.1	0.1	0.2	0.2
	F+M	mean	0.7	4.7	0.3	0.3	0.4	1.5	3.7
		s.d.	0.8	3.0	0.3	0.1	0.3	1.0	2.2
GMSI									
Adults only	F	mean	3.2	4.1	2.0	2.1	2.7	3.9	4.3
		s.d.	0.9	1.1	0.0	0.3	0.7	1.1	0.5
	M	mean	3.6	4.5	2.5	2.3	3.1	4.2	5.0
		s.d.	0.7	0.5	0.9	0.9	1.0	0.7	0.0
	F+M	mean	3.3	4.8	2.2	2.1	2.8	4.0	4.6
		s.d	0.9	0.9	0.6	0.3	0.8	0.9	0.5

n =number; χ^2 = Chi-squared value; n.s. = not significant ($P > 0.05$); ** = $0.001 < P < 0.01$; *** = $P < 0.001$; s.d. = standard deviation.

Breeding season

The GSI and GMSI show a peak in gonad development around the 1978–79 Early-wet season and a steady increase in development from the 1979 Mid-dry season to the 1979–80 Early-wet season peak (fig 32, table 29). Most of the mature fish were found in the 1978–79 Early-wet season, although they were found at other seasons, except the 1978–79 Mid-wet season. All ripe fish, except for one female, were captured in the 1978–79 Wet season. Spent female fish were found in all seasons between the 1978 Late-dry and the 1979 Mid-dry, and spent males from the 1978–79 Mid-wet through to the 1979 Mid-dry.

Thus the data suggest that the main breeding season was the 1978–79 Early-wet season, possibly with some spawning during the preceding Late-dry season. Although fish were maturing towards the 1979 Late-dry and 1979–80 Early-wet seasons, no evidence of actual spawning was observed.

Midgley (1980) observed large numbers of running-ripe male and female plotosids appearing to spawn soon after the start of flow down Magela Creek during the 1979–80 Wet season; this phenomenon was only observed over two days.

Site of spawning

Ripe fish were identified in a wide range of habitats (table 30), including sandy creekbed sites and escarpment mainchannel waterbodies, channel backflow billabongs, and corridor and floodplain billabongs. Thus this species most likely spawns throughout its preferred range. Midgley (1980) observed plotosids apparently spawning in water about 0.5 m deep amongst grass and timber immediately upstream of Magela Crossing, below a corridor waterbody.[64] *Tandanus tandanus* from southern Australia is reported to breed in ponds (Davis 1977b).[65]

Table 30 Possible sites of spawning of *N. ater* as indicated by the abundance (*n*) of mature, ripe and spent fish

	Gonad stage					
	Mature (V)		Ripe (VI)		Spent (VII)	
Habitat	F	M	F	M	F	M
Escarpment						
Mainchannel waterbody	8	6	2	–	3	1
Lowlands						
Sandy creekbed	3	11	4	–	4	1
Backflow billabong	4	3	1	–	5	5
Corridor	11	4	1	–	22	5
Floodplain billabong						
Upper	12	8	5	1	21	4
Lower	1	–	–	–	–	–

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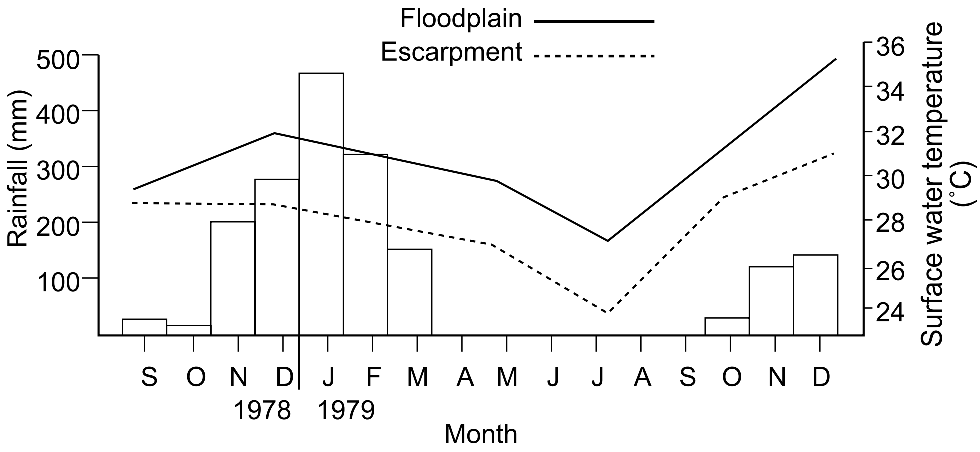
[64] From observations in the Ross River in northern Queensland, Orr and Milward (1984) stated that *N. ater* is a lithophilic flood spawner that undertakes spawning migrations.

[65] Merrick and Midgley (1981) recorded *T. tandanus* spawning over a nest site in a flowing stream in south-eastern Queensland. The site had the following characteristics: coarse gravel substrate, water velocity 0.05–0.07 m/s, water depth 0.6 m and surface temperature 20°C. Hutchison (1992) recorded a run habitat within a flowing stream to be the probable spawning site of the closely related *T. bostocki* from the Murray River in Western Australia. Eggs appeared to be laid within the coarse substrate of the run.



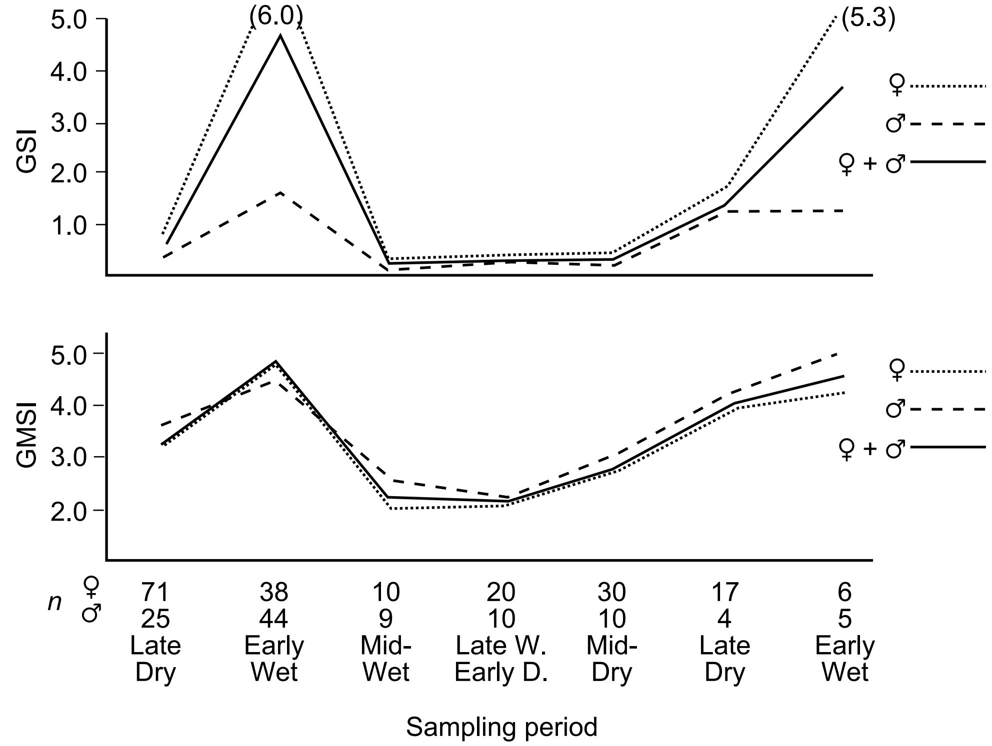


Figure 32 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *N. ater*

Fecundity

The eggs of 13 ripe ovaries (4.89 g to 92.21 g) were counted. The mean fecundity was 7890 (s.d. = 6060), and the range was 2540 to 26 070 eggs.[66]

Oocyte diameter ranged from 0.85 to 1.64 mm with a mean of 1.40 mm. Within the ovaries were small clusters of tiny eggs (mean diameter = 0.16 ± 0.012 mm).[67] Midgley (1980) reported plotosid eggs were demersal, non-adhesive and 2 mm in diameter when water-

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[66] Orr and Milward (1984) estimated fecundities of *N. ater* to range from 14 600 to 20 400 for individuals 348–440 mm standard length taken from the Ross River, northern Queensland.

[67] Egg and larval development of *N. ater* have been described by Orr and Milward (1984).

hardened. Davis (1977b) found a linear relationship for *T. tandanus* between egg diameter and fish weight and length, and found that egg size increased with an increase in fecundity.

Summary

Neosilurus ater had a peak in reproductive development around the 1978–79 Early-wet season, although some may have spawned earlier. Gonads started maturing for the next season's spawning around the 1979 Mid-dry season. The data indicate that *N. ater* is probably capable of breeding throughout its entire preferred habitat. Around 8000 medium-sized (1.4 mm) eggs are spawned, although it is not known if the species lays these all at once or over many spawnings.

In the Murray–Darling river system and south-east coastal drainages *T. tandanus* matures after four years (Davis 1977b). It spawns during spring or summer when water temperatures rise above 24°C (Lake 1967). It builds a nest with pebbles or gravel (or sticks or small stones where gravel is scarce) up to two weeks before spawning. If a sudden drop in water level exposes the nest before egg laying, it is invariably abandoned, even if the water level is restored shortly afterwards, and *T. tandanus* builds another nest elsewhere. If water levels fluctuate often, spawning will not take place, even though several nests are built; the ovaries are then resorbed.

The large demersal eggs settle within interstices of the gravel without actually adhering, and one parent remains in attendance until after hatching. Fecundity varies from 2800 at 39 cm TL (0.8 kg) to 20 000 ova at 53 cm TL (2.3 kg) (Davis 1977b). Hatching takes about seven days at temperatures between 19° and 25°C, at which time the larvae are 7 mm long. The eyes and most of the body are pigmented, but there are no barbels or pectoral fins. Barbels appear in three days, and by three weeks the larvae have most of the characteristics of adult fish (Davis 1977b; Pollard et al 1980).

A noticeable difference between *T. tandanus* and the northern *N. ater* is the size of the oocyte. Although fecundities are comparable, the egg diameters are 2.3–3.0 mm for *T. tandanus* (and greater than 3.2 mm when water-hardened [Davis 1977b]) and 0.9–1.6 mm for *N. ater*.

Sexual dimorphism amongst the plotosids was observed. The urinogenital papilla in females was swollen and cylindrical, whereas that of the males was triangular. These external sexual characteristics were noticeable in *T. tandanus* after it reached one year old (Davis 1977b).

The main factor stimulating spawning is believed to be temperature (Davis 1977b), which may act either by stimulating maturation of the gonads or, indirectly, by increasing the food supply. Day-length and flooding have also been suggested as spawning stimuli.

Feeding habits

Overall diet

The stomachs of 202 specimens of *Neosilurus* sp. A (161 containing food) and 115 of *N. ater* (99 containing food) were examined. The overall diets are shown in fig 33; details of the components are given in table 31. The main components were aquatic insects (37% and 60%, respectively), microcrustaceans (7% and 8%) and unidentified organic material (33% and 15%). There appears to be a difference between the quantity of aquatic insects each species ate, but this is probably a result of the change in the classification system highlighting the seasonal availability of food items.

Table 31 Dietary composition of *Neosilurus* sp. A and *N. ater*

	Neosilurus sp. A						*N. ater*					Habitat			
	1978	1978–79	1978–79	Late-wet–	Overall		1979	1979	1979–80	Overall					
Stomach contents	Late-dry	Early-wet	Mid-wet	Early-dry 1979	Sub-mean	Main-mean	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean	Em	Bb	Cb	Fb
Aquatic plants															
Algae						0.8					1.4				
Miscellaneous	1.5	0.9	–	–	0.8		–	4.4	–	3.0		–	–	2.5	–
Conjugatophyta															
Mougeotia	–	–	–	0.4			–	–	–			–	–	–	–
Spirogyra	–	–	–	–	–		–	–	–	0.4		–	–	–	–
Hydrophytes						0.3					–				
Pseudoraphis	–	0.9	–	–	0.3		–	–	–	–		–	–	–	–
Aquatic animals															
Oligochaeta	–	0.9	–	–	0.3	0.3	–	–	–	–	–	–	–	–	–
Gastropoda						0.4					–				
Miscellaneous	–	–	1.2	1.4	0.4		–	–	–	–		–	–	–	–
Bivalvia						0.6					–				
V. angasi	0.9	–	–	1.4	0.6		–	–	–	–		–	–	–	–
Microcrustacea						6.6					8.0				
Conchostraca															
Miscellaneous	–	–	3.2	–	0.5		–	–	–	–		–	–	–	–
Cyzicus	–	11.3	16.4	2.1	5.1		2.4	–	–	0.3		–	–	2.0	–
Cladocera															
Miscellaneous	–	–	2.2	–	0.3		0.6	–	–	1.2		–	–	0.5	–
Diaphanosoma	–	0.8	–	–	0.3		–	–	20.0	3.5		20.0	–	–	4.4
Ostracoda	0.4	–	1.2	0.7	0.4		–	–	–	3.4		–	–	–	–
Copepoda	–	–	–	–	–		–	–	–	0.1		–	–	–	0.6
Macrocrustacea						0.8					–				
Macrobrachium	1.1	–	–	2.1	0.8		–	–	–	–		–	–	–	–
Insecta						36.8					60.3				
Fragmented	0.2	4.2	8.0	–	2.7		2.7	2.4	–	6.7		–	–	2.3	6.3
Ephemeroptera															
Baetidae	–	5.3	4.2	–	2.4		–	–	40.0	3.1		40.0	–	–	–
Tasmanocoenis	–	–	–	–	–		–	0.4	–	1.0		–	–	0.3	–
Odonata															
I. heterosticta	–	–	–	–	–		1.2	–	–	0.4		–	–	1.0	–
Libellulidae	–	1.1	7.6	–	1.6		4.4	4.4	–	5.2		–	45.0	3.8	0.6
Gomphidae	–	–	1.6	–	0.3		–	–	–	–		–	–	–	–

Table 31 continued

	Neosilurus sp. A						*N. ater*					Habitat			
	1978	1978–79	1978–79	Late-wet–	Overall		1979	1979	1979–80	Overall					
Stomach contents	Late-dry	Early-wet	Mid-wet	Early-dry 1979	Sub-mean	Main-mean	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean	Em	Bb	Cb	Fb
Hemiptera															
Naucoridae	–	–	–	–	–		0.6	–	–	0.2		–	–	0.5	–
Corixidae	–	0.4	4.0	–	0.8		–	–	–	0.2		–	–	–	1.3
Coleoptera	–	2.5	1.2	–	1.0		0.6	–	–	0.2		–	–	0.5	–
Diptera															
Chaoborinae	–	–	–	–	–		7.2	2.2	–	3.0		–	–	–	18.4
Chironomidae (larvae)	42.6	21.1	13.4	37.5	20.5		30.3	72.8	2.0	32.4		2.0	55.0	46.3	40.3
Chironomidae (pupae)	2.7	0.4	–	20.4	0.6		2.9	0.2	–	2.0		–	–	–	6.6
Miscellaneous (larvae)	1.8	2.5	–	–	1.4		–	–	–	–		–	–	–	–
Ceratopogonidae	–	3.9	–	–	1.3		0.3	–	–	0.8		–	–	0.3	–
Trichoptera															
Lepteroceridae	3.3	2.1	12.6	2.5	4.2		1.0	–	20.0	5.1		20.0	–	0.9	–
Teleostomi						1.3					–				
Scales	–	–	–	2.9	0.5		–	–	–			–	–	–	–
Egg material	0.6	1.9	–	–	0.8		–	–	–	–		–	–	–	–
Terrestrial plants															
Angiospermae						2.9					3.3				
Fragmented	8.5	–	–	–	2.9		7.1	3.9	–	3.3		–	–	6.8	3.8
Terrestrial animals															
Arachnida	1.5	1.0	–	–	1.1	1.1	–	–	–	–	–	–	–	–	–
Insecta															
Odonata						0.6					–				
Zygopteran (adults)	–	0.1	–	–	+		–	–	–	–		–	–	–	–
Anisopteran (adults)					0.6		–	–	–	–		–	–	–	–
Dipteran (larvae)	–	1.9	–	–	–		–	–	–	–		–	–	–	–
Scolopendromorpha	–	1.9	–	–	0.6	0.6	–	–	–	–	–	–	–	–	–
Parasites															
Trematoda	4.4	12.5	–	–	5.3	5.3	–	–	–	–	–	–	–	–	–
Nematoda	0.7	–	–	–	0.6	0.6	–	–	–	–	–	–	–	–	–
Detrital material	–	–	–	–	4.6	4.6	8.7	3.0	18.0	8.9	8.9	18.0	–	7.4	10.6
Inorganic material	4.8	20.0	–	–	3.4	3.4	3.5	4.4	–	1.4	1.4	–	–	5.5	–
Organic material	25.0	–	23.0	3.0	32.9	32.9	28.4	–	–	14.5	14.5	–	–	19.8	10.9
Number of empty fish	10	26	–	5	41	41	6	3	3	16	16	2	–	–	1
Number of fish with food	55	53	25	28	161	161	34	23	5	99	99	5	2	40	16

Figures represent the mean percentage volume determined by the estimated volumetric method.

All habitats are in the Magela system. Em = escarpment mainchannel; Bb = lowland backflow billabongs; Cb = corridor billabongs; Fb = floodplain billabongs

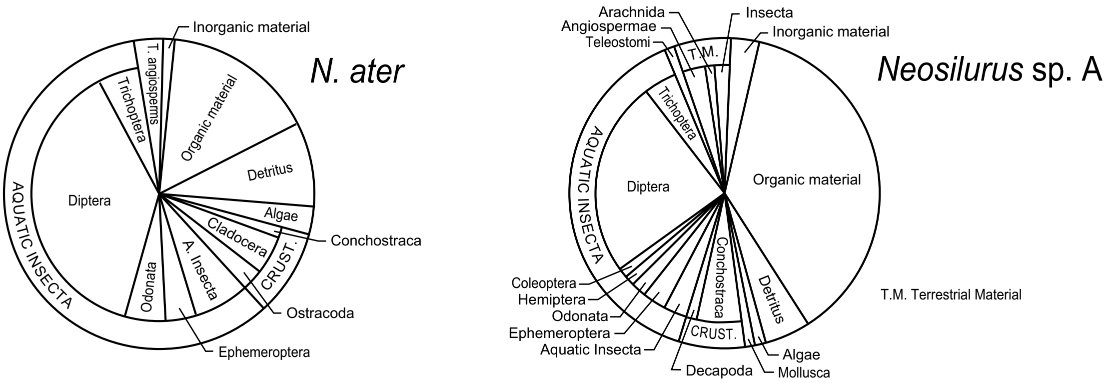

Figure 33 The main components of the diet of *Neosilurus* sp. A and *N. ater*

The main identifiable aquatic insects were chironomid, leptocerid, libellulid and baetid larvae. The main microcrustaceans *Neosilurus* sp. A ate were conchostracans, while *N. ater* ate mostly ostracods and copepods. Other food items were traces of algae, hydrophytes, oligochaetes, gastropods, bivalves, macrocrustaceans, teleosts, terrestrial plant material, and terrestrial arachnids, insects and scolopendromorphs.

Neosilurus ater/Neosilurus sp. A can therefore be classified as a meiophagous carnivore that feeds predominantly on benthic fauna.[68]

Pollard (1974) noted that little appeared to be known of the feeding of the 'neosilurine' group of plotosid catfishes. However, the feeding habits of the closely related *T. tandanus* in the Gwydir River, New South Wales, were investigated by Davis (1977*c*), who found that decapods (*Macrobrachium australiense* and *Cherax neopunctatus*) were the most important component of the diet by weight, followed by chironomids, fish (*Hypseleotris klunzingeri*) and miscellaneous aquatic invertebrates. Macrocrustaceans and fish were not a large component of the diet of *N. ater/Neosilurus* sp. A in the Alligator Rivers Region. Davis (1977*c*) reported that ontogenetic changes in the diet of *T. tandanus* were progressive: entomostracans to dipterans to fish to decapods. *Macrobrachium* was the main food in summer and chironomids in winter.

Seasonal differences

In sampling periods 1–4, respectively, 65 (15% empty), 79 (33% empty), 25 (0% empty) and 33 (15% empty) stomachs of *Neosilurus* sp. A were examined (all habitats combined).

In the 1978 Late-dry season, mainly chironomid larvae and other aquatic insects and some terrestrial plant material comprised the diet. Fewer chironomid larvae were eaten in the 1978–79 Early-wet season, while other aquatic insects (baetid larvae, coleopterans, ceratopogonid larvae) and microcrustaceans (*Cyzicus*) were eaten more often. By the Mid-wet season the diet consisted of microcrustaceans (*Cyzicus*) and a variety of aquatic insects (chironomid, leptocerid and libellulid larvae, and corixids and baetid larvae). During the Late-wet–Early-dry season, chironomid larvae and pupae become the most important food items.

In sampling periods 5–7, respectively, 40 (15% empty), 26 (11% empty) and 8 (38% empty) stomachs of *N. ater* were examined (all habitats combined).

During the 1979 Mid-dry season, *N. ater* ate mainly aquatic insects (chironomid, chaoborinid and libellulid larvae), terrestrial plant material and detritus. During the 1979 Late-dry season,

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[68] Pusey et al (1995b) found *N. ater* to primarily consume detritus in two rivers of the Australian wet tropics, northeastern Queensland.

it ate mainly chironomid larvae, as did *Neosilurus* sp. A in the previous year. The few specimens examined from the 1979–80 Early-wet season had eaten mainly baetid and leptocerid larvae, and microcrustaceans (this component appeared in the previous year for *Neosilurus* sp. A); however, *Diaphanosoma* was the main item in the 1979–80 Early-wet season, together with detrital material.

Habitat differences

A total of 66 stomachs of *N. ater* were examined (all seasons combined) from the Magela Creek catchment: 7 (29% empty) from escarpment mainchannel waterbodies; 2 (0% empty) from backflow billabongs; 40 (0% empty) from corridor billabongs; and 17 (6% empty) from floodplain billabongs. The highest proportion of specimens with empty stomachs was found in the escarpment mainchannel habitat.

The few specimens examined from escarpment habitats were feeding mainly on aquatic insects (mainly baetids and leptocerids), microcrustaceans (*Diaphanosoma*) and some detrital material. The two specimens from the backflow billabongs had eaten only aquatic insects (chironomid and libellulid larvae).

Neosilurus ater in the corridor waterbodies ate mainly chironomid larvae plus small portions of terrestrial plant and detrital material. The diet in the floodplain habitats was also dominated by chironomid larvae; however, there were also sizeable portions of chaoborinid larvae, chironomid pupae, detrital material and traces of terrestrial plant material.

Fullness

A summary of mean fullness indices of *Neosilurus* sp. A / *N. ater* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 32. These data are presented on the assumption that feeding times do not vary with habitat or season.

Seasonal changes

The mean seasonal fullness index (all habitats combined) fluctuated greatly, with peaks in the Late-wet–Early-dry and 1979 Late-dry season.

Habitat differences

In the Magela catchment the mean fullness indices of specimens from upstream of RUPA were highest in the shallow backflow billabongs and lowest in the escarpment mainchannel waterbody.

Downstream of RUPA the main indices were generally higher than those recorded in the upstream habitats; the mean fullness indices were highest in backflow and sandy corridor billabongs and lowest in corridor anabranch and floodplain billabongs.

In the Nourlangie catchment the range of mean fullness indices was larger than in the Magela catchment, possibly due to the smaller number of specimens examined from the latter catchment. The mean indices recorded in the escarpment mainchannel waterbodies and shallow backflow billabongs were comparable with those from equivalent habitats in the Magela catchment. The few specimens examined in the lowland sandy pool had high fullness indices.

Table 32 Mean fullness indices of *Neosilurus* sp. A and *N. ater* in different sampling periods and habitats

	Sampling period							
	Neosilurus sp. A				*N. ater*			
Habitat	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	1.1 (9)	n/s	n/s		0.3 (7)	n/s	0.9 (8)	0.8 (24)
Lowland shallow backflow billabong	n/s	n/s	2.0 (3)		3 (1)	n/s	n/s	2.3 (4)
Lowland sandy creekbed	n/s	1.0 (4)	n/s	n/s	n/s	n/s	n/s	1.0 (4)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	1.8	4.0 (2)	n/s	2.3 (4)	n/s	n/s	2.0 (36)
Lowland channel backflow billabong	n/s	1.0 (6)	4.0 (5)	2.5 (2)	3 (2)	n/s	n/s	2.5 (15)
Lowland shallow backflow billabong	n/s	4 (1)	2.4 (5)	3.7 (6)	5 (1)	n/s	n/s	3.3 (13)
Corridor sandy billabong	2.6 (20)	3.7 (3)	n/s	2.4 (8)	1.6 (10)	1.0 (7)	n/s	2.3 (48)
Corridor anabranch billabong	3.3 (11)	n/s	n/s	0.7 (16)	2.0 (2)	1.9 (7)	n/s	1.8 (36)
Floodplain billabong	1.7 (18)	0.7 (31)	2.7 (10)	2.8 (9)	2.1 (27)	3.3 (14)	n/s	1.7 (109)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	0.6 (14)	3.0 (3)	n/s	n/s	1 (1)	n/s	n/s	1.0 (18)
Lowland shallow backflow billabong	n/s	3.0 (5)	n/s	3 (1)	n/s	n/s	n/s	3.0 (6)
Lowland sandy creekbed	n/s	n/s	n/s	4.0 (2)	n/s	n/s	n/s	4.0 (2)
Seasonal mean (all sites)	2.2	1.5	1.5	3.0	1.9	3.1	1.3	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Summary

The habitats and periods of greatest apparent feeding activity where more than one fish was captured were:

Magela catchment

- lowland sandy creekbed (downstream of RUPA); 1978–79 Mid-wet season
- lowland channel backflow billabong; 1978–79 Mid-wet season
- lowland shallow backflow billabong (downstream of RUPA); 1978–79 Late-wet–Early-dry season
- corridor sandy billabong; 1978–79 Early-wet season

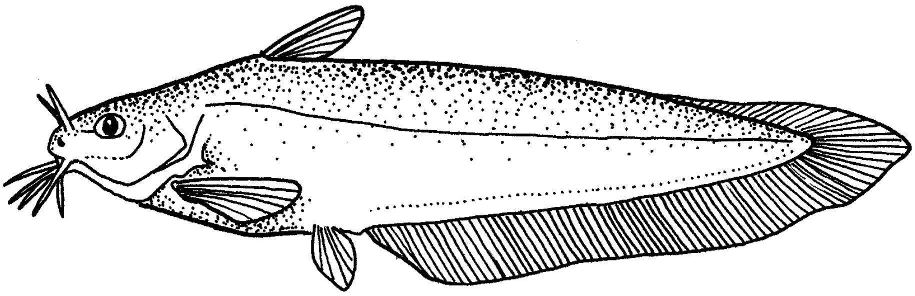
Nourlangie catchment

- lowland sandy creekbed; 1978–79 Late-wet–Early-dry season
- lowland shallow backflow billabong; 1978–79 Early-wet season
- escarpment mainchannel waterbody; 1978–79 Early-wet season

Family PLOTOSIDAE

3.10 *Neosilurus hyrtlii* (Steindachner)

Neosilurus hyrtlii is commonly known as Hyrtl's tandan or eel-tailed catfish. The data on *N. hyrtlii* and *Neosilurus* sp. B will be presented together. This species, a native to Australia, is found in the Timor Sea and Gulf of Carpentaria drainages, and many of the central desert streams of South Australia, Queensland and the Northern Territory.[69]



Neosilurus hyrtlii

Detailed information on catches at each site and in each season is given in volume 2. In summary, the species was commonly found in all backflow billabongs and in some lowland sandy creeks, corridor and floodplain billabongs. In the 1978 Late-dry season *Neosilurus* sp. B was found only in a lowland sandy creekbed site; during the Mid-wet season no specimens were captured; by Late-wet–Early-dry season *N. hyrtlii* was common in some backflow billabongs and moderately abundant in some escarpment perennial streams and floodplain billabongs.

Size composition

The lengths and weights of 43 *Neosilurus* sp. B and 121 *N. hyrtlii* were determined.

The records of *Neosilurus* sp. B may have been contaminated, particularly by *N. ater*; this will be indicated where possible. Seasonal length-frequency distributions and condition factors are based on *Neosilurus* sp. B to the Mid-wet season and on *N. hyrtlii* from then to the end of the study.

Neosilurus sp. B and *N. hyrtlii* and were mainly captured by gillnets, so the narrow peaks in the length-frequency distributions may have been partly caused by mesh selectivity. Some of the smaller specimens of *N. hyrtlii* were captured by seine net.

Length–weight relationship

The length–weight relationships for *Neosilurus* sp. B and *N. hyrtlii* were described respectively by the expressions:

$W = 0.42 \times 10^{-2} L^{3.19}$ $r = 0.99$ (length in cm, weight in g)

$W = 2.24 \times 10^{-2} L^{2.59}$ $r = 0.91$ (length in cm, weight in g)

---

[69] Herbert and Peeters (1995) and Herbert et al (1995) indicated that *N. hyrtlii* is found in almost all locations in Cape York Peninsula, and is particularly abundant in intermittent streams in the early to mid dry season, where they may school in their thousands. Accordingly, it is now known that the distribution of *N. hyrtlii* extends to the north-coast drainage division.

The difference in the form of these expressions may be the result of the difference in the size range of the two groups.

Seasonal mean lengths, weights and condition factors are shown in table 33. The condition of *Neosilurus* sp. B was highest in the 1978 Late-dry season and lowest in the 1978–79 Early-wet season. The condition of *N. hyrtlii* was low in the 1979 Late-wet–Early-dry season, but increased dramatically in the 1979 Mid-dry season; this increase may be related to the ending of the anoxic benthic conditions recorded in backflow billabongs during the previous season. After the Mid-dry season the condition of these fish fell again and remained low until the end of the study.

Table 33 Mean length, mean weight and condition factor of *Neosilurus* sp. B and *N. hyrtlii*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Neosilurus sp. B				
Late-dry (1978)	34	303.7	228.7	1.01
Early-wet (1978–79)	4	320.0	243.2	0.91
Mid-wet	0	–	–	–
All seasons combined	38	287.5	189.4	1.00
N. hyrtlii				
Late-wet–Early-dry (1979)	18	133.6	18.4	0.99
Mid-dry	42	147.8	26.8	1.11
Late-dry	26	139.9	19.1	0.91
Early-wet (1979–80)	19	130.5	16.0	0.91
All seasons combined	105	140.1	21.0	1.00

Length-frequency distribution

The range of lengths of *Neosilurus* sp. B was 110–405 mm TL and of *N. hyrtlii* 48–242 mm TL (fig 34). The difference in the minimum lengths may be attributable to differences in sampling periods; the large differences in maximum lengths were caused by contamination of the *Neosilurus* sp. B by large *N. ater* from escarpment habitats. Lake (1971) reported that most species of *Neosilurus* usually grow to only 200 mm TL, the exceptions being *N. hyrtlii* and *N. ater* which grow to 400 mm TL.

The mean length of *Neosilurus* sp. B was 287 mm TL and of *N. hyrtlii* 140 mm TL; this difference could be a consequence of the contamination of *Neosilurus* sp. B by *N. ater*. The LFM was 135 mm TL for both male and female *N. hyrtlii*, indicating that equal numbers of juveniles and adults were captured. Most *Neosilurus* sp. B were captured at 270–370 mm TL, and *N. hyrtlii* at 100–160 mm TL; the length distribution of the former displayed positive skew and the latter negative skew.

Seasonal changes in distribution

The smallest juvenile *N. hyrtlii* were captured in the Late-wet–Early-dry season. The largest adults were also found in this season, as well as in the 1979 Mid-dry season (fig 35).

Juvenile *N. hyrtlii* were most abundant in the Late-wet–Early-dry season when there were few adults. By the Mid-dry season the peaks of small juveniles had apparently progressed, leaving predominantly a large-juvenile/small-adult peak with fewer larger adults. During the 1979 Late-dry season the small-juvenile peak strengthened, and the number of adults in the sample declined. The 1979–80 Early-wet season was similar, with even fewer adults.

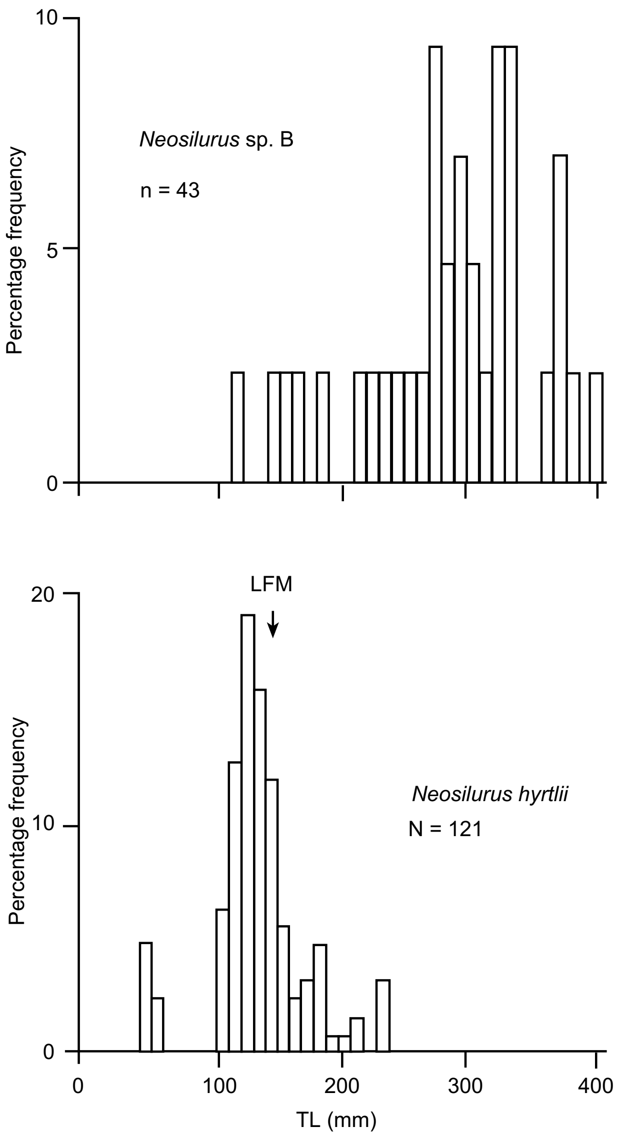


Figure 34 Length-frequency distribution of all *Neosilurus* sp. B and *N. hyrtlii* captured

Juveniles therefore appear to have recruited before the Late-wet–Early-dry season; they may have been classified as *Neosilurus* sp. A or C before this season.

Growth rate

No published information could be found on the growth of *N. hyrtlii*. Estimation of growth rates from the seasonal length-frequency distribution was impossible due to contamination of the *Neosilurus* sp. B group, mesh selectivity and the wide range of habitats sampled.

Habitat differences in distribution

Length-frequency distributions showing the habitat preferences of *Neosilurus* sp. B and *N. hyrtlii* caught at regular sampling sites in the Magela and Nourlangie Creek catchments are given in fig 36.

Neosilurus hyrtlii juveniles were captured mainly in lowland backflow billabongs and lowland sandy creekbed habitats. Large juveniles appeared in the escarpment perennial streams during the Mid-wet season and remained there until the end of the study. Adults were found in similar habitats, and also in shallow backflow billabongs upstream of RUPA. The largest specimens were found in backflow billabongs. Small adults observed in escarpment perennial streams during the Mid-wet season remained there until the end of the study.

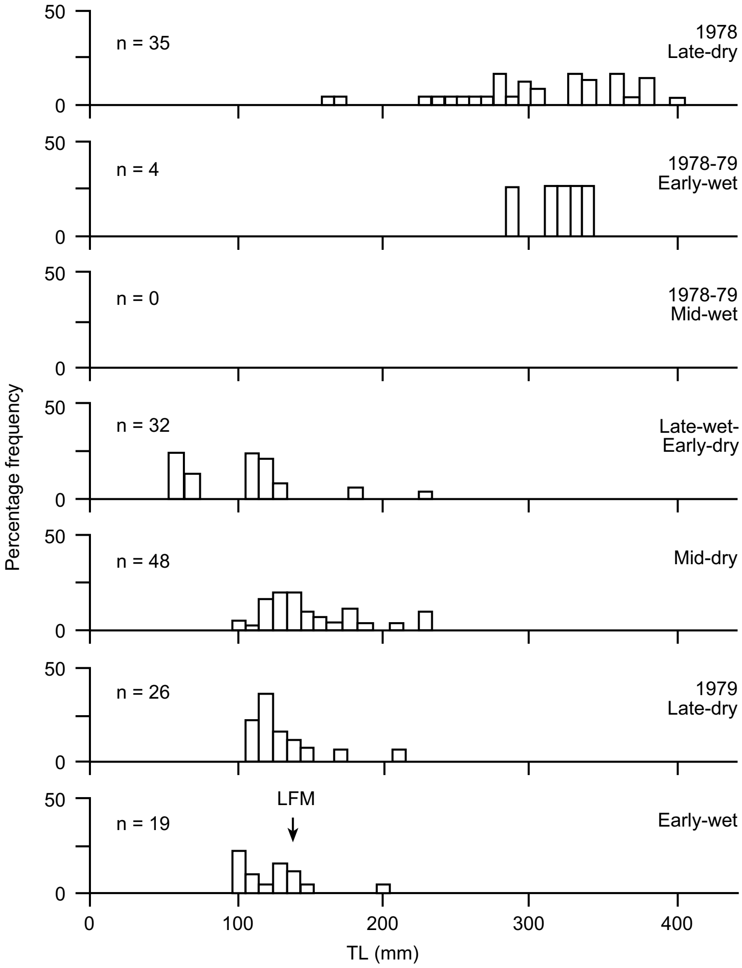


Figure 35 Seasonal length-frequency distribution of all *Neosilurus* sp. B and *N. hyrtlii* captured

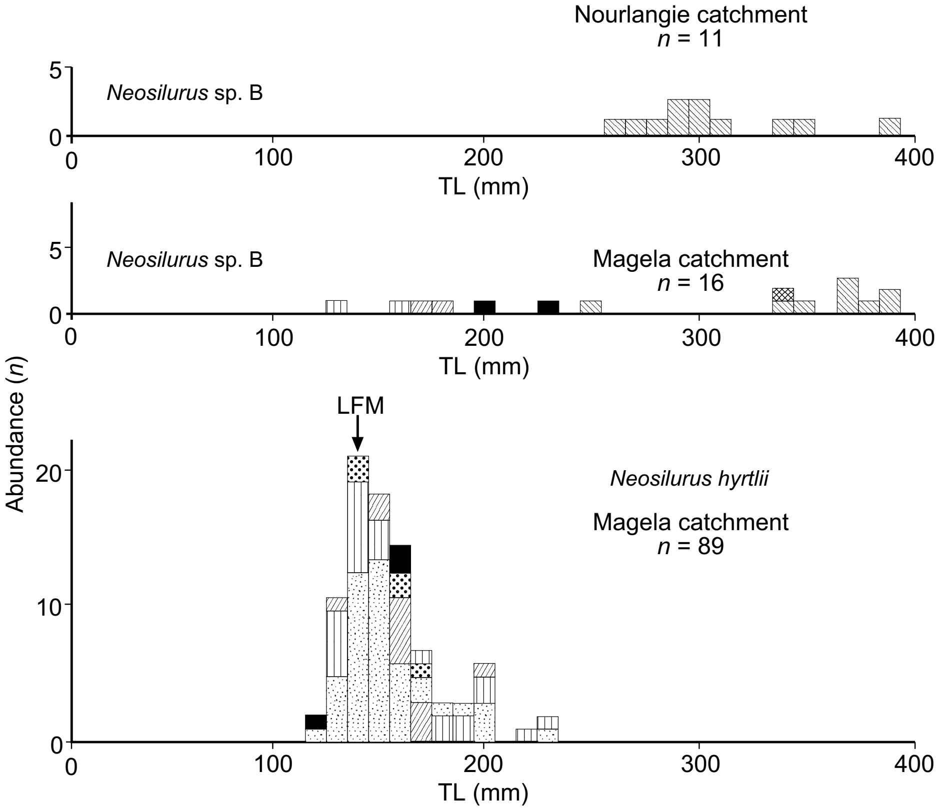


Figure 36 Length-frequency distributions and habitat preferences of *Neosilurus* sp. B and *N. hyrtlii* captured at regular sampling sites (see appendix 5 for key to the habitats)

As *Neosilurus* sp. B was contaminated, its juvenile and adult habitats are not described. The larger-sized specimens, assumed to be *N. ater*, were captured in escarpment mainchannel waterbodies. Smaller *Neosilurus* sp. B were found in similar habitats to *N. hyrtlii*.

Environmental associations

Rank numbers for *N. hyrtlii* and *Neosilurus* sp. B for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Neosilurus hyrtlii was found in waters with surface temperatures from 25° to 37°C (mean = 29.4°C) and bottom temperatures from 23° to 36°C (mean = 27.2°C). These means both ranked in the lower quarter, as would be expected for a primarily benthic-dwelling fish. However, specimens of '*Neosilurus*' have been found living in waters up to 38.8°C at Dalhousie Springs, South Australia, but they died when exposed to waters at 41.8°C (Ivantsoff & Glover 1974). *Neosilurus* sp. B was caught in waters with a similar range of temperatures to *N. hyrtlii* (26–37°C on the surface, 26–30°C on the bottom). The mean water temperatures for this colour-type (29.9°C surface and 28.2°C bottom) also ranked in the lower quarter (fig 170).

Dissolved oxygen

Dissolved oxygen concentrations in waters inhabited by *N. hyrtlii* ranged from 0.2 to 9.5 mg/L (mean = 6.5) on the surface, and from 1.0 to 9.7 mg/L (mean = 3.7) on the bottom. These means ranked in the upper-middle and lower-middle quarters, respectively. The range for *Neosilurus* sp. B was similar: 3.3–7.4 mg/L (mean = 5.8) on the surface, and 0.9–7.4 mg/L (mean = 5.2) on the bottom. These means ranked in the lower-middle and upper-middle quarters, respectively (see fig 171).

Visibility

Neosilurus hyrtlii was caught in waters with Secchi depths from 1–170 cm (mean = 39.9 cm). This mean was ranked in the lower quarter, indicating a tendency for *N. hyrtlii* to be found in more turbid waters. *Neosilurus* sp. B was caught in Secchi depths from 15–250 cm (mean = 136 cm). This mean, in contrast to that of *N. hyrtlii*, ranked at the top of the upper quarter, possibly because many *N. ater* from clear escarpment mainchannel waterbodies were classified as *Neosilurus* sp. B (see fig 172).

pH

The pH of waters in which *N. hyrtlii* was captured ranged from 4.0 to 8.6 on the surface (mean = 6.3) and from 5.2 to 7.3 (mean = 6.0) on the bottom. These means both ranked at the base of the upper-middle quarter. This range of pH was wider than for *Neosilurus* sp. B: 4.5–6.5 on the surface (mean = 5.8), and 5.3–6.5 (mean = 5.8) on the bottom. Both mean pH values ranked in the lower quarter (see fig 173).

Conductivity

Neosilurus hyrtlii was found in waters with surface and bottom conductivities between 4 and 620 µS/cm. The range was narrower for *Neosilurus* sp. B between 6 and 58 µS/cm, on both the surface and the bottom.

Habitat–structural variables

Substrate

Neosilurus hyrtlii was caught over the entire range of substrates. Of these, mud was the main one (upper-middle quarter), followed by clay (upper quarter), then sand, gravel, leaves, rocks and boulders. Both the range and order of substrates are similar to *P. rendahli* habitats. *Neosilurus* sp. B was also captured over the entire range of defined substrate types; sandy substrates were markedly dominant (upper quarter), followed by rocks (upper quarter), then leaves, boulders, mud and gravel (i.e. generally similar to *N. ater* from escarpment habitats) (see fig 174).

Hydrophytes

Neosilurus hyrtlii was typically found in vegetated waters (vegetation-occurrence index 64.4%) of submergent hydrophytes (42.5%), floating attached (32.8%) and emergent hydrophytes (21.1%). The percentage of floating attached vegetation was unusually high, as observed in other plotosids habitats.

Neosilurus sp. B was infrequently found in vegetated waters (vegetation-occurrence index 30%) as expected for a form that was typically found over sand and rocks. Most of the vegetation was floating unattached (40.9%) followed by floating-attached (27.3%), then submergent and emergent (9.1%).

Reproduction

The following information does not include the data on *Neosilurus* sp. B. Of the 121 *N. hyrtlii* collected during the last four sampling periods, 117 were examined for reproductive condition: 27 were sexually indistinguishable (length range 48–242 mm TL), 54 were females (110–240 mm TL) and 36 were males (110–240 mm TL). The gonad maturity stages differ macroscopically from the generalised description given in volume 1; a more accurate description of the stages for this species can be found in Davis (1977b).

Length at first maturity

Very few fish (10) were collected with gonads at stages greater than III, and thus the LFM was difficult to estimate. It appears to be 135 mm TL for both sexes (fig 37). Only two fish (males, 130 and 134 mm) were less than the LFM but had gonads at maturity stages greater than III.

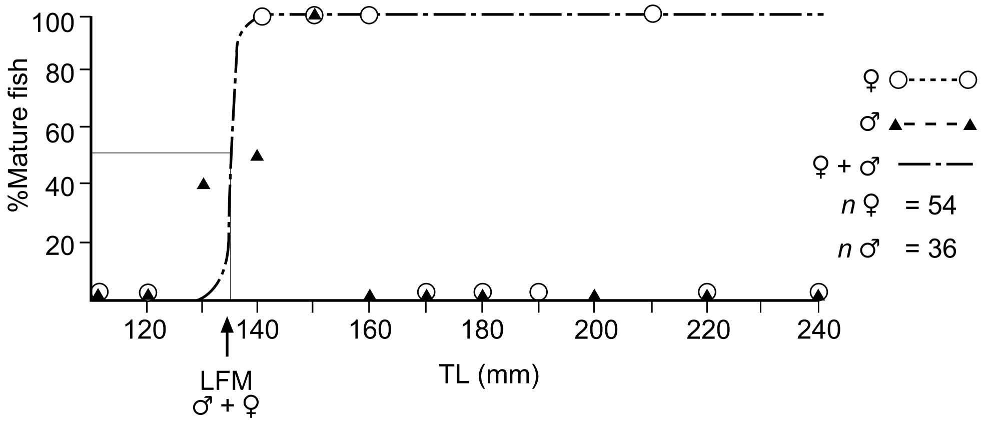


Figure 37 Estimated length at first maturity (LFM) of male and female *N. hyrtlii*

Sex ratio

The sex ratio was 1:1 in all seasons except the 1979 Late-wet–Early-dry, when there were significantly more females ($0.01 < P < 0.05$) in the entire population, and in the 1979 Late-dry season when there were significantly more females in the sample of mature fish (table 34).[70]

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[70] A sample of spawning *N. hyrtlii* taken during the Mid-wet season from the Ross River in northern Queensland had a sex ratio not significantly different from 1:1 (Orr & Milward 1984).

Table 34 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *N. hyrtlii* over all habitats

Parameter	Sex	Statistic	Sampling period: Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio						
Juveniles +	F	*n*	11	22	11	10
adults	M	*n*	2	15	10	9
		χ^2	6.2	1.3	0.04	0.05
		P	*	n.s.	n.s.	n.s.
Adults only	F	*n*	4	16	9	6
	M	*n*	1	13	1	3
		χ^2	1.8	0.3	6.4	1.0
		P	n.s.	n.s.	*	n.s.
GSI						
Adults only	F	mean	0.2	0.2	0.5	3.6
		s.d.	0.1	0.1	0.2	3.4
	M	mean	0.2	0.1	0.2	0.4
		s.d.	–	0.05	–	0.04
	F+M	mean	0.2	0.2	0.5	2.6
		s.d.	0.1	0.1	0.2	3.2
GMSI						
Adults only	F	mean	2.0	2.0	2.5	4.6
		s.d.	0.0	0.8	0.4	0.5
	M	mean	3.0	2.3	3.0	3.8
		s.d.	–	0.4	–	0.4
	F+M	mean	2.3	2.2	2.6	4.3
		s.d	0.6	0.6	0.4	0.6

n = number, χ^2 = Chi-squared value; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; s.d. = standard deviation

In the 1979 Late-wet–Early-dry season a large number of juvenile females, and in the 1979 Late-dry season a large number of juvenile males were caught. The causes of these unequal sex ratios are not known.

Breeding season

The GSI and GMSI both increased as the 1979–80 Early-wet season approached (fig 38, table 34). Maturing fish were collected during the 1979 Late-dry and 1979–80 Early-wet seasons; mature fish during the 1979–80 Early-wet season only. No ripe or spent fish were caught during the study, which suggests that *N. hyrtlii* matured during the 1979–80 Early-wet season but may not have spawned until the start of the Wet season proper.

Site of spawning

No evidence of spawning was observed. Only three mature fish were collected (from the backflow billabongs). Some members of the plotosid family spawn over gravel beds (Lake 1978, Davis 1977b) and others amongst grass and other aquatic vegetation or in shallow flowing waters (Midgley, pers comm).[71]

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[71] From observations in the Ross River in northern Queensland, Orr and Milward (1984) stated that *N. hyrtlii* is a lithophilic flood spawner which undertake spawning migrations.

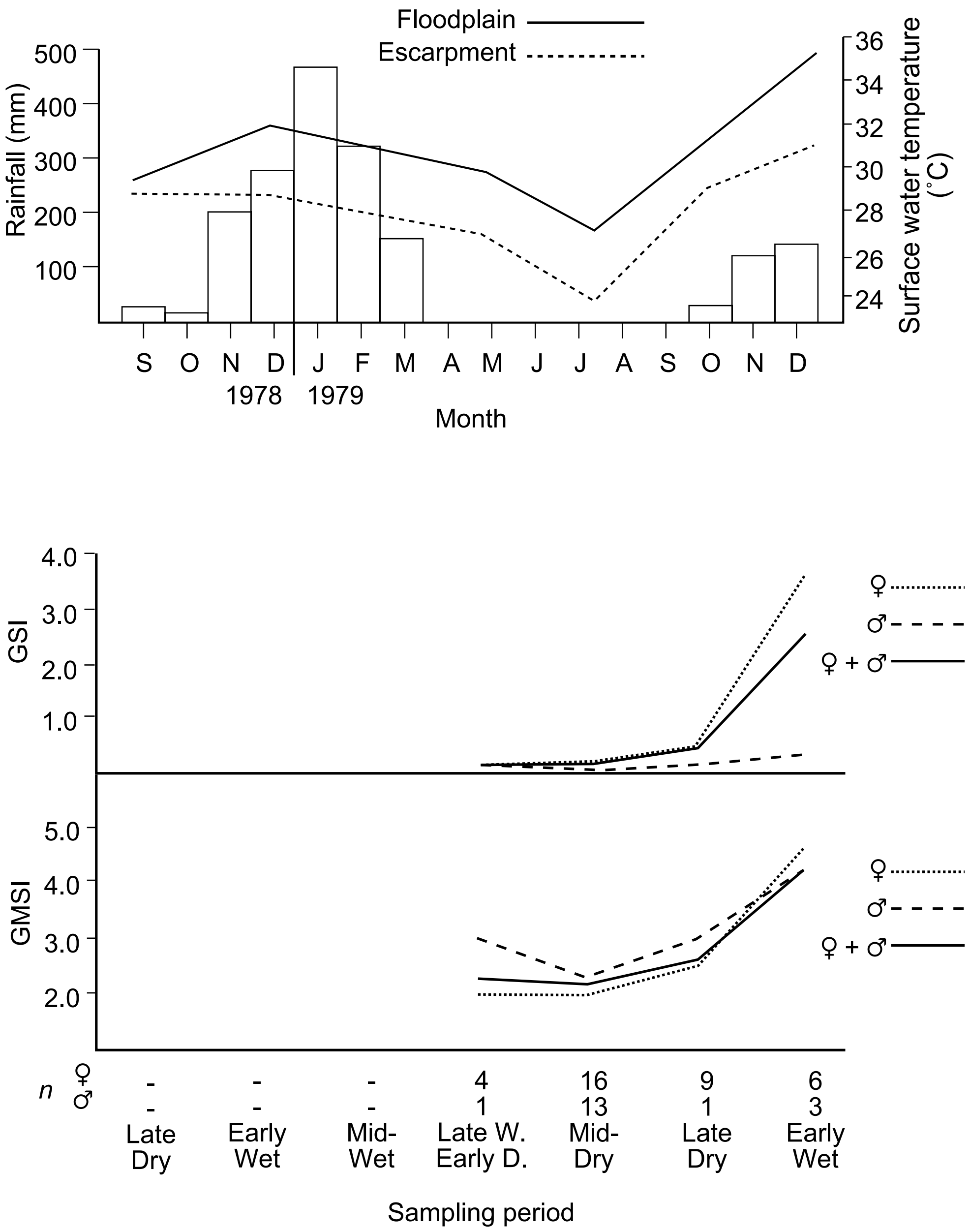

Figure 38 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *N. hyrtlii*

Fecundity

The one ovary examined weighed 7.26 g. It was from a 205 mm TL fish (weighing 63 g) with a GSI of 10.13. The estimated number of eggs was 3630.[72] Their average diameter was 1.3 ± 0.09 mm.[73]

Summary

Males and females had the same length range and LFM (135 mm TL). The sex ratio was 1:1 except for the entire sample during the Late-wet–Early-dry season (when many were juvenile females) and for the adult portion of the sample during the 1979 Late-dry season.

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[72] Orr and Milward (1984) estimated fecundities of *N. hyrtlii* to range from 1600 to 15 300 for individuals 186–267 mm standard length taken from the Ross River, northern Queensland.

[73] Egg and larval development of *N. hyrtlii* have been described by Orr and Milward (1984).

The GSI and GMSI indicated that the gonads developed towards the 1979–80 Early-wet season but, although mature gonads were found at that time, neither evidence nor sites of spawning were found. The fecundity was estimated at around 4000 eggs with average diameters of 1.3 mm.

Feeding habits

Overall diet

The stomachs of 62 of 73 *N. hyrtlii* and 125 of 142 *Neosilurus* sp. B contained food. The overall diets of *Neosilurus* sp. B and *N. hyrtlii* are shown in fig 39; details of the components are given in table 35. The main components of the diet were aquatic insects (52% and 55%, respectively) and microcrustaceans (28% and 5%). Teleost scales (5%) also appeared in the diet of *Neosilurus* sp. B. Inorganic material (3% and 6%) and unidentified organic material (14% and 22%) were found in the stomachs of both forms. The main aquatic insects eaten were chironomid larvae, and the main microcrustaceans were cladocerans and ostracods. Traces of algae, gastropods, macrocrustaceans, terrestrial insects and detrital material were also found in the stomachs.

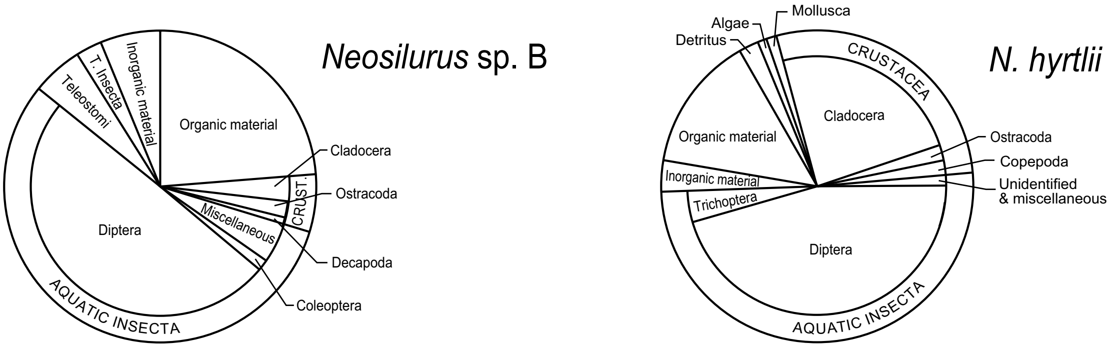

Figure 39 The main components of the diet of *Neosilurus* sp. B and *N. hyrtlii*

Neosilurus hyrtlii and *Neosilurus* sp. B can therefore be classified as meiophagous carnivores that feed predominantly on benthic fauna.[74] Differences in the diet of the two groups may have been partly caused by seasonal availability of food items, an effect highlighted by the change in classification halfway through the study. Pollard (1974) noted that little appears to be known of the diets of the ‘neosilurine’ catfishes.

Seasonal changes

In sampling periods 1 and 2 respectively, 34 (32% empty) and 4 (0% empty) stomachs of *Neosilurus* sp. B (all habitats combined) were examined. The highest proportion of specimens with empty stomachs was in the 1978 Late-dry season.

The diet in the 1978 Late-dry season was mainly aquatic insects (mainly chironomid larvae) with a small microcrustacean component. During the 1978–79 Early-wet season emphasis shifted from chironomid larvae to terrestrial dipterans, chironomid pupae and ceratopogonid larvae.

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[74] Pusey et al (1995b) found *N. hyrtlii* to consume detritus in two rivers of the Australian wet tropics, north-eastern Queensland. It was noted that it was possible that detritus was inadvertently ingested as they foraged for bivalve molluscs (*Sphaerium* sp.).

Table 35 Dietary composition of *Neosilurus* sp. B and *N. hyrtlii*

	Neosilurus sp. B				*N. hyrtlii*						Habitat	
	Season		Overall		Season				Overall			
	1978	1978–79			1979	1979	1979	1979–80			Magela Creek	
	Late-dry	Early-wet	Sub-mean	Main-mean	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean	Ls	Bb
Aquatic plants												
Algae				+						0.7		
Conjugatophyta												
Mougeotia	–	–	–		–	1.1	0.5	–	0.7		–	0.8
Aquatic animals												
Gastropoda				–						0.8		
Amerianna	–	–	–		–	–	–	–	0.8		–	–
Microcrustacea												
Conchostraca				5.0						28.3		
Cyzicus	–	–	–		0.8	–	–	–	0.2		–	
Cladocera												
Miscellaneous	1.7	–	3.0		36.9	0.3	–	–	7.3		–	8.2
Diaphanosoma	–	–	–		–	2.9	–	57.5	17.3		–	4.2
Ostracoda	2.6	–	2.0		7.7	–	3.0	–	1.5		–	2.7
Copepoda												
Cyclops	–	–			–	–	2.0	9.4	2.0		–	3.5
Macrocrustacea												
Macrobrachium	0.9	–	0.7		–	–	–	–	–		–	–
Insecta				54.8						51.7		
Fragmented	7.0	–	5.3		–	–	1.0	–	0.7		1.7	–
Ephemeroptera												
Baetidae	–	–	–		–	0.5	–	–	0.2		1.7	–
Odonata												
Libellulidae	–	–	–		–	–	–	–	0.4		–	–

Table 35 continued

	Neosilurus sp. B				*N. hyrtlii*						Habitat	
	Season		Overall		Season				Overall			
	1978	1978–79			1979	1979	1979	1979–80			Magela Creek	
	Late-dry	Early-wet	Sub-mean	Main-mean	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean	Ls	Bb
Hemiptera												
Corixidae	–	–	–		–	–	0.3	–	0.4		–	0.1
Coleoptera	–	3.8	0.5		–	–	–	–	–			
Diptera												
Chironomidae (larvae)	46.1	10.0	45.0		23.9	62.5	54.3	21.7	42.8		83.3	46.3
Chironomidae (pupae)	–	12.5	1.7		–	2.9	11.8	0.3	3.3		–	5.6
Ceratopogonidae	–	17.5	2.3		–	–	–	–	0.1		–	–
Trichoptera												
Leptoceridae	–	–	–		15.4	–	10.0	–	3.8		–	6.8
Teleostomi				5.3								
Scales	7.0	–	5.3		–	–	–	–	–		–	–
Terrestrial plants												
Angiospermae	–	–	–			–	–	–	–		–	–
Terrestrial animals				3.2	–							
Insecta												
Diptera (larvae)	–	23.7	3.2		–	–	–	–	–		–	–
Parasites												
Trematoda	4.4	12.5	5.0	5.0	–	–	–	–	–	–	–	–
Nematoda	0.6	–	0.4	0.4	–	–	–	–	0.4	0.4	–	0.7
Detrital material	–	–	–		–	–	7.8	–	1.5	1.5	–	2.6
Inorganic material	4.8	20.0	6.3	6.3	–	3.2	9.5	–	3.0	3.0	13.3	2.5
Organic material	25.0	–	20.2	20.2	15.4	25.7	–	11.1	14.1	14.1	–	16.3
Number of empty fish	11	–	11	11	2	13	–	1	17	17	–	1
Number of fish with food	23	4	62	62	13	38	20	18	125	125	12	60

Figures represent the mean percentage volume determined by the estimated volumetric method. All habitats are in the Magela system. Ls = lowland sandy creek bed; Bb = lowland backflow billabongs

In sampling periods 4–7, respectively, 15 (13% empty), 51 (25% empty), 20 (0% empty) and 19 (5% empty) stomachs of *N. hyrtlii* (all habitats combined) were examined. The highest proportion of specimens with empty stomachs were in the 1979 Mid-dry season and the lowest in the following Late-dry season.

The diet in the Late-wet–Early-dry season consisted mainly of microcrustaceans (cladocerans and ostracods) and aquatic insects (chironomid and leptocerid larvae). By the 1979 Mid-dry season, the microcrustacean component was smaller and the diet was dominated by chironomid larvae, which continued to be the main component, with some chironomid pupae and leptocerid larvae (similar to *Neosilurus* sp. B in the previous year). During the 1979–80 Early-wet season there was a shift to microcrustaceans (mainly cladocerans and copepods) and chironomids became of secondary importance. Microcrustaceans did not appear in the diet of *Neosilurus* sp. B during the previous Early-wet season.

Habitat differences

In the Magela Creek catchment, 12 (0% empty) stomachs of *N. hyrtlii* were examined (all seasons combined) from lowland sandy creekbeds and 61 (2% empty) from backflow billabongs.

The specimens captured in the lowland sandy creekbeds were feeding mainly on chironomid larvae. In the backflow billabongs, they were eating mainly aquatic insects (chironomid larvae and pupae, leptocerid larvae) and to a lesser extent, microcrustaceans (cladocerans, ostracods and copepods).

Fullness

A summary of mean fullness indices of *N. hyrtlii/Neosilurus* sp. B for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 36. These data are presented on the assumption that feeding times do not vary with habitat or season.

Seasonal changes

The mean seasonal fullness index (all habitats combined) rose in the 1978–79 Early-wet season and remained high until the 1979 Mid-dry season. No specimens were sampled in the Mid-wet season; however, this species was observed in escarpment perennial streams during this season. During the 1979–80 Early-wet season the index then fell to a level lower than that recorded the previous year.

Habitat differences

In the Magela catchment the few specimens from shallow backflow billabongs upstream of RUPA had mean fullness indices much lower than in equivalent downstream habitats.

Downstream of RUPA, the highest fullness indices were recorded in specimens from shallow backflow billabongs and the sandy corridor waterbody. Indices were lower for specimens from lowland sandy creekbeds and channel backflow billabongs and floodplain billabongs.

Only a few specimens were examined from the Nourlangie catchment; indices were comparable in the backflow billabongs.

Table 36 Mean fullness indices of *Neosilurus* sp. B and *N. hyrtlii* in different sampling periods and habitats

	Sampling period							
	Neosilurus sp. B				*N. hyrtlii*			
Habitat type	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Lowland shallow backflow billabong	n/s	n/s	n/s	n/s	3.0 (1)	2.8 (5)	n/s	2.8 (6)
Downstream of RUPA:								
Lowland sandy creekbed pool	0 (2)	n/s	n/s	n/s	3.5 (11)	4.0 (1)	n/s	3.1 (14)
Lowland channel backflow billabong	n/s	n/s	n/s	4.0 (1)	3.1 (15)	3.5 (14)	2.0 (8)	3.0 (38)
Lowland shallow backflow billabong	n/s	n/s	n/s	3.7 (11)	4.0 (14)	3.0 (1)	3.0 (1)	3.8 (27)
Corridor sandy billabong	n/s	4.0 (1)	n/s	n/s	n/s	n/s	n/s	4 (1)
Floodplain billabong	n/s	n/s	n/s	2.9 (11)	3.0 (3)	n/s	n/s	2.9 (14)
Nourlangie Creek catchment (regular sites only)								
Lowland channel backflow billabong	n/s	n/s	n/s	4 (2)	n/s	n/s	n/s	4 (2)
Lowland shallow backflow billabong	n/s	n/s	n/s	4.0 (2)	3.0 (1)	n/s	n/s	3.7 (3)
Seasonal mean (all sites)	1.1	3.3	n/s	3.4	3.7	3.3	2.1	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Summary

The habitats and periods of greatest apparent feeding activity where more than one fish was captured were:

Magela catchment

- lowland shallow backflow billabong (downstream of RUPA); Late-wet–Early-dry season; Mid-dry season
- lowland channel backflow billabong; 1979 Late-dry season
- lowland sandy creekbed; Mid-dry season

Nourlangie catchment

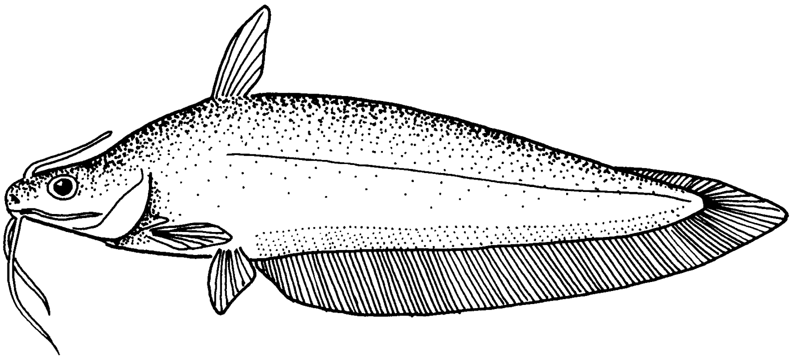
- lowland shallow backflow billabong; Late-wet–Early-dry season
- lowland channel backflow billabong; Late-wet–Early-dry season

Family PLOTOSIDAE

3.11 *Porochilus rendahli* (Whitley)

In the Oenpelli area, the Aboriginal name of this genus of eel-tailed catfishes is Maroonung or Nahgool. It is also generally known as Rendahl's catfish. Data on *P. rendahli* will be presented together with that on *Neosilurus* sp. C.

Porochilus rendahli is endemic to Australia. Miller (in Taylor 1964) found this species in billabongs and creeks of the Oenpelli area and in lower riverine floodplain billabongs of the East Alligator River. Previously it had been found in the Northern Territory only in the Howard, Roper and Emerald (Groote Eylandt) Rivers.



Porochilus rendahli

Detailed information on catches at each site and in each season is given in volume 2. In summary, *P. rendahli* (and *Neosilurus* sp. C) was common to moderately abundant in all lowland backflow billabongs and floodplain billabongs; it also occurred in some corridor waterbodies and escarpment perennial streams. The fewest specimens of *Neosilurus* sp. C were caught in the Mid-wet season; the greatest number of *P. rendahli* were caught in the Mid-dry.

Size composition

The lengths and weights of 328 *P. rendahli* and 147 *Neosilurus* sp. C were recorded.

Seasonal length-frequency distributions and condition factors are based on *Neosilurus* sp. C through the Mid-wet season and then on *P. rendahli*. *Neosilurus* sp. C was probably contaminated by *N. hyrtlii*.

Neosilurus sp. C and *P. rendahli* captured by the 26 mm mesh gillnet and the seine net were similar in size; *Neosilurus* sp. C was also captured by 44 and 58 mm mesh gillnets and the resultant peaks are apparent in the distribution.

Length–weight relationship

The length–weight relationships for *Neosilurus* sp. C and *P. rendahli* were described respectively by the expressions:

$W = 0.68 \times 10^{-2} L^{3.02}$ r = 0.89 (length in cm, weight in g)

$W = 0.44 \times 10^{-2} L^{3.16}$ r = 0.99 (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors of *Neosilurus* sp. C and *P. rendahli* are shown in table 37. Seasonal condition factors were near unity for both groups except during the Mid-wet season, when they dropped to a very low level, possibly because of spawning activity.

Table 37 Mean length, mean weight and condition factor of *Neosilurus* sp. C and *P. rendahli*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Neosilurus sp. C				
Late-dry (1978)	65	177.9	41.12	1.01
Early-wet (1978–79)	28	128.1	14.99	0.99
Mid-wet	15	157.1	21.15	0.76
Overall	108	156.5	27.56	1.00
P. rendahli				
Late-wet–Early-dry (1979)	78	97.6	6.25	1.05
Mid-dry	117	123.2	12.14	0.98
Late-dry	109	120.8	11.50	0.99
Early-wet (1979–80)	14	140.8	18.71	0.99
Overall	318	116.3	10.32	1.00

Length-frequency distribution

The lengths of *Neosilurus* sp. C ranged from 91 to 385 mm TL and of *P. rendahli* from 36 to 195 mm TL (fig 40). The difference in the minimum length may be attributed to seasonal growth effects; the large difference in maximum length was most likely caused by contamination of *Neosilurus* sp. C by large *N. hyrtlii* and *N. ater*. Pollard (1974) reported that Midgley found a yellow-finned plotosid catfish (*Neosilurus* sp. C) of 585 mm TL in the study area during 1972; however, this specimen was possibly a large *N. ater*.

The mean length of all *Neosilurus* sp. C was 156 mm TL and that of *P. rendahli* was 116 mm TL. The difference is most likely an artefact of contamination of *Neosilurus* sp. C by other plotosid species. The LFM for male and female *P. rendahli* were 100 and 110 mm TL respectively, indicating that more adults than juveniles were captured. The length-frequency distribution of *Neosilurus* sp. C showed negative skew and the distribution of *P. rendahli* showed slight positive skew; the two groups had coincident peaks with modes of 120–130 mm TL.

Seasonal changes in distribution

The smallest specimens of *Neosilurus* sp. C were caught in the 1978–79 Early-wet season (fig 41). They were much larger than the smallest specimens of *P. rendahli,* which were caught in the Late-wet–Early-dry season. This difference may result from the seasonal recruitment of juveniles.

The largest specimens of *Neosilurus* sp. C were captured in the Mid-wet and Late-dry seasons, and of *P. rendahli* in the Mid-dry season.

The small-adult size-range of both *Neosilurus* sp. C and *P. rendahli* had major peaks throughout the study. A large peak of juvenile *P. rendahli* occurred together with small adults during the Late-wet–Early-dry season. By the Mid-dry season the juvenile peak had apparently merged towards the small adult peak, with slightly larger adults also being captured. During the 1979 Late-dry season the length-frequency distribution was very similar in form to the previous season, with a reduction in the number of large adults captured. Only a few small adults (with a modal progression from the previous season) were captured in the 1979–80 Early-wet season.

Juveniles appear therefore to have recruited in the Late-wet–Early-dry season.

Growth rate

No published information on the growth of *P. rendahli* was found. Estimation of growth rates from the seasonal length-frequency distributions was very difficult due to contamination of *Neosilurus* sp. C, mesh selectivity, and the range of habitats sampled. However, the apparent merging of juveniles, which were initially present in the Late-wet–Early-dry season, into the small adult component in the Mid-dry season indicates that this species may attain its LFM within the first year of life.

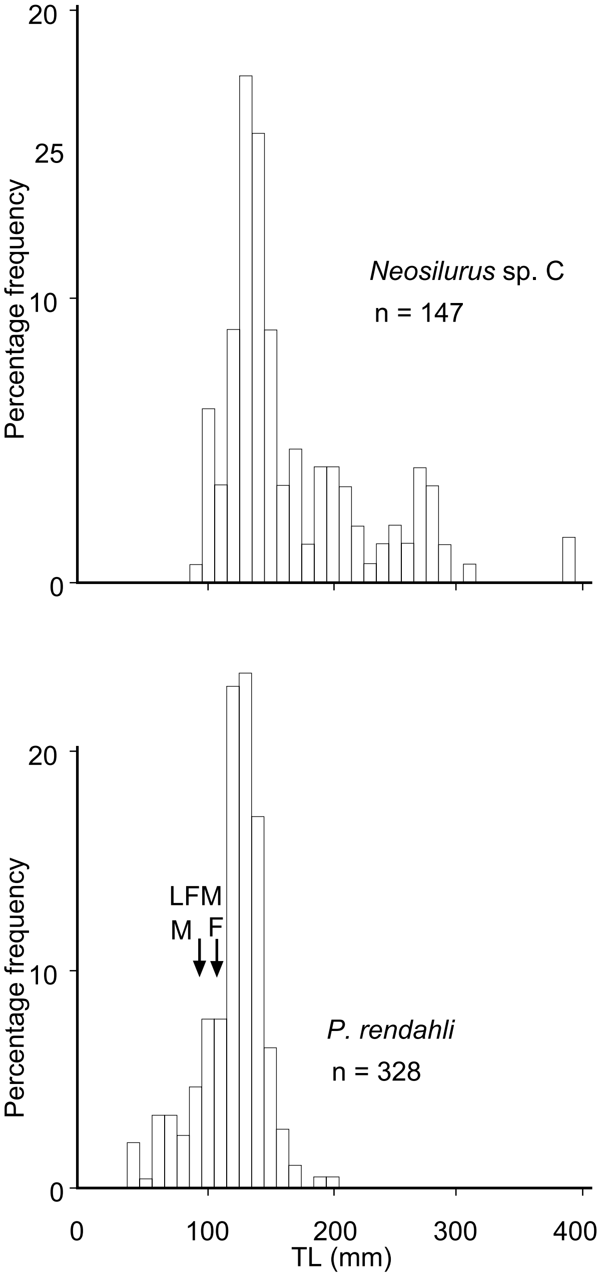


Figure 40 Length-frequency distribution of all *Neosilurus* sp. C and *P. rendahli* captured

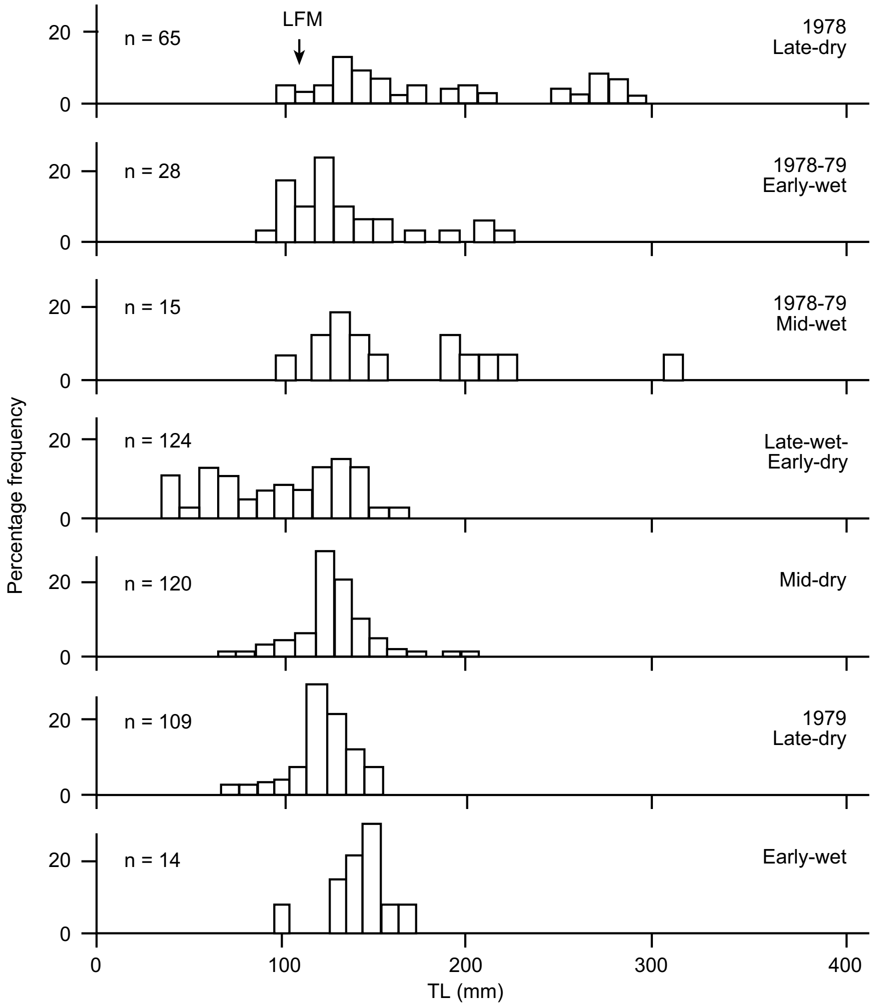


Figure 41 Seasonal length-frequency distribution of all *Neosilurus* sp. C and *P. rendahli* captured

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *Neosilurus* sp. C and *P. rendahli* captured in regular sampling sites of the Magela and Nourlangie Creek catchments are given in figure 42.

Porochilus rendahli juveniles were found only in backflow billabongs (mainly the shallow ones) and floodplain billabongs; the smallest juveniles were most common in the latter habitat and larger juveniles in the former. Juvenile *P. rendahli* were observed in the escarpment perennial streams of the Nourlangie Creek catchment during the 1979 Late-dry season.

Adults were found in the same habitats as juveniles. Most adults were found in lowland shallow backflow billabongs up and downstream of RUPA; the largest adult was found in the latter habitat. Adults were observed in escarpment perennial streams of the Nourlangie Creek catchment during the Late-wet–Early-dry season.

In the Magela Creek catchment *Neosilurus* sp. C was mainly caught in lowland channel backflow billabongs and, less often, in the lowland shallow backflow billabongs and in floodplain billabongs. As *N. hyrtlii* were captured in mainly lowland channel backflow billabongs, it may have contaminated the data on *Neosilurus* sp. C. The largest specimen, which was caught in an escarpment mainchannel waterbody, was most likely *N. ater*.

In the Nourlangie Creek catchment *Neosilurus* sp. C was caught only in backflow billabongs, with a slight preference for channel types.

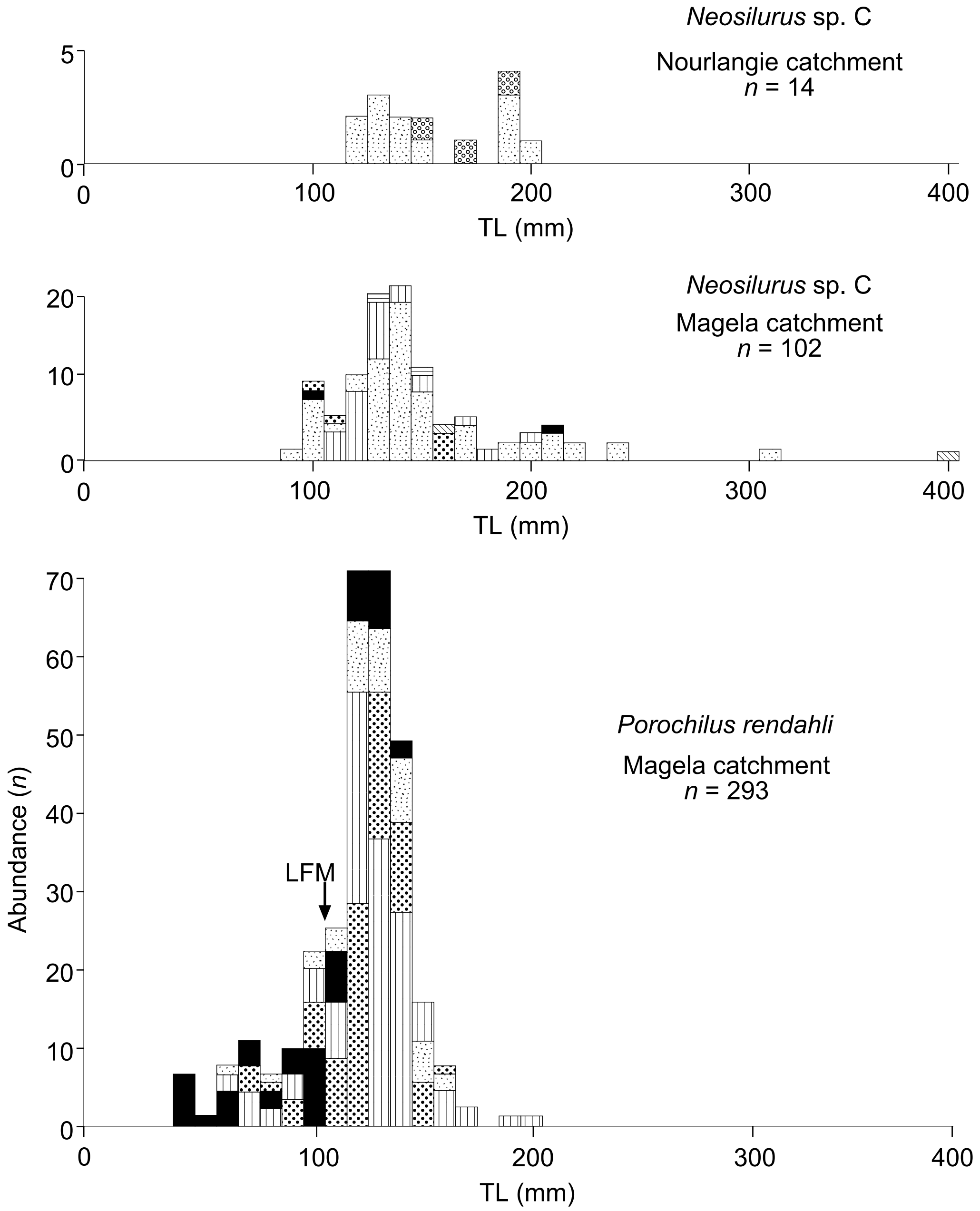


Figure 42 Length-frequency distributions and habitat preferences of *Neosilurus* sp. C and *P. rendahli* captured at regular sampling sites (see appendix 5 for key to the habitats)

Environmental associations

Rank numbers for *P. rendahli* and *Neosilurus* sp. C for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Water temperatures at sites where *P. rendahli* was captured ranged from 26° to 38°C (mean = 30°C) on the surface, and from 23° to 34°C on the bottom (mean = 28°C). These means both ranked in the lower quarter. This species was found in habitats ranging from escarpment perennial streams to floodplain billabongs, as reflected in the range of water temperatures. *Neosilurus* sp. C was found in waters with temperatures between 27° and 41°C (mean = 31°C) on the surface, and between 27° and 34°C (mean = 28.9°C) on the bottom (see fig 170). These means ranked in the upper-middle and lower quarters. A tolerance of extremely high water temperatures is indicated.

Dissolved oxygen

Dissolved oxygen concentrations in waters in which *P. rendahli* was caught ranged from 1.0 to 9.7 mg/L (mean = 5.6) on the surface, and from 2.0 to 9.5 mg/L (mean = 3.8) on the bottom. These means were ranked in the lower and lower-middle quarters. *Neosilurus* sp. C was also caught in waters with a wide range of DO concentrations: from 3.8 to 8.8 mg/L (mean = 6.0) on the surface, and from 0.5 to 6.0 mg/L (mean = 3.3) on the bottom (see fig 171). These means ranked in the lower-middle and lower quarters, respectively. Like other plotosid catfishes, this species can apparently tolerate low DO concentrations.

Visibility

Secchi depths recorded at sites where *P. rendahli* was caught ranged from 1 to 170 cm (mean = 31 cm), indicating a tendency to be found in turbid waters; this mean depth ranked at the base of the lower quarter. *Neosilurus* sp. C showed a similar range of associated Secchi depths: from 3 to 150 cm (mean = 42 cm) (see fig 172). This mean ranked at the base of the lower-middle quarter.

pH

The pH of waters from which *P. rendahli* was taken ranged from 4.8 to 7.7 (mean = 6.2) on the surface, and from 5.2 to 7.3 (mean = 6.0) on the bottom. These means were both ranked at the top of the lower-middle quarter. *Neosilurus* sp. C was found in similar pH conditions: surface readings ranged from 4.3 to 8.8 (mean = 6.4) and bottom readings from 4.5 to 7.4 (mean = 5.9). These means were placed in upper and lower-middle quarters, respectively (see fig 173).

Conductivity

Porochilus rendahli was captured in waters with conductivities between 10 and 600 µS/cm on the bottom. This wide range corresponds with the distribution of the species from perennially flowing to lentic waterbodies. *Neosilurus* sp. C was found in waters with surface conductivities between 6 and 230 µS/cm, and with bottom conductivities between 6 and 280 µS/cm.

Habitat–structural variables

Substrate

Porochilus rendahli was mainly found over muddy substrates (top of upper quarter) followed by clay (upper quarter), then gravel and sand. This association with mud and clay substrates corresponds with the high turbidities of waters in which this species was captured. *Neosilurus* sp. C had a similar range: it was most commonly found in waters with mud substrates (upper quarter), followed by clay (upper-middle quarter), then sand, leaves, boulders and gravel.

Hydrophytes

Porochilus rendahli was typically found in heavily vegetated waters (vegetation-occurrence index 89.8%) with submergent (41.7%), emergent (27.2%) and floating-attached (25.6%) hydrophytes.[75] *Neosilurus* sp. C was found in moderately vegetated waters (vegetation-occurrence index 63.6%) with submergent (38.8%), emergent (27.7%) and floating-attached (26.6%) hydrophytes. For both species, as for the other plotosids, the percentage of floating unattached hydrophytes was high.

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[75] Herbert and Peeters (1995) and Herbert et al (1995) indicated that in Cape York Peninsula streams *P. rendahli* are usually associated with aquatic vegetation.

Reproduction

The generalised gonad description given in volume 1 does not fit this species accurately. A more accurate description of gonad stages found in the plotosid family is given in Davis (1977b).

A total of 350 *P. rendahli* and *Neosilurus* sp. C (both henceforth referred to as *P. rendahli*) were examined for reproductive condition. This resulted in 29 juvenile or sexually indistinguishable fish (length range 36–144 mm TL), 209 females (60–288 mm TL) and 112 males (70–385 mm TL) being identified. The larger males and females were most likely specimens of *N. ater* that were included with *Neosilurus* sp. C before a taxonomic key was available.

Length at first maturity

The LFM for *P. rendahli,* calculated on 10-mm-length groups, was estimated to be 100 mm for males and 110 mm for females (fig 43). Two females (100 mm TL, stage V; and 99 mm TL, stage IV) and one male (95 mm TL, stage IV) were found maturing at a length less than the LFM.

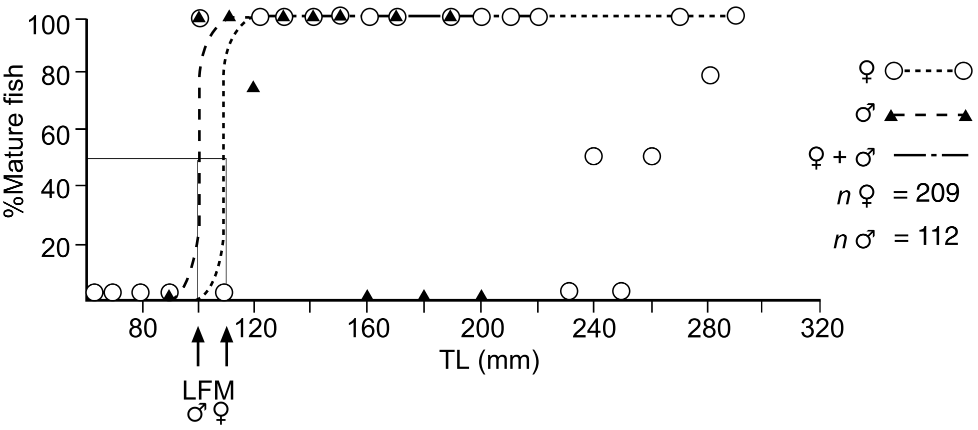

Figure 43 Estimated length at first maturity (LFM) of male and female *P. rendahli*

Sex ratio

Chi-squared tests (Zar 1974) indicated that significantly more females than males were present in the samples of all fish (except during the 1978–79 Early-wet and Mid-wet seasons) and of adults only (except during the 1978–79 Early-wet to the Late-wet–Early-dry seasons) (see table 38). These results suggest that females became distinguishable at an earlier stage before spawning than the males.

Breeding season

The GSI and GMSI indicated *P. rendahli* has a well-defined breeding season with clear peaks of gonad development during the 1978–79 and 1979–80 Early-wet seasons; after the 1978–79 Early-wet season peak the GSI and GMSI fell to the baseline level and remained low until the 1979–80 Early-wet season peak (table 38 and fig 44).

Mature fish were captured during the 1978 Late-dry and the 1978–79 and 1979–80 Early-wet seasons and, although no ripe fish were collected, spent fish were identified in the 1978–79 Mid-wet and Late-wet–Early-dry seasons. These data confirm that spawning is in the Early-wet season and suggest that the resorption and recovery of gonads after spawning can take a long time, as spent gonads were identified up to two seasons (four months) after the spawning period.

Table 38 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *P. rendahli* in all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	45	15	6	36	58	39	10
adults	M	*n*	17	13	7	19	33	19	4
		χ^2	12.64	0.14	0.08	5.25	6.9	6.9	2.6
		P	***	n.s.	n.s.	*	**	**	n.s.
Adults only	F	*n*	44	11	6	28	47	38	9
	M	*n*	15	13	6	18	25	19	4
		χ^2	14.3	0.2	0	2.2	6.7	6.3	1.9
		P	***	n.s.	n.s.	n.s.	**	*	n.s.
GSI									
Adults only	F	mean	1.1	4.8	0.4	0.2	0.3	0.5	5.2
		s.d.	1.1	1.4	0.5	0.1	0.08	0	1.7
	M	mean	0.3	0.6	0.5	0.06	0.1	0.2	0.7
		s.d.	0.3	0.4	0.06	0.05	0.05	0.1	0.1
	F+M	mean	0.8	2.5	0.2	0.1	0.2	0.3	3.3
		s.d.	1.0	2.4	0.4	0.1	0.1	0.2	2.7
GMSI									
Adults only	F	mean	3.1	4.7	2.0	2.1	2.4	2.2	4.3
		s.d.	0.6	0.4	0	0.4	0.5	0.2	0.4
	M	mean	2.6	4.3	1.7	1.7	1.9	2.1	3.5
		s.d.	0.5	0.4	0.9	0.7	0.4	0.6	0.9
	F+M	mean	2.9	4.5	1.8	1.9	2.2	2.1	4.0
		s.d	0.6	0.5	0.6	0.5	0.5	0.5	0.7

n = number; χ^2 = Chi-squared value; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.01$; *** = $P < 0.001$; s.d. = standard deviation

Site of spawning

All mature and spent fish were caught in backflow billabongs (table 39) or artificial dams such as those near Nabarlek mining camp and Retention Pond 1 in RUPA.

Table 39 Possible sites of spawning of *P. rendahli* as indicated by the abundance (*n*) of mature, ripe and spent fish

	Gonad stage					
	Mature (V)		Ripe (VI)		Spent (VII)	
Habitat	F	M	F	M	F	M
Lowlands						
Sandy creekbed	–	–	–	–	–	–
Backflow billabong	6	4	–	–	9	3
Artificial	3	–	–	–	–	–

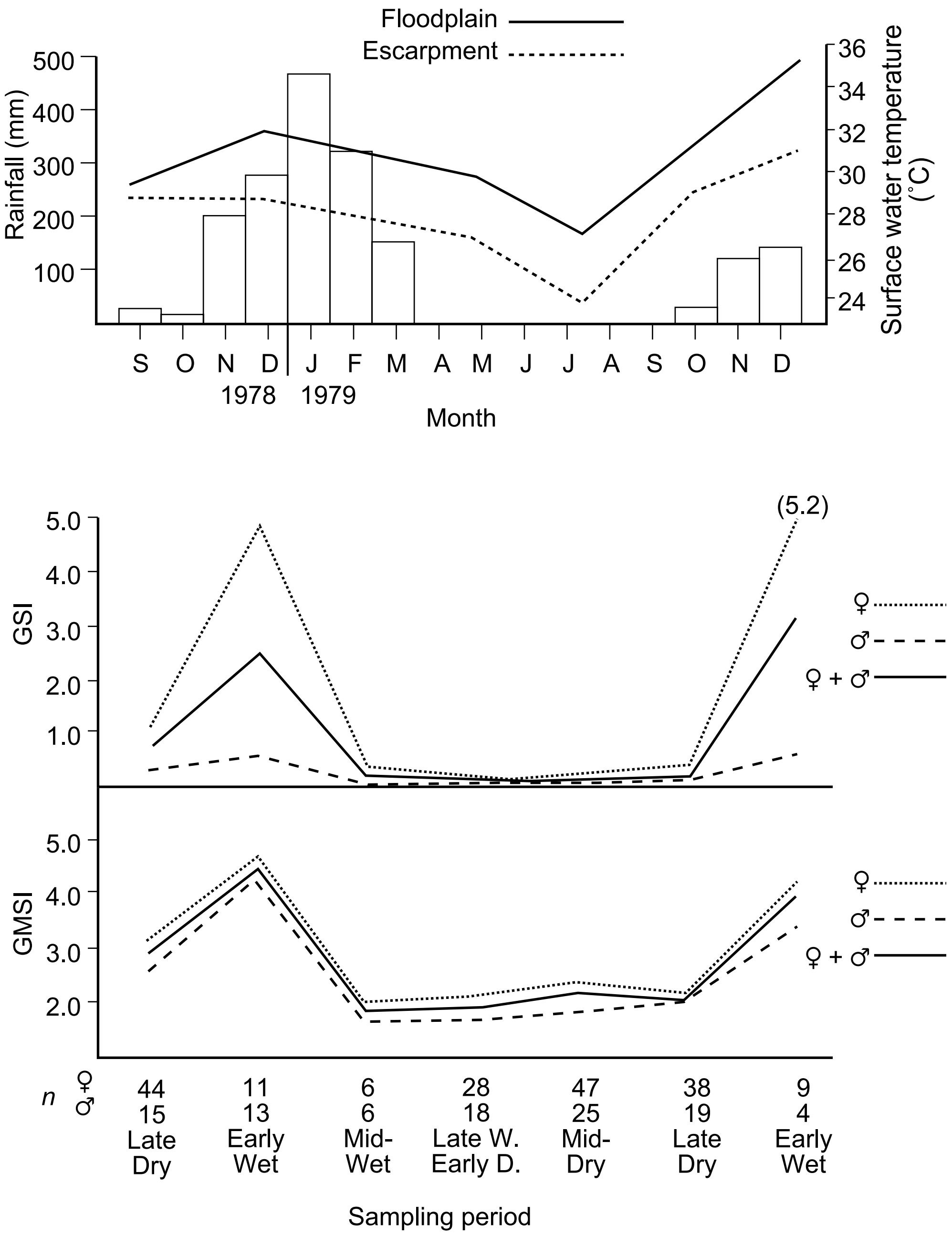

Figure 44 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *P. rendahli*

Fecundity

The ovaries of eight fish were examined. Egg numbers ranged from 240 (fish length 100 mm TL, weight 6.3 g, GSI 3.62) to 3465 (fish length 209 mm TL, weight 80 g, GSI 7.25), with an average egg count of 900 eggs. The egg diameter means ranged from 1.1 mm (fish length 139 mm TL, weight 19.3 g, GSI 5.36) to 1.5 mm (fish length 148 mm TL, weight 25 g, and GSI 4.18), with an average diameter of around 1.3 mm.

Summary

Male and female *P. rendahli* matured at approximately the same length: 100 mm for males and 110 mm TL for females. Females appeared to start gonad development earlier than males and were, therefore, sexually distinguishable before the males; this produced unequal sex ratios in the samples preceding the spawning period.

There was a well-defined breeding season during the 1978–79 and 1979–80 Early-wet seasons, with both GSI and GMSI falling rapidly to a baseline level after spawning and remaining low until the next breeding season. *Porochilus rendahli* appears to spawn only in backflow billabongs and in artificial dams. It lays around 900 eggs with an average diameter of 1.3 mm.

Feeding habits

Overall diet

The stomachs of 125 *Neosilurus* sp. C and 301 *P. rendahli* were examined; 114 and 283, respectively, contained food. The overall diets are presented in fig 45; details of the components are given in table 40. The main components were aquatic insects (45% and 42%, respectively) and microcrustaceans (19% and 36%). The main aquatic insects were chironomid larvae and the main microcrustaceans were cladocerans. Other items in the stomachs were unidentified organic material (17%), detrital material (3%) and traces of algae, gastropods, aquatic arachnids, macrocrustaceans and teleost scales.

Porochilus rendahli and *Neosilurus* sp. C can therefore be classified as meiophagous carnivores that feed predominantly on benthic fauna. Apparent differences in their diets may partly be caused by seasonal differences in the availability of food items when these classification types were in use. No literature on the feeding habits of *P. rendahli* was found.[76]

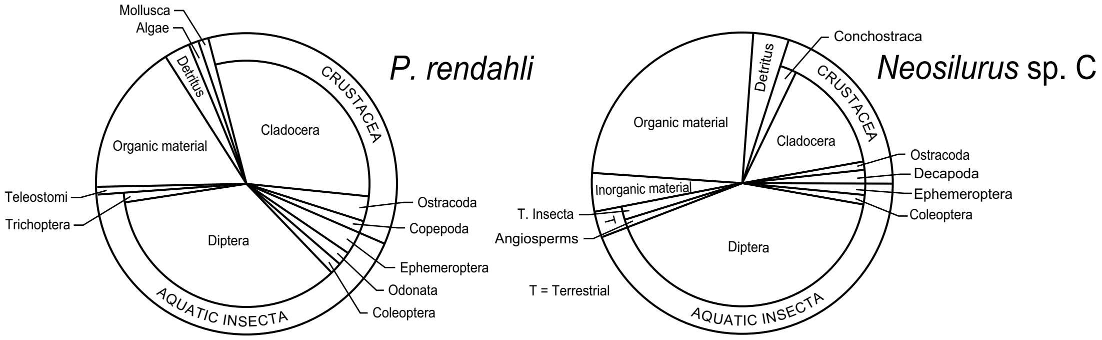

Figure 45 The main components of the diet of *Neosilurus* sp. C and *P. rendahli*

Seasonal changes

In sampling periods 1–3, respectively, 69 (13% empty), 39 (33% empty) and 16 (37% empty) stomachs of *Neosilurus* sp. C were examined (all habitats combined). The highest proportions of specimens with empty stomachs were found in the 1978–79 Early-wet and Mid-wet seasons.

The diet in the 1978 Late-dry season consisted mainly of chironomid larvae and cladocerans. During the 1978–79 Early-wet and Mid-wet seasons large amounts of unidentified organic material were found in the stomachs; however, chironomid larvae remained important and conchostracans and ostracods were eaten instead of the cladocerans in the Late-dry season. Mainly chironomid larvae, with only traces of microcrustaceans, were eaten in the Mid-wet season.

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[76] Smith (1998) indicated that in the Fly River system of Papua New Guinea, the closely-related *P. obbesi* primarily consumed aquatic insects, detritus/mud, crustaceans and aquatic plants in that order. Worms, terrestrial plants and terrestrial insects were also consumed, but in low quantities.

Table 40 Dietary composition of *Neosilurus* sp. C and *P. rendahli*

	Neosilurus sp. C					*P. rendahli*						Habitat		
	Season			Overall		Season				Overall		Magela system		Nourlangie system
Stomach contents	1978 Late-dry	1978–79 Early-wet	1978–79 Mid-wet	Sub-mean	Main-mean	1979 Late-wet–Early-dry	1979 Mid-dry	1979 Late-dry	1979–80 Early-wet	Sub-mean	Main-mean	Bb	Fb	Bb
Aquatic plants														
Algae					0.1						0.3			
Miscellaneous	–	0.4	–	0.1		–	–	–	–	–		–	–	–
Conjugatophyta														
Mougeotia	–	–	–	–		1.2	–	–	–	0.3		–	1.4	–
Aquatic animals														
Gastropoda					–						1.1			
Amerianna	–	–	–	–		1.6	0.7	1.7	–	1.1		0.9	1.9	1.5
Arachnida											0.5			
Hydracarina	–	–	–	–		–	1.3	–	–	0.5		–	2.4	–
Microcrustacea					19.0						35.5			
Conchostraca														
Cyzicus	–	10.4	–	2.4		0.3	0.5	–	–	0.3		0.4	–	–
Cladocera														
Miscellaneous	25.1	–	–	15.5		26.3	4.2	–	–	8.5		6.4	17.1	7.7
Diaphanosoma	–	–	2.0			14.5	20.3	24.1	50.0	22.0		18.8	22.9	41.5
Ostracoda	0.3	2.3	1.0	1.0		4.1	3.4	0.4	–	2.5		1.3	7.4	–
Copepoda														
Miscellaneous	–	–	–	0.1		0.8	2.5	–	–	1.2		1.0	2.4	–
Cyclops	–	–	–	–		–	–	3.5	–	1.0		1.4	–	–
Macrocrustacea					1.8						–			
Macrobrachium	3.3	–	–	1.8		–	–	–	–	–		–	–	–
Insecta					44.5						41.5			
Ephemeroptera														
Baetidae	1.0	–	–	0.5		2.0	6.0	–	–	2.9		2.7	2.4	7.7
Odonata														
I. heterosticta	–	–	–	–		–	5.3	–	–	2.1		1.5	4.8	–
Hemiptera														
Corixidae	0.2	–	–	1.0		–	–	–	–	–		–	–	–

Table 40 continued

	Neosilurus sp. C					*P. rendahli*						Habitat		
	Season			Overall		Season				Overall		Magela system		Nourlangie system
Stomach contents	1978 Late–dry	1978–79 Early-wet	1978–79 Mid-wet	Sub-mean	Main-mean	1979 Late-wet–Early-dry	1979 Mid-dry	1979 Late-dry	1979–80 Early-wet	Sub-mean	Main-mean	Bb	Fb	Bb
Coleoptera														
Miscellaneous	–	2.7	–	0.7		–	–	0.6	–	0.2		0.2	–	–
Berosus	–	–	–	–		1.2	–	–	–	0.3		–	1.4	–
Diptera														
Chaoborinae	0.5	–	–	0.8		–	–	–	7.1	0.5		–	–	–
Chironomidae (larvae)	46.4	21.9	34.0	38.7		38.6	33.9	30.7	7.1	32.3		38.5	21.7	23.9
Chironomidae (pupae)	0.4	0.2	–	0.7		0.6	3.0	2.6	–	2.1		2.9	–	1.5
Ceratopogonidae	1.5	–	–	1.3		–	0.7	–	–	0.3		0.4	–	–
Trichoptera														
Hydroptilidae	–	–	–	–		0.1	0.1	–	–	0.1		–	–	0.8
Lepteroceridae	–	4.2	3.0	1.7		1.0	0.6	0.7	–	0.7		1.0	–	–
Teleostomi					+						0.5			
Scales	–	0.2	–	+		–	–	–	–	–		–	–	–
Egg material	–	–	–	–		–	1.3	–	–	0.5		–	2.4	–
Terrestrial plants					0.5						–			
Angiospermae	0.7	–	–	0.5		–	–	–	–	–		–	–	–
Terrestrial animals														
Insecta					1.6						–			
Odonata														
Zygopteran (adults)	1.5	–	–	0.8		–	–	–	–	–		–	–	–
Anisopteran (adults)	1.6	–	–	0.8		–	–	–	–	–		–	–	–
Parasites														
Trematoda	0.2	–	–	0.3	0.3	–	1.3	–	–	0.5	0.5	–	–	7.7
Nematoda	0.1	–	–	+	+	–	–	–	–	–	–			
Detrital material														
Inorganic material	3.2	8.3	3.0	3.8	3.8	–	–	–	–	–	–	–	–	–
Organic material	12.3	41.7	52.0	25.2	25.2	7.8	14.9	24.1	35.7	17.1	17.1	17.7	11.9	7.7
Number of empty fish	9	13	6	11	11	1	13	4	–	18	18	9	6	2
Number of fish with food	60	26	10	114	114	51	76	54	14	283	283	132	42	13

Figures represent the mean percentage volume determined by the estimated volumetric method. Fb = Floodplain billabong; Bb = Lowland backflow billabong

In sampling periods 4–7, respectively, 52 (2% empty), 89 (15% empty), 58 (3% empty) and 14 (4% empty) stomachs of *P. rendahli* were examined (all habitats combined). The highest proportions of specimens with empty stomachs occurred in the 1979 Mid-dry season.

Chironomid larvae were the main food items in the stomachs from the Late-wet–Early-dry season to the 1979 Late-dry season. Microcrustaceans (mainly cladocerans) were also important food items in those seasons and in the 1979–80 Early-wet season they were the most common food item.

Habitat differences

Magela catchment

A total of 141 (6% empty) stomachs of *P. rendahli* were examined (all seasons combined) from backflow billabongs, and 48 (13% empty) from floodplain billabongs.

The diet in the backflow billabongs was based mainly on chironomid larvae followed by cladocerans (mainly *Diaphanosoma*). In the floodplains the variety of major food items was slightly greater: the aquatic insects included chironomid, baetid and *Ischnura heterosticta* larvae, and the microcrustaceans included cladocerans, ostracods and copepods.

Nourlangie catchment

A total of 15 stomachs of *P. rendahli* was examined (all seasons combined) from backflow billabongs; 2 did not contain food.

In the Nourlangie catchment, *P. rendahli*'s diet was very similar to that in the Magela Creek catchment; however, the proportion of microcrustaceans (mainly cladocerans) was slightly higher.

Fullness

A summary of mean fullness indices of *P. rendahli/Neosilurus* sp. C for different sampling periods and habitat types is shown in table 41. These data are presented on the assumption that feeding times do not vary with habitat or season.

Seasonal changes

The mean seasonal fullness index (all habitats combined) increased during the 1978–79 Early-wet season and then decreased into the Mid-wet season. It increased again in the Late-wet–Early-dry season, fell in the Mid-dry season, and index rose again in the 1979–80 Early-wet season, as in the previous year.

Habitat differences

In the Magela catchment, the mean two fullness indices calculated for specimens from the shallow backflow billabongs upstream of RUPA were lower than for specimens from backflow billabongs downstream.

Downstream of RUPA the highest mean indices were recorded from the shallow backflow billabongs, with slightly lower indices from channel backflow and floodplain billabongs.

The mean fullness indices of specimens from lowland habitats in the Nourlangie catchment were lower than those recorded from equivalent Magela Creek habitats; however, the shallow backflow billabong specimens had similar mean indices to those from the channel backflow billabongs in the Magela catchment.

Table 41 Mean fullness indices of *P. rendahli* in different sampling periods and habitats

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Lowland shallow backflow billabong	n/s	n/s	n/s	n/s	1.3 (11)	1.8 (19)	n/s	1.6 (30)
Downstream of RUPA:								
Lowland channel backflow billabong	2.1 (20)	1.8 (6)	4.5 (2)	2.6 (17)	2.0 (18)	1.8 (6)	2.3 (3)	2.2 (72)
Lowland shallow backflow billabong	1.8 (9)	3.1 (20)	n/s	3.7 (34)	2.4 (23)	2.4 (39)	3.0 (3)	2.8 (128)
Corridor anabranch billabong	n/s	3.0 (1)	n/s	1.0 (1)	n/s	n/s	n/s	2.0 (2)
Floodplain billabong	n/s	n/s	5.0 (1)	2.8 (23)	1.2 (10)	1.5 (2)	n/s	2.3 (36)
Nourlangie Creek catchment (regular sites only)								
Lowland channel backflow billabong	n/s	3.0 (1)	0.8 (11)	3.5 (2)	n/s	n/s	n/s	1.3 (14)
Lowland shallow backflow billabong	1.7 (3)	3.0 (5)	n/s	4.0 (1)	1.7 (14)	n/s	n/s	2.1 (23)
Seasonal mean (all sites)	2.0	2.8	1.6	3.0	2.0	2.1	3.2	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Summary

The habitats and periods of greatest apparent feeding activity where more than one fish was captured were:

Magela catchment

- lowland channel backflow billabong; 1978–79 Mid-wet season
- lowland shallow backflow billabong (downstream of RUPA); 1979 Late-wet–Early-dry season
- floodplain billabong; 1979 Late-wet–Early-dry season

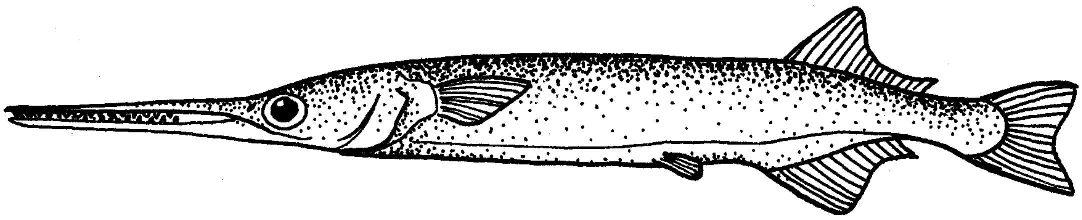
Nourlangie catchment

- lowland channel backflow billabong; 1979 Late-wet–Early-dry season
- lowland shallow backflow billabong; 1978–79 Early-wet season

Family BELONIDAE

3.12 *Strongylura krefftii* (Gunther)

Strongylura krefftii is commonly known as the freshwater longtom or needle fish. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3) and in southward-flowing rivers of Papua New Guinea. Pollard (1974) found this species to be plentiful in the Magela Creek catchment in sandy corridor waterbodies, floodplain billabongs, lowland backflow billabongs, and lowland sandy creekbeds. In the Nourlangie system he found it in lowland sandy creekbeds and escarpment mainchannel billabongs. Miller (in Taylor 1964) found it in large billabongs in the Oenpelli area.



Strongylura krefftii

This species is a member of a predominantly marine genus and family, but is restricted to freshwaters in northern Australia and southern New Guinea.[77] It normally swims and feeds on the surface, but is also found lurking under overhanging vegetation and amongst tree roots.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found commonly in all floodplain, corridor and lowland backflow billabongs; it was also common in lowland sandy creekbeds downstream of RUPA and in escarpment mainchannel waterbodies, but rarely in escarpment perennial streams. It was found in the most sites in the Late-wet–Early-dry season, and in the fewest in the Late-dry season.

Size composition

The lengths and weights of 224 specimens were determined. The main peak in the overall length-frequency distribution was caused by the cumulative effect of overlapping sampling methods (ie seine nets and gillnets). The mesh selectivity of gillnets is magnified with this species due to the elongated body shape and its relation to the critical girth at capture.

Length–weight relationship

The length–weight relationship was described by the expression:

$$W = 0.98 \times 10^{-3} L^{3.2} \qquad r = 0.94 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 42. The seasonal condition factor decreased slightly in the transition from the 1978 Late-dry season to the 1978–79 Early-wet season (probably due to spawning activity) and then increased into the Mid-wet. It then decreased through the Late-wet–Early-dry season to reach a low by the Mid-dry season. Increasing availability of small forage fish in contracting Dry-season billabongs

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[77] Herbert and Peeters (1995) indicated that *S. krefftii* can also be found in estuaries in north-eastern Queensland.

may have caused the improvement in body condition by the 1979 Late-dry season. The single specimen captured in the 1979–80 Early-wet season was in good condition (K = 1.22).

Table 42 Mean length, mean weight and condition factor of *S. krefftii*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	48	358.3	87.8	0.96
Early-wet	16	424.0	144.2	0.93
Mid-wet (1978–79)	54	257.8	31.9	1.10
Late-wet–Early-dry (1979)	34	288.3	44.4	0.98
Mid-dry	39	326.5	54.6	0.81
Late-dry	25	386.3	113.8	0.98
Overall	216	316.1	61.00	1.00

Length-frequency distribution

The smallest specimen caught was 50 mm LCF, and the largest was 640 mm LCF (fig 46). Lake (1971) reported that this species grows to only 750 mm. The mean and modal lengths were 316 and 300 mm LCF respectively. The LFM was 290 mm LCF for males and 410 mm LCF for females. Most specimens captured (mainly with the seine net and the smaller mesh gillnets) were between 210 and 360 mm LCF. There was a series of small peaks, possibly caused by mesh selectivity of the various gillnets used, for specimens with lengths greater than 400 mm LCF.

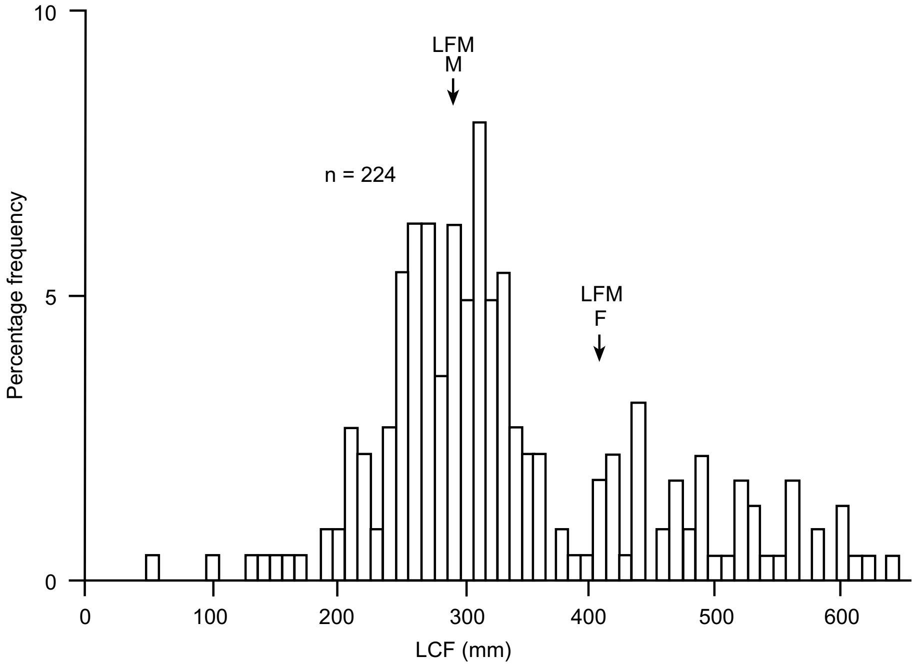

Figure 46 Length-frequency distribution of all *S. krefftii* captured

Seasonal changes in distribution

As the smallest specimens were captured in the Mid-wet season (fig 47), this is probably the main period for juvenile recruitment. The smallest specimens collected in the 1978–79 Early-wet season and both Late-dry seasons were much larger than the smallest specimens collected in the other seasons. The largest specimen was caught in the 1979 Late-dry season.

The seasonal mean lengths of all specimens captured are shown in table 42. The mean lengths peaked in both Late-dry to Early-wet transition seasons, but then fell dramatically when large numbers of small recruits entered the populations in the Mid-wet season. These recruits were present in catches for the remainder of the study (except in the 1979–80 Early-wet season, when the sample size was small) and mean lengths increased due to their growth; the resulting 1979 Late-dry length-frequency distribution was similar in form to the distribution recorded in the 1978 Late-dry season.

Growth rate

No published information could be found on the growth rate of *S. krefftii*. Estimation of growth rate from the seasonal length-frequency distributions is difficult due to mesh selectivity, the frequency with which small specimens appear to be recruited into the populations, and the wide range of habitats sampled.

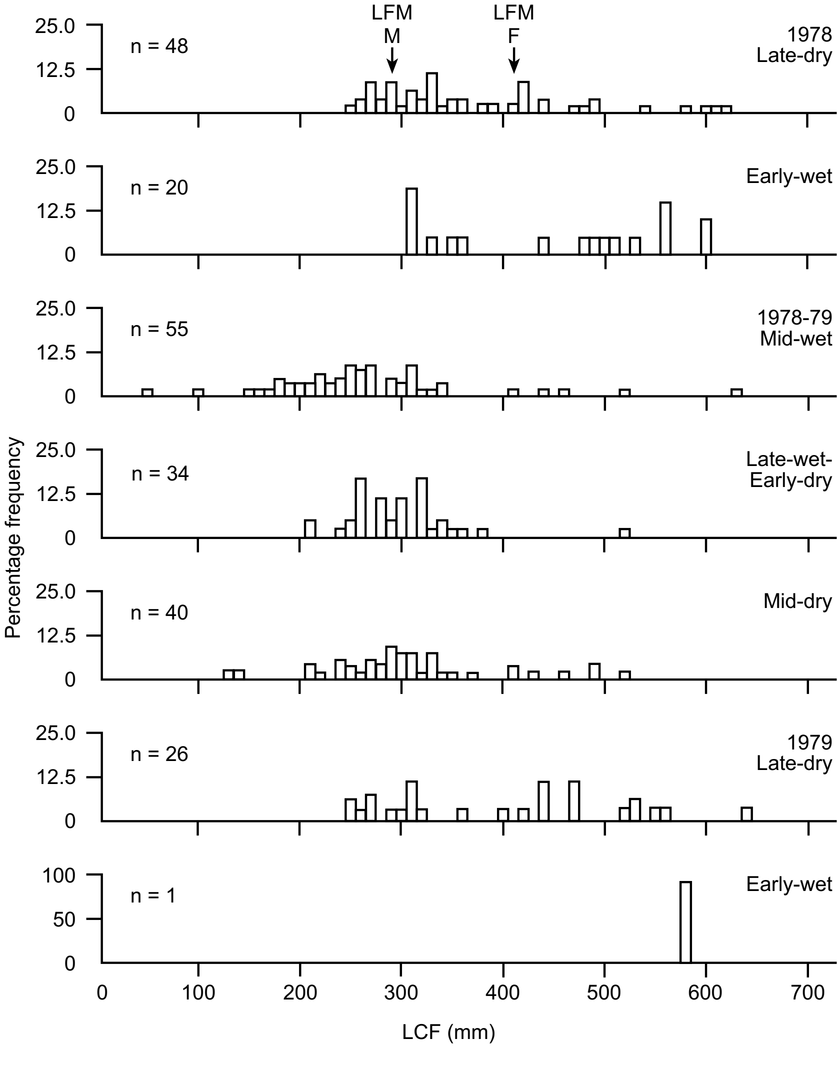

Figure 47 Seasonal length-frequency distribution of all *S. krefftii* captured

However, the increase in mean lengths of the recruits that first appeared in the Mid-wet season (table 42) gives a tentative estimate of growth if followed to the 1979 Late-dry season, although it would be a slight overestimate, as larger numbers of adults were captured towards the end of the 1979 Dry season. The growth increment in the roughly eight-month period is about 130 mm, indicating a yearly increment of 200 mm. Therefore, the small specimens that appeared in the Mid-wet season were possibly over a year old, and males may attain the LFM during their second year and females by the end of their second year of life. The whereabouts of the small recruits (0–1 year olds) before the Wet seasons is unknown.

Habitat differences in distribution

Length-frequency distributions showing the habitat preferences of *S. krefftii* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are given in figure 48.

As a result of the apparently large difference (130 mm) between the LFM of males and females, it is difficult to distinguish juveniles from adults in length-frequency distributions for the sexes combined. The specimens were therefore divided into three groups: small (< 200 mm LCF, all juveniles); intermediate (201–360 mm LCF, large juveniles and small adults; most specimens fell into this group); and large (> 361 mm LCF, mostly adults).

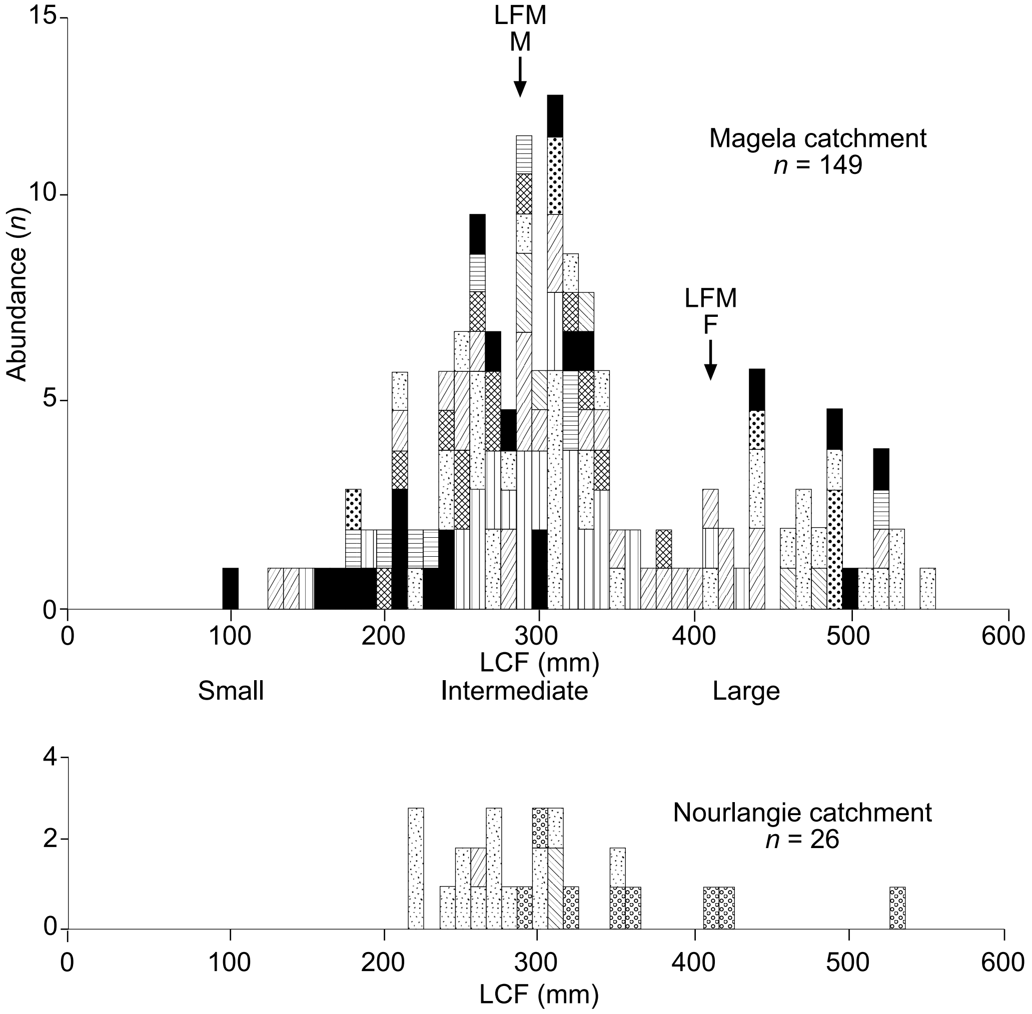

Figure 48 Length-frequency distributions and habitat preferences of *S. krefftii* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment

The small specimens were collected mainly from floodplain billabongs, but were also found in lowland sandy creekbeds, corridor waterbodies (dispersal routes) and shallow backflow billabongs. The smallest specimen (50 mm LCF) was collected from a floodplain billabong.

The few intermediate-sized specimens collected in floodplain billabongs were towards the lower end of the size range. Most were captured in backflow billabongs (mainly shallow types) and sandy creekbeds, with smaller numbers being found in corridor and escarpment mainchannel waterbodies.

The large specimens, including the largest (550 mm LCF), were found in a lowland channel backflow billabong. The smaller specimens of this group were captured mainly in lowland sandy creekbeds. Large specimens were also captured in escarpment mainchannel billabongs, floodplain and corridor waterbodies, and lowland shallow backflow billabongs.

Nourlangie catchment

No small specimens were captured, probably as a result of low sampling effort. Most of the intermediate-sized specimens were captured in lowland backflow billabongs; the smaller ones mainly in the channel-type billabongs, and the larger mainly in shallow backflow billabongs. Some intermediate-sized specimens appeared in escarpment perennial streams during the Mid-wet season. All large specimens were found in shallow backflow billabongs.

Environmental associations

Rank numbers for *S. krefftii* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

The water temperature at sites where *S. krefftii* was captured ranged from 24° to 38°C (mean = 30°C) on the surface, and from 24° to 34°C (mean = 29°C) on the bottom. Both of these means ranked in the lower-middle quarter (see fig 170). The implied tolerance of a wide range of water temperatures corresponds to the wide distribution of this species from lower escarpment to floodplain waters. The range of surface-water temperatures may be more indicative of this species' range of tolerance, since *S. krefftii* is primarily a surface swimmer and feeder (Pollard 1974).

Dissolved oxygen

Dissolved oxygen concentrations ranged from 3.7 to 9.1 mg/L (mean = 6.3) on the surface, and from 0.2 to 7.0 mg/L (mean = 3.9) on the bottom. The means were ranked in the upper and lower-middle quarters respectively (see fig 171). The range of DO concentrations reflects the wide distribution of the species, from escarpment to lowland waters. This species was present in the Leichhardt Billabong fish kill (Bishop 1980), during which DO concentrations in surface waters fell below 0.1 mg/L.

Visibility

Secchi depths ranged from 1 to 360 cm, with a mean depth of 72 cm. This mean ranked in the upper-middle quarter (see fig 172).

pH

Strongylura krefftii was taken from waters with surface pH from 4.5 to 8.6 (mean = 6.4), and bottom pH from 4.5 to 7.3 (mean = 6.1). These means ranked in the lower and lower-middle quarters respectively (see fig 173). As with the preceding physico–chemical variables, a wide range of tolerance is indicated.

Conductivity

Surface conductivities ranged from 6 to 98 µS/cm; bottom water conductivities from 4 to 78 µS/cm. These ranges are narrow compared with the conductivities associated with other species, and with the other physico–chemical variables recorded for this species.

Habitat–structural variables

Substrate

As might be expected from its wide distribution in the system, *S. krefftii* was captured over the entire range of substrate types defined in this study. Mud (upper quarter) was the most common, followed by sand (lower-middle quarter), then clay, gravel, leaves, rocks and boulders (see fig 174).

Hydrophytes

Strongylura krefftii was found in moderate to highly vegetated waters (vegetation-occurrence index 74.2%) with submergent (43.1%), emergent (29.1%) and floating-attached hydrophytes (26.1%). Pollard (1974) often observed this species lurking under overhanging vegetation and amongst tree roots (eg *Pandanus* sp.), and Lake (1971) noted that this species lays tendrilled eggs that adhere to submerged vegetation; hydrophytes and bank vegetation may therefore play a significant role in the ecology of this species.

Reproduction

Of the 217 *S. krefftii* examined for reproductive condition, 47 were sexually indistinguishable (length range 52–362 mm LCF), 68 were females (133–640 mm LCF) and 102 were males (195–615 mm LCF).[78]

Length at first maturity

The smallest maturing specimens (gonad stage greater than III) were a 317 mm LCF female and a 267 mm LCF male; however, the LFM was estimated to be 410 mm and 290 mm, respectively (fig 49); all calculations were based on 10 mm-length groups.

The LFM for the females was surprisingly high (no maturing females were identified between 317 and 420 mm). Length frequencies were plotted for each sex to investigate the possibility of a sex reversal (fig 49), however, this phenomenon was not evident from the distribution.

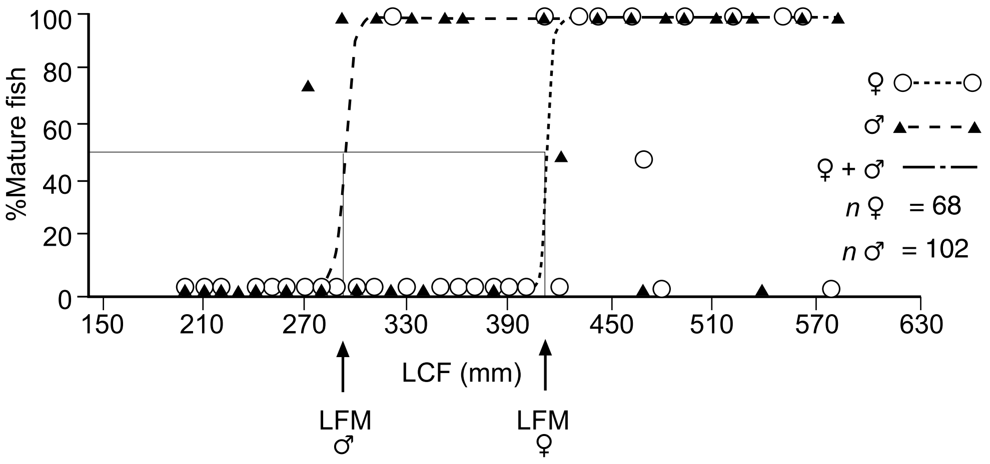

Figure 49 Estimated length at first maturity (LFM) of male and female *S. krefftii*

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[78] Hortle (1988) demonstrated that this species was sexually dimorphic, with males above 175 mm standard length becoming spotted and males above 400 mm developing a dorsal hump.

Sex ratio

A chi-squared test on the sex ratio of all adults and juveniles indicated a significantly ($P < 0.001$) greater proportion of males during the 1978–79 Mid-wet season (all other seasons had a 1:1 ratio) (table 43); the preponderance of males may have been due to a localised behavioural characteristic or migration during that season.

The ratio of adult males to adult females was significantly different ($P<0.001$) from 1:1 in the 1978–79 Mid-wet season and, at <0.05 level, in the 1978 Late-dry, 1978–79 Early-wet, 1979 Late-wet–Early-dry and Mid-dry seasons.

Most of the females captured were juveniles (fig 50); whereas the small LFM for males resulted in most males being classed as adults, which gave an unequal sex ratio.

Breeding season

Less than 0.1% of the specimens were identified as mature, ripe or spent. The GSI was low and changed very little throughout the year (fig 51 and table 43). There was a slight increase in gonad development during the 1978–79 Early-wet season, as indicated by both the GSI and GMSI.

Table 43 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *S. krefftii* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	15	5	6	12	14	14	2
Adults	M	*n*	22	12	32	8	18	10	0
		χ^2	1.3	2.9	17.8	0.8	0.5	0.7	2.0
		P	n.s.	n.s.	***	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	6	2	0	1	4	6	1
	M	*n*	17	10	12	7	12	9	0
		χ^2	5.3	5.3	12	4.5	4	0.6	1
		P	*	*	***	*	*	n.s.	n.s.
GSI									
Adults only	F	mean	0.7	2.2	–	0.4	0.4	0.7	2.8
		s.d.	0.4	1.6	–	–	0.05	0.1	–
	M	mean	0.2	0.4	0.2	0.03	6.4	0.2	–
		s.d.	0.1	0.2	0.1	0.05	0.5	0.1	–
	F+M	mean	0.3	0.7	–	0.1	0.4	0.4	–
		s.d.	0.3	0.9	–	0.2	0.4	0.3	–
GMSI	F	mean	3.3	4.5	–	2	4	3.9	3
Adults only		s.d.	1.0	2.1	–	–	0	0.7	–
	M	mean	2.7	4.8	3	1.4	3.5	3.5	–
		s.d.	1.1	1.1	0.9	0.5	0.8	0.9	–
	F+M	mean	2.8	4.7	–	1.5	3.6	3.7	–
		s.d	1.1	1.2	–	0.5	0.7	0.8	–

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; *** = $P < 0.001$; s.d. = standard deviation.

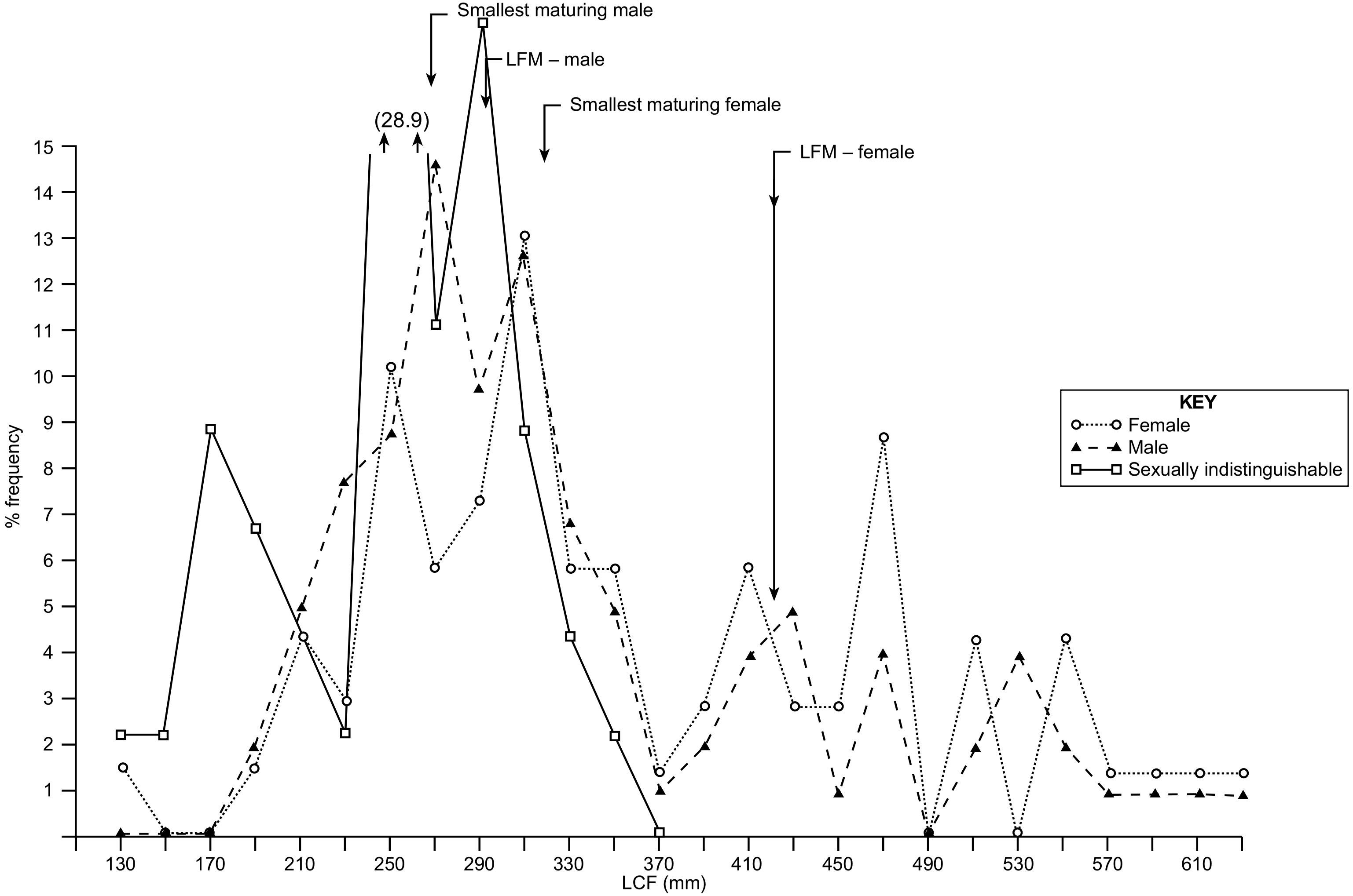

Figure 50 Length-frequency distributions of male, female and sexually indistinguishable *S. krefftii*

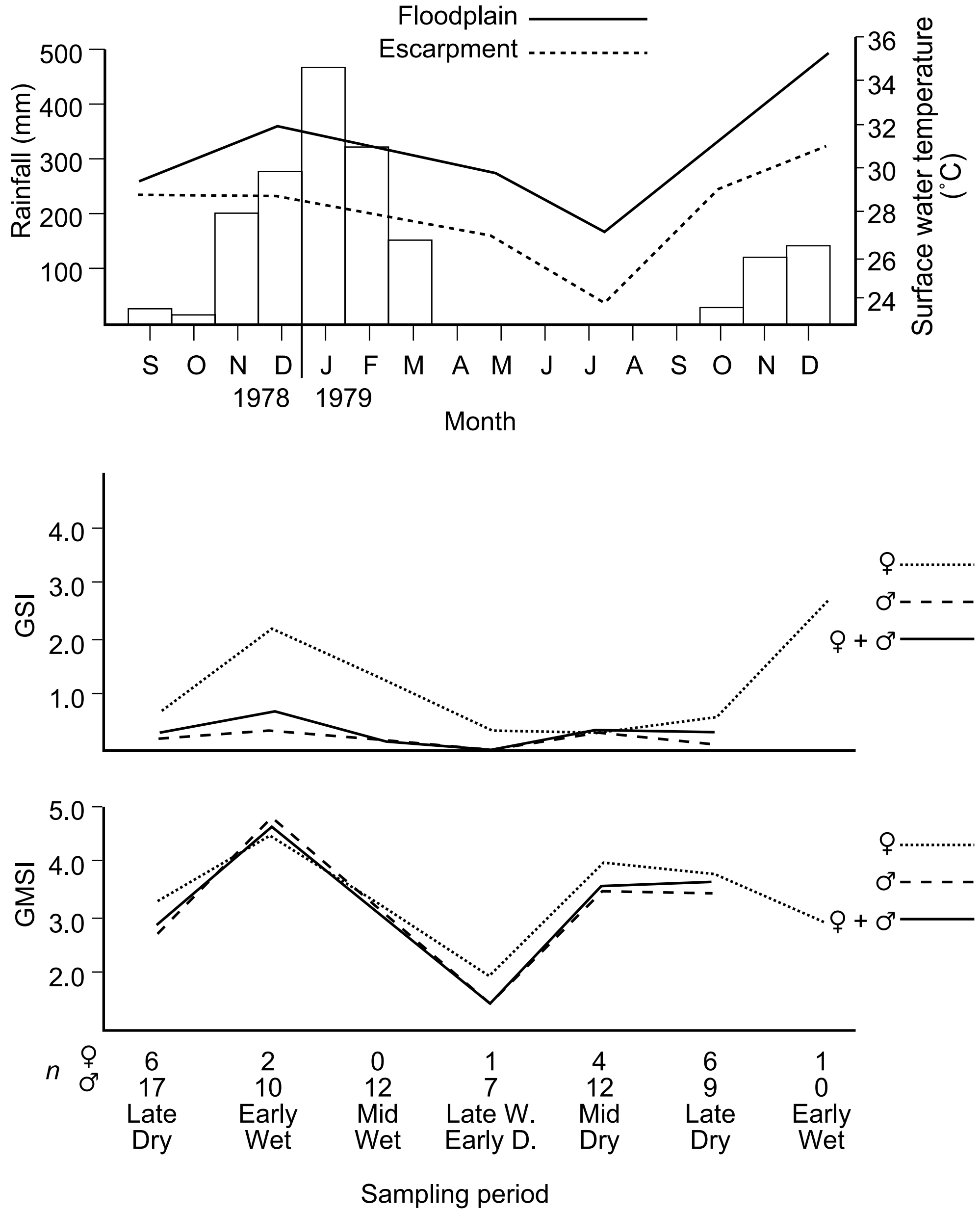

Figure 51 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *S. krefftii*

Mature fish were captured during the 1978 Late-dry and 1978–79 Early-wet and the 1979 Mid-dry and Late-dry seasons. Ripe fish were captured in the 1978 Late-dry and Early-wet seasons only, while spent fish were captured in the 1978–79 Mid-wet and Late-wet–Early-dry seasons.

Thus, the evidence suggests that *S. krefftii* matured towards the end of the 1978 Dry season and spawned around the 1978 Late-dry and 1978–79 Early-wet seasons. Most of the juvenile fish were collected during the 1978–79 Mid-wet; fish in the smallest size class (50–99 mm LCF) were most likely progeny from the previous Late-dry and/or Early-wet season spawning, which indicates a very fast rate of growth.

Site of spawning

Running-ripe fish were collected from a wide range of habitats (table 44), including an escarpment mainchannel waterbody (Sawcut Gorge), two lowland sandy creekbed sites (Magela bed) and three lowland shallow backflow billabongs (Djalkmara Billabong, Goanna Billabong and Nourlangie Rock).

Table 44 Possible sites of spawning for *S. krefftii* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	–	1	1	–	–	1	–
Lowlands							
Sandy creekbed	–	–	–	4	–	–	1
Backflow billabong	3	4	1	4	1	–	2
Corridor	–	–	–	–	–	1	4
Floodplain billabong							
Upper	–	–	–	–	–	–	7

Spent fish were found in the escarpment area (Sawcut Gorge), a backflow billabong (Goanna Billabong) and a corridor waterbody (Mudginberri corridor).

Most of the juvenile fish were collected in the corridor and floodplain billabongs; possibly the planktonic eggs or larvae or both are carried to the lower reaches of the system by the flood waters that begin flowing during or soon after spawning has occurred in the higher reaches.

Fecundity

No ovaries of *S. krefftii* were collected and very little data are available on the reproductive biology of this species.

Summary

There was a large proportion of males in the population during the 1978–79 Mid-wet season, and there appears to be a large difference between the LMF for males and females (290 and 420 mm respectively). No sex reversal or hermaphroditism was evident. Only a very small proportion of fish (0.01% of the total number of males and females) had gonad maturation stages greater than IV; however, this small sample suggested that the gonads were maturing towards the end of the Dry season and that spawning was taking place around the Late-dry and Early-wet seasons. Possible spawning sites ranged from an escarpment mainchannel waterbody to backflow billabongs and sandy creekbed habitats (table 44).[79] Juveniles were predominantly collected from corridor and floodplain billabongs, which suggests that eggs or larvae or both may have been carried downstream with the flood waters.

The eggs of this family generally have adhesive tendrils, which act as hold-fasts to each other and to objects in the water. They are relatively large (up to 4 mm in diameter), and incubation takes 1–5 weeks, at temperatures around 24°C (Lake 1971; Breder & Rosen 1966), (probably less in the warmer waters of the Alligator Rivers Region).

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[79] Quoting communication with A. Orr of James Cook University, Smith (1998) indicated that *S. krefftii* have been observed spawning within macrophyte beds along the shore of Lake Moondarra in north-western Queensland. In the Fly River system of Papua New Guinea it is apparent that *S. krefftii* prefer to breed in floodplain lagoons rather than the main river channel (Smith 1998).

Feeding habits

Overall diet

The stomachs of 215 specimens were examined; 132 contained food. The overall diet of *S. krefftii* is summarised in fig 52; the components of the diet are listed in table 45.

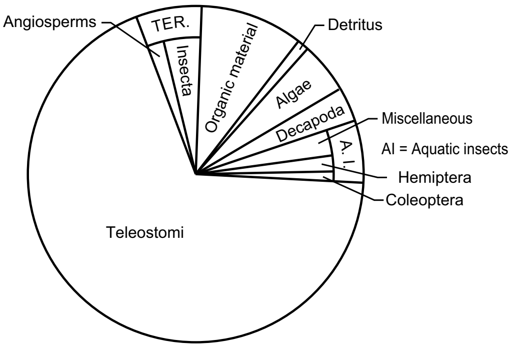

Figure 52 The main components of the diet of *S. krefftii*

The main components were teleosts (69%) and unidentified organic material (11%) (possibly mainly digested teleost flesh). The identifiable teleosts were mainly *Ambassis* spp., *M. splendida inornata*, *P. rendahli* and *A. percoides*. The remains of five other fish species were also identified. Small quantities of filamentous green algae, aquatic crustaceans (mainly *Macrobrachium*), surface-dwelling insects, terrestrial plant material and terrestrial insects were also in the stomachs. *Strongylura krefftii* can therefore be classified as a macrophagous carnivore/piscivore feeding opportunistically in (mainly) surface waters.[80] These data correlate well with those of Pollard (1974), who noted that it was a predatory species feeding on smaller fishes (especially atherinids, although few identifiable fish of this family were found in the stomachs in the present study, and melanotaeniids). Haines (1979) noted this species and the closely related *S. strongylura* are piscivores in the Purari River. Both jaws of this species are lengthened into a beak and have needle-sharp teeth for holding fish; the prey is first bitten sideways and then turned end-on to be swallowed head first (Lake 1971).

A total of 159 stomachs of *S. krefftii* were examined (all seasons combined) 8 (50% empty) from escarpment mainchannel waterbodies, 27 (30% empty) from lowland sandy creekbeds, 82 (55% empty) from shallow backflow billabongs, 24 (17% empty) from corridor waterbodies and 18 (28% empty) from floodplain billabongs in the Magela Creek catchment. The highest proportions of empty stomachs were in fish from shallow backflow billabongs and escarpment mainchannel waterbodies, and the lowest from corridor waterbodies.

Seasonal changes

In sampling periods 1–6, respectively, 47 (32% empty), 17 (64% empty), 52 (27% empty), 34 (38% empty), 39 (39% empty) and 25 (56% empty) stomachs of *S. krefftii* were examined (all habitats combined). The fish with the highest proportions of empty stomachs were caught in the Late-dry seasons and those with the lowest proportion in the Mid-wet season.

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[80] In an estuarine situation in northeastern Florida Bay USA, Ley et al (1994) found the diet of the closely-related *S. notata* to be dominated by fishes and insects. This species was observed capturing foods in a variety of ways — lunging down on benthic prey from above, skimming prey from the surface, and leaping out of the water to capture insects on overhanging trees. Diets varied greatly but not systematically among sites sampled.

Table 45 Dietary composition of *S. krefftii*

	Habitat						Season							
	Magela system					Nourlangie system	1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Aquatic plants														
Algae														4.3
Miscellaneous	–	–	2.4	–	–	–	7.5	–	–	4.3	–	–	2.5	
Conjugatophyta														
Mougeotia	–	10.5	0.3	–	2.3	–	–	–	–	11.4	–	–	1.8	
Aquatic animals														
Macrocrustacea														3.1
Macrobrachium	–	12.6	4.1	–	–	–	8.4	16.7	–	–	2.1	–	3.1	
Insecta														5.8
Fragmented	–	5.3	–	–	–	–	9.4	–	–	–	–	9.1	3.0	
Hemiptera														
Gerridae	–	1.6	–	–	–	–	0.9	–	–	–	–	–	0.2	
Anisops	–	0.3	2.7	–	–	–	2.0	–	–	–	4.2	–	1.3	
Corixidae	–	–	2.7	–	–	–	–	–	–	4.8	–	–	0.8	
Coleoptera	–	–	–	–	–	–	2.2	–	–	–	–	–	0.5	
Teleostomi														69.3
Fragmented	25.0	10.5	30.8	50.0	38.5	55.6	26.6	50.0	52.6	28.1	35.4	36.4	37.8	
Scale	12.5	–	–	–	–	–	1.6	–	–	–	–	–	0.4	
N. erebi	–	–	–	–	7.7	–	–	–	2.6	–	–	–	0.8	
Neosilurus spp.	–	–	2.7	–	–	–	–	–	–	–	4.2	–	0.8	
P. rendahli	–	–	5.4	–	–	5.6	–	–	–	4.8	4.2	9.1	2.3	
M. splendida inornata	25.0	–	16.2	20.0	7.7	16.7	–	–	23.6	23.8	4.2	–	11.4	

Table 45 continued

	Habitat						Season						Overall	
	Magela system					Nourlangie system	1978	1978–79	1978–79	1979	1979	1979		
Stomach contents	Em	Ls	Bb	Cb	Fb	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Craterocephalus spp.	–	–	–	–	–	–	2.5	–	–	–	–	–	0.6	
C. stercusmuscarum	–	–	–	–	7.7	–	–	–	–	4.8	–	–	0.8	
Ambassis spp.	–	10.5	10.8	20.0	15.4	22.2	9.4	–	18.4	4.8	20.8	–	12.1	
A. percoides	–	5.3	–	–	–	–	–	–	–	–	4.2	9.1	1.5	
L. unicolor	25.0	–	2.7	–	–	–	–	–	2.6	–	–	–	0.8	
Terrestrial plants														
Angiospermae														3.6
Miscellaneous	–	8.7	5.4	5.0	–	–	2.3	–	–	4.8	4.2	18.2	3.6	
Terrestrial animals														
Insecta														1.0
Fragmented	–	3.2	–	–	–	–	1.9	–	–	–	–	–	0.5	
Orthoptera	–	–	–	–	5.0	–	–	–	–	–	–	5.9	0.5	
Parasites														0.8
Nematoda	–	5.3	–	–	0.4	–	3.1	–	–	–	–	0.5	0.8	
Detrital material	–	–	–	–	–	–	3.7	–	–	–	–	–	0.9	0.9
Inorganic material	–	–	0.3	–	–	–	–	–	–	0.5	–	–	0.1	0.1
Organic material	12.5	26.3	13.5	5.0	15.4	–	18.4	33.3	–	8.1	16.7	11.8	11.3	11.3
Number of empty fish	4	8	45	4	5	5	15	11	14	13	15	14	83	83
Number of fish with food	4	19	37	20	13	18	32	6	38	21	24	11	132	132

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs Cb = corridor billabongs; Fb = floodplain billabongs

The fish component of the diet varied seasonally: the proportion was lowest in the two Late-dry seasons and the Early-wet season, and highest in the Mid-wet season. In the Late-dry season, *Ambassis* and *Craterocephalus* were typical foods, and in the Mid- to Late-wet season, *M. splendida inornata*, *Ambassis* spp., *P. rendahli*, *C. stercusmuscarum* and *L. unicolor*. In the Late-dry seasons, the diet included traces of algae, *Macrobrachium*, various surface-dwelling aquatic insects, terrestrial insects and terrestrial plant material. In the Late-wet–Early-dry season, large volumes of filamentous green algae (which bloomed during this season), corixids and some terrestrial plant material were eaten; during the Mid-dry season *Macrobrachium*, *Anisops* (a surface-dwelling hemipteran insect) and terrestrial plant material were eaten.

Organic material (possibly partly digested fish flesh) was highest in the 1978–79 Early-wet and lowest in the Mid-wet and Late-wet–Early-dry seasons. Spiruroid nematodes were found in greatest abundance in the stomachs during the Late-dry seasons.

Habitat differences

Magela catchment

The small number of *S. krefftii* examined from the escarpment mainchannel waterbody were feeding exclusively on fish, of which *M. splendida inornata* and *L. unicolor* were identifiable. Fish were less important (although the large amount of unidentified organic material was probably digested fish flesh) in the diet in sandy creekbeds, where the prey were *Ambassis* spp. and *A. percoides*. *Strongylura krefftii* ate a variety of other foods in the sandy pools, including filamentous green algae (which it may have ingested incidentally when preying on species that seek shelter in the extensive algal mats that grow in some pools at the end of the Wet season), *Macrobrachium*, miscellaneous aquatic and terrestrial insects, and terrestrial plant material. Spiruroid nematodes (probably *Philometra*) were often found in abundance in the stomachs of fish from the sandy creekbeds.

Fish were the most important food items in the lowland backflow billabongs, where *M. splendida inornata*, *Ambassis* spp., plotosid catfishes and *L. unicolor* were the identifiable species. Traces of filamentous green algae, *Macrobrachium*, surface-dwelling aquatic insects and terrestrial plant material were a smaller portion of the diet than in the sandy pools. *S. krefftii* in the corridor waterbodies were feeding almost exclusively (except for some terrestrial plant material) on fish, as in the escarpment habitat. *Ambassis* spp. and *M. splendida inornata* were identifiable in the stomachs from the corridor waterbodies. Fish were also the most important food items in the floodplain billabongs (*Ambassis* spp., *C. stercusmuscarum, M. splendida inornata* and *N. erebi* were identifiable); some filamentous green algae and terrestrial orthopterans were also found in the stomachs.

Nourlangie catchment

The stomach contents of 23 specimens from lowland shallow backflow billabongs were examined; 18 stomachs contained food. *Strongylura krefftii* fed exclusively on fish in this catchment, unlike in comparable habitats in the Magela Creek system; however, the sample size from the Nourlangie catchment was smaller. The most abundant identifiable fish prey were the same in both catchments: *Ambassis* spp., *M. splendida inornata*, *P. rendahli* (which are among the most abundant small fish species found in these areas).

Fullness

Mean fullness indices of *S. krefftii* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments are summarised in table 46. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 46 Mean fullness indices of *S. krefftii* in different sampling periods and habitats

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	1.0 (2)	n/s	n/s	n/s	n/s	n/s	n/s	0.5 (2)
Lowland shallow backflow billabong	n/s	n/s	0 (1)	n/s	n/s	n/s	n/s	0 (1)
Downstream of RUPA:								
Lowland sandy creekbed pool	1.6 (11)	n/s	1.0 (2)	0.7 (3)	1.0 (7)	1.4 (5)	n/s	1.3 (28)
Lowland channel backflow billabong	0.3 (3)	0.6 (11)	1.0 (1)	0.7 (7)	0.8 (13)	0 (10)	0 (1)	0.4 (46)
Lowland shallow backflow billabong	1.0 (1)	0 (2)	1.0 (2)	1.8 (12)	1.0 (10)	1.4 (7)	n/s	1.3 (32)
Corridor sandy billabong	n/s	n/s	2.5 (11)	2.0 (2)	0.5 (2)	n/s	n/s	2.1 (15)
Corridor anabranch billabong	n/s	n/s	3.6 (5)	0 (2)	2.0 (2)	n/s	n/s	2.4 (9)
Floodplain billabong	1.0 (2)	3.0 (1)	1.8 (11)	0.8 (4)	2.0 (1)	1.0 (1)	n/s	1.5 (20)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	2.5 (2)	n/s	0 (2)	n/s	n/s	n/s	n/s	1.3 (4)
Lowland channel backflow billabong	n/s	2.5 (6)	1.5 (11)	0.5 (2)	1.0 (1)	n/s	n/s	1.7 (20)
Lowland shallow backflow billabong	2.0 (1)	0.3 (3)	n/s	4.0 (2)	2.4 (5)	n/s	n/s	2.2 (12)
Lowland sandy creekbed	1.6 (5)	n/s	n/s	1.0 (2)	n/s	n/s	n/s	1.1 (7)
Seasonal mean (all sites)	1.2	0.7	1.8	1.1	1.1	0.8	0	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Seasonal changes

The mean fullness index (all habitats combined) fell to its lowest during the 1978–79 Early-wet season and then rapidly reached a peak during the Mid-wet season, after which it fell close to the level recorded in the 1978 Late-dry. It fell again in the 1979 Late-dry season; only one fish from the 1979–80 Early-wet season was examined.

Habitat differences

In the Magela catchment upstream of RUPA, the sample sizes were too small for the mean fullness indices to have significance. Downstream of RUPA, the highest indices occurred in the corridor waterbodies. Channel backflow billabongs had the lowest indices.

In the Nourlangie catchment, mean fullness indices were highest in backflow billabongs (in contrast to the Magela catchment).

Summary

The habitats and periods of greatest apparent feeding activity where more than one fish was captured were:

Magela catchment

- corridor waterbodies; 1978–79 Mid-wet season, 1979 Late-wet–Early-dry season, 1979 Mid-dry season

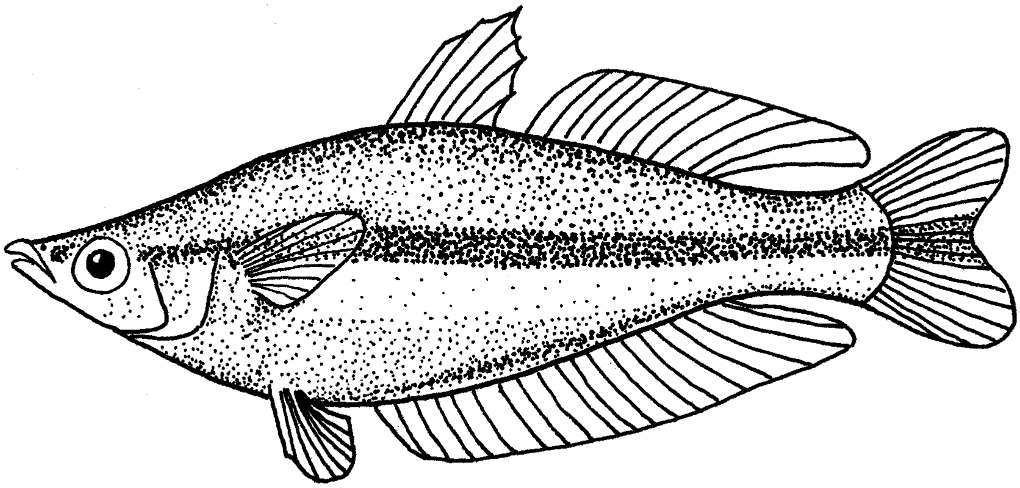
Nourlangie catchment

- lowland shallow backflow billabong; 1979 Late-wet–Early-dry season, 1979 Mid-dry season
- escarpment mainchannel waterbody; 1978 Late-dry season
- lowland channel backflow billabong; 1978–79 Early-wet season

Family MELANOTAENIIDAE

3.13 *Melanotaenia nigrans* (Richardson)

Melanotaenia nigrans is commonly known as the black-banded rainbowfish. It is found in the freshwater streams of far northern Australia and on several offshore islands such as Groote Eylandt in the Gulf of Carpentaria and Prince of Wales Island in Torres Strait, and in south-west Papua New Guinea. The western limit of its Australian distribution appears to be streams feeding into Bynoe Harbour, about 40 km south of Darwin. Pollard (1974) found juveniles over sandy areas in Magela Creek and observed large specimens while diving in Hickey Creek (Nourlangie Creek system) and in Cooper Creek (near Nabarlek). Miller (cited in Taylor 1964) found this species in billabongs and streams in the Oenpelli area.



Melanotaenia nigrans

This and all other melanotaeniids are permanent inhabitants of freshwaters and make good tropical aquarium fishes. Very little is known, however, about the biology of this species.[81] It usually lives in streams with *M. splendida australis* and/or *M. splendida inornata* (Allen 1978a) or both. Most specimens have been collected from the lower reaches of streams within about 50 km of the coast; however, two specimens examined by Allen from the Upper South Alligator River catchment had been collected some 130 km upstream.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found to be abundant in escarpment perennial and seasonal streams and to be common in all escarpment mainchannel waterbodies and some lowland sandy creekbed habitats (mainly upstream of RUPA); it was rare in lowland backflow and floodplain billabongs.

Melanotaenia nigrans was seldom found rarely in escarpment mainchannel terminal waterbodies but was abundant in some plateau habitats. It was found in the greatest number

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[81] Information on the biology of this species has since become available in Ivantsoff et al (1988). *Biology and early development of eight fish species from the Alligator Rivers Region.* Technical memorandum 22, Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

of sites during the Late-wet season (mainly escarpment sites), and in the fewest sites in the Late-dry season (mainly escarpment streams).

Size composition

The lengths and weights of 579 specimens were determined. *Melanotaenia nigrans* was captured by seine nets (10 and 2 mm mesh) and dipnets (2 mm mesh). The latter caught more of the smaller specimens.

Length–weight relationship

The length–weight relationship was described by the following expression:

$$W = 1.40 \times 10^{-2} L^{2.80} \qquad r = 0.96 \text{ (weight in g, length in cm)}$$

Seasonal mean lengths, weights and condition factors are shown in table 47. From the 1978 Late-dry season the seasonal condition factor increased from its lowest point to reach a stable level (near unity) between the 1978–79 Early-wet and the Mid-wet seasons. By the Late-wet–Early-dry season, condition peaked, but fell by the Mid-dry season; condition in the 1979 Late-dry season was slightly higher than in the 1978 Late-dry season. As in the previous year, the condition improved in the 1979–80 Early-wet season, which may have been caused by spawning activity or greater food availability or both (terrestrial insects, which are a large part in the diet, may be washed into the water with the first Wet season flushes in escarpment perennial streams).

Table 47 Mean length, mean weight and condition factor of *M. nigrans*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	76	35.9	0.48	0.95
Early-wet (1978–79)	36	40.2	0.70	1.01
Mid-wet	15	31.1	0.34	1.00
Late-wet–Early-dry (1979)	68	34.6	0.50	1.11
Mid-dry	57	38.1	0.58	0.98
Late-dry	111	38.8	0.61	0.97
Early-wet (1979–80)	24	36.8	0.56	1.04
Overall	387	37.0	0.55	1.00

Length-frequency distribution

The smallest specimen captured was 10 mm LCF; the largest was 68 mm LCF (fig 53). Specimens between 100 and 120 mm were occasionally observed in escarpment perennial streams in the Nourlangie Creek catchment. Roberts (1978) found *M. nigrans* ranging in length from 9.1 to 94.7 mm in the Fly River catchment, Papua New Guinea. Pollard (1974) states that this species reputedly grows to 120 mm.

The mean and modal lengths of the specimens captured were 37 and 40–41 mm LCF, respectively (there was a secondary mode at 36–37 mm). The LFM for males was 39 mm and for females 27 mm, indicating that more adults than juveniles were captured. Most specimens captured were between 16 and 49 mm LCF.

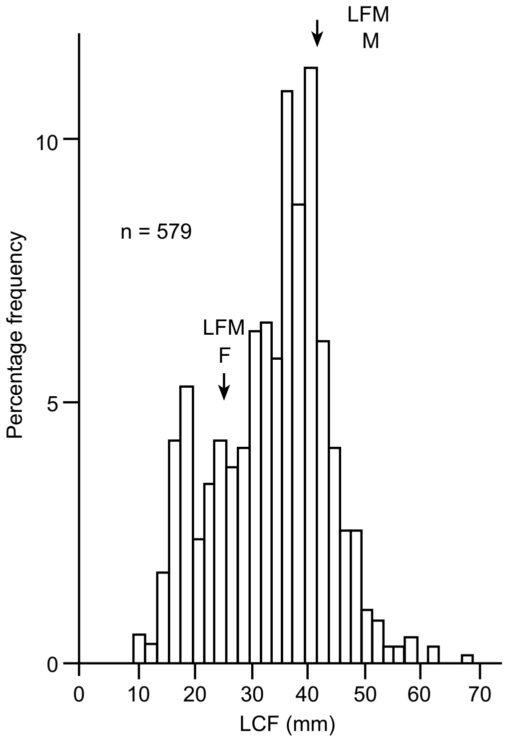

Figure 53 Length-frequency distribution of all *M. nigrans* captured

Seasonal changes in distribution

The smallest juveniles were caught in the 1979–80 Early-wet season, the Late-dry seasons and the Mid-dry season. In escarpment perennial streams the smallest juveniles were observed in the Early-wet seasons. The smallest specimens caught during the Late-wet–Early-dry season were much larger than the smallest specimens caught in other seasons (as was the case with *M. splendida inornata*). In escarpment perennial streams, the smallest specimen observed in the Mid-dry season was larger than the smallest observed in other seasons. The largest specimens were captured in the Late-dry seasons in escarpment perennial streams, and observed in the 1978–79 Early-wet season.

There appear to be differences in the timing of the presence of small juveniles and large adults in escarpment perennial streams and other habitats. They may be caused by differences in the most favourable spawning times, the dispersion times of juveniles and adults between escarpment populations, or both.

The size-range of specimens in the 1978 Late-dry season was wide, with small peaks for juvenile and intermediate-sized specimens (fig 54). By the 1978–79 Early-wet season mainly larger-sized specimens were caught; only a few juveniles were caught, though many were seen in escarpment perennial streams.

During the Mid-wet season the larger specimens disappeared from catches, to be replaced by intermediate-sized juveniles; the size-range of specimens observed in escarpment perennial streams was the same as the range of those captured. By the Late-wet–Early-dry season the juvenile intermediate peak had progressed approximately 10 mm; no other peaks had appeared in the distribution though some larger specimens were observed in escarpment perennial streams.

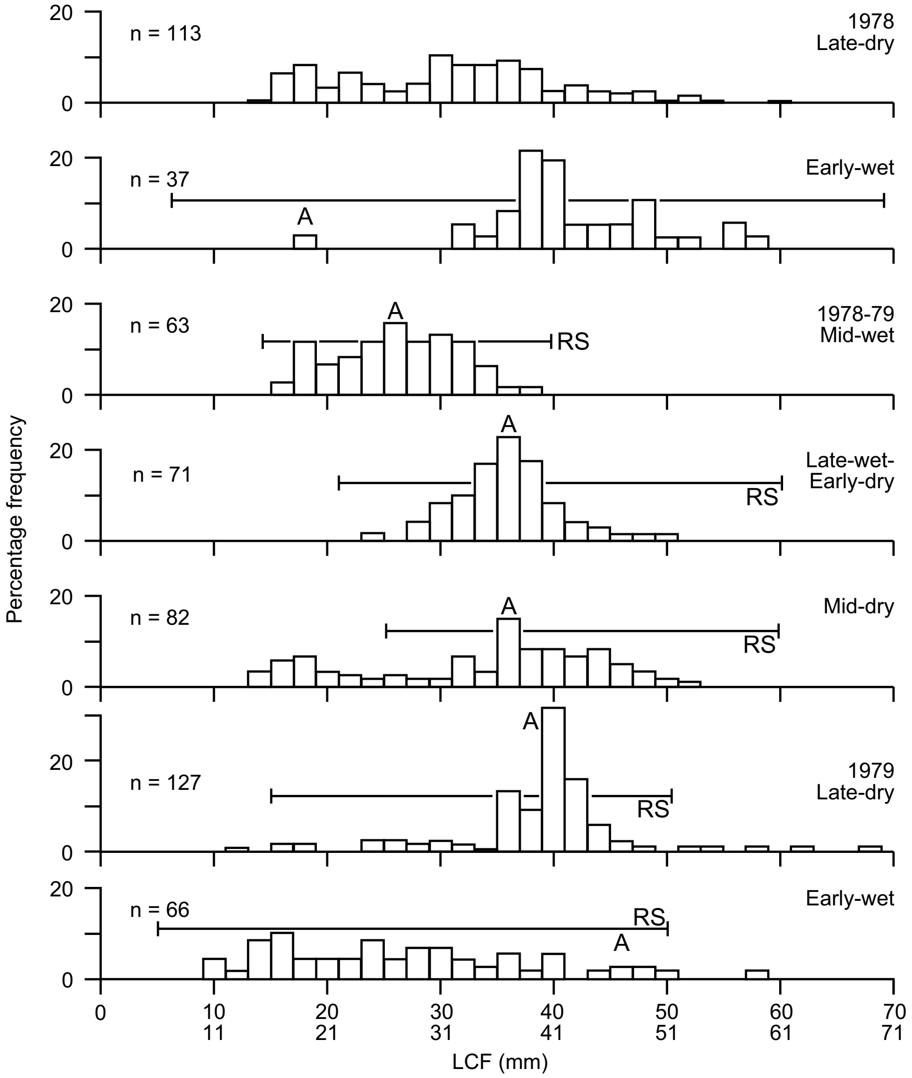

Figure 54 Seasonal length-frequency distribution of all *M. nigrans* captured during the study period. Size range at Radon Springs (RS) is shown.

The length-frequency distribution in the Mid-dry season had a smaller peak of intermediate-sized juveniles, with an additional juvenile peak. By the 1979 Late-dry season the former peak had increased to near the length at first maturity for males; there was a wide size range of specimens in this sample, with the most notable feature being the reappearance of large adults. During the 1979–80 Early-wet season the major peak of the previous season had almost disappeared, along with the larger specimens; additionally, and in contrast to the same season in 1978–79, there were more juveniles and intermediate-sized specimens.

Juveniles therefore appeared to recruit in all seasons except perhaps the Late-wet–Early-dry; the most intense recruitment was in the Mid-wet and Mid-dry seasons. Recruitment appeared to be stronger in the 1978 Late-dry than the 1979 Late-dry season, and in the 1979–80 Early-wet than the 1978–79 Early-wet season (many juveniles were observed, but not captured, in this season). Mortality of large specimens appeared to be highest between the Late-dry and Mid-wet seasons.

Growth rate

No published information on the growth of *M. nigrans* was found. Estimation of growth rate from seasonal length-frequency distributions was difficult due to the frequency with which juveniles were recruited to the populations and the range of habitats sampled. However, modal progressions were apparent for juveniles from the 1978–79 Early-wet season (A on fig 54) (modal length 18–19 mm LCF) until the 1979–80 Early-wet season (median length 48 mm LCF). *Melanotaenia splendida inornata* apparently grew the same amount in the same period of time. Growth appeared to be fastest in the Early-wet to Mid-wet season, by which time the juveniles measured about 33 mm LCF. This indicates that juvenile females present in the 1978–79 Early-wet season could attain the LFM by the Mid-wet season and juvenile males by the following Dry season (assuming the apparent growth rates are not complicated by sex differences in growth).[82]

Habitat differences in distribution

Length-frequency distributions showing the habitat preferences of *M. nigrans* captured in regular sampling sites in the Magela catchment are given in fig 55.

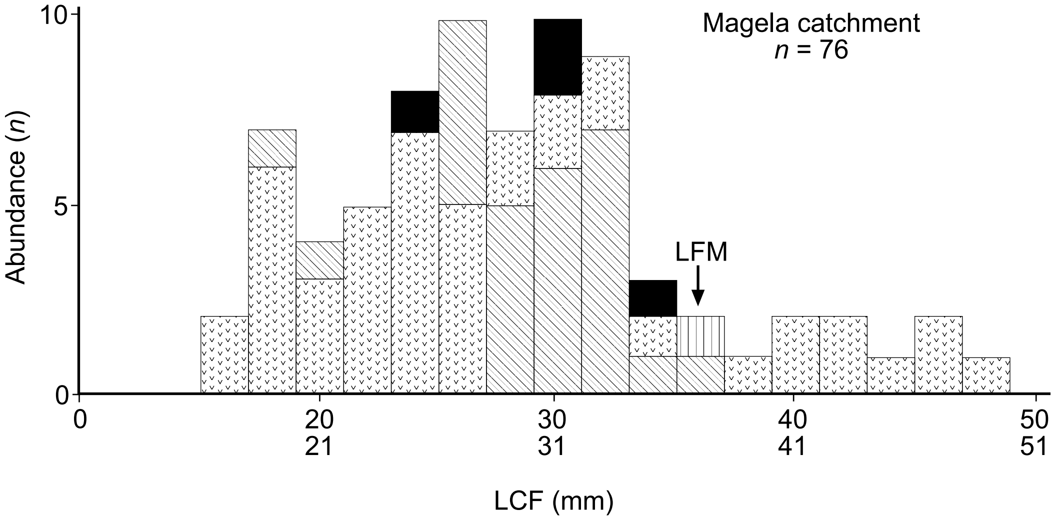

Figure 55 Length-frequency distributions and habitat preferences of *M. nigrans* captured at regular sampling sites in the Magela catchment (see appendix 5 for key to the habitats)

It was difficult to delineate juvenile–adult boundaries on length-frequency distributions for combined sexes, as the LFM for males and females was very different; the male and female components of these distributions should therefore be analysed separately in any future studies.

The habitat preferences of this species will be presented in terms of small specimens (less than the mean length [36–37 mm LCF] of all specimens examined) and large specimens (greater than the mean length). Specimens under 25 mm LCF are considered to be juveniles. Length-frequency distributions for specimens caught in escarpment perennial streams were not available for this report; however, many sizes of *M. nigrans* were abundant in such streams.

The smallest specimens were captured in lowland sandy creekbeds upstream of RUPA towards the escarpment zone; most of the small specimens were caught in these pools, though many of the larger ones were found in escarpment mainchannel waterbodies. A few specimens were caught in floodplain billabongs, which are fed in the Mid-wet season by waters from the escarpment seasonal streams in which *M. nigrans* was abundant.

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[82] Under laboratory conditions with a water temperature of 26°C, Ivantsoff et al (1988) indicated that *M. nigrans* can attain a total length of 21 mm in 52 days.

Small specimens were also common in the upper reaches of first-order streams in RUPA during the Mid-wet and Late-wet–Early-dry seasons; specimens are known to occur in the catchment of Retention Pond No. 1, and Pollard (1974) found this species in costeans in RUPA during 1972.

Most of the larger specimens were found in lowland sandy creekbeds upstream of RUPA towards the escarpment zone. A few of the smaller large specimens were found in escarpment mainchannel waterbodies and backflow billabongs.

Large specimens were captured in escarpment mainchannel waterbodies and lowland sandy creekbed habitats in the Nourlangie Creek system.

Environmental associations

Rank numbers for *M. nigrans* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

This species was captured at water temperatures between 23° and 35°C (mean = 28°C) on the surface, and between 23° and 32°C (mean = 27.5°C) on the bottom.[83] Both of these means were placed in the lower quarter (see fig 170). These ranges are slightly wider than the temperature tolerance range suggested by Allen (1978a) for melanotaeniid fishes (25–33°C). The highest surface water temperature apparently tolerated by *M. nigrans* is lower than the upper tolerance limit of 34.4°C found by Beumer (1979b) for *M. splendida splendida*. Most of the specimens of *M. nigrans* captured during this study were found in the cooler waters of the escarpment.

Dissolved oxygen

Dissolved oxygen concentration in waters in which *M. nigrans* was found ranged from 3.7 to 7.2 mg/L (mean = 5.7) on the surface, and from 5.0 to 6.8 mg/L (mean = 5.6) on the bottom. These means were ranked in the lower-middle and upper quarters respectively (see fig 171). The high bottom-water DO values are characteristic of the cool, flowing waters of the escarpment zone, in which *M. nigrans* was typically captured.

Visibility

Secchi depths for waters in which *M. nigrans* was caught ranged from 30 to 200 cm (mean = 136 cm) (see fig 172). This mean was ranked in the upper quarter, as would be expected for the clear waters and rocky or sandy substrates of the escarpment streams in which this species was mainly found.

pH

Surface and bottom water pH at sites where *M. nigrans* was found ranged from 3.9 to 6.7 (mean = 5.1) and from 3.9 to 6.2 (mean = 5.3) respectively (see fig 173). Both means were ranked at the base of the lower quarter. *M. nigrans* appears to be able to tolerate more acidic conditions than those found by Allen (1978b) for melanotaeniid fishes in general (6.5–6.9).[84]

Conductivity

Surface-water conductivities ranged from 4 to 180 µS/cm, and bottom-water conductivities from 4 to 12 µS/cm. Such low values indicate a preference for flowing waters with low levels

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[83] Crowley and Ivantsoff (1982) indicated that at temperatures greater than 26°C all observed pairs of *M. nigrans* spawned each day under laboratory conditions.

[84] Ivantsoff et al (1988) indicated that *M. nigrans* thrived and bred well under laboratory conditions in waters of pH 7.6–7.8.

of dissolved solids. *Melanotaenia nigrans* and most other melanotaeniids generally live in freshwater (Pollard 1974). However, Beumer (1979a) found that the upper extreme of salinity tolerance of the closely related *M. splendida splendida* was 18 ppt.

Habitat–structural variables

Substrate

Melanotaenia nigrans was most frequently found over sandy substrates (upper-middle quarter), followed by boulders (upper quarter), then rocks, leaves and mud (see fig 174). Sandy and rocky bottoms are characteristic of the clear waters of the escarpment zone.

Hydrophytes

Hydrophyte abundance in waters in which *M. nigrans* was captured was low (vegetation-occurrence index 23.4%).[85] At the few sites where there were hydrophytes, submergent and emergent vegetation were almost equally dominant (34 and 32%).

Reproduction

From a total of 579 fish captured, 211 were examined for reproductive condition: 72 males (length range 24–66 mm LCF), 81 females (23–50 mm LCF), and 58 that were sexually indistinguishable.[86]

Length at first maturity

The LFM for females was 27 mm LCF (4 mm greater than the length at which ovaries could be identified). Except for one small (24 mm LCF) ripe male, no others under 38 mm LCF were found (fig 56); the LFM was 39 mm LCF for the males. In other melanotaeniid species males and females have been recorded as maturing at almost the same lengths (Beumer 1979b; see also the section on *M. splendida inornata*). The large apparent difference found in this study may be an artefact of the very small number of maturing male *M. nigrans* captured.

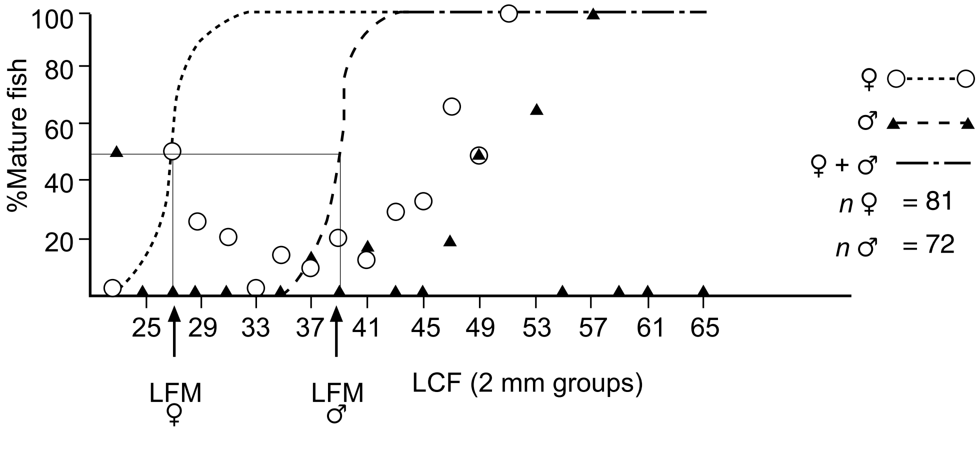

Figure 56 Estimated length at first maturity (LFM) of male and female *M. nigrans*

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[85] In contrast to this finding, Herbert and Peeters (1995) indicated that *M. nigrans* in streams of Cape York Peninsula prefer areas with dense aquatic vegetation.

[86] Ivantsoff et al (1988) indicated that *M. nigrans* is sexually dimorphic and dichromatic. In males, the spines of the first dorsal are usually extended and may lie well past the origin of the second dorsal when not erect. The posterior rays of the second dorsal and anal fins are extended caudally and may extend past the origin of the caudal fin. In females, the first dorsal spines are short, not reaching the origin of the second dorsal. The posterior rays of the anal and second dorsal fin are not extended. The spines and outer rays of the ventral fins of some males are also extended and may reach past the vent and the origin of the anal fin.

Sex ratio

A 1:1 ratio was found for all seasons over the total sample; however, the proportion of males was significantly less in nearly all seasons when only adult fish were analysed (table 48). This was due to the small number of maturing males caught or identified (either because of difficulty in assessing the true maturation stage of the testes or possibly because of some behavioural trait of the maturing male fish).

Table 48 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *M. nigrans* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles + adults	F	*n*	3	20	5	9	10	22	12
	M	*n*	7	16	6	4	13	18	8
		χ^2	1.6	0.4	0.1	1.9	0.4	0.4	0.8
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	3	20	5	8	10	19	12
	M	*n*	3	7	0	0	9	7	3
		χ^2	0.0	6.25	5.0	8.0	0.05	5.53	5.4
		P	n.s.	*	*	*	n.s.	*	*
GSI									
Adults only	F	mean	2.1	4.3	0.3	0.6	2.6	1.0	2.7
		s.d.	0.8	1.7	0.1	0.9	1.9	0.9	0.8
	M	mean	0.2	0.9	–	–	0.4	0.2	0.3
		s.d.	0.1	0.3	–	–	0.2	0.2	0.3
	F+M	mean	1.2	3.4	–	–	1.5	0.8	2.2
		s.d.	1.2	2.1	–	–	1.8	0.8	1.2
GMSI									
Adults only	F	mean	4.0	3.4	1.0	1.4	3.3	2.5	3.4
		s.d.	1.7	1.1	0.0	0.7	1.1	1.2	0.5
	M	mean	2.0	4.0	–	–	2.2	2.0	2.0
		s.d.	0.0	0.8	–	–	0.8	1.0	1.0
	F+M	mean	3.0	3.5	–	–	2.8	2.4	3.1
		s.d	1.5	1.1	–	–	1.1	1.2	0.8

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; s.d. = standard deviation.

Breeding season

Very few of the fish captured were mature, ripe or spent (table 49): two ripe fish were caught in the 1978 Late-dry season, three mature or spent fish in the 1978–79 Early-wet season, and one spent fish in the 1979 Late-dry season. Small (less than 20 mm) juvenile fish were caught in all seasons except the 1979 Late-wet–Early-dry season, with the smallest fish being caught in the 1979–80 Early-wet season.

The mean GSI and GMSI were relatively high for most of the year (fig 57) with a trough in the 1978–79 Mid-wet and Late-wet–Early-dry seasons. The highest peak in gonad development occurred in the 1978–79 Early-wet season, with smaller peaks in the 1979 Mid-dry and 1979–80 Early-wet seasons. Without further information, the breeding season of *M. nigrans* cannot be defined.

Table 49 Possible sites of spawning of *M. nigrans* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	–	–	–	–	–	–	2
Seasonal feeder stream	–	2	–	–	1	–	9
Perennial stream	–	–	1	1	–	–	71
Lowlands							
Sandy creekbed habitats	–	–	–	–	–	–	11

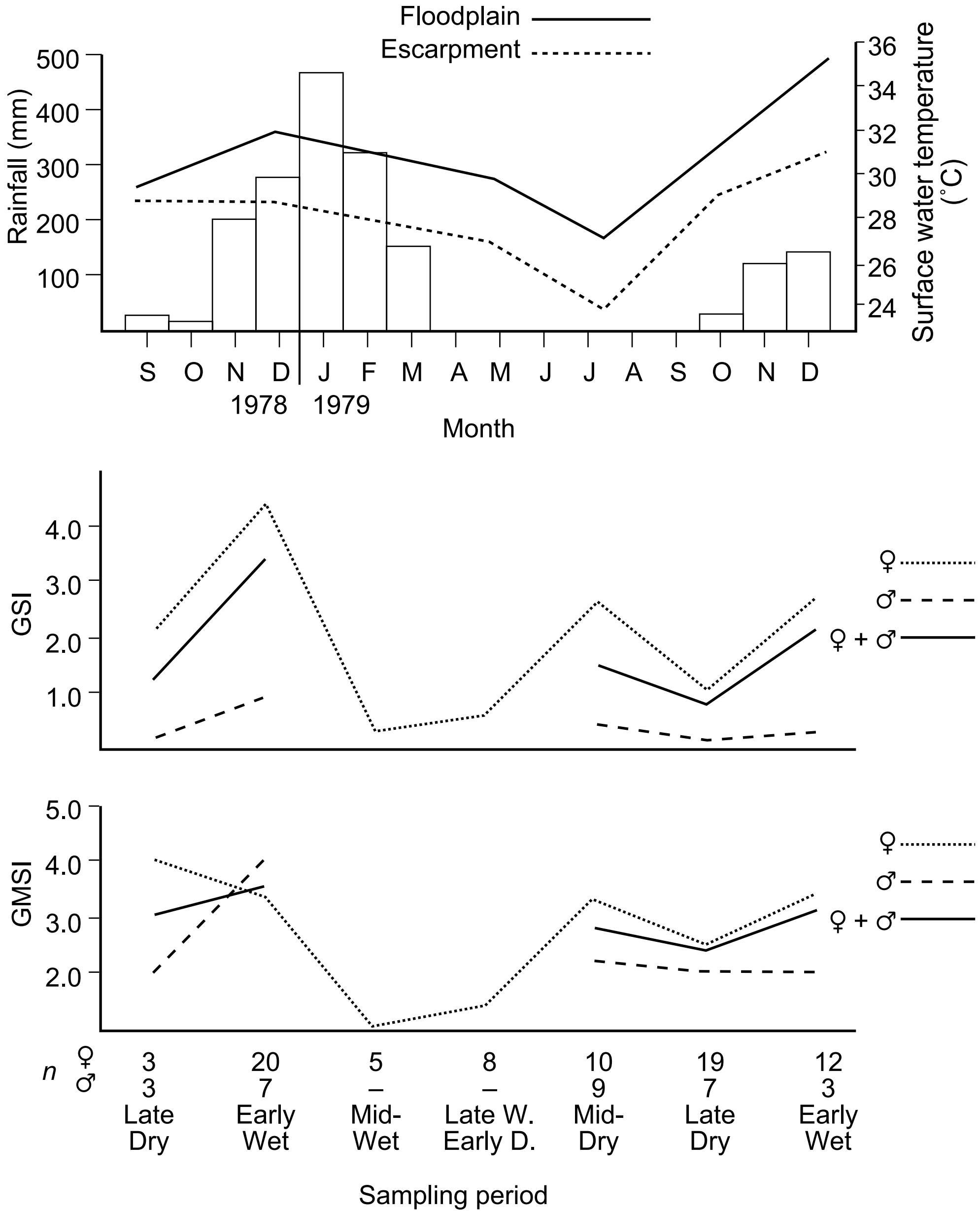

Figure 57 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *M. nigrans*

Site of spawning

The spawning sites cannot be accurately determined, as juvenile fish were only collected with seldom-used methods (2 mm mesh seine net, dipnet and poisoning). Small juveniles were observed in an escarpment perennial stream (Radon Springs) (table 49) in all sampling periods and especially in the Early-wet seasons. Mature and spent fish were found in a small escarpment seasonal stream off Hickey Creek during the 1978–79 Early-wet season. Breeding thus possibly occurs in small escarpment streams with deep pools.

Fecundity

In the ten ovaries of *M. nigrans* examined, the number of eggs ranged from 220 to 500 (mean = 344); egg diameters were not measured. These fish were not mature, so numbers only indicate developing eggs within the ovary, not how many might actually ripen during spawning.

Summary

Due to disparities in fishing methods between sites and habitats, it is difficult to define the reproductive cycle of *M. nigrans*. The LFM of males appeared to be unusually high compared with that of females, and significantly more adult female fish were identified than adult males. This suggests there was a sampling bias or gonad-staging error.[87]

Generally, *M. nigrans* appears to breed in small escarpment streams that contain deep shaded pools with roots and submerged vegetation around the edges. Eggs may be attached by threads to such vegetation. Spawning is possibly continuous, with a few eggs laid at a time, or opportunistic whenever conditions are favourable. A peak of reproductive activity occurred during the 1978–79 Early-wet season.[88]

Feeding habits

Overall diet

The stomach contents of 206 specimens were examined; 200 stomachs contained food. A summary of the diet is given in fig 58; the components are listed in table 50.

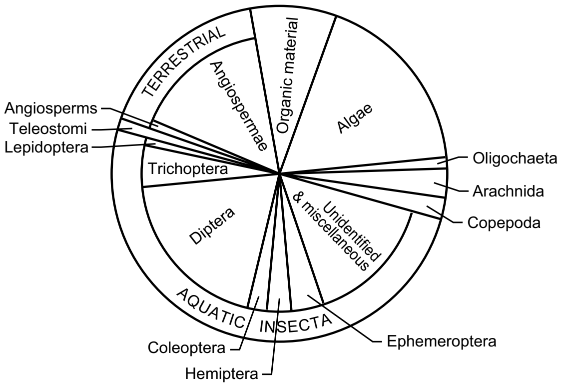

Figure 58 The main components of the diet of *M. nigrans*

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[87] Ivantsoff et al (1988) indicated that under stable laboratory conditions, large females (> 50 mm TL) produced more than 50 eggs per day at the peak of the spawning season. Smaller females (28–35 mm TL) which were only just sexually mature shed fewer eggs, 20–30 per day and spawning did not occur daily.

[88] Ivantsoff et al (1988) has subsequently described mating behaviour, egg and embryonic development, and larval development.

Table 50 Dietary composition of *M. nigrans*

	Habitat						Season								
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ep	Ls	Fb	Ep	Ls	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants															
Algae															17.3
Miscellaneous	–	3.1	6.0	–	–	4.4	5.3	5.6	–	–	9.4	37.6	–	9.2	
Desmidaceae															
Closterium	–	–	–	–	–	–	5.3	–	–	–	–	–	–	0.5	
Dinophyceae	–	–	–	–	–	–	–	–	–	–	–	1.9	–	–	
Conjugatophyta															
Mougeotia	9.6	0.2	4.2	6.3	–	23.1	35.8	10.0	8.3	8.3	–	–	0.5	7.6	
Aquatic animals															
Oligochaeta	–	4.0	–	–	–	–	–	–	3.5	–	–	–	–	0.5	0.5
Arachnida															3.0
Miscellaneous	–	–	–	20.0	–	–	–	–	–	3.0	–	–	–	0.4	
Hydracarina	–	0.8	9.0	21.3	–	2.7	1.1	2.8	2.6	3.2	5.6	1.9	0.5	2.6	
Microcrustacea															2.5
Cladocera															
Miscellaneous	–	–	1.0	–	–	–	–	–	0.9	–	–	–	–	0.1	
Diaphanosoma	–	0.9	–	–	–	–	–	–	–	–	–	–	3.0	0.3	
Copepoda															
Miscellaneous	–	3.7	–	–	–	–	–	–	–	–	2.6	4.3	–	1.3	
Harpacticoida	–	–	–	–	–	–	–	–	5.2	–	–	–	–	0.8	
Insecta															49.3
Fragmented	15.8	29.0	19.2	25.0	1.5	1.1	21.1	–	10.0	8.5	32.2	7.4	40.0	14.5	
Ephemeroptera															
Baetidae	8.3	0.8	5.2	–	–	–	–	–	7.9	–	–	–	2.8	1.4	
Atalophlebia	–	3.0	–	–	2.5	6.7	–	8.3	–	1.9	–	–	10.0	2.8	
Hemiptera															
Gerridae	8.3	1.5	4.0	–	–	–	5.3	–	3.5	–	–	2.4	–	1.5	
Corixidae	–	–	0.4	–	–	–	–	–	3.5	–	0.4	–	–	0.6	
Coleoptera															
Miscellaneous	–	1.5	–	–	–	6.2	–	7.8	–	–	–	3.3	–	2.1	
Helminthidae (larvae)	–	0.1	–	–	–	–	–	–	–	–	–	–	0.3	+	
Diptera															
Chironomidae (larvae)	8.3	10.7	2.8	–	10.0	5.3	18.4	8.6	3.8	2.4	6.5	2.9	6.5	7.0	

Table 50 continued

	Habitat						Season								
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ep	Ls	Fb	Ep	Es	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Chironomidae (pupae)	8.3	6.3	7.8	–	62.5	2.2	–	2.8	10.2	46.2	4.1	7.4	–	10.3	
Ceratopogonidae	1.7	0.7	0.4	–	–	–	–	–	0.7	–	0.4	–	2.3	0.4	
Simuliidae	–	5.2	–	–	–	–	–	–	–	–	11.7	–	1.5	1.7	
Tabanidae	8.3	0.9	–	–	–	–	–	–	–	–	2.2	2.4	–	0.8	
Trichoptera															
Leptoceridae	–	11.6	6.8	–	5.0	–	–	–	3.5	3.7	13.5	10.0	3.3	5.3	
Lepidoptera															
Pyralidae	–	2.5	–	–	–	–	–	–	–	–	2.6	–	5.0	0.9	
Teleostomi															0.5
M. nigrans	–	1.5	–	–	–	–	–	–	–	–	3.7	–	–	0.5	
Terrestrial plants															
Angiospermae															0.9
Fragmented	15.0	–	–	–	–	–	–	–	6.2	–	–	–	–	0.9	
Terrestrial animals															
Insecta															15.7
Fragmented	–	0.6	4.0	–	–	9.8	–	12.2	3.5	–	–	–	2.0	2.9	
Diptera															
Miscellaneous (adults)	–	3.3	12.0	–	–	–	–	–	10.3	–	–	2.4	6.0	2.6	
Culicidae (adults)	–	3.0	–	–	–	–	–	–	–	–	–	4.8	–	1.0	
Hymenoptera															
Formicidae															
Miscellaneous	–	4.4	13.2	–	–	18.0	–	22.5	10.0	–	4.6	0.7	12.0	7.7	
Oecophylla	7.9	–	–	–	5.0	–	–	–	3.3	3.7	–	2.4	–	1.5	
Scolopendromorpha	–	1.3	–	–	–	–	–	–	–	–	–	–	4.5	0.5	0.5
Parasites															
Nematoda	–	0.2	–	5.0	–	–	–	–	–	0.7	0.4	–	–	0.2	0.2
Detrital material	–	–	–	–	3.5	–	–	–	–	2.6	–	–	–	0.4	0.4
Inorganic material	–	0.1	–	–	–	–	–	–	–	–	0.2	0.5	–	0.1	0.1
Organic material	8.3	4.5	–	22.5	10.0	18.9	7.9	19.4	3.5	10.7	–	7.1	–	9.7	7.7
Number of empty fish	–	3	2	–	–	1	2	1	2	–	1	1	1	6	6
Number of fish with food	12	67	25	4	20	45	19	36	29	27	27	42	20	200	200

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ep = perennial stream; Es = escarpment seasonal stream; Ls = lowland sandy creek bed; Fb = floodplain billabongs

The main food items were aquatic insects (49%), algae (17%) and terrestrial insects (16%). The aquatic insects were mainly chironomid pupae and larvae, and leptocerid and *Atalophlebia* larvae; the identifiable algae mainly green filamentous species; and the terrestrial insects mainly ants and winged dipterans. Aquatic arachnids (3%), microcrustaceans (3%) and traces of oligochaetes, teleosts, terrestrial plant material, scolopendromorphs, detritus and inorganic material were also found in the stomachs. There were also appreciable quantities of unidentified organic material (8%). *M. nigrans* can therefore be classified as a meiophagous omnivore feeding opportunistically across substrates and in surface waters, with possibly less emphasis on mid-water areas.

Adults (Pollard 1974) sampled had eaten mainly small insects and insect larvae from the water's surface; no herbivorous component was recorded. He conjectured that juveniles ate mainly zooplankton. *M. fluviatilis* is reported to be essentially a carnivore, feeding on insects and small crustaceans, but also eating much algae (Munro [in McDowall 1980]). *M. nigrans* found in pools and riffles that drain into the Magela floodplain were primarily opportunistic surface feeders, exploiting a range of small food items such as winged dipterans and formicids, non-aquatic insects and dipteran larvae (Sanderson 1979).

Seasonal changes

In sampling periods 1–7, respectively, 21 (9% empty), 37 (3% empty), 31 (6% empty), 27 (0% empty), 28 (3% empty), 42 (0% empty) and 20 (0% empty) stomachs of *M. nigrans* were examined (all habitats combined). The highest proportion of specimens with empty stomachs was found in the 1978 Late-dry and 1978–79 Mid-wet season.

During the 1978 Late-dry season, the algal and aquatic insect components of the diet were large. By the 1978–79 Early-wet season they were smaller, and terrestrial insects (particularly ants) became important in the diet. In the Mid-wet season, the fish ate a variety of items; however, aquatic and terrestrial insects appeared to be the most important. Aquatic insects (mainly chironomid larvae) became more important in the Late-wet–Early-dry season and remained so until the 1979 Late-dry when their contribution decreased. Both the aquatic and terrestrial insect components increased during the 1979–80 Early-wet season. Algae peaked in importance again during the 1979 Late-dry season but decreased, as in the previous year, in the Early-wet season.

Habitat differences

Magela catchment

A total of 113 stomachs of *M. nigrans* were examined (all seasons combined): 12 (0% empty) from escarpment mainchannel waterbodies, 70 (40% empty) from escarpment perennial streams, 27 (7% empty) from lowland sandy creekbeds, and 4 (0% empty) from floodplain billabongs. The sample from lowland sandy creekbeds had the highest proportion of specimens with empty stomachs.

The diet in the escarpment mainchannel waterbodies was based mainly on aquatic insects, with small amounts of terrestrial insects and plant material and algae. In the perennial streams, algae and terrestrial plant material were less important, while aquatic insects and, to a lesser extent, oligochaetes and microcrustaceans, were more important.

The diet in the lowland sandy creekbeds had much larger algal and terrestrial insect components, with the addition of *Hydracarina*. The few specimens examined from the floodplains were feeding mainly on aquatic arachnids (mainly *Hydracarina*) and aquatic insects, and a small amount of algae.

Nourlangie catchment

A total of 66 stomachs of *M. nigrans* were examined (all seasons combined) from escarpment streams: 20 from perennial and 46 from seasonal. Only one specimen, from a seasonal stream, had no food in its stomach.

Aquatic insects (mainly chironomid pupae) were most important in the diet in the escarpment perennial streams, as was the case in the equivalent Magela Creek habitat; green tree ants (*Oecophylla*) also appeared in the diet. In the seasonal escarpment stream, large quantities of algae and terrestrial insects (ants) and, to a much lesser extent, aquatic insects were eaten.

Fullness

A summary of mean fullness indices of *M. nigrans* for different sampling periods and habitat types is shown in table 51. These data are presented on the assumption that feeding times do not vary with habitat or season.

Seasonal changes

The mean seasonal fullness index (all habitats combined) peaked in the 1978–79 Early-wet season and then fell during the Mid-wet and Late-wet–Early-dry seasons. It rose to another high in the 1979 Mid-dry and Late-dry seasons and fell again during the 1979–80 Early-wet season.

Table 51 Mean fullness indices of *M. nigrans* in different sampling periods and habitats

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	n/s	n/s	3.1 (10)	n/s	n/s	3.5 (2)	n/s	3.2 (12)
Lowland sandy creekbed	n/s	n/s	2.3 (18)	0 (1)	3.8 (8)	n/s	n/s	2.6 (27)
Downstream of RUPA:								
Lowland shallow backflow billabong	n/s	n/s	n/s	0 (1)	n/s	n/s	n/s	0 (1)
Floodplain billabong	n/s	n/s	n/s	3.3 (4)	n/s	n/s	n/s	3.3 (4)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	n/s	n/s	3.0 (3)	n/s	n/s	n/s	n/s	3.0 (3)
Lowland sandy creekbed	0 (1)	n/s	n/s	0 (1)	n/s	n/s	n/s	0 (2)
Seasonal mean (all sites)	2.5	3.5	2.7	2.4	3.5	3.5	2.6	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

Specimens from upstream of RUPA in the escarpment mainchannel waterbodies had higher mean fullness indices than those in lowland sandy creekbeds. The mean fullness indices for specimens captured in escarpment perennial streams (where most specimens were captured) were not available when this report was being prepared.

Downstream of RUPA the single specimen captured from backflow billabongs had not been feeding. The few captured on the floodplain had high fullness indices.

The few specimens captured in the Nourlangie catchment had higher indices in the escarpment mainchannel waterbody. The mean fullness indices for specimens captured in escarpment perennial streams (where most specimens were captured) were not available when this report was being prepared.

Summary

The habitats (not including escarpment perennial streams) and periods of greatest feeding activity were:

Magela catchment

- lowland sandy creekbeds (upstream of RUPA); 1979 Mid-dry season
- escarpment mainchannel waterbody; 1979 Late-dry season

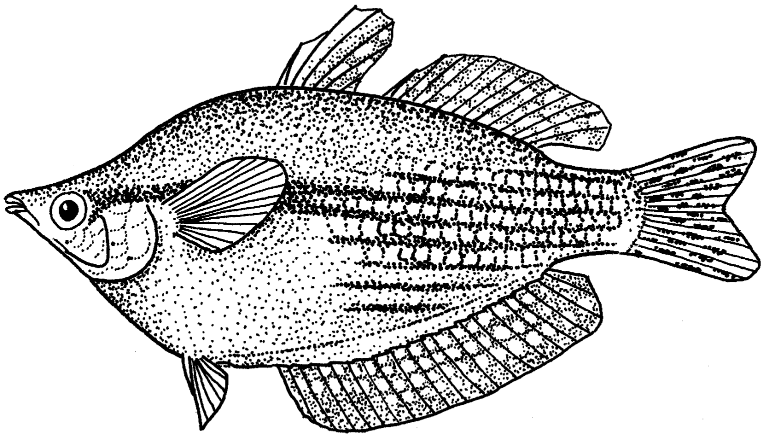
Nourlangie catchment

- escarpment mainchannel waterbody; 1978–79 Mid-wet season

Family MELANOTAENIIDAE

3.14 *Melanotaenia splendida inornata* (Castelnau)

Melanotaenia splendida inornata is commonly known as the chequered rainbow-fish. In Australia it is found in the river systems of the Northern Territory and Queensland that flow into the Arafura Sea and Gulf of Carpentaria (see map 3). The limits of its distribution appear to be the Mary River just east of Darwin, and the Jardine River near the tip of Cape York Peninsula.[89] Pollard (1974) found that large specimens were common in waterbodies of the Magela Creek system, and that juveniles occurred over shallow sandy areas together with *M. nigrans*; in the South Alligator River system, adults were observed in Sawcut Creek; and some large specimens were observed in Cooper Creek. Miller (cited in Taylor 1964) reported this species was abundant in billabongs and creeks in the Oenpelli area. A closely related subspecies is also known from southern Papua New Guinea.



Melanotaenia splendida inornata

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was moderately abundant in almost all sites and habitats examined. It was found in the fewest sites (18) in the 1978 Late-dry season (moderately abundant in lowland sandy creekbed habitats and many lowland backflow billabongs, and common in corridor and floodplain billabongs); it was found in the greatest number of sites (25) during the Mid-wet season.

Size composition

The lengths and weights of 3636 specimens were determined. Most specimens were captured by 10 mm seine net, with only the larger specimens being captured by gillnet (26 mm mesh). Mesh selectivity influenced the minimum size of specimens captured and may also have been responsible for small number of intermediate to large-sized adults captured. Very small specimens were frequently captured when the seine meshes were clogged by hydrophytes and filamentous algae.

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[89] Surveys in Cape York Peninsula by Herbert et al (1995) indicated that this subspecies extends down the east coast of the Cape to the Lockhart River. Accordingly, *M. splendida inornata* are now known to occur in the north-east coastal division.

Length–weight relationship

The length–weight relationship was described by the expression:

$$W = 1.10 \times 10^{-2} L^{3.12} \qquad r = 0.99 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 52. The seasonal condition factor decreased slightly between the 1978 Late-dry season and the 1978–79 Early-wet season, possibly due to spawning activity. It then increased to peak in the Mid-wet season and gradually declined until the 1979 Late-dry season, after which it declined more sharply; condition in the 1979–80 Early-wet season was much lower than in the same season the previous year.

Environmental conditions (including food availability) in the Wet season appeared to be more favourable to good body condition than in the Dry seasons, and the 1978 Dry season appeared to be more favourable than the 1979 Dry season.[90]

Table 52 Mean length, mean weight and condition factor of *M. splendida inornata*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	364	37.5	0.69	1.00
Early-wet (1978–79)	118	38.0	0.70	0.98
Mid-wet	826	43.4	1.10	1.02
Late-wet–Early-dry (1979)	953	45.4	1.24	1.00
Mid-dry	525	43.8	1.10	0.99
Late-dry	149	43.9	1.10	0.98
Early-wet (1979–80)	117	45.2	1.14	0.94
Overall	3052	43.2	1.06	1.00

Length-frequency distribution

The smallest specimen captured in the study was 12 mm LCF; the largest was 98 mm LCF (fig 59). Haines (1979) found that this species (*Nematocentris*, syn. *Melanotaenia*) ranged in length between 60 and 99 mm in the Purari River catchment. Pollard (1974) noted that *M. splendida inornata* reputedly grows to 120 mm LCF.

The mean and modal lengths for all specimens captured were 43.2 and 40–41 mm LCF respectively. The LFM for males was 33 mm LCF and for females 28 mm LCF, indicating that more adults than juveniles were captured. The slight negative skew apparent in the distribution was possibly caused by the reduced survival of larger specimens, and mesh selectivity resulting in no fish less than 10 mm LCF being captured. Most specimens were between 20 and 60 mm LCF.

Seasonal changes in distribution

The smallest juveniles were caught (in order of abundance) in the 1978–79 Early-wet, 1979–80 Early-wet, Mid-wet and Mid-dry seasons. The smallest specimens captured during the Late-wet–Early-dry season were much larger than the smallest specimens captured in other seasons. The largest specimen was caught (in order of abundance) in the Late-wet–Early-dry, Mid-dry, Mid-wet and 1979 Late-dry seasons. The largest specimens captured during the Early-wet seasons were much smaller than the largest specimens captured in other seasons.

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[90] Milton and Arthington (1984) indicated that body condition of *M. splendida fluviatilis* from south-eastern Queensland varied between seasons, peaking in May (both sexes) and lowest in April and August.

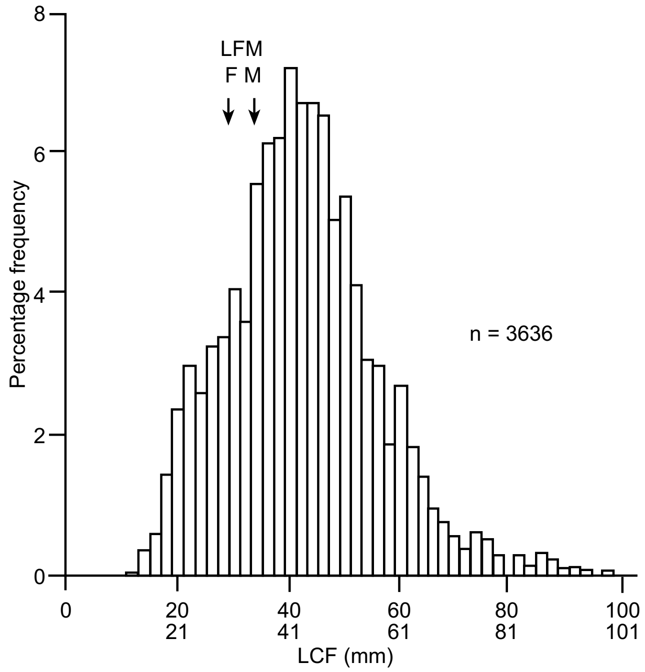

Figure 59 Length-frequency distribution of all *M. splendida inornata* captured

In the 1978 Late-dry season, the catch mainly consisted of larger juveniles and small adults, with a few larger adults (fig 60). By the 1978–79 Early-wet season there was a strong juvenile component and a slightly reduced small-adult peak; the larger adults had disappeared from the samples.

During the Mid-wet season the juvenile peak diminished considerably, with a corresponding increase in the small-adult peak; larger adults reappeared in the samples during this season. The form of the length-frequency distribution in the Late-wet–Early-dry season was similar to that recorded in the Mid-wet season with a slight overall progression to larger-sized specimens.

Another juvenile peak appeared during the Mid-dry season. The form of this distribution persisted into the 1979 Late-dry season with slight progressions and merging of the juvenile peak into the small-adult peak; the large adults comprised a smaller percentage of the samples, but had not diminished in numbers as they had in the equivalent 1978 season. By the 1979–80 Early-wet season the small-adult (to intermediate-sized by now) peak was most pronounced and all large adults had disappeared as they had by the end of the 1978 Dry season. Small numbers of juveniles were present in the 1979–80 Early-wet season, but the peak was only a trace compared with the peak recorded in the same season in 1978–79.

Juveniles apparently recruited in all seasons except the Late-wet–Early-dry. Recruitment peaked during the 1978–79 Early-wet and 1979 Mid-dry seasons; it was less intense in the 1978–79 Early-wet season, possibly because main flows had not started by the time of sampling. Adult mortality appeared to be highest at the end of the Dry season.

Growth rate

No published information on the growth of *M. splendida inornata* was found.[91] Estimation of growth rate from seasonal length-frequency distributions was difficult due to the frequent

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[91] Data given by Milton and Arthington (1984) for *M. splendida fluviatilis* from south-eastern Queensland indicate the following standard lengths for ages 1, 2, 3 and 4 years: 33/37 mm (male/female), 47/53 mm, 60/64 mm and 72 mm (female only). Under laboratory conditions with a water temperature of 26°C, Ivantsoff et al (1988) indicated that *M. splendida inornata* can attain a total length of 20 mm in 86 days.

recruitment of juveniles and the range of habitats sampled. However, modal progressions were apparent for juveniles from the 1978–79 Early-wet season (modal length 22–23 mm LCF; A on fig 60) until the 1979–80 Early-wet season (modal length 50–51 mm LCF).

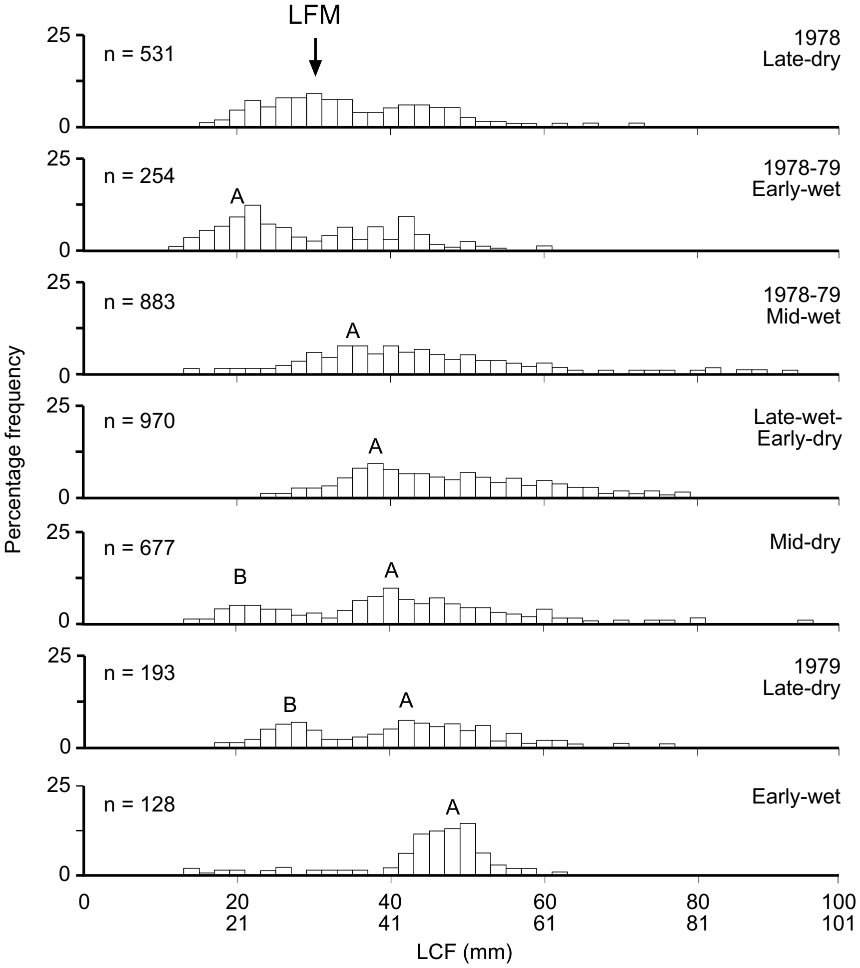

Figure 60 Seasonal length-frequency distribution of all *M. splendida inornata* captured

Over a year the mode had progressed about 30 mm LCF. Growth was fastest between the Early-wet and Mid-wet seasons when the LCF reached about 40 mm LCF, which indicates that juveniles present in the Early-wet season had reached the LFM by the Mid-wet season. The growth of juveniles present in the Mid-dry season (B on fig 60) was slower than that of those present in the Early-wet season.

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *M. splendida inornata* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are given in fig 61.

Magela catchment

The smallest juveniles (12–17 mm LCF) were found in lowland sandy creekbed habitats, lowland shallow backflow billabongs and corridor waterbodies. Overall, juveniles were found in a very wide variety of habitats, though most commonly in floodplain billabongs, sandy corridor waterbodies, sandy creekbed habitats and backflow billabongs of the lowlands, and in small numbers in escarpment mainchannel waterbodies and anabranch corridor waterbodies. No juveniles were observed in escarpment perennial streams.

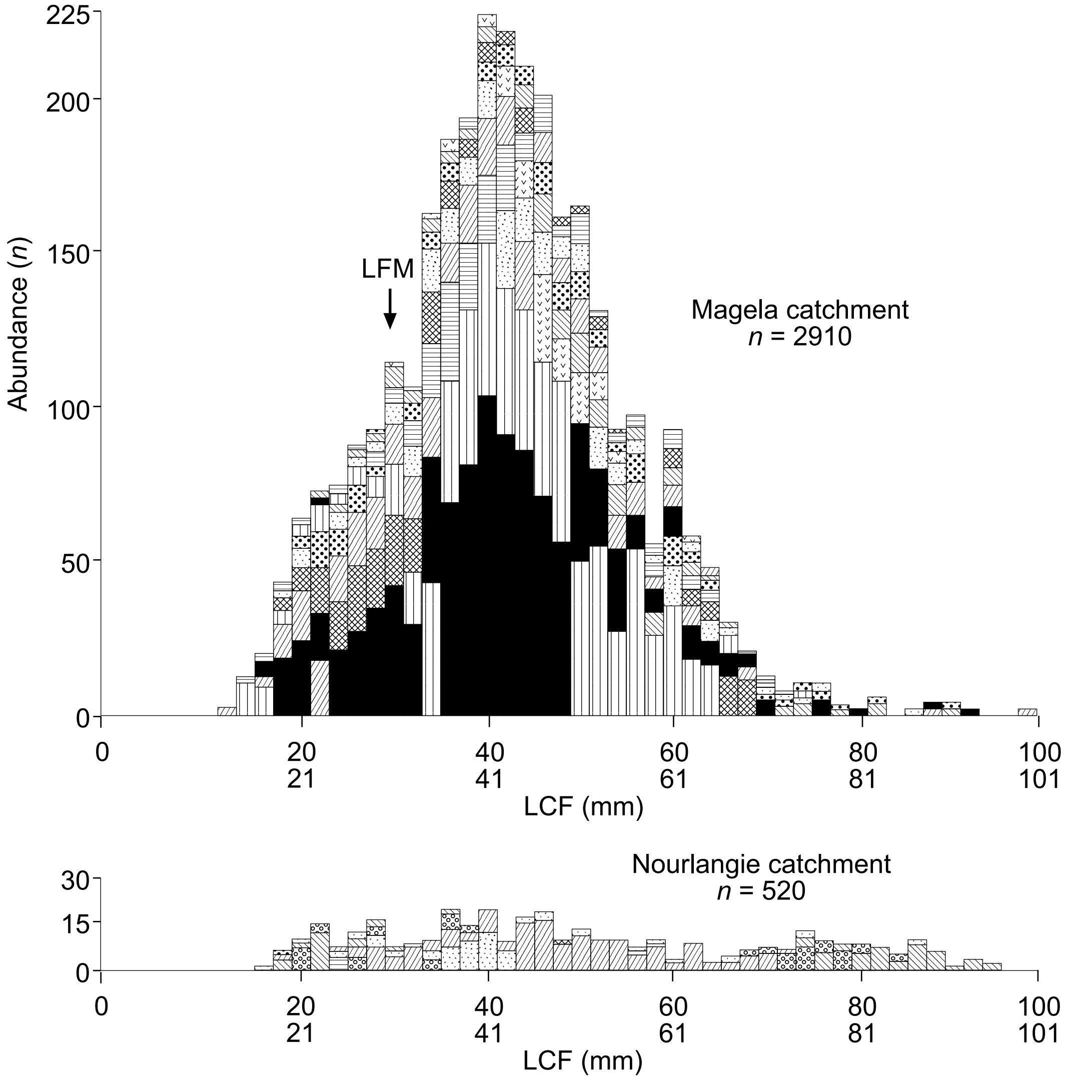

Figure 61 Length-frequency distributions and habitat preferences of *M. splendida inornata* captured at regular sampling sites (see appendix 5 for key to the habitats)

Smaller adults (30–70 mm LCF) were found most frequently in floodplain and lowland shallow backflow billabongs, and to a lesser extent in sandy creekbed habitats, lowland channel backflow billabongs, corridor anabranch billabongs and escarpment mainchannel billabongs. Small adults were noticeably less abundant in sandy corridor waterbodies than were large juveniles.

Larger adults were found in a wide variety of habitats, though mostly in escarpment mainchannel waterbodies, floodplain billabongs, lowland sandy creekbeds (in which the largest specimen was captured) and lowland backflow billabongs. During the 1978 Late-dry season, adults were found only in escarpment perennial streams.

Nourlangie catchment

Juveniles were captured in all habitats examined. The smallest juvenile was found in a channel backflow billabong. The larger juveniles were most often found in sandy creekbed habitats. Juveniles were observed in escarpment perennial streams in the Mid-wet and 1979–80 Early-wet season.

Small adults were found most frequently in sandy creekbed habitats (as were the large juveniles) and the larger adults in escarpment mainchannel waterbodies (as was the largest specimen). Adults were also found in lowland backflow billabongs, with smaller specimens found most often in channel billabongs and larger specimens in shallow backflow billabongs. Adults were observed in escarpment perennial streams in the Mid-wet, Late-wet–Early-dry and 1979–80 Early-wet seasons.

Environmental associations

Rank numbers for *M. splendida inornata* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Surface-water temperatures ranged from 23° to 40°C (mean = 30.6°C);[92] bottom-water temperatures ranged from 23° to 36°C (mean = 29.5°C). Both of these means were ranked in the upper-middle quarters (see fig 170). This species was thus found in cool to very warm waters; indeed, *M. splendida inornata* was captured in all habitats from the escarpment area to the floodplains. As with *M. nigrans*, the observed temperature range was greater than the one proposed by Allen (1978a), and was the broadest found in the present study.

Dissolved oxygen

Dissolved oxygen concentrations in waters in which *M. splendida inornata* was captured ranged from 0.9 to 8.2 mg/L (mean = 5.8) on the surface, and from 2.0 to 6.8 mg/L (mean = 4.9) on the bottom. These means were placed in the lower-middle and upper-middle quarters respectively (see fig 171). As with *M. nigrans*, the relatively high bottom-water DO concentrations may indicate an association with moving or well-mixed waters.

Visibility

Secchi depth readings ranged from 1 to 270 cm. The mean of 44 cm was ranked in the lower-middle quarter (see fig 172).

pH

The pH of waters in which *M. splendida inornata* was found ranged from 4.6 to 8.3 (mean = 6.1) on the surface and from 4.5 to 7.3 (mean = 5.9) on the bottom. These means were both ranked in the lower-middle quarter (see fig 173). *Melanotaenia splendida inornata* was found in waters with a wider, less acidic pH range than was *M. nigrans*, again modifying Allen's (1978a) suggested range of tolerance of melanotaeniids to pH (6.5–6.9).

Conductivity

Conductivity readings for waters in which *M. splendida inornata* was found ranged from 2 to 220 µS/cm at the surface, and from 2 to 64 µS/cm in the bottom waters. This wide range of conductivities matches the wide distribution of the species, from permanent flowing escarpment streams to lower-reach billabongs.[93]

Habitat–structural variables

Substrate

The type of substrate over which *M. splendida inornata* was found varied widely, as might be expected from its distribution. Sand (upper-middle quarter) was the principal substrate,

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[92] Crowley and Ivantsoff (1982) indicated that at temperatures greater than 26°C all observed pairs of *M. splendida inornata* spawned each day under laboratory conditions.

[93] Williams and Williams (1991) found that mortalities of adults of *M. splendida* from the Murray-Darling River system occurred at salinities of 22–36 ppt. A preliminary toxicity study (Williams [1987] cited in Williams and Williams [1991]) on eggs and fry indicated mortalities commence at 10 ppt salinity. The corresponding conductivities are far higher than any recorded in the Alligator Rivers Region.

followed by mud (lower-middle quarter), then clay, leaf litter and boulders (see fig 174). Allen (1978a) noted that members of the family Melanotaeniidae are found in a variety of ecological conditions, from clear, rapidly flowing waters to small muddy pools.

Hydrophytes

Melanotaenia splendida inornata was generally found in waters with moderately thick vegetation (vegetation-occurrence index 72.1%): submergent plants (42.6%), followed closely by emergent plants (34.4%). As with *M. nigrans* habitats, there was a relatively high proportion of floating vegetation.

Reproduction

A total of 1121 fish were assessed for reproductive stage and GSI; 470 of these were female, 444 male and 207 sexually indistinguishable.[94] The gonads of *M. splendida inornata* are singular and readily differentiated, even at an early stage of development. The testes are flattened, whitish, elongated and irregularly triangular; the ovaries are rounded and translucent yellowish.

Length at first maturity

The LFM for *M. splendida inornata* was estimated to be 25 mm for females and 33 mm for males (fig 62).[95] Calculations were based on 5 mm groups and only 8 mm separates the two lengths. The smallest maturing male and female were recorded at 28 and 29 mm, respectively. Both sexes of *M. splendida splendida* matured in north-eastern Queensland at between 36 and 40 mm (Beumer 1979b).

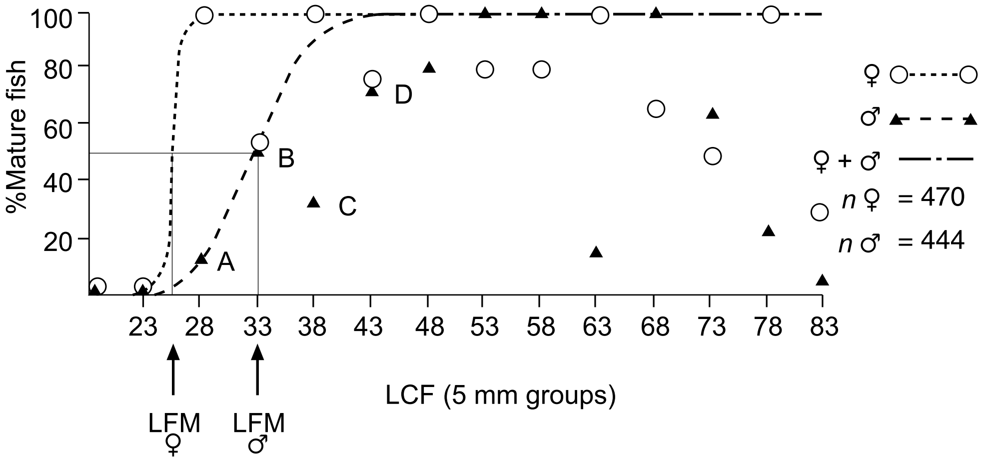

Figure 62 Estimated length at first maturity (LFM) of male and female *M. splendida inornata*

Sex ratio

There was a 1:1 ratio of males to females in all seasons (except for the 1978–79 Mid-wet sample) for both juveniles + adults and for adult fish only (table 53). During the 1978–79 Mid-wet season significantly more females were captured. It was also the period of the least gonadal development; if the male gonads had regressed to such an extent that the animals were classified as immature, this would have proportionally increased the number of females,

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[94] Ivantsoff et al (1988) indicated that *M. splendida inornata* is sexually dimorphic and dichromatic. Details of the sex differences are the same as given in footnotes for *M. nigrans*.

[95] Milton and Arthington (1984) indicated the minimum length at spawning for *M. s. fluviatilis* from south-eastern Queensland was 30.8 mm SL.

as they remained sexually identifiable. A chi-squared test (Zar 1974) on each habitat type in the Magela system (table 54) found no significant deviation from a 1:1 ratio (at the 5% significance level) in any habitat.[96]

Table 53 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *M. splendida inornata* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet-Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	60	48	147	98	65	39	13
adults	M	*n*	54	40	110	94	80	49	18
		χ^2	0.32	0.73	5.33	0.8	1.6	1.14	0.81
		P	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	59	39	145	98	62	32	11
	M	*n*	43	32	110	93	72	28	17
		χ^2	2.51	0.69	4.80	0.13	0.75	0.27	1.29
		P	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	2.7	3.8	0.6	1.0	1.9	1.9	3.9
		s.d.	0.6	1.2	0.4	0.4	1.0	0.7	1.1
	M	mean	0.4	0.7	0.1	0.2	0.3	0.3	0.8
		s.d.	0.1	0.1	0.1	0.1	0.2	0.1	0.2
	F+M	mean	1.5	2.1	0.4	0.6	1.0	1.2	2.3
		s.d.	1.3	1.8	0.4	0.5	1.0	0.9	1.8
GMSI									
Adults only	F	mean	3.6	3.0	2.1	2.4	3.2	3.1	3.9
		s.d.	0.5	1.0	1.0	0.7	0.8	0.6	0.6
	M	mean	3.0	3.6	1.7	2.4	3.0	2.6	3.5
		s.d.	0.5	0.5	0.6	0.9	0.7	0.8	0.8
	F+M	mean	3.3	3.3	1.9	2.4	3.1	2.9	3.7
		s.d	0.6	0.8	0.9	0.8	0.7	0.7	0.7

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; s.d. = standard deviation.

Table 54 Sex ratio of *M. splendida inornata* found in the main habitat types during the 1978–79 Mid-wet season. None of the ratios was significantly different.

Sex ratio	Habitat
15:14	Escarpment mainchannel waterbody
22:36	Shallow backflow billabong
13:22	Lowland sandy creekbed pool
14:21	Shallow channel billabong
3:4	Corridor sandy billabong
10:3	Corridor anabranch billabong
13:23	Floodplain billabong

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[96] Milton and Arthington (1984) indicated that the sex ratio for all *M. s. fluviatilis* collected from south-eastern Queensland significantly differed from the expected 1:1 ratio (more females were present).

Breeding season

Melanotaeniids generally do not reproduce seasonally (Roberts 1978; Beumer 1979b; Fisher 1955), although *M. fluviatilis* is reported to breed in the Murray–Darling system during summer, depositing a few eggs at a time over many days (Lake 1978).

Melanotaenia splendida inornata has a relatively high GSI and GMSI throughout the year (fig 63, table 53), with peaks of reproductive development around the Early-wet season and a low in the Mid-wet season, when a high proportion of spent fish were found. Only four ripe specimens were found during the 1978 Late-dry and 1978–79 Early-wet seasons. All spent fish were captured during the 1978–79 Mid-wet season and 1979 Late-wet–Early-dry seasons. Juveniles (less than 20 mm LCF) were captured during all seasons except the 1979 Late-wet–Early-dry.

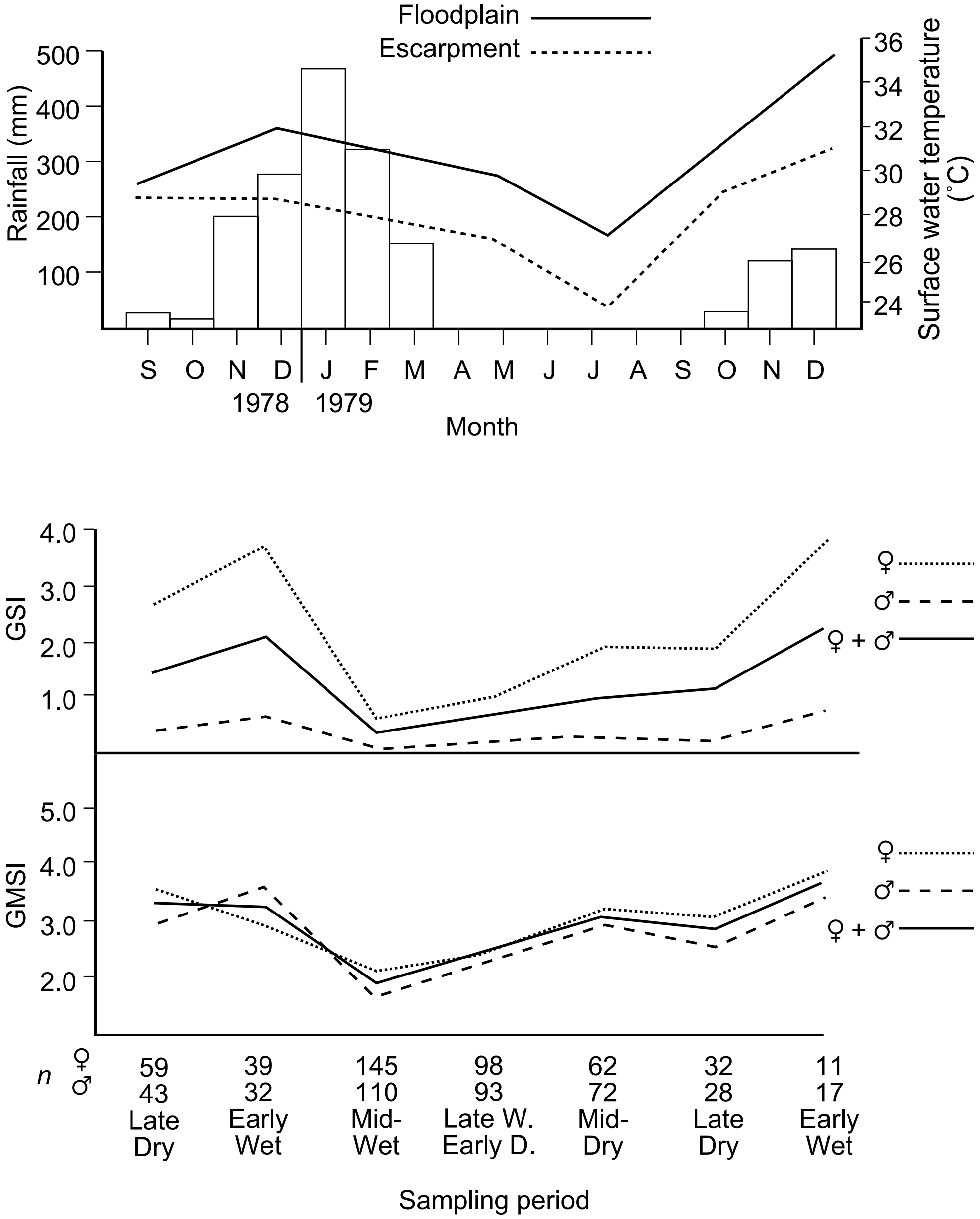

Figure 63 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *M. splendida inornata*

The presence of ripe and spent fish, together with the high GSI and GMSI values, suggests that *M. splendida inornata* spawns for an extended period during the Early-wet seasons, and that its gonads are developing for the next year's spawning by the Late-wet–Early-dry season. These results correspond closely to those of Beumer (1979b) for northern specimens of *M. splendida splendida*. Beumer also recorded juveniles throughout the year and suggested that this species spawned throughout the year with a peak before and during flood periods.

Site of spawning

Running-ripe fish were found only in the lowland sandy creekbeds; however, four fish at this stage were captured. Spent fish and juveniles were captured in all habitats sampled in both the Magela and Nourlangie systems (see table 55).

Table 55 Possible sites of spawning of *M. splendida inornata* as indicated by the abundance (*n*) of ripe, spent and juvenile fish

	Gonad stage				
	Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	
Escarpment					
Mainchannel waterbody	–	–	2	4	5
Lowlands					
Sandy creekbed	3	1	8	–	63
Backflow billabong	–	–	4	–	52
Corridor	–	–	2	1	19
Floodplain billabong					
Upper	–	–	1	–	40

Melanotaenia splendida inornata is a ubiquitous spawner, as is *M. splendida splendida,* which spawns in both slow-flowing waters and in backwaters of flood waters (Beumer 1979b). Both species are reported (*M. splendida splendida* by Beumer 1979b; and *M. splendida inornata* by Midgley 1980) to migrate upstream at the onset of the Wet season.

Fecundity

In the eight gonads examined, the number of eggs ranged from 70 to 370 (mean = 171). The diameters ranged from 0.5 to 0.72 mm (mean = 0.6 mm). Tendrils were observed on the eggs. Beumer (1979b) did not calculate the fecundity of *M. splendida splendida,* as that species has a long spawning period and ripe oocytes were continuously spawned; however, he stated that the fecundity was low, and that the eggs were large (0.25–0.60 mm).[97]

Summary

Melanotaenia splendida inornata maintains a relatively high GSI and GMSI throughout the year. Although juveniles are present throughout the year, the occurrence of running-ripe and spent fish, and the higher values of GSI and GMSI, suggest this species mainly spawns at the onset of the Wet season. *Melanotaenia splendida inornata* is sexually dimorphic, with males having longer and more brightly coloured fins, especially during the breeding season.

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[97] Ivantsoff et al (1988) indicated that under stable laboratory conditions, large females (> 50 mm TL) produced possibly more than 100 eggs per day at the peak of the spawning season. Smaller females (28–35 mm TL) which were only just sexually mature shed fewer eggs, 20–30 per day and spawning did not occur daily. Milton and Arthington (1984) indicated that *M. s. fluviatilis* from south-eastern Queensland had fecundities which varied considerably: 35–333 (mean = 132) eggs per individual.

Both *M. splendida splendida* and *M. splendida inornata* are reported to migrate upstream at the onset of the breeding season (Beumer 1979b; Midgley 1980), which corresponds to the start of creek flow after the Dry season. They appear to breed throughout the system and lay a small number of relatively large eggs at a time; these are attached to aquatic vegetation by fine threads from the egg membrane.[98] Observations of *M. fluviatilis* in the Murray–Darling system suggest the incubation period is nine days at 20°C (Lake 1971) and the newly hatched larvae are at an advanced stage of development.

Feeding habits

Overall diet

The stomachs of 1109 specimens were examined; 1072 contained food. The diet is summarised in fig 64; components of the diet are given in table 56.

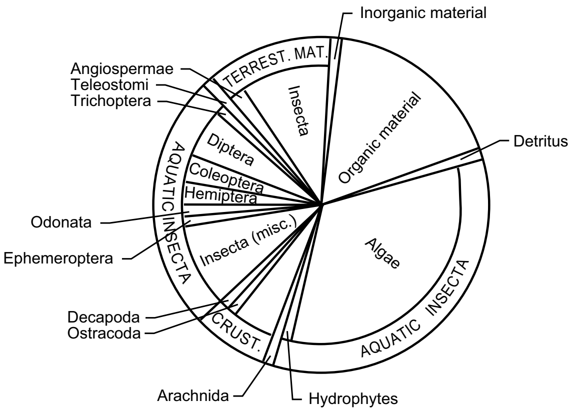

Figure 64 The main components of the diet of *M. splendida inornata*

The main components were algae (29%), aquatic insects (25%), terrestrial insects (15%) and microcrustaceans (7%). The algal component consisted mainly of green filamentous species. A variety of aquatic insects was eaten; the main identifiable species were chironomid larvae and pupae, and coleopterans. The main terrestrial insects were formicids (ants) and the main microcrustaceans were cladocerans. Traces of hydrophytes, oligochaetes, gastropods, arachnids, macrocrustaceans, teleosts, terrestrial plants, detritus and inorganic material were also found in the stomachs. Large quantities of unidentified organic material (15%) were also found. *Melanotaenia splendida inornata* can therefore be classified as a meiophagous omnivore feeding opportunistically throughout the waterbodies.

Pollard (1974) suggested this species probably eats small insects and, as with *M. nigrans*, does not mention any herbivorous component of its diet. Haines (1979) classified *M. splendida inornata* as an insectivore/detritophage in the Purari River catchment. Sanderson (1979) noted that *M. splendida inornata* in Magela floodplain billabongs ate a variety of food items — chiefly aquatic insects, vegetable matter (algae) and organic detritus. In the pools and riffles that enter the floodplain in the Wet season, *M. splendida inornata* fed mainly on non-aquatic insect forms such as winged diptera and ants. Sanderson concluded that this species was predominantly a mid-water/surface-feeder in the littoral zone of the floodplain billabongs and an opportunistic surface feeder in pools and riffles.[99]

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[98] Ivantsoff et al (1988) has subsequently described mating behaviour, egg and embryonic development, and larval development.

[99] Pusey et al (1995b) found *M. splendida splendida* to consume large quantities of terrestrial insects in two rivers of the Australian wet tropics, north-eastern Queensland.

Table 56 Dietary composition of *M. splendida inornata*

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																	
Algae																	29.3
Miscellaneous	–	4.0	4.3	0.3	5.8	–	0.7	2.4	6.4	0.4	–	3.3	4.8	10.4	–	3.0	
Closterium	–	–	–	–	–	–	3.8	–	1.5	–	–	–	–	–	–	0.2	
Dinophyceae	–	1.0	0.1	–	0.1	–	–	–	–	–	–	0.6	0.1	–	–	0.1	
Cyanophyta	–	–	0.2	–	0.4	–	–	–	1.7	–	0.2	–	–	–	–	0.3	
Conjugatophyta																	
Mougeotia	13.4	8.9	18.9	28.6	32.5	34.6	66.2	16.8	3.1	5.9	20.3	48.6	40.7	18.0	3.1	23.3	
Spirogyra	–	1.2	3.1	7.3	1.1	4.0	–	–	–	–	7.0	1.2	–	–	–	2.4	
Hydrophytes																	0.9
Eriocaulon	–	0.1	–	–	–	–	–	–	–	–	+	–	–	–	–	+	
Najas	–	1.0	1.3	–	0.6	–	–	2.5	–	–	0.3	–	4.7	–	–	0.7	
Vallisneria	1.1	–	–	0.6	–	–	–	–	–	–	0.2	–	0.7	–	–	0.2	
Aquatic animals																	
Oligochaeta	–	–	–	–	–	–	–	–	–	–	0.2	–	–	–	–	0.1	0.1
Gastropoda																	0.1
Amerianna	–	–	–	–	0.6	–	–	–	–	–	–	–	0.7	–	–	0.1	
Arachnida																	0.8
Araenae	–	–	0.8	–	–	0.6	–	–	–	–	0.8	–	–	–	–	0.3	
Porohalacaridae	–	+	–	–	–	–	–	–	–	–	–	–	–	0.1	–	+	
Hydracarina	–	0.6	0.3	0.8	0.7	–	–	–	1.4	1.3	0.2	0.1	0.8	0.2	–	0.5	
Microcrustacea																	7.2
Conchostraca	–	–	+	–	–	–	–	–	0.4	–	–	–	–	–	–	0.1	
Cladocera																	
Miscellaneous	–	–	2.2	0.6	0.6	–	–	0.1	3.2	1.5	1.8	+	+	–	–	1.2	
Diaphanosoma	–	9.8	7.5	3.8	1.9	–	–	–	–	17.3	–	1.5	1.0	3.5	48.6	4.3	
Ostracoda	–	1.6	1.2	0.1	0.6	–	–	–	–	1.2	0.9	0.6	0.6	–	–	0.6	
Copepoda	–	–	–	–	–	–	–	1.4	0.8	–	0.3	–	–	1.2	–	0.3	
Macrocrustacea																	1.0
Macrobrachium (juveniles)	–	–	0.7	–	0.6	–	–	–	–	2.2	–	–	–	–	–	0. 3	
Macrobrachium (adults)	1.8	–	0.9	0.6	0.6	–	–	1.4	3.3	0.7	–	0.5	0.7	–	–	0.7	

Table 56 continued

	Habitat								Season							Overall	
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Insecta																	25.3
Fragmented	11.7	10.7	10.8	5.0	8.0	14.1	0.8	14.6	14.2	8.6	14.2	3.0	6.9	6.4	4.4	9.6	
Ephemeroptera																	
Baetidae	0.6	1.0	1.7	0.1	–	–	–	–	1.5	2.2	0.7	–	0.1	–	–	0.7	
Atalophlebia	–	–	–	–	–	–	–	–	–	0.6	–	–	–	–	–	0.1	
Odonata																	
Coenagrionidae	1.8	–	–	–	–	–	–	–	–	–	0.3	–	–	–	–	0.1	
I. heterosticta	–	–	0.7	–	–	–	–	–	–	–	–	–	1.4	–	–	0.2	
Gomphidae	–	–	0.3	–	–	–	–	1.4	1.7	–	–	–	–	–	–	0.2	
Libellulidae	–	–	1.0	–	–	–	–	–	0.4	–	–	1.5	–	–	–	0.3	
Hemiptera																	
Naucoridae	–	–	–	–	–	–	–	–	–	–	–	0.5	–	–	–	0.1	
Gerridae	1.3	0.8	0.5	0.8	1.2	–	–	1.9	0.9	0.7	1.4	0.5	–	0.4	–	0.8	
Viliidae	–	1.0	1.2	–	0.4	–	–	–	1.1	–	1.1	–	–	–	–	0.5	
Anisops	–	0.1	–	–	–	–	–	–	0.3	1.2	–	–	–	–	–	0.2	
Corixidae	0.1	2.0	0.5	1.8	1.6	–	–	0.3	2.4	2.6	0.3	0.5	0.3	5.1	–	1.3	
Megaloptera																	
Austrosialis	–	–	0.1	–	–	–	–	–	–	–	0.1	–	–	–	–	+	
Coleoptera																	
Miscellaneous (adults)	6.3	4.3	3.4	2.1	0.3	4.7	1.8	1.8	10.0	0.4	2.2	–	3.3	4.0	0.7	2.8	
Miscellaneous (larvae)	–	–	0.4	–	0.6	–	–	–	0.4	–	0.7	–	–	–	–	0.3	
Diptera																	
Chaoborinae	–	–	–	–	1.2	–	–	–	–	–	0.6	–	–	–	–	0.2	
Chironomidae (larvae)	0.2	2.9	1.3	4.3	4.4	6.5	1.3	11.1	2.1	8.6	1.7	1.1	1.6	14.4	0.3	3.4	
Chironomidae (pupae)	–	1.0	3.0	2.2	0.7	4.3	–	9.4	3.1	3.3	1.7	3.1	2.9	5.4	–	2.8	
Ceratopogonidae	–	0.6	0.4	–	–	–	0.4	–	1.2	0.6	–	–	–	–	–	0.2	
Simuliidae	1.8	–	–	–	0.6	–	–	–	–	–	0.3	–	0.7	–	–	0.2	
Trichoptera																	
Leptoceridae	2.6	0.7	1.3	0.7	1.2	–	3.0	0.3	2.5	0.2	1.1	0.5	0.2	2.4	–	0.9	
Miscellaneous (pup.)	–	–	1.3	–	–	–	–	–	–	–	1.2	–	–	–	–	0.4	
Teleostomi																	1.3
Fragmented	1.8	1.1	0.4	1.3	0.6	–	0.2	–	0.8	0.7	1.2	0.6	–	–	–	0.7	
Scales	–	0.3	–	–	–	–	–	–	–	–	0.1	–	–	–	–	+	

Table 56 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Egg material	–	–	0.9	1.9	–	–	–	1.3	–	–	2.0	–	–	–	–	0.6	
Terrestrial plants																	
Angiospermae																	2.2
Fragmented	0.9	–	–	0.6	–	–	–	–	–	0.5	0.7	2.5	4.8	–	–	1.4	
Miscellaneous	–	0.9	2.5	0.1	3.6	–	–	–	0.7	–	0.2	–	–	–	–	0.1	
Seed material	–	–	2.2	0.7	–	–	–	–	–	–	0.6	0.5	3.3	–	–	0.7	
Terrestrial animals																	
Arachnida	1.1	–	–	–	–	1.1	–	–	–	–	0.2	–	0.4	–	–	0.1	0.1
Insecta																	15.0
Fragmented	14.3	6.3	2.3	2.8	1.4	18.3	1.9	10.0	6.7	–	4.7	1.0	7.6	–	11.9	5.0	
Odonata																	
Zygopteran (adults)	–	–	–	1.9	–	–	–	–	2.1	–	–	–	–	–	–	0.3	
Anisopteran (adults)	–	0.4	0.3	–	0.6	–	–	–	–	–	0.7	–	–	–	–	0.2	
Coleopteran																	
Miscellaneous	–	–	1.0	–	0.5	1.9	–	–	0.6	–	1.2	–	–	–	–	0.4	
Dipteran																	
Miscellaneous	1.8	3.9	–	–	–	–	–	–	–	–	1.5	–	–	–	–	0.5	
Chironomidae (adults)	–	–	0.2	–	–	–	–	–	–	–	0.2	–	–	–	–	0.1	
Culicidae (adults)	1.8	–	–	–	–	–	–	–	–	–	–	–	–	1.2	0.7	0.1	
Trichoptera	–	–	–	–	0.6	–	–	–	–	–	0.3	–	–	–	–	0.1	
Hymenoptera																	
Formicidae																	
Miscellaneous	17.3	14.7	5.1	3.6	1.3	4.9	–	0.6	1.2	7.8	10.4	–	1.5	5.8	30.5	6.5	
Oecophylla	13.6	1.0	0.8	0.5	6.2	–	7.1	–	1.9	1.0	4.1	–	1.0	–	–	1.8	
Parasites																	
Cestoda	–	–	0.3	–	–	–	–	–	–	–	0.3	–	–	–	–	0.1	0.1
Nematoda	–	–	0.4	0.2	0.1	–	–	0.8	0.8	–	0.3	–	–	0.1	–	0.2	0.2
Detrital material	–	–	1.2	4.3	–	–	–	–	–	–	–	1.0	5.1	1.2	–	1.0	1.0
Inorganic material	0.3	3.1	2.0	0.5	–	1.4	–	–	2.7	0.9	0.8	–	0.1	3.9	–	1.1	1.1
Organic material	4.9	15.5	12.0	22.4	18.4	3.5	13.0	20.6	18.7	17.7	10.9	27.7	4.1	16.5	–	15.1	15.1
Number of empty fish	–	4	10	12	7	–	–	2	5	8	3	10	2	9	–	37	37
Number of fish with food	55	102	305	160	171	51	56	72	144	138	336	195	145	83	31	1072	1072

Figures represent the mean percentage volume determined by the estimated volumetric method.
Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs; Fb = floodplain billabongs

Seasonal changes

In sampling periods 1–7, respectively, 149 (3% empty), 146 (5% empty), 339 (1% empty), 205 (5% empty), 147 (1% empty), 92 (10% empty) and 31 (0% empty) stomachs of *M. splendida inornata* were examined (all habitats combined). The highest proportions of specimens with empty stomachs were found in the Late-dry and Late-wet–Early-dry seasons.

The algal component of the diet increased in importance during the Mid-wet season and remained the most important food item during the Late-wet–Early-dry and 1979 Mid-dry seasons. It became less important during the 1979 Late-dry season and reached a low in the Early-wet season, as it had in the previous year.

Aquatic insects were a large component throughout the study; Chironomid larvae and pupae were most important; in the 1978–79 Early-wet and 1979 Late-dry seasons, coleopterans and corixids were most important in the Late-dry seasons. The greatest variety of aquatic insects was eaten in the Mid-wet season. Terrestrial insects became important in the diet during the Early-wet and Mid-wet seasons; the greatest variety was found in the latter season.

Microcrustaceans were found most commonly in the stomachs during the Early-wet seasons. Unidentified organic material comprised large portions of the stomach contents in all seasons other than the 1979 Mid-dry and the 1979–80 Early-wet.

Habitat differences

Magela catchment

The stomachs of 826 *M. splendida inornata* (all seasons combined) were examined: 55 (0% empty) from escarpment mainchannel waterbodies, 106 (4% empty) from lowland sandy creekbeds, 315 (3% empty) from lowland backflow billabongs, 172 (7% empty) from corridor waterbodies, and 178 (4% empty) from floodplain billabongs, caught in the Magela Creek catchment. The highest proportions of specimens with empty stomachs were found in the corridor waterbodies and the lowest proportions in the escarpment mainchannel waterbodies.

In the escarpment mainchannel waterbodies, terrestrial insects were most abundant in the stomachs, followed by aquatic insects and green filamentous algae (*Mougeotia*). In the lowland sandy creekbeds, terrestrial insects were slightly less important and microcrustaceans were also eaten. The diet in the backflow billabongs encompassed a variety of food items, including algae, microcrustacea and aquatic insects.

In the corridor waterbodies the diet consisted mainly of algae and aquatic insects; there was also a large unidentified organic material component. In the floodplain billabongs the algal component was large, aquatic insects were of secondary importance, and there was a large unidentified organic material component. Terrestrial insects also appeared in the diet but microcrustaceans were of minor importance.

Nourlangie catchment

The stomachs of 181 *M. splendida inornata* (all seasons combined) from Nourlangie Creek catchment were examined: 51 (0% empty) from escarpment mainchannel waterbodies, 56 (0% empty) from lowland sandy creekbeds, and 74 (2% empty) from backflow billabongs. Few specimens had empty stomachs.

In the escarpment mainchannel waterbodies, algae were the main food, with smaller portions of terrestrial and aquatic insects; in equivalent habitats in the Magela Creek catchment the algal component was smaller. In the sandy creekbeds, the algal component in the diet was higher and terrestrial and aquatic insects were even less important. In the backflow billabongs, larger quantities of aquatic insects (mainly chironomid larvae and pupae) were eaten along with terrestrial insects and much less algae; traces of microcrustaceans were also found in the stomachs.

Fullness

The mean fullness indices of *M. splendida inornata* for different sampling periods and habitat types are shown in table 57. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 57 Mean fullness indices for *M. splendida inornata* in different sampling periods and habitats

	Sampling period							
Habitat	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites only)								
Upstream of RUPA								
Escarpment main-channel waterbody	2.0	n/s	3.3 (36)	n/s	3.5	4.0 (3)	3.7 (10)	3.4 (49)
Lowland shallow backflow billabong	4.2 (10)	n/s	3.0 (12)	n/s	3.5 (10)	2.6 (11)	n/s	3.3 (43)
Lowland sandy creekbed	n/s	3.0 (2)	3.4 (14)	n/s	n/s	n/s	3.5 (10)	3.4 (26)
Downstream of RUPA								
Lowland sandy creekbed	3.5 (17)	2.9 (24)	3.1 (36)	3.3 (8)	n/s	2.2 (5)	n/s	3.1 (90)
Lowland channel backflow billabong	2.0 (4)	3.3 (12)	3.6 (45)	3.4 (31)	0 (1)	1.3 (4)	0 (1)	3.3 (97)
Lowland shallow backflow billabong	2.9 (13)	2.5 (28)	3.4 (67)	3.4 (51)	3.4 (24)	2.7 (3)	n/s	3.2 (186)
Corridor sandy billabong	1.5 (2)	2.1 (2)	3.7 (1)	0.6 (10)	3.9 (10)	2.9 (10)	n/s	2.5 (35)
Corridor anabranch billabong	3.5 (12)	2.3 (4)	3.7 (16)	3.9 (10)	3.9 (10)	2.4 (10)	n/s	3.4 (62)
Floodplain billabong	3.5 (26)	2.8 (22)	2.8 (56)	2.8 (53)	3.6 (50)	3.2 (30)	n/s	3.1 (237)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	n/s	2.6 (11)	3.3 (22)	n/s	3.3 (18)	n/s	n/s	3.1 (51)
Lowland channel backflow billabong	4.0 (2)	2.6 (5)	2.8 (8)	3.1 (10)	3.6 (10)	4.0 (2)	n/s	3.2 (37)
Lowland shallow backflow billabong	2.2 (6)	3.5 (3)	3.0 (2)	2.6 (10)	4.0 (6)	3.4 (9)	n/s	3.1 (36)
Lowland sandy creekbed	3.0 (10)	0 (1)	0.7 (11)	3.6 (20)	3.2 (10)	4.0 (4)	n/s	2.8 (56)
Seasonal mean (all sites)	3.1	2.7	3.2	3.1	3.5	3.0	3.5	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Seasonal changes

The mean seasonal index (all seasons combined) fell slightly during the 1978–79 Early-wet season and then returned to a higher level for the remainder of the study. Peaks occurred during the 1979 Mid-dry and 1979–80 Early-wet seasons (unlike in the previous year).

Habitat differences

In the Magela catchment, mean fullness indices were much the same in all habitats (indicating opportunistic feeding habits), the possible exception being the corridor sandy billabong, where a slightly lower index was recorded.

In the Nourlangie catchment, mean fullness indices were similar in all habitats and comparable with the Magela Creek catchment; the possible exception was the lowland sandy creekbed pool where a slightly lower index was recorded.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland shallow backflow billabong (upstream of RUPA); 1978 Late-dry season
- corridor sandy billabong; 1979 Mid-dry season
- corridor anabranch billabong; 1979 Late-wet–Early-dry season, 1979 Mid-dry season

Nourlangie catchment

- lowland channel backflow billabong; 1978 Late-dry season, 1979 Late-dry season
- lowland shallow backflow billabong; 1979 Mid-dry season
- lowland sandy creekbed pool; 1979 Late-dry season.

Family MELANOTAENIIDAE

3.15 *Melanotaenia splendida australis* (Castelnau)

Melanotaenia splendida australis is commonly known as the red-tailed or western rainbowfish. Only a few specimens of this species were collected in the escarpment mainchannel waterbodies of the Jim Jim Creek system (South Alligator River system). *Melanotaenia splendida australis* and *M. splendida inornata* are so closely related that Allen (1978a) was tempted to consider the latter a subspecies of *australis*. During the breeding season, *M. splendida australis* is fairly easily distinguished from *M. splendida inornata* by the red colouration of the caudal fin.[100]

Melanotaenia splendida australis occurs in river systems of north-western Australia; the Ashburton River forms the western and southern limit of its distribution. It is common in most streams of the Kimberley region and the northwestern Northern Territory from the Fitzroy River to the Adelaide River, just east of Darwin. The *solata* variety (Allen considered that *M. solata* [Taylor 1964] falls within the range of *M. splendida australis* with regard to colour pattern, morphometrics and meristics) has been reported from several localities east of Darwin, including the upper South Alligator River and Yirrkala, Groote Eylandt, and Bickerton Island.

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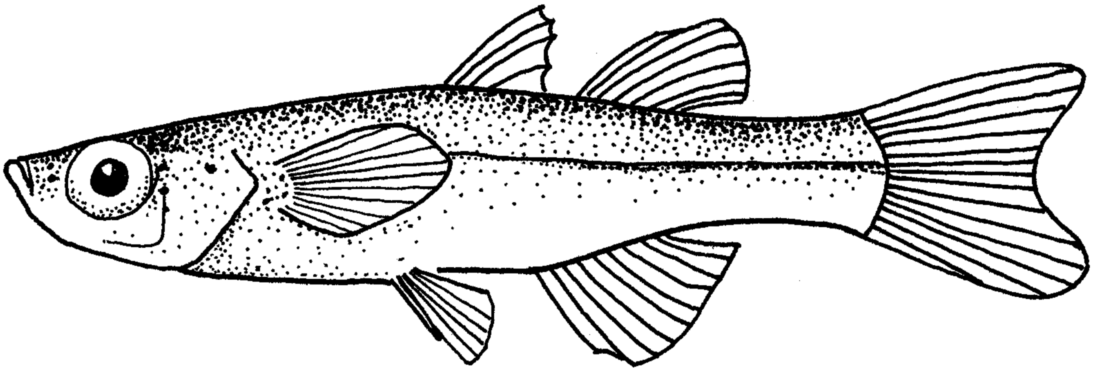
[100] Ivantsoff et al (1988) has subsequently described aspects of the mating behaviour, egg and embryonic development, and larval development. Under laboratory conditions with a water temperature of 26°C, Ivantsoff et al (1988) indicated that *M. s. australis* can attain a total length of 25 mm in 78 days.

Family PSEUDOMUGILIDAE

3.16 *Pseudomugil tenellus* (Taylor)

Pseudomugil tenellus is commonly known as the Arnhem Land blue-eye or the delicate blue-eye. Members of this genus usually inhabit coastal brackish or fresh waters, and are not usually found very far inland. This species has so far been recorded only from the East Alligator River catchment. It was originally described by Taylor (1964) from specimens collected by R. Miller in 1948 from the Oenpelli area; it is fairly closely related to *P. gertrudae* (Weber), which occurs in the north-east coast and Gulf of Carpentaria drainage systems (see map 3).[101] It is also found in southern Papua New Guinea and the Aru Islands.



Pseudomugil tenellus

Midgley (1973) collected this species in the Magela Creek near Jabiru, where they were rare, and in lower riverine floodplain billabongs, where they were common. Miller (cited in Taylor 1964) reported it was abundant in large billabongs and creeks below escarpment waterfalls in the Oenpelli area.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found commonly in all floodplain billabongs and in some corridor and lowland backflow billabongs and in one escarpment perennial stream. It was also found in a vegetated lowland sandy creekbed habitat of the Nourlangie Creek system. It was found in the greatest number of sites during the Mid-wet season, and in the fewest during the 1978 Late-dry and the Late-wet–Early-dry seasons.

Size composition

The lengths and weights of 232 specimens were recorded. Small juveniles were captured most frequently in the 10 mm mesh seine net when it was clogged by hydrophytes and filamentous algae.

Length–weight relationship

As many specimens weighed less than 0.1 g (thus being classified as zero weight) an expression for the length–weight relationship could not be calculated.

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[101] *P. gertrudae* was recorded in the Alligator Rivers Region in the early 1980s (K Bishop, pers obs).

Seasonal mean lengths, weights and condition factors are shown in table 58 (note small sample size). Similar condition factors (near unity) were recorded for specimens collected in 1978–79 Early-wet and Mid-wet seasons. The single specimen examined in the Late-wet–Early-dry season had exceptionally high body condition.

Table 58 Mean length and weight, and condition factor of *P. tenellus*

	n	Mean length (mm)	Mean weight (g)	Condition factor (K)
Early-wet (1978–79)	10	28.2	0.31	0.99
Mid-wet	3	29.3	0.30	0.98
Late-wet–Early-dry (1979)	1	22.0	0.40	1.14
Overall	14	27.9	0.31	1.00

Length-frequency distribution

The smallest specimen captured was 14 mm LCF; the largest was 31 mm LCF (fig 65). *Pseudomugil tenellus* reputedly grows to 40 mm (Pollard 1974). The closely related diadromous *P. signifer* grows to 65 mm but is found most commonly at lengths between 25 and 45 mm (Ivantsoff 1980).

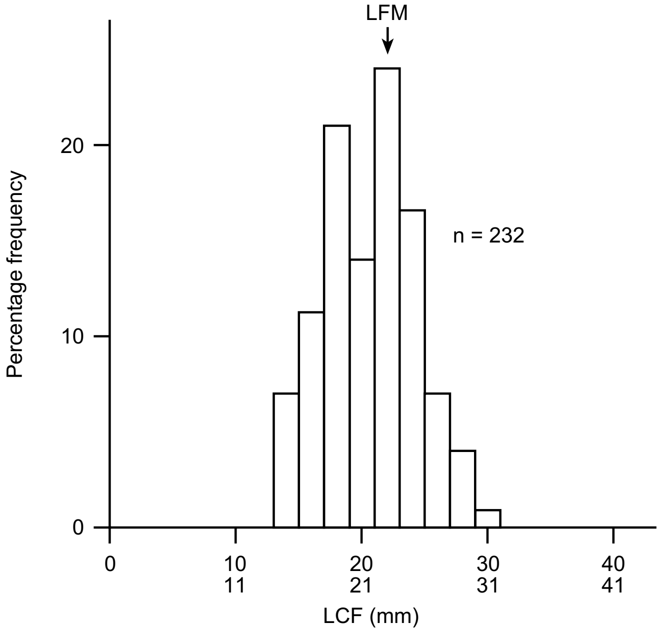

Figure 65 Length-frequency distribution of all *P. tenellus* captured

The mean and modal lengths of all specimens captured were, respectively, 22.5 and 22–23 mm LCF; based on mean length, *P. tenellus* was the smallest species found in the study area. A secondary mode occurred at 18–20 mm LCF. The LFM was 23 mm LCF for both sexes, indicating fairly equal proportions of adults and juveniles were captured during the study.

Seasonal changes in distribution

The smallest juveniles were found between the 1978–79 Mid-wet and the 1979 Late-dry seasons. Very few juveniles were found in the 1978–79 Early-wet season. The largest adults were found in the 1978–79 Early-wet and the Mid-wet seasons.

The length-frequency distributions in the 1979 Late-dry and the Mid-wet seasons (as well as the overall distribution) have two modes, separated by only 2 mm (fig 66). These modes may be a result of sexual differences in growth rates (a possibility that merits verification).

Juveniles and smaller adults dominated the samples in the 1978 Late-dry season. Juvenile recruitment appeared very weak in the 1978–79 Early-wet season, when adults were most common. No specimens of *P. tenellus* were captured in the 1979–80 Early-wet season; however, in the 1979 Late-dry season juveniles dominated the samples more completely than they had in the equivalent 1978 season.

There were many juveniles and fewer adults in the Mid-wet season. By the Late-wet–Early-dry season there a strong juvenile component and a stronger small-adult component, resulting in a clear bimodal distribution with modes separated by 6 mm.

In summary, juvenile recruits were found in all seasons except the 1978–79 and 1979–80 Early-wet seasons; recruitment appeared to peak in the Late-wet–Early-dry season.

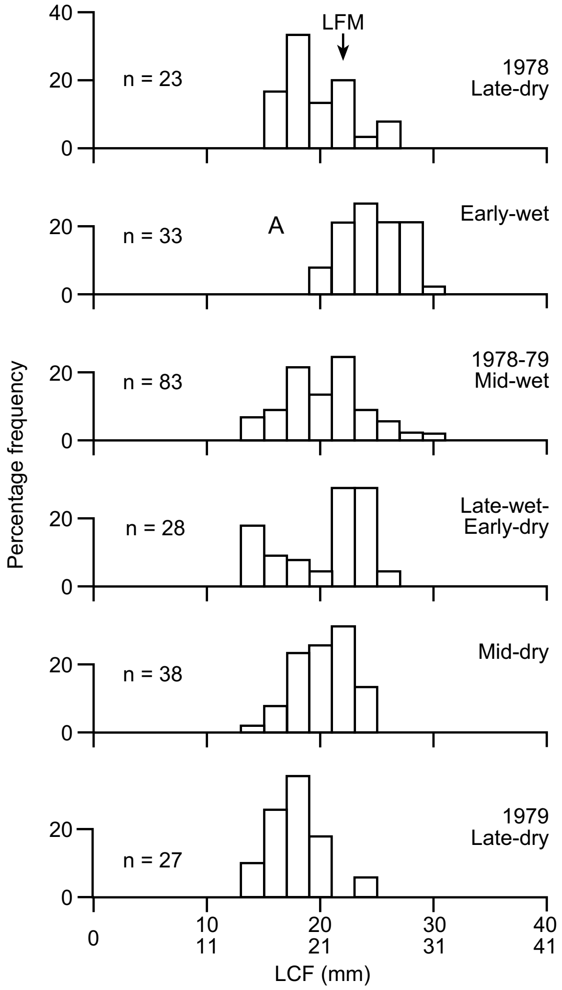

Figure 66 Seasonal length-frequency distribution of all *P. tenellus* captured

Growth rate

No published information on the growth of *P. tenellus* was found. Estimation of growth rate from the seasonal length-frequency distribution is difficult due to frequency with which juveniles were recruited to the populations, and the wide range of habitats sampled. However, during the two months between the 1978 Late-dry season and the 1978–79 Early-wet season (when juvenile recruitment was minimal; A on fig 66), the length-frequency distribution shifted approximately 5 mm. If this is a true growth effect, then this species could attain LFM within its first year of life.[102]

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *P. tenellus* caught in regular sampling sites in the Magela and Nourlangie Creek catchments are given in figure 67.

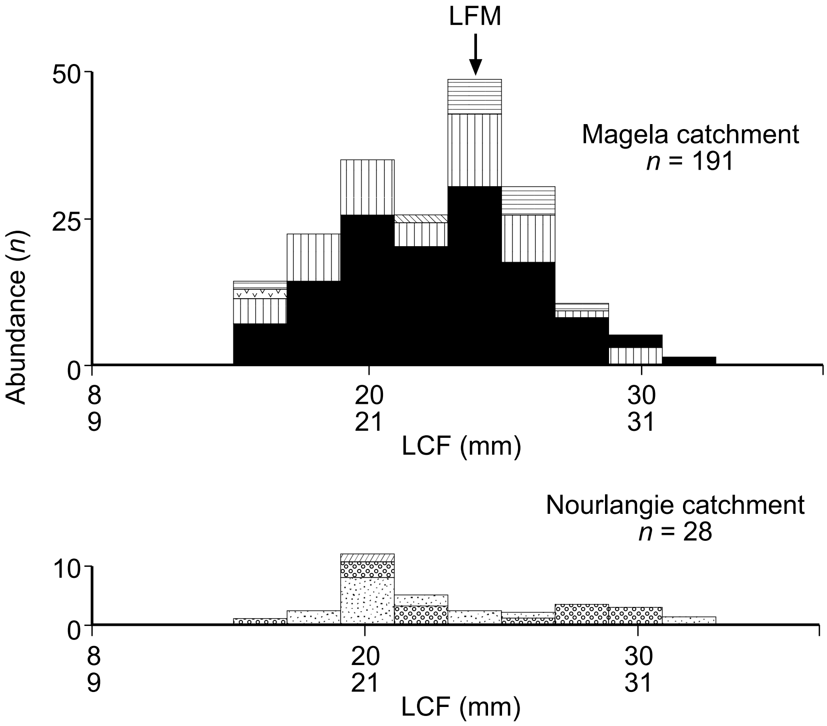

Figure 67 Length–frequency distributions and habitat preferences of *P. tenellus* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment

Juveniles were mainly found in floodplain billabongs and, to a lesser extent, in lowland shallow backflow billabongs downstream of RUPA. The smallest juveniles were caught in the latter habitats as well as in corridor anabranch and lowland sandy creekbed habitats upstream of RUPA. Some larger juveniles were found in escarpment mainchannel waterbodies.

Adults were found in essentially the same habitats as the juveniles; however, higher proportions of adults were found in corridor anabranch billabongs. Some adults were found in the upper reaches of first-order streams in RUPA during the Mid-wet and Late-wet–Early-dry seasons. The largest adults were found in floodplain billabongs.

Nourlangie catchment

Juveniles and adults were found in backflow billabongs in this system. A few juveniles were found in sandy creekbed habitats and in escarpment perennial streams (in tree-root-entangled side pools of the main stream) during the Mid-wet season. The smallest juvenile was caught in a shallow backflow billabong; the largest adult in a channel backflow billabong.

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[102] Under laboratory conditions with a water temperature of 26°C, Ivantsoff et al (1988) indicated that *P. tenellus* can attain a total length of 19–28 mm in 144 days. By 13 months, 3 males attained a total length of 40–43 mm.

Environmental associations

Rank numbers for *P. tenellus* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Pseudomugil tenellus was found in water temperatures from 27° to 38°C (mean = 31.4°C) on the surface, and 25° to 36°C (mean = 30.1°C) on the bottom (see fig 170). Both of these means ranked at the base of the upper quarter, indicating this species has an apparent preference for warmer waters, which accords with its distribution in lowland and floodplain habitats.

Dissolved oxygen

Dissolved oxygen concentrations ranged from 5.0 to 7.8 mg/L (mean = 6.6 mg/L) on the surface and from 5.2 to 5.9 mg/L (mean = 5.5 mg/L) on the bottom. Both means were ranked in the upper quarter (see fig 171).

Visibility

Secchi depths ranged between 3 and 360 cm. The mean depth of 50 cm ranked in the lower-middle quarter (see fig 172).

pH

The pH values of surface waters ranged from 5.0 to 7.1 with a mean of 6.0, which ranked in the lower quarter. This relatively narrow range may be a function of the small number of readings ($n = 12$) taken for this species (see fig 173). No bottom-water pH readings were taken in these waters.

Conductivity

Surface-conductivity values ranged from 6 to 120 µS/cm; the only bottom-water value measured was 12 µS/cm. The narrowness of this range is probably largely an artefact of the small number of readings taken.

Habitat–structural variables

Substrate

Pseudomugil tenellus was captured over the entire range of substrates defined in this study: most often clay (upper quarter), followed by mud (lower-middle quarter), sand, rocks, gravel, leaves and boulders (see fig 174).

Hydrophytes

Pseudomugil tenellus was caught in the most heavily vegetated waters (vegetation-occurrence index 91.8%) in this study: the most dominant vegetation type was submergent, followed closely by emergent, then floating attached hydrophytes.[103] This association with abundant vegetation may be related to the species' observed behaviour of laying eggs in strings amongst aquatic vegetation (Pollard 1974).

Reproduction

The gonads of 188 specimens were examined: 35 males (length range 17–30 mm LCF), 69 females (16–31 mm LCF) and 84 sexually indistinguishable (14–27 mm LCF). No gonads developed beyond stage V were found in females or beyond stage IV in males.

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[103] Herbert and Peeters (1995) indicated that they usually found *P. tenellus* amongst dense aquatic vegetation in gently flowing waters of streams draining Cape York Peninsula.

Length at first maturity

An 18 mm LCF female was found maturing, but no others were found until 24 mm LCF. The males were first found maturing at 23 mm LCF, the estimated LFM for both sexes (fig 68). The samples were too small, especially of the males, to accurately estimate the LFM; however, it was obvious that at 23 mm LCF significant numbers of fish were capable of maturing.

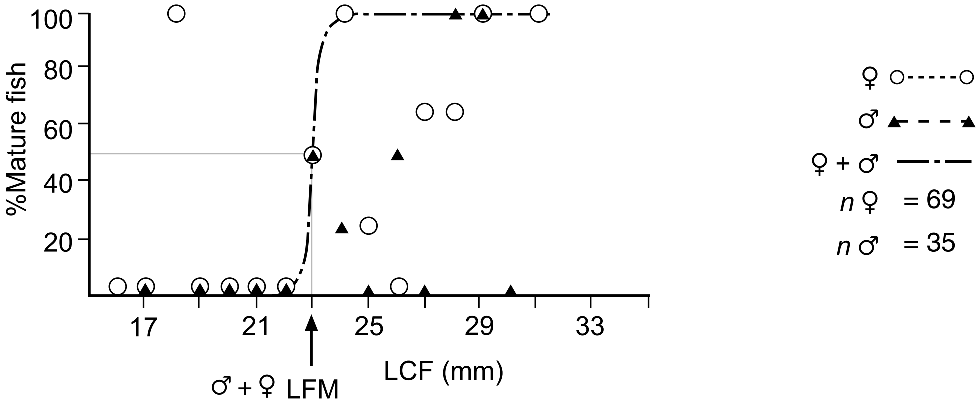

Figure 68 Estimated length at first maturity (LFM) of male and female *P. tenellus*

Sex ratio

The ratio of males to females was not significantly different from 1:1 in any season, except the 1978–79 Mid-wet (when $P < 0.001$ for juvenile + adult fish and $0.001 < P < 0.01$ for adult fish only), and the 1979 Late-wet–Early-dry (when a slight ($0.01 < P < 0.05$) difference was found in the adult + juvenile group).

When the ratio was unequal, there were more females than males (table 59). Misidentification of male gonads was unlikely to be the cause, as equal ratios were found in other seasons (eg Mid-dry season) when the mean GSI and GMSI were also low.

A significant number of females in the 1979 Late-wet–Early-dry season were juveniles; thus the sex ratio differed from 1:1 in the juveniles + adults sample but the ratio was not significantly different from 1:1 for the adult group. In the Mid-wet season sample there was also a discrepancy between the number of juvenile and adult females. Possibly females grow faster than the males and are recruited earlier into the breeding population (ie develop identifiable ovaries).

Breeding season

The GSI and GMSI for females indicated a significant peak in gonad development in the 1978–79 Early-wet season. Fewer males were captured, but their GSI and GMSI also declined after the 1978–79 Early-wet season (fig 69). No running-ripe fish were found; however, nearly all maturing males and females, and mature females were collected in the 1978–79 Early-wet season, with some maturing females collected in the 1978–79 Mid-wet season. The highest GSI readings were also found during the 1978–79 Early-wet and juvenile fish were generally captured in the three subsequent seasons. The data, although sparse, suggest that spawning most likely occurred during the 1978–79 Early-wet season, although spawning may be aseasonal, with peaks of activity during the Early-wet season.[104]

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[104] Under laboratory conditions, Howe (1987) found that *P. tenellus* spawning occurred mainly in summer months. Spawning did not follow a daily pattern, but continued over several days followed by a period of 1–2 weeks inactivity. A water change, which frequently lowered the temperature, or the introduction of new plants sometimes induced spawning after a period of inactivity.

Table 59 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *P. tenellus* over all habitats

Parameter	Sex	Statistic	Sampling period						
			Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles + adults	F	*n*	1	13	34	11	9	1	0
	M	*n*	1	16	6	2	10	0	0
		χ^2	0	0.3	19.6	6.2	0.05	1.0	–
		P	n.s.	n.s.	***	*	n.s.	n.s.	–
Adults only	F	*n*	1	12	19	6	7	1	0
	M	*n*	0	15	4	2	4	0	0
		χ^2	1	0.3	9.8	2	0.8	1	–
		P	n.s.	n.s.	**	n.s.	n.s.	n.s.	–
GSI									
Adults only	F	mean	1.0	5.7	2.8	2.1	1.2	2.0	–
		s.d.	–	4.0	1.1	1.7	0.8	–	–
	M	mean	–	1.6	1.0	6.5	0.8	–	–
		s.d.	–	1.0	0.8	0	0.3	–	–
	F+M	mean	–	3.5	2.4	1.7	1.0	–	–
		s.d.	–	3.4	1.2	1.6	0.7	–	–
GMSI									
Adults only	F	mean	2.0	3.8	2.6	2.2	1.6	2.0	–
		s.d.	–	1.3	0.9	1.0	0.8	–	–
	M	mean	–	3.1	1.8	1.0	1.8	–	–
		s.d.	–	1.0	0.5	0.0	0.5	–	–
	F+M	mean	–	3.4	2.4	1.9	1.6	–	–
		s.d	–	1.2	0.9	1.0	0.7	–	–

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.01$; *** = $P < 0.001$; s.d. = standard deviation.

Site of spawning

There is no direct evidence (eg running-ripe fish or significant numbers of mature fish) that *P. tenellus* actually breeds in the Magela Creek system (table 60). However, the presence of juveniles in the Magela system and adults up as far as the escarpment area suggests that it may do so.

Pseudomugil signifer, a closely related species from south-eastern Australia, prefers a weedy environment in flowing brackish water, close to the shore, where it lays large eggs separately on aquatic plants or on sand just below the surface. Ivantsoff (in McDowall 1980) found that a saline environment was essential for breeding.[105]

Fecundity

The two ovaries examined contained 33 and 45 eggs, with a mean oocyte diameter of 1.0 mm.[106]

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[105] Under laboratory conditions, Howe (1987) found that *P. tenellus* spawned in the roots of a floating water plant.

[106] Under laboratory conditions, Howe (1987) found that *P. tenellus* released the largest number of eggs (3–15) in one day compared with three other *Pseudomugil* species studied (1–8).

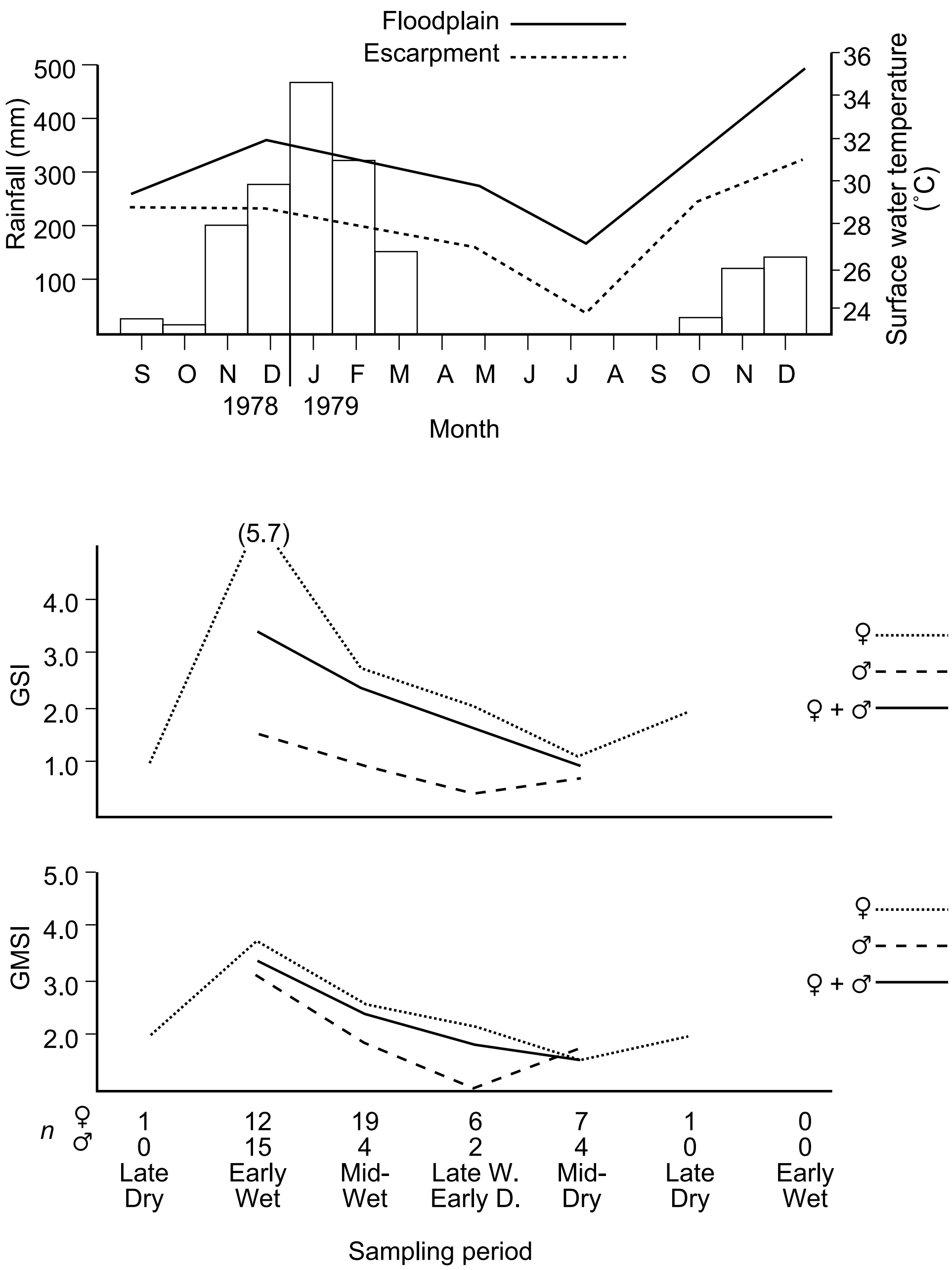

Figure 69 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *P. tenellus*

The eggs of atherinid species that have been studied are large and are normally laid in strings amongst aquatic vegetation. They are reported to take about two weeks to hatch at 21–26°C. The young mature at 12 months (Pollard 1974; Lake 1978).

Summary

Maturing *P. tenellus* were found in floodplain billabongs, and, occasionally, backflow billabongs but the area of spawning is not known. *Pseudomugil signifer*, from south-east Australia, requires a saline environment for breeding. The large eggs of *P. tenellus* are laid in strings amongst aquatic vegetation. Related species have a two-week incubation, after which the young move back up the river system, where they mature within 12 months.[107]

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[107] Howe (1987) and Ivantsoff et al (1988) have subsequently described spawning behaviour, egg surface morphology and embryonic development of *P. tenellus*.

Table 60 Possible sites of spawning of *P. tenellus* as indicated by the abundance (*n*) of mature, ripe and juvenile fish

	Gonad stage				
	Mature (V)		Ripe (VI)		Juveniles
Habitat	F	M	F	M	
Lowlands					
Sandy creekbed habitat	–	–	–	–	2
Backflow billabong	6	4	–	–	5
Corridor	3	2	–	–	1
Floodplain billabong					
Upper	1	1	–	–	6

Sexual dimorphism has been reported in other species of *Pseudomugil*, although it was not observed in this study (most likely because specimens were not captured in breeding condition).[108] The males of *P. signifer* have filamentous extensions to pelvic, anal and both dorsal fins (Ivantsoff, in McDowall 1980).

Feeding habits

Overall diet

The stomach contents of 189 specimens were examined; 180 contained food. The diet of *P. tenellus* is summarised in fig 70; the components are detailed in table 61.

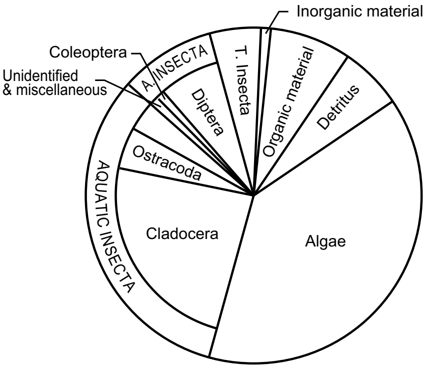

Figure 70 The main components of the diet of *P. tenellus*

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[108] Ivantsoff et al (1988) indicated that differences in colour of the body and especially fins make the sexes of *P. tenellus* easily distinguishable. The larger size of the fins in males, especially the second dorsal and the anal, make the distinction unequivocal.

Table 61 Dietary composition of *P. tenellus*

	Habitat				Season							
	Magela system			Nourlangie system	1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Bb	Cb	Fb	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Aquatic plants												
Algae												38.7
Miscellaneous	–	29.3	22.7	–	–	–	–	37.3	–	99.5	16.2	
Dinophyceae	17.9	–	–	–	–	–	3.3	–	9.1	–	2.8	
Cyanophyta												
Miscellaneous	–	–	0.3	5.3	1.8	–	1.7	–	–	–	0.7	
Lyngbiya	–	–	3.3	–	–	11.1	–	–	–	–	1.7	
Conjugatophyta												
Mougeotia	8.2	17.1	22.8	15.8	4.4	–	7.1	27.7	60.6	–	17.3	
Aquatic animals												
Microcrustacea												31.9
Cladocera												
Miscellaneous	3.6	1.4	24.2	–	–	3.7	40.5	1.8	–	–	14.3	
Diaphanosoma	10.7	30.7	–	15.8	–	21.1	5.4	1.4	26.1	–	9.9	
Ostracoda	3.2	–	–	45.8	–	7.4	11.5	3.2	–	–	5.3	
Copepoda	3.6	1.4	–	–	–	–	6.7	6.4	–	–	3.0	
Insecta												8.8
Fragmented	3.6	1.8	–	5.0	–	9.3	–	–	–	–	1.4	
Coleoptera												
Miscellaneous	3.6	–	–	–	–	3.7	–	–	–	–	0.6	
Diptera												
Chironomidae (larvae)	1.1	8.6	6.1	1.6	5.9	14.8	5.7	4.6	4.2	0.5	6.1	
Chironomidae (pupae)	–	–	1.0	–	5.6	–	–	–	–	–	0.5	
Terrestrial animals												
Insecta												5.0
Egg material	32.1	–	–	–	–	–	15.0	–	–	–	5.0	
Parasites												
Trematoda	3.6	–	0.2	–	1.2	–	0.7	4.6	–	–	0.9	0.9
Detrital material	5.4	–	10.7	–	5.8	7.4	0.8	–	–	–	6.3	6.3
Inorganic material	–	–	1.1	–	–	3.7	–	–	–	–	0.6	0.6
Organic material	3.6	9.6	7.6	10.5	29.4	17.8	1.7	13.2	–	–	7.6	7.6
Number of empty fish	–	–	3	6	3	4	2	–	–	–	9	9
Number of fish with food	28	28	92	19	17	27	60	22	33	21	180	180

Figures represent the mean percentage volume determined by the estimated volumetric method. Bb = lowland backflow billabongs Cb = corridor billabongs; Fb = floodplain billabongs

The main items were algae (39%), microcrustaceans (32%) and aquatic insects (9%). The identifiable algae were green filamentous and blue-green algae and dinoflagellates. The microcrustaceans were mainly cladocerans, ostracods and copepods. Chironomid larvae were the main aquatic insects eaten. Other food items found in the stomachs were terrestrial insects (5%) and detritus (6%). *Pseudomugil tenellus* can therefore be classified as a microphagous omnivore feeding opportunistically from the benthos and mid-water areas of the waterbodies.

Pollard (1974) noted that the diet of this species was unknown, though other members of the genus, eg *P. signifer*, are thought to be essentially plankton feeders; in freshwaters *P. signifer* feeds on mosquito larvae at the very margins of the water (Ivantsoff, in McDowall 1980). The algal component of the diet of *P. tenellus* appears to be only slightly less important than the aquatic animal component.

Seasonal changes

In sampling periods 1–6, respectively, 20 (15% empty), 31 (13% empty), 62 (3% empty), 22 (0% empty), 33 (0% empty), 21 (0% empty) stomachs of *P. tenellus* were examined (all habitats combined). The highest proportions of specimens with empty stomachs were found in the 1978 Late-dry and 1978–79 Early-wet seasons.

The diet in the 1978 Late-dry season was mainly based on detritus (with associated unidentified organic material) and small quantities of chironomid larvae and pupae, and algae; no microcrustaceans were eaten. In the 1978–79 Early-wet microcrustaceans appeared in the diet and detritus decreased in importance; aquatic insects also appeared in the diet during this season. In the Mid-wet season *P. tenellus* ate mainly microcrustaceans (particularly cladocerans) with smaller amounts of terrestrial and aquatic insects.

By the Late-wet–Early-dry season algae were the main component of the diet and remained so until the 1979 Late-dry season, when they were essentially the only food item, which is in contrast to the diet in the 1978 Late-dry season.

Habitat differences

Magela catchment

A total of 151 combined stomachs of *P. tenellus* were examined (all seasons combined): 28 (0% empty) from backflow billabongs, 28 (0% empty) from corridor waterbodies and 95 (3% empty) from floodplain billabongs.

The diet in the backflow billabongs was made up of fairly equal portions of algae and microcrustaceans (a wide variety) and a large terrestrial insect (mainly egg material) component (which was not present in the other two habitats). In the floodplain billabongs, *P. tenellus* ate substantial quantities of detritus.

Nourlangie catchment

In all, 25 stomachs of *P. tenellus* were examined (all seasons combined) from backflow billabongs. A high proportion (24%) of the stomachs were empty. The diet was based mainly on ostracods, cladocerans (*Diaphanosoma*), and green filamentous and blue-green algae.

Fullness

The mean fullness indices of *P. tenellus* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments are summarised in table 62. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 62 Mean fullness indices of *P. tenellus* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Habitat mean
Magela Creek catchment (regular sites only)							
Upstream of RUPA:							
Lowland sandy creekbed pool	n/s	n/s	3.0 (2)	n/s	n/s	n/s	3.0 (2)
Downstream of RUPA:							
Lowland shallow backflow billabong	0 (1)	3.0 (2)	2.4 (14)	2.8 (5)	3.3 (6)	n/s	2.6 (28)
Corridor anabranch billabong	n/s	n/s	n/s	3.6 (10)	1.7 (3)	n/s	3.2 (13)
Floodplain billabong	2.4 (19)	3.0 (21)	2.4 (23)	2.5 (6)	3.3 (20)	2.8 (20)	2.8 (109)
Nourlangie Creek catchment (regular sites only)							
Lowland channel backflow billabong	n/s	0 (1)	1.5 (12)	n/s	n/s	n/s	1.4 (13)
Lowland shallow backflow billabong	n/s	0.7 (7)	n/s	0 (1)	2.7 (3)	n/s	1.2 (11)
Lowland sandy creekbed pool	n/s	n/s	n/s	n/s	0 (1)	n/s	0 (1)
Seasonal mean (all sites)	2.5	2.4	2.3	3.1	3.1	2.8	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Seasonal changes

The mean seasonal fullness index (all habitats combined) remained fairly stable between the 1978 Late-dry and the 1978–79 Mid-wet seasons; it then rose to a higher level and remained stable to the end of the study.

Habitat differences

In the Magela catchment the few specimens found upstream of RUPA in lowland sandy creekbeds had fullness indices comparable with downstream habitats. In the Nourlangie catchment the mean fullness indices were generally much lower than in the Magela catchment.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- corridor anabranch billabong; 1979 Late-wet–Early-dry season
- lowland shallow backflow billabong; 1979 Mid-dry season
- floodplain billabong; 1979 Mid-dry season

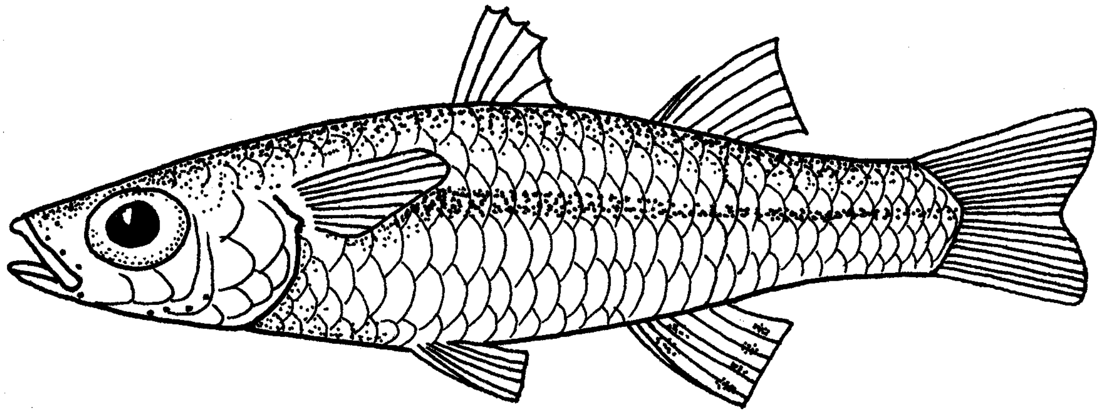
Nourlangie catchment

- lowland shallow backflow billabong; 1979 Mid-dry season.

Family ATHERINIDAE

3.17 *Craterocephalus marianae* (Ivantsoff, Crowley & Allen)

Craterocephalus marianae is commonly known as Mariana's freshwater hardyhead. It belongs to a mainly freshwater genus, with some estuarine and marine species. *Craterocephalus marianae* is found only in the Timor Sea drainage (see map 3). Pollard (1974) found this species (then identified as *C. marjoriae*) in very large schools over shallow, sandy areas. It was one of the most plentiful species in Magela Creek and its associated sandy-bottomed waterbodies.



Craterocephalus marianae

Details of the catches at each site and in each season are given in volume 2. In summary, this species was abundant in all escarpment mainchannel waterbodies, moderately abundant in most lowland sandy creekbed habitats and rare in some lowland backflow billabongs. It was found in the greatest number of sites in the 1978 Late-dry season (mainly escarpment mainchannel and lowland sandy creekbed habitats); it was found in the fewest sites during the Mid-wet season (mainly escarpment mainchannel waterbodies).

Size composition

The lengths and weights of 1730 specimens were determined. All specimens were captured by 10 mm mesh seine net. Very small specimens were frequently captured when filamentous algae clogged the mesh.

Length–weight relationship

The mean length–weight relationship was described by the expression:

$$W = 1.43 \times 10^{-2} L^{2.95} \qquad r = 0.98 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 63. The seasonal condition factor was stable (near unity) between the 1978 Late-dry and Mid-wet seasons. It rose dramatically in the Late-wet–Early-dry season to a record level, only to fall to its lowest by the Mid-dry season. This rise and fall may have been associated with spawning activity, as evidenced by the presence of large numbers of juveniles in the Mid-dry season. By the 1979 Late-dry season the condition factor had returned to a level close to that recorded in the 1978 Late-dry season.

Table 63 Mean length, mean weight and condition factor of *C. marianae*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	372	34.6	0.57	1.02
Early-wet (1978–79)	39	38.9	0.79	1.01
Mid wet	139	41.4	0.95	1.01
Late-wet–Early-dry (1979)	32	39.1	0.91	1.15
Mid-dry	152	42.8	1.00	0.96
Late-dry	192	32.1	0.45	1.01
Early-wet (1979–80)	74	37.3	0.61	0.88
Overall	1000	36.6	0.66	1.00

The condition factor fell to a very low level in the 1979–80 Early-wet season. Most specimens were captured during the first flow of the Wet season, which went as far downstream as Georgetown Billabong in the Magela Creek bed and then began to recede. Extreme water temperatures (> 40°C) and limited food availability (eg harpacticoid copepods would not have established in interstitial substrate waters) may have caused the poor body condition in this season.[109]

Length-frequency distribution

The smallest specimen captured in the study was 12 mm LCF; the largest was 72 mm LCF (fig 71). Ivantsoff (in McDowall 1980) reported that this species grows to 80 mm LCF.

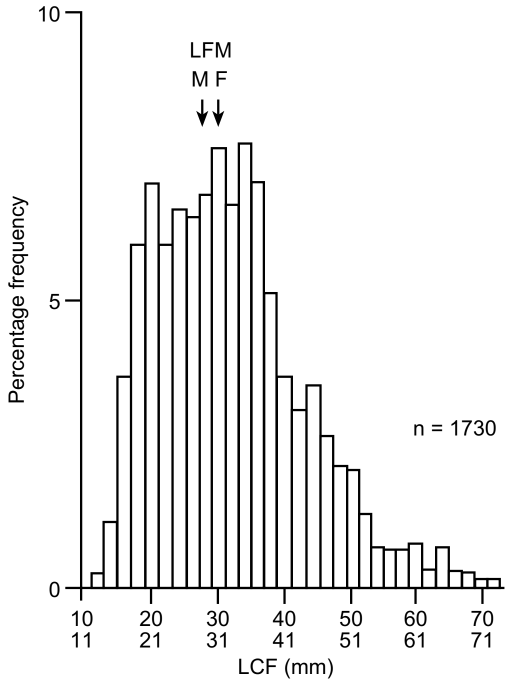


Figure 71 Length-frequency distribution of all *C. marianae* captured

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[109] Ward (1982) investigated the causes of dry-season mortality of *C. marianae* dwelling in pools within the lowland sandy creek habitat of Magela Creek.

The mean and modal lengths of all specimens captured were 32.5 and 34–35 mm LCF, respectively. A secondary mode occurred at 30–31 mm LCF. The LFM was 29 mm LCF for males and 32 mm LCF for females, indicating that slightly more adults than juveniles were captured. Most specimens were between 18 and 39 mm LCF; a slight negative skew was apparent in the distribution, indicating lower survival rates for larger-sized specimens.

Seasonal changes in distribution

The smallest juveniles were caught during the 1978 Late-dry, Late-wet–Early-dry and the 1979 Mid-dry seasons. The smallest specimen caught in the 1978–79 Mid-wet season was a large 29 mm LCF. The largest adults were caught in the Mid-wet and Mid-dry seasons.

Juveniles and small adults dominated the samples during the 1978 Late-dry season and larger adults were fewer (fig 72). By the 1978–79 Early-wet season there were noticeably fewer specimens near the LFM; the numbers of small to intermediate-sized adults increased dramatically at 36–37 mm LCF. The length-frequency distribution in the 1979 Late-dry season resembled that recorded in the 1978–79 Early-wet season, with differences caused by a narrower size range of specimens and a general shift to small adult specimens, leaving a noticeable gap in the numbers of large juveniles.

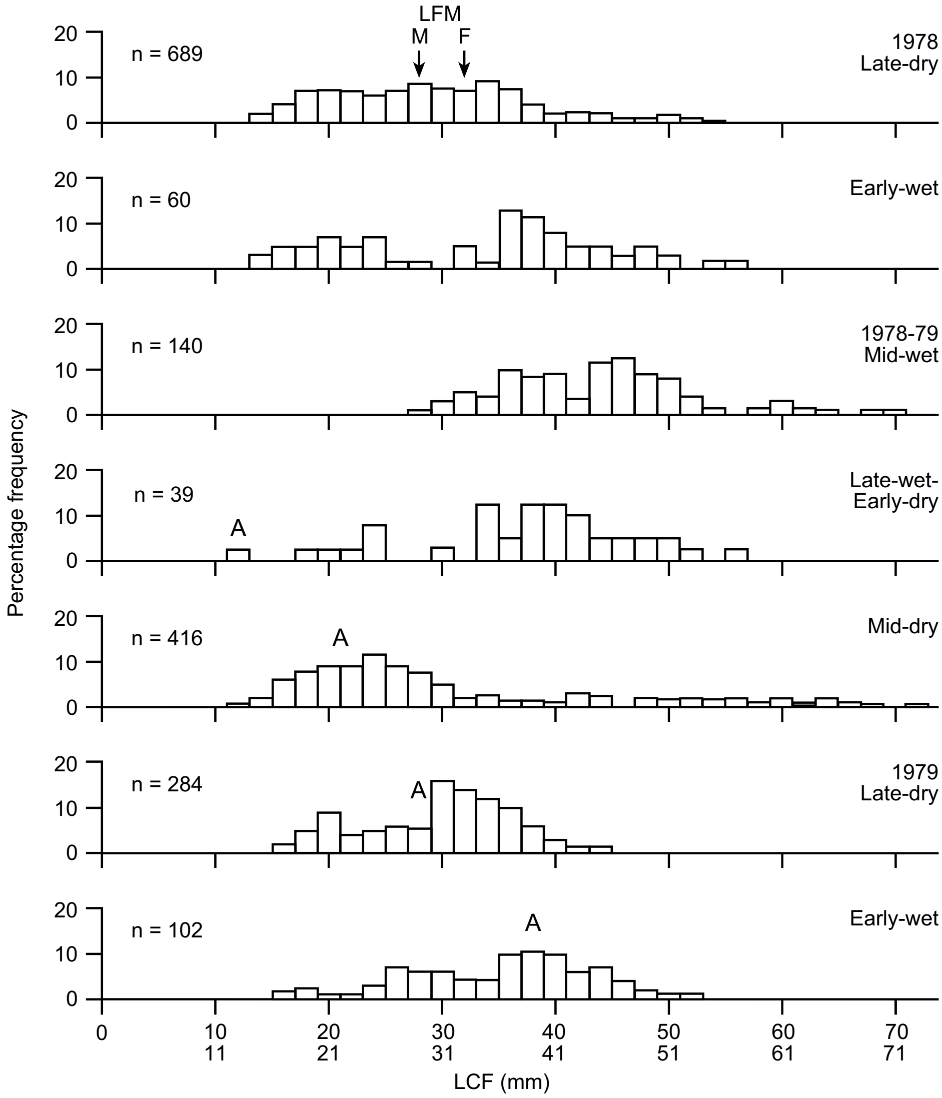

Figure 72 Seasonal length-distribution of all *C. marianae* captured

The 1979–80 Early-wet season length-frequency distribution was dominated by intermediate-sized adults and, to a lesser extent, by large juveniles and small adults; few small juveniles were captured in this season.

Very few large adults were found in the Late-dry and Early-wet seasons. Virtually no juveniles were found in the Mid-wet season, when samples were dominated by small to intermediate-sized adults and a few large adults. By the Late-wet–Early-dry season there were a few juveniles and many small and intermediate-sized adults in the samples, but few large adults. During the Mid-dry season a wide size-range of adults (though few in number) were captured together with very large numbers of juveniles.

Juveniles therefore recruited in all seasons except the Mid-wet (although this may have been an artefact of the difficulty of sampling flood-swollen creeks), and recruitment peaked in the Mid-dry and Late-dry seasons. Recruitment appeared to be most successful in the 1978 season.

Growth rate

Estimation of growth rate from seasonal length-frequency distributions was difficult due to frequency with which juveniles are recruited and the range of habitats sampled. However, modal progressions were apparent for juveniles from the Mid-dry season (24–25 mm LCF) until they reached the size of small adults (38–39 mm LCF) in the 1978–79 Early-wet season (about four months later).

If this apparent growth is real, then the LFM may be attained in less than eight months.[110] The closely related *C. fluviatilis* takes about eight months to grow from 25 to 33 mm in more temperate freshwater habitats (Llewellyn 1979).

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *C. marianae* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are given in figure 73.

Magela catchment

The smallest juveniles were found in lowland sandy creekbeds and escarpment mainchannel waterbodies; most of the juveniles were found in these habitats (especially the former). A few larger juveniles were found in corridor waterbodies and lowland backflow billabongs (mainly channel types). No juveniles were found in escarpment perennial streams.

The adults were captured in essentially the same habitats as the juveniles (ie mainly lowland sandy creekbeds where the largest specimen was found) and escarpment mainchannel waterbodies. Larger numbers of adults than juveniles were found in sandy creekbed habitats upstream of RUPA. No adults were found in escarpment mainchannel waterbodies.

Nourlangie catchment

Most juvenile and adult *C. marianae* were captured in escarpment mainchannel waters, and a few in lowland sandy creekbed sites and even lowland shallow backflow billabongs. *C. marianae* was also abundant in occasionally sampled sandy corridor waterbodies and the lower reaches of escarpment perennial streams. The adults captured in the Nourlangie catchment were larger than those in the Magela catchment.

Environmental associations

Rank numbers for *C. marianae* for the physico–chemical and habitat–structural variables are shown in table 155.

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[110] Under laboratory conditions with a water temperature of 26°C, Ivantsoff et al (1988) indicated that *C. marianae* can attain a total length of 21–28 mm in 127 days, and 43–44 mm in 245 days.

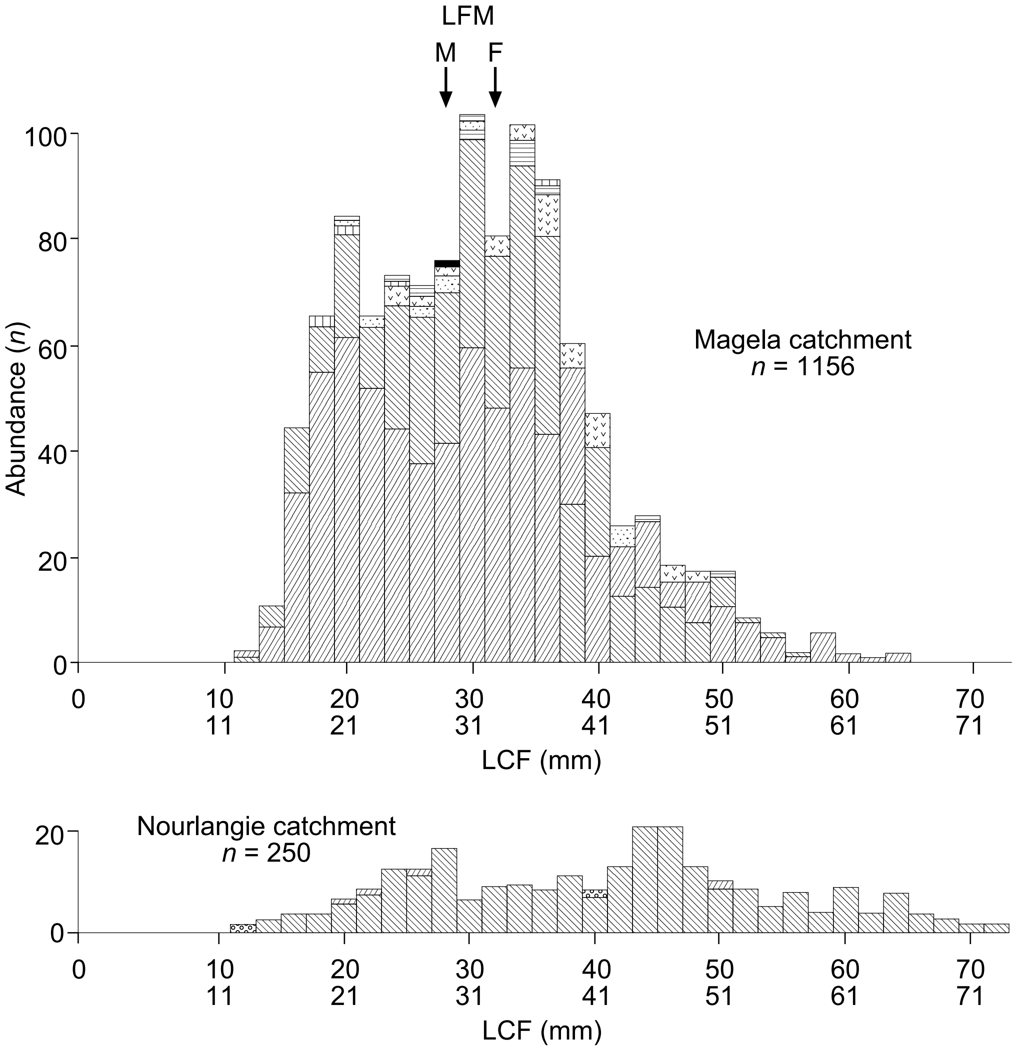

Figure 73 Length-frequency distributions and habitat preference of *C. marianae* captured at regular sampling sites (see appendix 5 for key to habitats)

Physico–chemical variables

Temperature

Surface-water temperatures ranged between 25° and 40°C (mean = 30.6°C), and bottom-water temperatures from 23° and 35°C (mean = 29.6°C). These means ranked in the lower-middle and upper-middle quarters, respectively (see fig 170). *Craterocephalus marianae* appears to tolerate a wide range of temperatures, as it was captured in both escarpment and lowland waters. The related *C. dalhousiensis* can also tolerate a range of temperatures, from 20° to 38.8°C, in natural conditions (Ivantsoff & Glover 1974). Llewellyn (1979) found that *C. fluviatilis* spawned when the water temperature exceeded 24°C, so water temperature may not be of significance to the breeding patterns of *C. marianae*.

Dissolved oxygen

Dissolved oxygen concentrations ranged from 3.2 to 8.2 mg/L (mean = 6.2) at the surface, and from 5.2 to 6.8 mg/L (mean = 6.2) at the bottom. These means ranked in the upper-middle and upper quarters, respectively (see fig 171). Such high bottom DO concentrations might be expected for a species that was commonly found in shallow waters (see Pollard 1974).

Visibility

Secchi depth readings ranged from 1 to 130 cm (mean = 44 cm). This mean ranked in the lower-middle quarter (see fig 172). Since *C. marianae* is usually found in shallow, sandy watercourses, the low Secchi depth values are caused more by the shallowness of the water at many habitats than by the lack of clarity of the water.

pH

The pH values ranged from 4.3 to 8.3 (mean = 6.3) on the surface, and from 5.4 to 7.0 (mean = 6.2) on the bottom. These means both ranked in the upper-middle quarter. Tolerance to a wide range of pH values is indicated (see fig 173).

Conductivity

Water conductivities ranged from 4 to 160 µS/cm on the surface, and from 2 to 64 µS/cm on the bottom. Such low values may be a function of this species' preference for waters with sandy substrates and possible underground seepage. *Craterocephalus* spp. are thought to be primarily freshwater dwellers (Pollard 1974); however, the closely related *C. eyresii* has been found living in inland waters of 39 ppt salinity (Ruello 1976).

Habitat–structural variables

Substrate

Craterocephalus marianae was most commonly found in waters with sandy substrates (upper quarter), followed by leaf litter (upper quarter) then rocks and mud (see fig 174). Both *C. marianae* and *C. stercusmuscarum* were often found in sandy-bottomed waterbodies of the Magela Creek system (Pollard 1974).

Hydrophytes

Craterocephalus marianae was found not commonly found in vegetated waters (vegetation-occurrence index 46.3%): submergent hydrophytes (50.8%), emergent (34.4%) and floating-attached vegetation. *Craterocephalus stercusmuscarum* was found in similarly vegetated habitats.

Reproduction

The reproductive state of the 374 specimens was assessed: 186 females (length range 20–70 mm LCF), 137 males (22–67 mm LCF) and 51 sexually indistinguishable (13–44 mm LCF).[111]

Length at first maturity

The smallest sexually maturing males and females were 22 and 28 mm LCF, respectively. The LFM, estimated from 2 mm groupings, was 29 mm LCF for males and 32 mm LCF for females (fig 74).

Sex ratio

The sex ratio was 1:1 for both juveniles + adults and adults only in all seasons, except during the 1978 Late-dry and 1979 Mid-dry seasons, when there were significantly more females than males in the juveniles + adults sample. In the 1978 Late-dry season there were also more females amongst the adult fish (table 64).

A further breakdown of the sex ratios for each site in the 1978 Late-dry and 1979 Mid-dry seasons revealed that in most cases there were more females present but the differences were not significant at the 5% level except at a small sandy creekbed pool.

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[111] Semple (1986) indicated that females over 30 mm SL had more convex dorsal profiles than the males, making them appear deeper anteriorly. Gravid females developed distended bellies. No colour changes associated with spawning were observed in either sex.

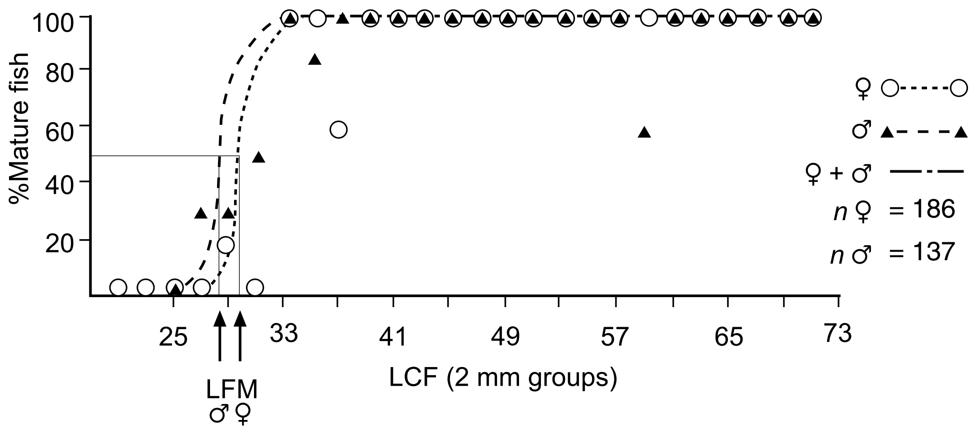

Figure 74 Estimated length at first maturity (LFM) of male and female *C. marianae*

The predominance of females suggests a behavioural characteristic of the fish at a particular time of the year, as conditions in the 1978 Late-dry and the 1979 Mid-dry seasons were very similar, and fish were unable to migrate between pools. Misidentification of male fish as sexually indistinguishable was unlikely, as the sex ratios recorded differed in only two seasons and such misidentification is most likely in the earliest stages of gonad development (which was generally only in the Mid-wet season, when a 1:1 ratio was recorded).

Breeding season

Both GMSI and GSI were high throughout the year, with a peak in gonad development around the Early-wet seasons and a trough in the 1978–79 Mid-wet season (fig 75, table 64).[112] Juveniles were present, and the gonads appeared to be well developed, throughout most of the year. Stage V and stage VI gonads were found in male fish in almost all seasons, while mature and ripe female fish were more common in the 1978 Late-dry and both Early-wet seasons.

Both males and females had well-developed gonads throughout the year, and there may have been occasional spawning, but the main spawning appears to have occurred in the 1978–79 Early-wet season, with gonads starting to develop again after the Mid-wet season.

Site of spawning

C. marianae appears to spawn in the escarpment mainchannel waterbodies and lowland sandy creekbed streams or pools (table 65). Some juveniles and mature specimens were captured in other areas such as lower riverine floodplain billabongs and tidal billabongs. *Craterocephalus marianae* has not to date been bred successfully in still water ponds (H. Midgley, pers. comm.).[113]

Fecundity

The egg counts of three ovaries were 380, 388 and 429. In two of the ovaries the egg diameters were 0.73 ± 0.05 mm (*n* = 10) and 0.75 ± 0.07 mm (*n* = 10). The ovaries contained eggs of different sizes, indicating progressive development. Thus *C. marianae* appears to have a medium to large store of relatively large eggs, although it is not known how many eggs are spawned at a time.[114] The family Atherinidae typically produce relatively large eggs with adhesive filaments, which attach them to vegetation, gravel or other objects in the water (Lake 1971).

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[112] Under laboratory conditions, Semple (1986) found that males displayed spawning behaviour when water temperature exceeded 25.5°C. The female spawned during 3–5 days and each spawning period was followed by a rest period of 3–5 days.

[113] Under laboratory conditions, Semple (1986) found that *C. marianae* spawned within beds of aquatic plants.

[114] Under laboratory conditions, Semple (1986) found that *C. marianae* released 30–250 eggs in spawning periods lasting 3–5 days.

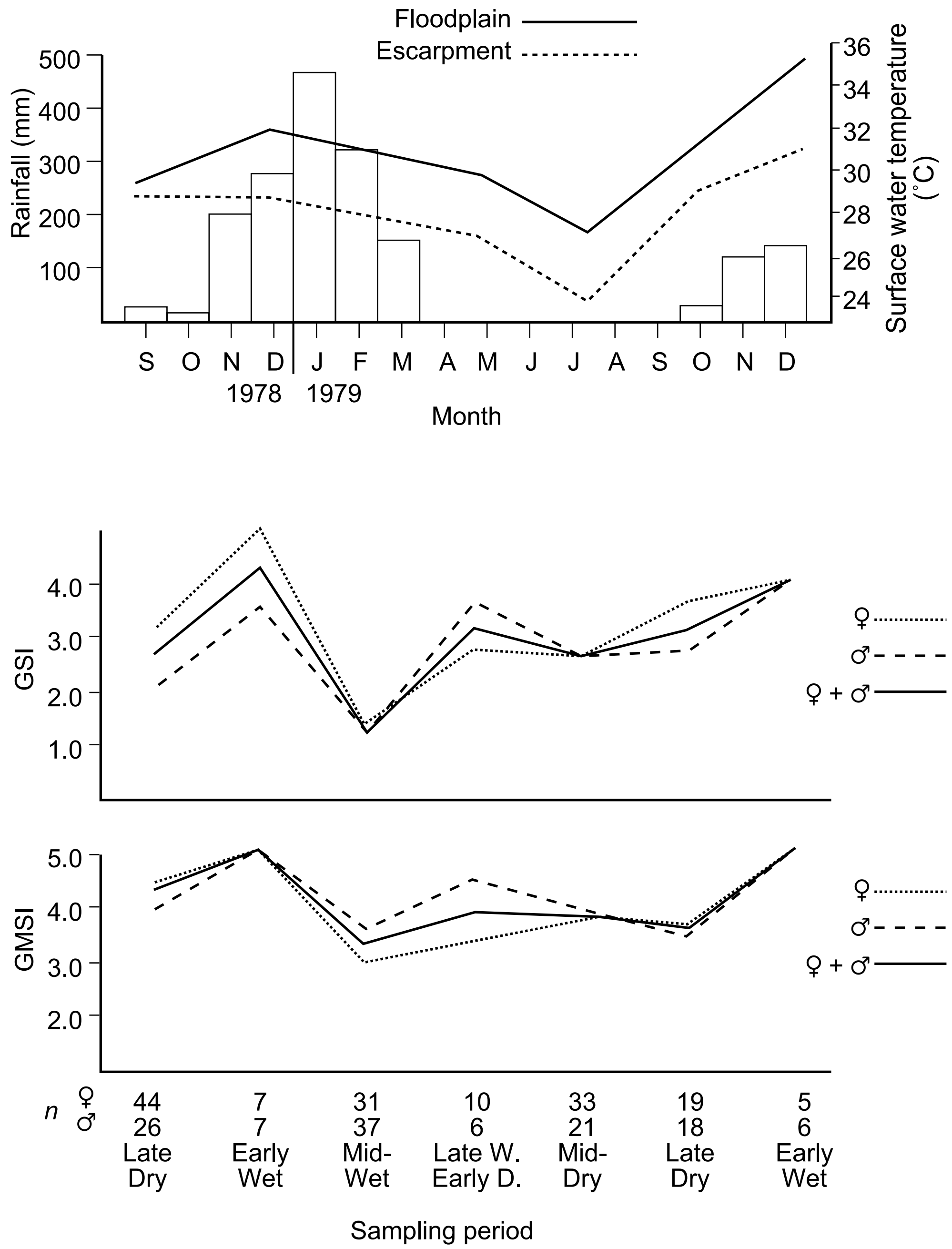

Figure 75 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *C. marianae*

Summary

Craterocephalus marianae most likely breeds in the larger escarpment pools and lowland sandy creekbed streams and pools, producing a medium to large clutch of large eggs that attach by filaments to aquatic vegetation, gravel or other objects in the water. Spawning appears to be aseasonal, with a peak in gonad development at the start of the Wet season.[115] The gonads are not paired and the ovary is covered by a distinctive black mesovarium that, unlike in *C. stercusmuscarum,* does not adhere closely to the ovary.

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[115] Semple (1986) and Ivantsoff et al (1988) have subsequently described spawning behaviour, egg surface morphology and embryonic development of *C. marianae.*

Table 64 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *C. marianae* over all habitats

Parameter	Sex	Statistic	Sampling period Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	56	8	39	11	46	21	5
+ adults	M	*n*	37	7	37	6	26	18	6
	χ^2	3.9	0.07	0.05	1.5	5.6	0.2	0.09	
		P	*	n.s.	n.s.	n.s.	*	n.s.	n.s.
Adults only	F	*n*	44	7	31	10	33	19	5
	M	*n*	26	7	37	6	21	18	6
	χ^2	4.6	0.0	0.5	1.0	2.7	0.03	0.09	
		P	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
(Adults only)	F	mean	3.2	5.1	1.4	2.8	2.6	3.7	4.1
		s.d.	1.0	1.1	0.6	0.7	0.9	1.1	1.9
	M	mean	2.1	3.6	1.2	3.7	2.7	2.8	4.1
		s.d.	1.3	2.0	0.5	1.5	1.5	1.6	1.8
	F+M	mean	2.7	4.3	1.3	3.2	2.7	32	4.1
		s.d.	1.3	1.8	0.6	1.2	1.2	1.4	1.7
GMSI									
(Adults only)	F	mean	4.5	5.0	3.0	3.4	3.8	3.7	5.0
		s.d.	0.7	0.0	0.9	0.5	0.5	0.4	0.8
	M	mean	4.0	5.1	3.6	4.5	4.0	3.5	5.1
		s.d.	0.9	1.6	1.1	0.5	0.8	1.0	0.9
	F+M	mean	4.3	5.1	3.3	3.9	3.9	3.6	5.0
		s.d	0.8	1.2	1.0	0.8	0.7	0.7	0.8

n = number; χ^2 = Chi-squared value; P = probability; n.s = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; s.d. = standard deviation.

Table 65 Possible sites of spawning of *C. marianae* as indicated by the abundance (*n*) of ripe and spent fish and juveniles

	Gonad stage Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	
Escarpment					
Mainchannel waterbody	5	15	1	2	30
Lowlands					
Sandy creekbed habitat	13	7	5	8	55
Backflow billabong	7	–	–	–	–
Floodplain billabong					
Lower	–	–	–	–	2
Estuarine habitat					
Upper reaches	–	3	–	–	–

Feeding habits

Overall diet

The stomachs of 373 specimens were examined; 365 contained food. The diet is summarised in fig 76; the components of the diet are given in table 66. The main components of the diet were aquatic insects (41%), microcrustaceans (34%) and algae (7%). The aquatic insects were mainly chironomids, leptocerids and ceratopogonid larvae. The main identifiable microcrustaceans were harpacticoid copepods and cladocerans. The identifiable algae were mainly green filamentous species. Inorganic material (4%) and unidentified organic material (13%) were also found in the stomachs, as well as traces of oligochaetes, aquatic arachnids, macrocrustaceans, teleosts, anuran larvae, and detritus. *Craterocephalus marianae* can thus be classified as a microphagous carnivore (perhaps occasionally an omnivore, unless it ingests plant material incidentally) feeding opportunistically, primarily on the bottom and secondarily in mid-water.

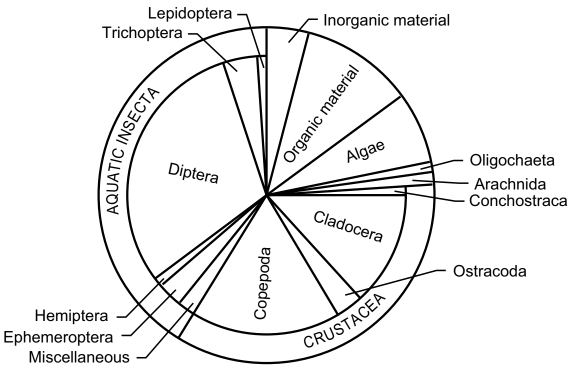


Figure 76 The main components of the diet of *C. marianae*

Pollard (1974) speculated that the diet of *C. marianae* probably included insect larvae and small insects from the water's surface and that the young might eat zooplanktonic crustaceans (eg copepods). However, in the present study, although aquatic insects were common, no surface-dwelling or terrestrial insects were found in the diet, and all size groups of *C. marianae* were eating copepods and other zooplankton.

The presence in the diet of inorganic material and a large component of chironomid larvae and harpacticoid copepods (some species of which are found in the interstices of substrate material [Williams 1968]) indicates that *C. marianae* is generally a benthic feeder. This diet is in accord with its modified protrusible jaws (premaxillary process long and slender [Ivantsoff, in McDowall 1980]), which enable it to direct the mouth obliquely downwards to feed across mainly sand substrates (pers. obs.).

Seasonal changes

In sampling periods 1–7, respectively, 117 (4% empty), 25 (0% empty), 79 (0% empty), 20 (5% empty), 80 (3% empty), 40 (0% empty) and 12 (0% empty) stomachs of *C. marianae* were examined (all seasons combined). The proportion of specimens with empty stomachs was low throughout the study.

Aquatic insects were important in the diet throughout the study. Chironomid larvae were most important in the Early-wet seasons and the Late-wet–Early-dry season. Chironomid pupae were most important in the 1978–79 Early-wet and Mid-wet seasons. Baetids were most common in the stomachs in the 1978–79 Early-wet and the Late-wet–Early-dry season. Leptocerids were very important in the diet during the 1979 Late-dry season.

Table 66 Dietary composition of *C. marianae*

	Habitat						Season								
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Em	Ls	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants															
Algae															6.7
Miscellaneous	4.8	2.4	–	–	0.8	–	4.7	–	–	–	5.3	–	–	2.6	
Chlorophyceae															
Desmidaceae	0.1	–	–	–	–	–	–	–	0.1	–	–	–	–	+	
Closterium	–	–	–	0.7	–	–	–	–	–	–	–	–	–	+	
Conjugatophyta															
Mougeotia	0.1	1.1	–	–	10.8	–	–	4.8	8.0	7.9	0.3	–	–	2.6	
Spirogyra	–	–	–	–	7.8	–	–	–	7.1	–	–	–	–	1.5	
Aquatic animals															
Oligochaeta	–	0.6	–	7.9	–	–	0.8	–	1.9	–	–	–	–	0.6	0.6
Arachnida															1.0
Porohalacaridae	0.1	–	–	–	–	–	0.1	–	–	–	–	–	–	+	
Hydracarina	0.3	–	–	–	0.1	–	–	–	–	–	0.3	–	–	1.0	
Microcrustacea															34.2
Conchostraca	–	–	–	–	–	–	3.2	–	–	–	–	–	–	1.0	
Cladocera															
Miscellaneous	12.6	3.2	70.0	–	6.3	22.5	23.6	–	1.1	2.1	15.0	2.3	–	11.1	
Diaphanosoma	1.5	3.2	–	–	1.7	–	–	4.0	1.2	8.4	0.5	2.5	16.7	1.9	
Ostracoda	12.6	–	–	–	–	–	–	–	11.7	–	–	0.3	–	2.6	
Copepoda															
Miscellaneous	1.4	–	20.0	47.9	–	–	8.6	–	0.6	–	–	–	–	2.8	
Harpacticoida	10.0	23.5	–	–	18.1	–	–	–	14.3	–	19.4	63.5	16.7	14.8	
Macrocrustacea															0.2
Macrobrachium (juv)	–	0.4	–	–	–	–	0.5	–	–	–	–	–	–	0.2	
Insecta															40.5
Fragmented	0.1	1.5	–	–	5.1	–	0.8	7.2	5.1	–	0.1	–	–	1.9	
Ephemeroptera															
Baetidae	1.1	1.6	–	28.7	1.1	–	3.0	8.0	1.0	11.6	–	–	–	2.3	
Tasmanocoenis	–	3.1	–	–	–	–	–	–	–	–	5.7	–	–	1.2	

Table 66 continued

	Habitat						Season								
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Em	Ls	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Hemiptera															
Corixidae	0.5	1.7	–	–	1.4	–	0.4	–	1.3	–	3.1	–	–	1.0	
Coleoptera															
Miscellaneous (larvae)	0.3	–	–	–	–	–	0.8	–	–	–	–	–	–	0.2	
Diptera															
Culicidae	–	–	–	–	0.1	–	–	–	0.1	–	–	–	–	+	
Chironomidae (larvae)	29.9	30.0	–	–	23.4	–	20.0	47.6	10.5	63.7	33.7	1.5	66.7	24.5	
Chironomidae (pupae)	–	2.1	–	–	1.4	–	–	4.0	3.8	–	–	–	–	1.1	
Ceratopogonidae	2.8	3.0	–	–	4.8	–	4.3	4.8	–	1.1	9.2	–	–	3.7	
Trichoptera															
Leptoceridae	17.6	1.1	–	–	0.4	–	1.0	–	1.4	–	1.0	29.8	–	4.1	
Lepidoptera															
Pyralidae	2.6	–	–	–	–	–	–	–	–	–	2.5	–	–	0.5	
Teleostomi															+
Scales	0.1	–	–	–	–	–	–	–	–	–	–	0.3	–	+	
Anura													0.3		
Miscellaneous (larvae)	–	–	–	–	–	25.0	–	4.0	–	–	–	–	–	0.3	
Parasites															
Nematoda	–	–	–	0.7	0.5	–	0.1	–	0.4	–	–	–	–	0.1	0.1
Detrital material	–	1.1	–	–	–	–	1.4	–	–	–	–	–	–	0.4	0.4
Inorganic material	1.6	7.5	–	–	2.4	–	1.5	0.8	14.2	–	2.6	–	–	4.1	4.1
Organic material	–	12.9	10.0	14.3	13.8	52.5	25.3	14.8	16.1	5.3	1.3	–	–	12.8	12.8
Number of empty fish	–	4	2	–	–	–	5	–	–	1	2	–	–	8	8
Number of fish with food	74	142	10	7	72	4	112	25	79	19	78	40	12	365	365

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs

Microcrustaceans were common in the diet throughout the study; harpacticoid copepods were most important during the 1979 Late-dry season; cladocerans were important in the 1978 Late-dry season and then again after the Wet season, and also in the 1979–80 Early-wet season; ostracods were most important during the Mid-wet season.

Algae were most common in the stomachs between the 1978–79 Mid-wet and Late-wet–Early-dry seasons, after which they became less common.

Habitat differences

Magela catchment

A total of 239 stomachs of *C. marianae* were examined (all seasons combined) in the Magela Creek catchment: 74 (0% empty) from escarpment mainchannel waterbodies; 146 (3% empty) from lowland sandy creekbeds; 12 (17% empty) from backflow billabongs; and 7 (0% empty) from floodplain billabongs. The highest proportion of specimens with empty stomachs was found in backflow billabongs.

The diet in the escarpment mainchannel waterbodies was based primarily on aquatic insects (chironomid and leptocerid larvae) and microcrustaceans (cladocerans, ostracods and harpacticoid copepods). In the lowland sandy creekbeds, harpacticoid copepods were eaten more intensively; inorganic material and unidentified organic material were also more common in the stomachs. The few specimens examined from the lowland backflow billabongs were eating only microcrustaceans (cladocerans). Copepods, along with baetid larvae and oligochaetes, were the main food items in the corridor waterbodies.

Nourlangie catchment

A total of 76 stomachs of *C. marianae* were examined (all seasons combined) from the Nourlangie Creek catchment: 72 from the escarpment mainchannel waterbody and 4 from lowland sandy creekbeds.

Mainly aquatic microcrustaceans (harpacticoid copepods and cladocerans), aquatic insects (chironomid and ceratopogonid larvae) and green filamentous algae were eaten in the escarpment mainchannel waterbody. The proportions of algae eaten in the escarpment habitat were larger in the Nourlangie Creek catchment than in the Magela Creek catchment. The few specimens from lowland sandy creekbeds were feeding on equal amounts of cladocerans and anuran larvae; there was also a large amount of unidentified organic material in their stomachs.

Fullness

A summary of mean fullness indices of *C. marianae* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 67.

Seasonal changes

After the 1978 Late-dry season the mean seasonal fullness index (all habitats combined) rose slightly through the 1978–79 Early-wet season to peak in the Mid-wet season. In the Late-wet–Early-dry season the index fell slightly and then rose to peak by the 1979 Late-dry season.

Habitat differences

In the Magela catchment, upstream of RUPA, the highest mean fullness indices were found in fish from the escarpment mainchannel waterbody and the lowest in the few specimens from the shallow backflow billabong.

Downstream of RUPA, the highest mean indices (equivalent to those found upstream of RUPA) were found in lowland sandy creekbed sites and corridor anabranch billabongs; the lowest indices were found in channel backflow billabongs.

Table 67 Mean fullness indices of *C. marianae* in different sampling periods and habitats

Habitat	Sampling period Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	3.4 (10)	n/s	3.9 (14)	n/s	3.9 (20)	4.0 (20)	3.5 (10)	3.8 (74)
Lowland shallow backflow billabong	2.3 (3)	n/s	n/s	n/s	n/s	n/s	n/s	2.3 (3)
Lowland sandy creekbed pool	n/s	n/s	3.1 (15)	2.5 (10)	3.7 (16)	n/s	3.0 (2)	3.2 (43)
Downstream of RUPA:								
Lowland sandy creekbed pool	2.8 (30)	3.6 (11)	3.6 (9)	3.6 (10)	3.0 (30)	3.9 (20)	n/s	3.3 (110)
Lowland channel backflow billabong	1.4 (9)	n/s	n/s	n/s	n/s	n/s	n/s	1.4 (9)
Lowland shallow backflow billabong	2.7 (3)	n/s	n/s	n/s	n/s	n/s	n/s	2.7 (3)
Corridor sandy billabong	n/s	2.5 (2)	n/s	n/s	n/s	n/s	n/s	2.5 (2)
Corridor anabranch billabong	3.0 (3)	n/s	n/s	n/s	n/s	n/s	n/s	3.0 (3)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	4.6 (5)	2.9 (11)	3.2 (36)	n/s	3.3 (18)	n/s	n/s	3.3 (70)
Lowland sandy creekbed pool	2.3 (3)	0 (1)	n/s	n/s	n/s	n/s	n/s	1.7 (4)
Seasonal mean (all sites)	2.9	3.2	3.4	3.1	3.5	4.0	3.4	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

In the Nourlangie catchment, the mean indices recorded in the escarpment mainchannel waterbody were slightly lower than those recorded in equivalent Magela Creek habitats. The few specimens examined from the lowland sandy creekbed pool had very much lower indices than those recorded in the Magela catchment.

Summary

The habitats and periods of greatest feeding activity were:

Magela catchment

- escarpment mainchannel waterbody; 1979 Late-dry season, 1978–79 Mid-wet season, 1979 Mid-dry season
- lowland sandy creekbeds (downstream of RUPA); 1979 Late-dry season

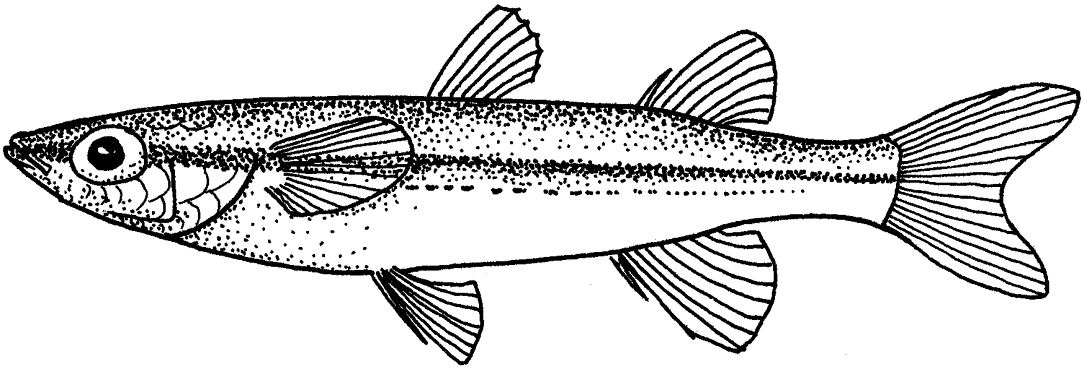
Nourlangie catchment

- escarpment mainchannel waterbody; 1978 Late-dry season, 1979 Mid-dry season

Family ATHERINIDAE

3.18 *Craterocephalus stercusmuscarum* (Gunther)

Craterocephalus stercusmuscarum is commonly known as the fly-specked hardyhead, Worrel's hardyhead or (in the Murray–Darling system) the Mitchellian freshwater hardyhead. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3). Subspecies have been found in the northern rivers of the Murray–Darling system (where it has been known as *C. fluviatilis*), in freshwater lakes on Fraser Island, and in the rivers of southern Queensland. Pollard (1974) found that larger specimens of this species were relatively uncommon, compared with *C. marianae,* in shallow sandy habitats of the Magela Creek system. In contrast, Miller (cited in Taylor 1964) found this species to be abundant in large billabongs in the Oenpelli area. This species belongs to a mainly freshwater genus, but it also has representatives in estuarine and marine waters.



Craterocephalus stercusmuscarum

Craterocephalus stercusmuscarum was relatively abundant at the sites examined in the present study; detailed information on catches at each site and in each season is given in volume 2. In summary, this species was moderately abundant in all corridor waterbodies, lowland sandy creekbed sites and most floodplain billabongs. It was also common in lowland backflow billabongs (in contrast to *C. marianae*) and escarpment mainchannel waterbodies; it was rare in perennial streams. It was found in the greatest number of sites during the Mid-wet season, and in the least number of sites during the 1978 Late-dry season.

Size composition

The lengths and weights of a total of 1976 specimens were determined. The smallest juveniles were captured most frequently in the 10 mm mesh seine net when the meshes were clogged by filamentous algae.

Length–weight relationship

The length–weight relationship was described by the expression:

$$W = 1.10 \times 10^{-2} L^{2.88} \qquad r = 0.97 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 68. The seasonal condition factor was stable (near unity) between the 1978 Late-dry season and the Mid-wet season and dropped slightly in the Late-wet–Early-dry season. This fall in condition may be attributed to spawning activity, the anoxic conditions recorded in most backflow billabongs during this season, or both. The condition factor rose in the Mid-dry season, only to drop dramatically in the 1979 Late-dry season (well below that recorded in the equivalent 1978 season) and remain low in the 1979–80 Early-wet season. This drop in condition may have been associated with adverse environmental conditions in the 1979 Dry season.

Table 68 Mean length, mean weight and condition factor of *C. stercusmuscarum*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late dry (1978)	138	37.7	0.50	1.00
Early-wet (1978–79)	165	36.8	0.48	1.01
Mid-wet (1979)	228	42.2	0.71	1.02
Late-wet–Early-dry (1979)	46	42.0	0.65	0.96
Mid-dry	89	35.3	0.41	0.99
Late-dry	22	36.5	0.42	0.91
Early-wet (1979–80)	23	41.9	0.63	0.93
Overall	711	38.9	0.55	1.00

Length-frequency distribution

The smallest specimen captured in the study was 12 mm LCF; the largest was 68 mm LCF (fig 77). Ivantsoff (in McDowall 1980) reported that this species grows to 90 mm LCF, while Pollard (1974) noted that it reputedly grew to only 70 mm LCF.

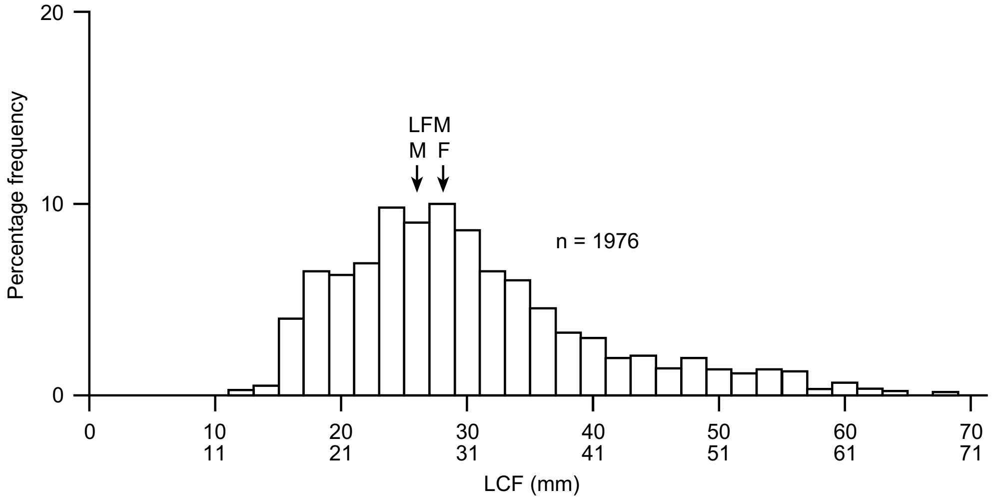


Figure 77 Length-frequency distribution of all *C. stercusmuscarum* captured

The mean and modal lengths of all specimens captured were 30.4 and 28–29 mm LCF, respectively. The LFM for males was 27 mm and for females 29 mm, which indicates that slightly more adults than juveniles were captured. Most specimens were between 15 and 40 mm LCF. The noticeable negative skew in the distribution indicated lower survival rates for larger fish.

Seasonal changes in distribution

The smallest juveniles were found between the 1979 Late-wet–Early-dry and Late-dry seasons. The largest adults were found in the Late-wet–Early-dry season, followed closely by the Mid-wet season (fig 78).

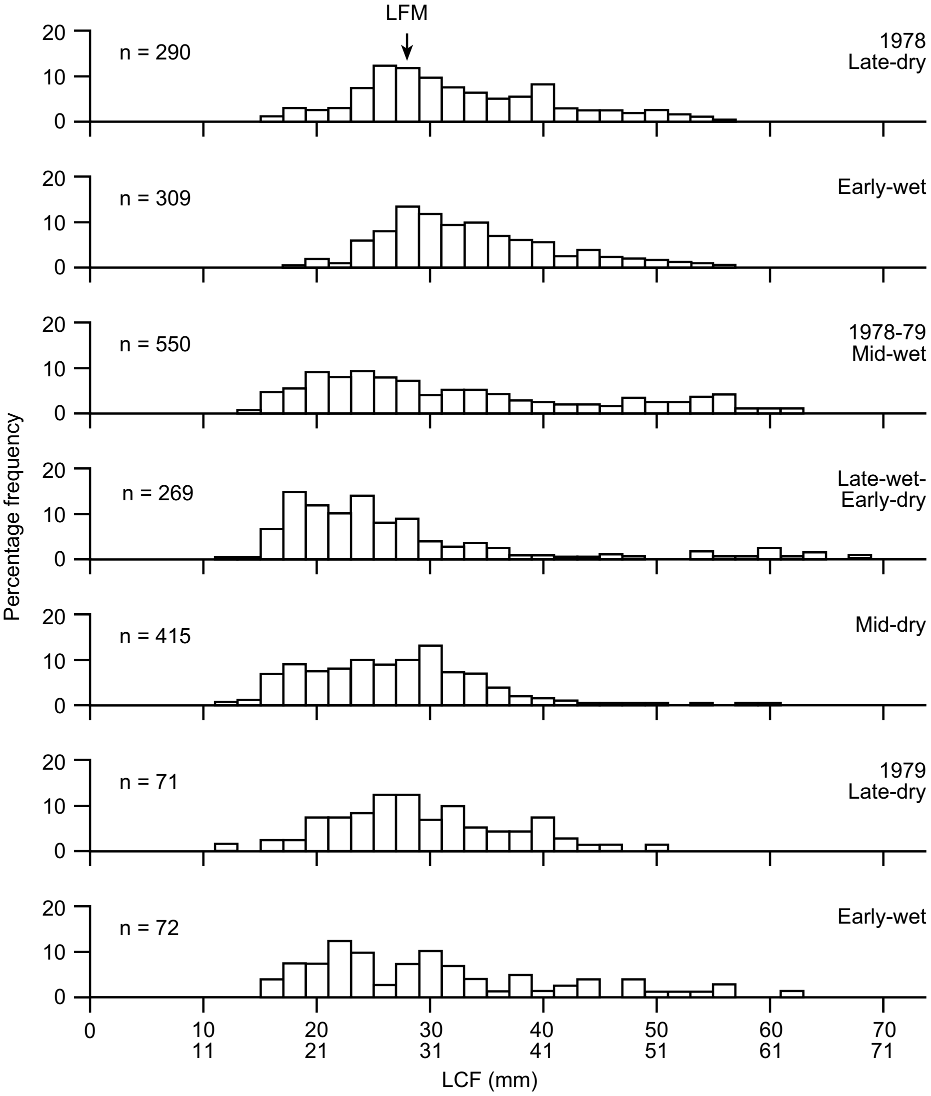


Figure 78 Seasonal length-frequency distribution of all *C. stercusmuscarum* captured

In the 1978 Late-dry season, most specimens were large juveniles and small adults, with smaller numbers of large adults. By the 1978–79 Early-wet season, there were more small adults than large juveniles, as the latter had grown over this period. The length-frequency distribution in the 1979 Late-dry season was essentially similar in form to that in the equivalent 1978 season; however, there was a juvenile peak during the Early-wet season of 1979–80, unlike the previous year.

By the 1978–79 Mid-wet season a strong and wide juvenile peak appeared in the distribution, and the small adults from the previous season had survived and grown, resulting in a continuous size-range of adults (which were abundant) during this season. In the Late-wet–Early-dry season there was another strong and wide juvenile peak, but a much reduced — and discontinuous — size-range of adults. By the Mid-dry season the juveniles still dominated the samples, with a slight shift towards larger specimens and small adults; the larger adults that were present in the Mid-wet season had almost disappeared.

Juveniles recruited at all seasons, especially perhaps between the Mid-wet and Mid-dry seasons. The survival rate of large adults appeared to be highest in the Mid-wet season, declining into the 1979 Dry season.

Growth rate

Estimation of growth from the seasonal length-frequency distributions is very difficult due to the frequency with which juveniles recruited and the wide range of habitats sampled.

Llewellyn (1979) noted that the southern subspecies (as *C. fluviatilis*) attains 25 mm in four months, 35 mm in one year, and 45 mm in two years, in temperate waters of New South Wales. If the growth rates of the two forms are similar, then *C. stercusmuscarum* may attain its LFM by 4–5 months (ie juveniles present in the Mid-wet season may be spawning by the Mid-dry season).[116]

Habitat differences in distribution

Length-frequency distributions showing the habitat preferences of *C. stercusmuscarum* caught in regular sampling sites in the Magela and Nourlangie Creek catchments are given in fig 79.

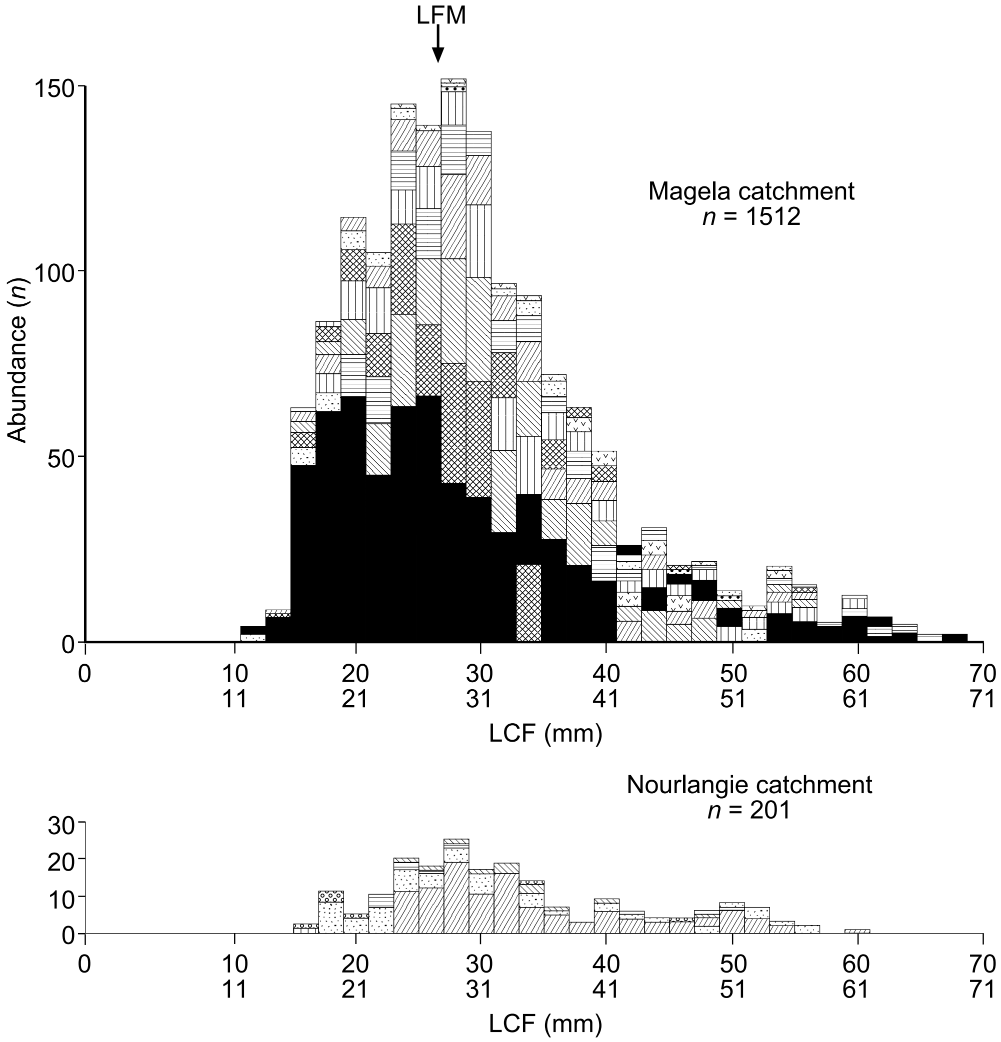


Figure 79 Length-frequency distributions and habitat preferences of *C. stercusmuscarum* captured at regular sampling sites (see appendix 5 for key to the habitats)

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[116] Under laboratory conditions with a water temperature of 26°C, Ivantsoff et al (1988) indicated that *C. stercusmuscarum* can attain a total length of 29–32 mm in 127 days, and 46–57 mm in 14 months. Milton and Arthington (1983) presented data that indicated that *C. stercusmuscarum* in a stream in south-eastern Queensland can attain a standard length of 33 mm within its first year of life.

Magela catchment

The smallest juveniles (12–13 mm LCF) were captured in sandy corridor waterbodies, lowland sandy creekbeds and lowland channel backflow billabongs. The juveniles were found most often in floodplain billabongs, followed by corridor and escarpment mainchannel waterbodies; smaller numbers were found in backflow billabongs and sandy creekbed habitats (in contrast to *C. marianae*). Juveniles appeared in escarpment perennial streams during the 1979 Late-dry season.

Small adults were found in the same habitats as the large juveniles, with slightly more in sandy creekbed habitats. Large adults were found fairly evenly across a wide range of habitats, especially escarpment mainchannel billabongs, lowland sandy creekbeds and lowland backflow billabongs. Slightly fewer were found in floodplain billabongs (although the largest specimen was captured from one).

Nourlangie catchment

Small juveniles were most frequently captured in backflow billabongs (especially channel types); larger juveniles were captured mainly in lowland sandy creekbed habitats, although a few were found in escarpment mainchannel waterbodies.

Adult *C. stercusmuscarum* were mainly captured in sandy creekbed habitats (as was the largest specimen recorded in the catchment). Smaller numbers were recorded in backflow billabongs (again especially channel types) and escarpment mainchannel billabongs. A few small adults were recorded in escarpment perennial streams during the Mid-wet season.

Environmental associations

The rank numbers for *C. stercusmuscarum* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Surface-water temperatures ranged from 25° to 43°C (mean = 30.9°C), bottom-water temperatures ranged from 24° to 36°C (mean = 29.7°C). These means both ranked in the upper-middle quarter (see fig 170). This range is wider than that of *C. marianae,* which is less widely distributed than *C. stercusmuscarum*.

Dissolved oxygen

Dissolved oxygen concentrations in waters where *C. stercusmuscarum* was found ranged from 0.9 to 8.2 mg/L (mean = 5.7 mg/L) on the surface, and from 2.5 to 6.8 mg/L (mean = 5.3 mg/L) on the bottom (see fig 171). It appears that *C. stercusmuscarum* can tolerate lower DO concentrations than *C. marianae* can; this may explain why *C. stercusmuscarum* is not found only in the sandy shallows preferred by *C. marianae*.

Visibility

Secchi depths ranged from 2 to 190 cm (mean = 48 cm) (see fig 172). This mean ranked in the lower-middle quarter. The values are close to those recorded for *C. marianae*. Although the two species were typically found together in sandy, shallow watercourses by Pollard (1974), *C. stercusmuscarum* is also often found in other habitats, which may account for the slightly wider range of Secchi depths recorded for its habitats.

pH

The pH values of surface waters ranged from 4.0 to 8.1 (mean = 6.1), and of bottom waters from 5.1 to 7.0 (mean = 6.1). These means ranked in the lower-middle and upper-middle quarters, respectively (see fig 173). The similarity between the two species of *Craterocephalus* in their ranges of pH tolerance is notable.

Conductivity

Craterocephalus stercusmuscarum was found in waters with conductivities ranging from 4 to 220 µS/cm on the surface, and from 2 to 110 µS/cm on the bottom. These ranges are wider than the corresponding ranges for *C. marianae* and may indicate a tolerance of higher levels of dissolved solids.[117]

Habitat–structural variables

Substrate

Craterocephalus stercusmuscarum was typically found over sand (upper-middle quarter), followed closely by mud (lower-middle quarter), clay, and then leaf litter. Apart from the common preference for sandy substrates (which was less marked in *C. stercusmuscarum*), the two species of *Craterocephalus* differ in their preference for other substrates; there is a higher incidence of clay and mud in waters where *C. stercusmuscarum* was found.

Hydrophytes

This species was found in moderately to heavily vegetated waters (vegetation-occurrence index 78.8%). The order of dominance of hydrophyte types was the same as for *C. marianae:* normally submergent (44.5%) followed by emergent (34.1%) and floating-attached hydrophytes. *Craterocephalus stercusmuscarum*, which has a wider distribution, was often found in more heavily vegetated waters than was *C. marianae* (Pollard 1974).

Reproduction

From a total of 764 gonads, 429 females (18–67 mm LCF), 274 males (18–60 mm LCF) and 61 sexually indistinguishable fish (15–58 mm LCF) were identified.

Length at first maturity

Both sexes were found to be maturing at 22 mm LCF; however, the LFM was 29 mm LCF for females and 27 mm LCF for males (fig 80).[118]

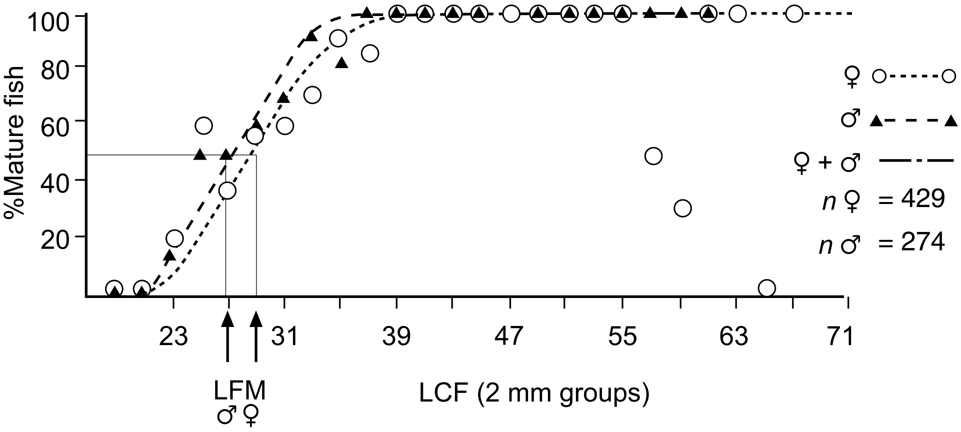

Figure 80 Estimated length at first maturity (LFM) of male and female *C. stercusmuscarum*

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[117] Williams and Williams (1991) found that mortalities of adults of *C. stercusmuscarum* from the Murray-Darling River system occurred at salinities of 36–50 ppt. The corresponding conductivities are far higher than any recorded in the Alligator Rivers Region.

[118] Milton and Arthington (1983) indicated that the minimum size at maturity for *C. stercusmuscarum* in a stream in south-eastern Queensland was 31 mm standard length.

In the Murray–Darling system, Ivantsoff (pers. comm.) found mature males and females of *C. fluviatilis* at 40 and 45.4 mm LCF, respectively. Growth estimates for *C. fluviatilis* suggested that they could mature at one years old in favourable conditions (the largest size observed was 104 mm, cf. 67 mm for *C. stercusmuscarum*).

Sex ratio

Significantly more females than males were caught during the 1978 Late-dry and 1979 Mid-dry seasons ($P < 0.001$) (table 69), and also in the 1978–79 Early-wet ($P < 0.05$). Ratios were not significantly different from 1:1 in the other seasons.[119] The sex ratios were almost identical to those for *C. marianae*. Although determining the sex of males was difficult, it is unlikely that this affected the results, as 1:1 ratios were found in seasons when male gonads were least developed (eg 1979–80 Early-wet season). Movements of fish between habitats was not generally possible during the Mid- and Late-dry seasons, so it is likely that a behavioural characteristic of one of the sexes at the sampling sites may have resulted in more females than males being collected. Conditions during the 1978 Late-dry and 1979 Mid-dry seasons were very similar; however, it is interesting to note that the sex ratio returned to around 1:1 by the 1979 Late-dry season.

Table 69 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *C. stercusmuscarum* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	77	99	84	52	70	34	13
+ adults	M	*n*	39	71	68	37	33	20	6
		χ^2	12.4	4.6	1.7	2.5	13.29	3.6	2.6
		P	***	*	n.s.	n.s.	***	n.s.	n.s.
Adults only	F	*n*	61	81	65	32	55	21	13
	M	*n*	32	64	62	24	25	11	6
		χ^2	9.0	2.0	0.1	1.1	11.25	3.1	2.6
		P	**	n.s.	n.s.	n.s.	***	n.s.	n.s.
GSI									
(Adults only)	F	mean	3.1	6.2	3.5	3.0	5.3	4.1	2.7
		s.d.	1.4	0.7	1.0	1.6	1.2	1.0	0.8
	M	mean	1.3	2.0	1.0	1.1	1.3	1.2	0.9
		s.d.	0.5	0.6	0.4	0.6	0.4	0.6	0.3
	F+M	mean	2.3	4.2	2.3	1.9	2.9	3.0	2.1
		s.d.	1.4	2.3	1.5	1.5	2.2	1.7	1.2
GMSI									
(Adults only)	F	mean	3.4	4.6	3.1	2.9	4.0	3.2	3.8
		s.d.	0.6	0.7	0.7	0.7	0.6	0.7	0.6
	M	mean	3.1	4.2	2.9	2.5	3.4	3.0	4.2
		s.d.	0.6	0.5	0.8	0.7	0.9	1.8	1.1
	F+M	mean	3.3	4.4	3.0	2.7	3.7	3.1	3.9
		s.d	0.6	0.6	0.7	0.7	0.8	1.2	0.6

n = number; χ^2 = Chi-squared value; p = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.01 < P < 0.001$; *** $P < 0.001$; s.d. = standard deviation.

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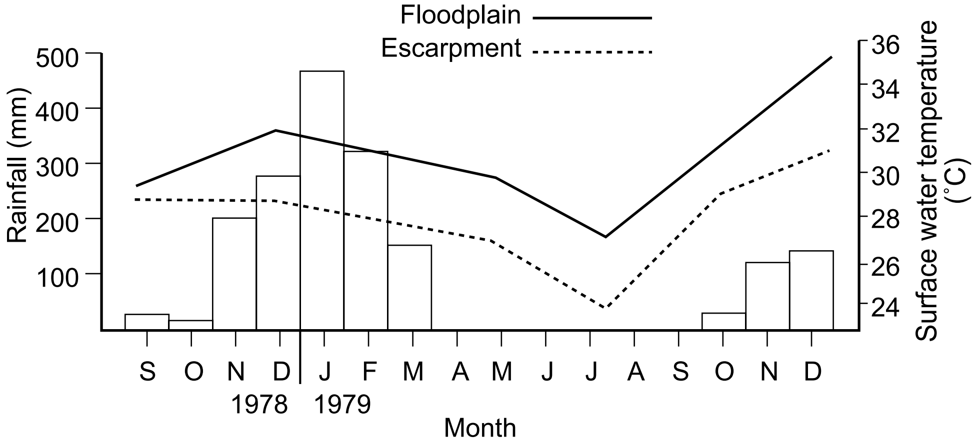
[119] Milton and Arthington (1983) indicated that sex ratios for *C. stercusmuscarum* in a stream in south-eastern Queensland did not vary significantly from the expected 1:1 ratio.

Breeding season

As for *C. marianae*, the GSI and GMSI were high for most of the year; the means for the females were significantly higher than those for the males in all seasons. There were peaks in reproductive development in the 1978 Early-wet and the 1979 Mid-dry seasons; in the latter, the female peak was greater than the male (fig 81, table 69). The highest GSI recorded was 6.2 for females and 2.00 for males (both in 1978–79 Early-wet season).



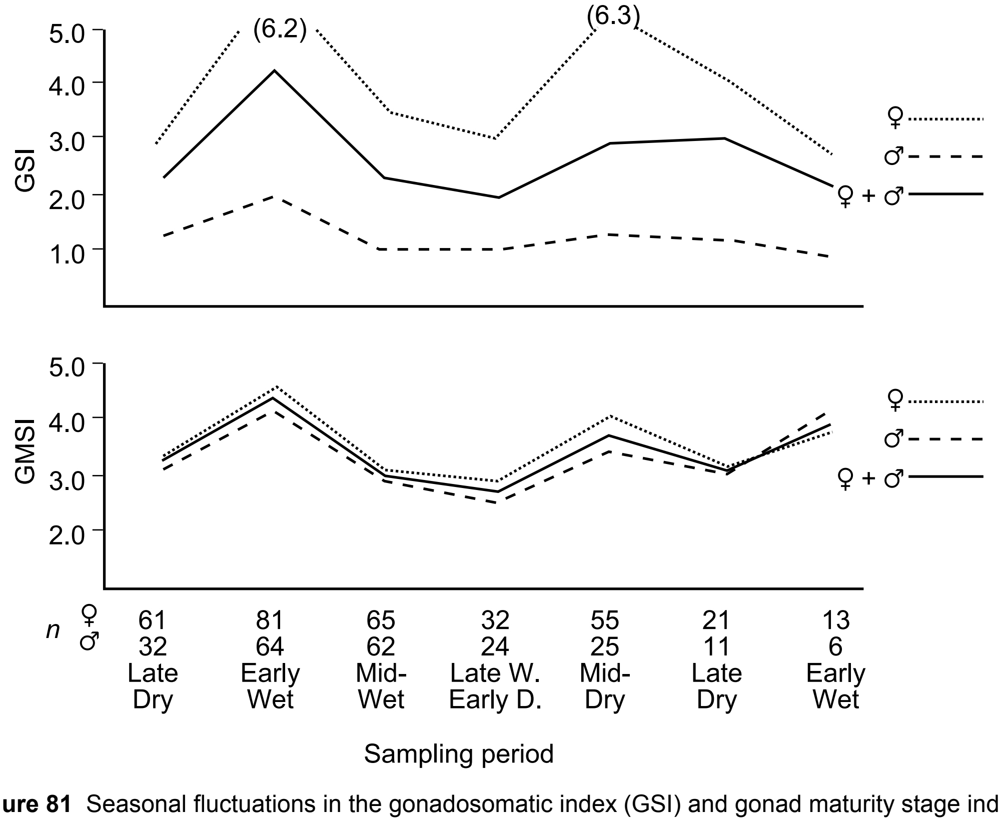


Figure 81 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) for male and female *C. stercusmuscarum*

The gonads of the closely related *C. fluviatilis* start developing in August for an extended breeding season from mid-October to mid-February; they spawn only when temperatures throughout the water column are above 23.6°C and there is some water flow. The highest GSI recorded for *C. fluviatilis* are 13.1 for females and 7.2 for males. However, the environmental conditions in the two seasons when the gonadal development of *C. stercusmuscarum* peaked were not alike: in the 1978–79 Early-wet season, water temperatures were above 28°C and flows were substantial; in the 1979 Mid-dry temperatures were below 25°C and there was no water flow. Spawning in this species may not necessarily be so dependent on the water temperature or presence of water flow.

Mature and ripe gonads were most common during the 1978–79 Early-wet season and, although no running ripe fish were captured during the 1979 Mid-dry season, maturing fish were found.

Maturing and running-ripe fish (both sexes) were caught from the 1978 Late-dry season through the next two seasons (ie until the 1979–80 Mid-wet season), which indicates a very extended breeding season. Although there was a peak in GSI (particularly female) in the 1979 Mid-dry season, and maturing males and females were collected then, no running-ripe fish were collected until the following two seasons (1979 Late-dry and 1979–80 Early-wet); all were males. This may also be due to the extended breeding season. The breeding season for *C. stercusmuscarum* appeared to start in the 1978 Late-dry season and extend through to the Mid-wet season, with gonads being well developed by the 1979 Mid-dry season. Juvenile fish (less than 20 mm) were captured in all but one season (1978–79 Early-wet), with the smallest being collected in the 1979 Late-wet–Early-dry and Mid-dry seasons.[120]

Site of spawning

During the 1978 Late-dry season, lowland sandy creekbeds contained specimens in spawning condition (83% of all females and 50% of males captured were running-ripe). In the 1978–79 Early-wet season, running-ripe fish were found in lowland sandy creekbeds, lowland shallow backflow billabongs and in a floodplain billabong (table 70). Running-ripe fish were also caught in lowland shallow backflow billabongs (1978–79 Mid-wet season), escarpment mainchannel waterbodies (1979 Late-dry season), and lowland sandy creekbeds (1979–80 Early-wet season).

Table 70 Possible sites of spawning of *C. stercusmuscarum* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	2	1	–	2	–	1	15
Seasonal feeder stream	–	–	–	–	–	–	11
Lowlands							
Sandy creekbed	14	4	10	4	–	–	18
Backflow billabong	5	5	4	–	–	–	1
Corridor	9	11	5	2	–	–	6
Floodplain billabong							
Upper	2	1	–	1	–	–	4

Small juveniles were caught in almost all habitats in the Magela Creek system, from escarpment mainchannel waterbodies through to floodplain billabongs. In the Nourlangie

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[120] Under laboratory conditions, Ivantsoff et al (1988) found that spawning becomes infrequent after spring and summer. The most common pattern for spawning was fish to spawn for several days, followed by variable periods of rest.

system maturing fish were caught in an escarpment mainchannel waterbody and in lowland sandy creekbeds; small juveniles (< 14 mm LCF) were collected from an escarpment spring-fed stream, a mainchannel waterbody and a lowland sandy creekbed.[121]

Fecundity

The gonads of *C. stercusmuscarum* are single and the ovary is covered by a black mesovarium. Nine gonads were examined. The mean number of eggs was 71 (range = 55–90). The mean egg diameter was 1.0 mm (*n* = 20) (range = 0.9–1.1 mm). There were two size-classes of eggs (the smaller was about 0.4 mm in diameter) and some eggs of intermediate sizes.[122]

The ova of *C. fluviatilis* in the Murray–Darling system develop progressively during an individual's spawning period, which appears to last for well over a month. Three size-classes of oocytes were found (0.04–0.10, 0.11–0.90 and above 0.90 mm diameter); the largest oocyte had a diameter of 1.52 mm. The fecundity range for *C. fluviatilis,* counting the largest eggs only, was between 20 and 107, and no correlation between the number of ova present in the ovary and the size of the fish was found (Llewellyn 1979).

The eggs of *C. stercusmuscarum* are spherical, transparent and demersal with a thick, sticky shell (Ivantsoff, in McDowall 1980). Adhesive filaments on the eggs are reported to be a general characteristic of the Atherinidae (Breder & Rosen 1966; Llewellyn 1979). The filaments attach the eggs to submerged objects.

Llewellyn (1979) recorded that the prolarvae of *C. fluviatilis* are about 3.4 mm in length and are well developed at hatching. He thought it unlikely that *C. fluviatilis* provided parental care because the spawning season was long, and the eggs are randomly dispersed throughout weedy areas; the same most likely applies to *C. stercusmuscarum*. Ivantsoff (1980) reported that *C. stercusmuscarum* spawned randomly, dispersing the eggs by spreading them over rocks or in crevices. The females rub against rocks and the males usually wait immediately behind to fertilise the eggs.

Summary

The sexes of *C. stercusmuscarum* have some characteristic markings. The females have a distinctive black mesovarium surrounding the singular ovary while the males are yellower on the ventral surface of their body; the yellow becomes stronger as the breeding season approaches.[123]

The breeding season extended from the 1978 Late-dry season through to the 1978–79 Mid-wet season. After a short quiescent period, the gonads developed again, ready for further breeding by the 1979 Mid-dry season. There was at least some spawning in the 1979 Late-dry and 1979–80 Early-wet seasons.

Craterocephalus stercusmuscarum bred in a wide range of habitats, from the larger escarpment area streams, the lowland sandy creekbeds and streams and shallow backflow billabongs to corridor waterbodies. Small specimens were most abundant in the escarpment area and lowland sandy streams and pools.

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[121] Under laboratory conditions, Ivantsoff et al (1988) found that *C. stercusmuscarum* spawned within beds of aquatic plants.

[122] Ivantsoff et al (1988) indicated that under stable laboratory conditions, females shed about 20 eggs per spawning. Milton and Arthington (1983) indicated that the mean fecundity for *C. stercusmuscarum* in a stream in south-eastern Queensland was 70 eggs/individual (range 5–126).

[123] Milton and Arthington (1983) found that male specimens in Queensland waters became more intensely golden below the mid-lateral stripe.

Craterocephalus stercusmuscarum probably uses similar breeding strategies to *C. fluviatilis* (Llewellyn 1979): progressive development of ova within the ovary while spasmodic spawning takes place, leading to an extended breeding season for each individual; a relatively small number of large demersal eggs, with adhesive filaments scattered randomly amongst the aquatic vegetation; an unknown length of incubation period, but are well developed prolarvae at hatching.[124]

Feeding habits

Overall diet

The stomachs of 766 specimens were examined; 731 contained food. The diet is summarised in fig 82; the components are listed in table 71. The main components of the diet were aquatic insects (38%), microcrustaceans (37%) and algae (9%).

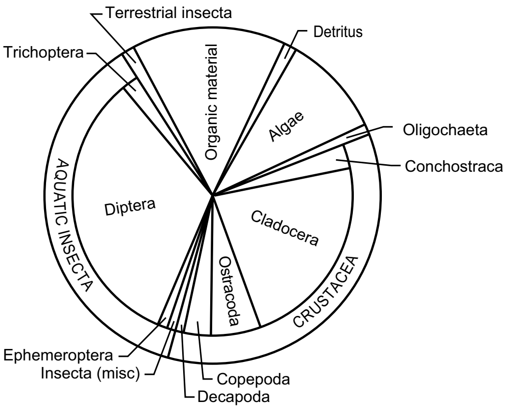

Figure 82 The main components of the diet of *C. stercusmuscarum*

The aquatic insect component consisted mainly of chironomid larvae and pupae. The main microcrustaceans were cladocerans, ostracods and copepods. The algae were mainly green filamentous types and many phytoplankton species. Traces of hydrophytes, aquatic arachnids, macrocrustaceans, terrestrial insects and plant material, detritus and inorganic material were also found in the stomachs. *Craterocephalus stercusmuscarum* can therefore be classified as a microphagous carnivore (occasionally an omnivore), feeding opportunistically on the bottom and mid-water.[125]

Pollard (1974) noted that the diet of this species was unknown, but that it might include mosquito larvae. Ivantsoff (in McDowall 1980) suggested this species was carnivorous and fed on small insects, which would help regulate local insect populations. The microcrustacean and algal components of the diet had not previously been recorded by research workers. Sanderson (1979) noted that *C. stercusmuscarum* from the Magela floodplain fed mainly upon cladocerans, ostracods, algae (single cell and filamentous green species) and organic detritus.

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[124] Ivantsoff et al (1988) has subsequently described mating behaviour, egg and embryonic development, and larval development.

[125] Pusey et al (1995b) found *C. stercusmuscarum* to consume large quantities of aquatic insects in two rivers of the Australian wet tropics, north-eastern Queensland.

Table 71 Dietary composition of *C. stercusmuscarum*

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																	
Algae																	8.6
Miscellaneous	1.5	3.4	0.2	0.1	1.1	–	2.8	–	2.4	–	–	2.2	0.9	2.2	–	1.0	
Chrysophyta																	
Volvox	–	–	–	–	0.3	–	–	–	–	–	–	–	–	0.5	–	+	
Chlorophyceae																	
Desmidaceae	0.2	–	0.3	–	–	–	–	–	–	–	0.3	–	–	–	–	0.1	
Bacillariophyceae	–	–	–	–	4.9	–	–	–	–	–	–	–	5.3	–	–	0.8	
Dinophyceae	–	1.1	0.8	1.3	0.1	–	2.6	4.6	–	–	0.1	3.8	1.0	3.5	–	0.9	
Conjugatophyta																	
Mougeotia	2.2	–	2.3	7.5	11.3	–	3.1	16.0	0.3	0.5	0.9	16.7	13.9	6.4	3.2	5.3	
Spirogyra	–	–	2.1	0.1	–	–	–	–	–	–	1.6	–	–	–	2.4	0.4	
Hydrophytes																	0.1
Najas	–	0.5	–	–	–	–	–	–	–	–	0.3	–	–	–	–	0.1	
Aquatic animals																	
Oligochaeta	–	–	–	1.5	0.2	–	–	–	0.9	0.6	0.8	–	–	–	–	0.5	0.5
Arachnida																	0.4
Porohalocaridae	0.7	–	–	–	0.6	–	–	–	0.4	–	–	–	0.6	–	–	0.2	
Hydracarina	1.7	–	+	–	0.8	–	–	2.7	1.0	–	–	–	–	–	–	0.2	
Microcrustacea																	36.5
Conchostraca																	
Miscellaneous	–	–	2.3	–	–	–	–	–	3.3	–	–	–	–	–	–	0.5	
Cyzicus	–	–	0.4	–	0.6	–	–	1.0	–	0.4	0.6	–	–	–	–	0.2	
Cladocera																	
Miscellaneous	3.9	6.8	14.4	4.3	14.7	41.7	13.9	13.2	24.6	7.1	12.9	14.6	3.5	4.1	–	11.3	
Diaphanosoma	9.0	7.4	16.6	15.8	28.2	–	5.7	2.7	–	20.8	7.1	19.5	24.6	21.4	47.1	15.4	
Ostracoda	5.8	5.4	9.1	3.9	11.2	–	–	9.3	–	0.5	21.8	2.5	3.3	–	0.3	6.1	
Copepoda																	
Miscellaneous	5.6	–	1.5	4.6	1.8	–	–	–	4.6	2.6	1.6	2.0	1.8	1.7	–	2.3	
Cyclops	–	–	–	1.6	–	–	–	–	–	–	–	–	0.9	2.4	–	0.3	
Harpacticoida	–	2.9	–	–	–	–	–	–	–	–	–	–	–	5.2	–	0.4	
Macrocrustacea																	0.5
Macrobrachium (adults)	–	0.4	–	–	–	–	–	–	0.3	–	0.6	–	–	–	–	0.2	
Macrobrachium (juv)	–	–	1.5	–	–	–	–	–	0.9	0.6	–	–	–	–	–	0. 3	
Insecta																	37.9

Table 71 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Fragmented	1.8	2.2	0.8	0.3	–	–	–	7.0	1.5	1.9	2.2	1.0	–	–	–	1.3	
Ephemeroptera																	
Baetidae	–	1.2	2.3	0.4	1.8	–	0.8	1.6	2.5	0.8	1.2	0.9	1.7	–	–	1.2	
Hemiptera																	
Corixidae	–	0.2	–	–	0.5	–	–	2.7	0.9	0.5	–	–	0.5	–	0.5	0.3	
Coleoptera																	
Miscellaneous (larvae)	–	0.6	0.3	–	–	–	–	–	–	0.4	0.2	–	–	–	–	0.1	
Hydrophilidae	–	–	–	0.3	–	–	–	–	–	–	0.2	–	–	–	–	0.1	
Diptera																	
Culicidae	1.1	–	–	–	–	–	–	–	–	–	–	–	–	–	4.0	0.1	
Chironomidae (larvae)	31.6	36.6	27.8	29.7	9.7	33.3	42.5	22.4	22.5	35.9	29.4	22.5	17.6	20.9	35.5	26.4	
Chironomidae (pupae)	–	8.0	5.8	1.7	1.7	8.3	5.0	8.1	0.9	5.5	1.9	4.5	7.7	0.7	3.2	3.7	
Ceratopogonidae	6.8	4.2	0.7	2.3	1.1	–	6.9	0.3	3.0	1.6	2.1	–	3.2	7.9	0.3	2.4	
Simuliidae	–	–	–	–	–	–	2.8	–	–	0.6	–	–	–	–	–	0.1	
Trichoptera																	
Hydroptilidae	–	–	–	–	–	–	–	2.7	–	–	0.6	–	0.9	–	–	0.3	
Leptoceridae	13.2	0.1	0.6	0.5	–	–	2.8	2.7	–	0.5	0.2	–	2.6	16.2	–	1.8	
Lepidoptera																	
Pyralidae	–	0.8	–	–	–	–	–	–	–	–	–	–	0.7	–	–	0.1	
Terrestrial plants																	
Angiospermae																	0.3
Fragmented	–	–	–	0.1	–	–	–	–	0.2	–	–	–	–	–	–	+	
Seed material	1.5	–	0.5	0.4	–	–	–	–	–	–	0.9	0.6	–	–	–	0.3	
Terrestrial animals																	
Insecta																	0.5
Orthoptera																	
Egg material	–	3.3	–	–	–	–	–	–	–	–	2.0	–	–	–	–	0.5	
Parasites																	
Nematoda	–	–	0.4	–	–	–	–	0.3	0.3	+	0.2	0.2	–	–	–	0.1	0.1
Detrital material	0	3.3	–	–	–	–	–	–	–	1.7	–	–	0.7	–	–	0.5	0.5
Inorganic material	0.2	1.6	–	0.4	–	–	–	–	0.7	0.8	0.2	–	0.2	–	–	0.4	0.4
Organic material	12.2	9.3	9.4	23.5	9.7	16.7	11.1	2.7	29.0	16.8	10.2	9.0	6.7	6.9	–	13.3	13.3
Number of empty fish	2	3	7	8	6	–	2	1	13	15	2	2	1	2	–	35	35
Number of fish with food	68	103	131	154	120	12	36	37	115	156	172	100	111	58	19	731	731

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs Cb = corridor billabongs; Fb = floodplain billabongs

Seasonal changes

In sampling periods 1–7, respectively, 128 (10% empty), 171 (9% empty), 174 (1% empty), 102 (2% empty), 111 (1% empty), 60 (3% empty) and 19 (0% empty) stomachs of *C. stercusmuscarum* were examined (all habitats combined). The highest proportions of specimens with empty stomachs were in the 1978 Late-dry and 1978–79 Early-wet seasons, though this pattern was not repeated in 1979–80.

Aquatic insects were important in the diet throughout the study. Chironomid larvae were most important in the Early-wet seasons and least important in the 1979 Mid-dry season; chironomid pupae were most important in the 1978–79 Early-wet and the 1979 Mid-dry seasons; ceratopogonid larvae were most import-ant in the 1979 Mid-dry and Late-dry seasons; leptocerid larvae were very important in the 1979 Late-dry season.

Microcrustaceans were also a substantial part of the diet throughout the study: cladocerans especially in the Late-wet–Early-dry and 1979 Mid-dry seasons, and also the 1979–80 Early-wet season; ostracods in the Mid-wet season; copepods in the Late-dry seasons.

The algal component was largest in the Late-wet–Early-dry season, and then gradually became smaller through the following Mid-dry and 1979 Late-dry seasons.

Habitat differences

Magela catchment

A total of 602 stomachs of *C. stercusmuscarum* were examined (all seasons combined): 70 (3% empty) from escarpment mainchannel waterbodies; 106 (3% empty) from lowland sandy creekbeds; 138 (5% empty) from lowland backflow billabongs; 162 (5% empty) from corridor waterbodies; 126 (5% empty) from floodplain billabongs. Few specimens with empty stomachs were found in any habitat examined.

The diet in the escarpment mainchannel waterbodies was based primarily on aquatic insects (chironomid, leptocerid, and ceratopogonid larvae) and to a lesser extent on microcrustaceans. The diet was similar in the lowland sandy creekbeds, with the minor difference that fewer leptocerid larvae and more chironomidae pupae were eaten. In the backflow billabongs the aquatic insect component was slightly smaller, the microcrustacean component slightly larger, and traces of algae were found in the stomachs.

In the corridor billabongs, *C. stercusmuscarum* had eaten mainly aquatic insects (chironomid larvae); in the floodplain billabongs it had eaten mainly microcrustaceans (cladocerans and ostracods). In both areas the diet had a noticeable algal component. In the corridor waterbodies, the large unidentified organic material component in the diet may have been associated with the microcrustacean component.

Nourlangie catchment

A total of 88 stomachs of *C. stercusmuscarum* were examined (all seasons combined): 12 (0% empty) from escarpment mainchannel waterbodies; 38 (5% empty) from lowland sandy creekbeds; 38 (3% empty) from backflow billabongs. Few specimens with empty stomachs were found in any habitat examined.

The diet in the escarpment mainchannel waterbodies, as in the Magela Creek catchment, was based primarily on aquatic insects (chironomid larvae and pupae) and microcrustaceans. The diets in the lowland habitats were similar in the two catchments. The algal component was more important in the sandy creekbeds and especially so in the backflow billabongs.

Fullness

A summary of mean fullness indices of *C. stercusmuscarum* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 72. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 72 Mean fullness indices for *C. stercusmuscarum* in different sampling periods and habitats

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	2.2 (10)	n/s	2.7 (21)	n/s	3.2 (10)	4.0 (20)	3.7 (10)	3.2 (71)
Lowland shallow backflow billabong	2.3 (3)	n/s	n/s	n/s	n/s	n/s	n/s	2.3 (3)
Lowland sandy creekbed pool	n/s	2.5 (12)	2.0 (2)	2.5 (2)	4.0 (10)	n/s	n/s	3.0 (26)
Downstream of RUPA								
Lowland sandy creekbed pool	2.8 (16)	3.0 (31)	3.3 (22)	2.6 (7)	2.0 (4)	1.8 (5)	n/s	2.9 (85)
Lowland channel backflow billabong	1.4 (9)	0 (1)	3.1 (19)	1.8 (11)	2.0 (2)	0 (1)	n/s	2.2 (43)
Lowland shallow backflow billabong	5.0 (4)	3.6 (35)	2.8 (25)	3.0 (21)	3.1 (14)	0 (1)	n/s	3.0 (100)
Corridor sandy billabong	1.1 (7)	1.6 (21)	3.3 (7)	3.2 (10)	3.5 (10)	n/s	n/s	2.0 (55)
Corridor anabranch billabong	1.8 (10)	2.5 (10)	3.4 (14)	0 (1)	2.0 (2)	3.1 (8)	n/s	3.1 (45)
Floodplain billabong	2.4 (16)	2.5 (37)	2.9 (14)	2.8 (20)	2.9 (5)	2.6 (22)	n/s	2.6 (114)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	n/s	2.2 (6)	0 (1)	n/s	n/s	n/s	n/s	1.9 (7)
Lowland channel backflow billabong	n/s	0 (1)	3.6 (10)	2.8 (10)	2.4 (10)	n/s	n/s	2.8 (31)
Lowland shallow backflow billabong	1.8 (5)	n/s	n/s	n/s	n/s	2.5 (2)	n/s	2.0 (7)
Lowland sandy creekbed	2.6 (10)	2.1 (15)	n/s	2.2 (11)	4.0 (2)	n/s	n/s	2.4 (38)
Seasonal mean (all sites)	2.4	2.6	3.0	2.7	3.1	3.1	3.9	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Seasonal changes

The mean seasonal fullness index (all habitats combined) increased slightly through the 1978–79 Early-wet season to peak in the Mid-wet season. In the Late-wet–Early-dry season the mean index fell slightly but rose again in the 1979 Mid-dry season; after the 1979 Late-dry season it rose dramatically into the 1979–80 Early-wet season.

Habitat differences

In the Magela catchment, upstream of RUPA, the mean fullness indices were highest in specimens from the escarpment mainchannel waterbody and lowland sandy creekbed sites, and lowest in the few specimens examined from the backflow billabong.

Downstream of RUPA the mean fullness indices were lower only in the channel backflow billabongs and corridor sandy billabongs, and slightly lower in the floodplain habitats.

In the Nourlangie catchment, the mean fullness indices were generally lower than in the Magela catchment. The highest mean indices were found in the channel backflow billabong and the lowest mean indices in the escarpment mainchannel waterbody.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland sandy creekbed (upstream of RUPA); 1979 Mid-dry season
- lowland shallow backflow billabongs (downstream of RUPA); 1978 Late-dry season, 1978–79 Early-wet season
- escarpment mainchannel waterbody; 1979 Late-dry season, 1979–80 Early-wet season

Nourlangie catchment

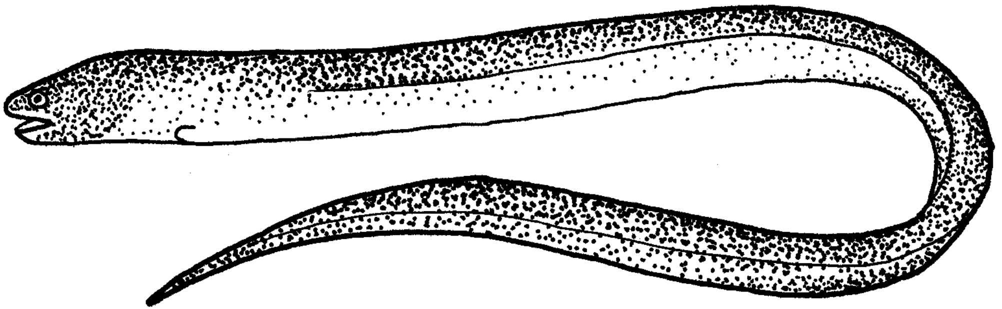
- lowland sandy creekbed; 1979 Mid-dry season
- lowland channel backflow billabong; 1978–79 Mid-wet season.

Family SYNBRANCHIDAE

3.19 *Ophisternon gutturale* (Richardson)

Ophisternon gutturale is commonly known as the one-gilled eel or swamp eel. It is found in the Timor Sea drainage system of northern Australia (see map 3). Pollard (1974) identified it as *Synbranchus bengalensis* in his collections from the Alligator Rivers Region. When Synbranchidae were revised by Rosen and Greenwood (1976), they noted the Northern Territory specimens identified as *S. bengalensis* that they examined were markedly different from more northern samples of what they referred to as *Ophisternon bengalense*. Although no Papua New Guinea samples were examined, the range of species of *Ophisternon* cannot be specified with precision,[126] the name *gutturale* was chosen to emphasise the need for more detailed analysis of the Old World genus *Ophisternon*. It seems clear, on the basis of a shared, derived maxillary character, that *bengalense* and *gutturale* are closely related.

Information on catches at each site and in each season is given in volume 2.



Ophisternon gutturale

Size composition

The two specimens captured had lengths of 84 and 111 mm TL. Both were caught in floodplain billabongs, the larger in the 1978 Late-dry season (Ja Ja Billabong) and the smaller in the Mid-wet season (at Jabiluka Billabong). Both sites had large volumes of submergent hydrophytes (mainly *Najas*), which clogged the meshes of the seine net, which aided in their capture.

Pollard (1974) noted that synbranchid eels grow to over 500 mm in length. Using a dip net, he caught only one small specimen (58 mm TL) (identified as *Synbranchus bengalensis*) — in Gulungul Creek, a small muddy creek in the lowlands of the Magela Creek catchment. Thirty-five specimens, from 60 to 282 mm TL, were caught by R. Miller in large billabongs and creeks in the Oenpelli area (Taylor 1964).

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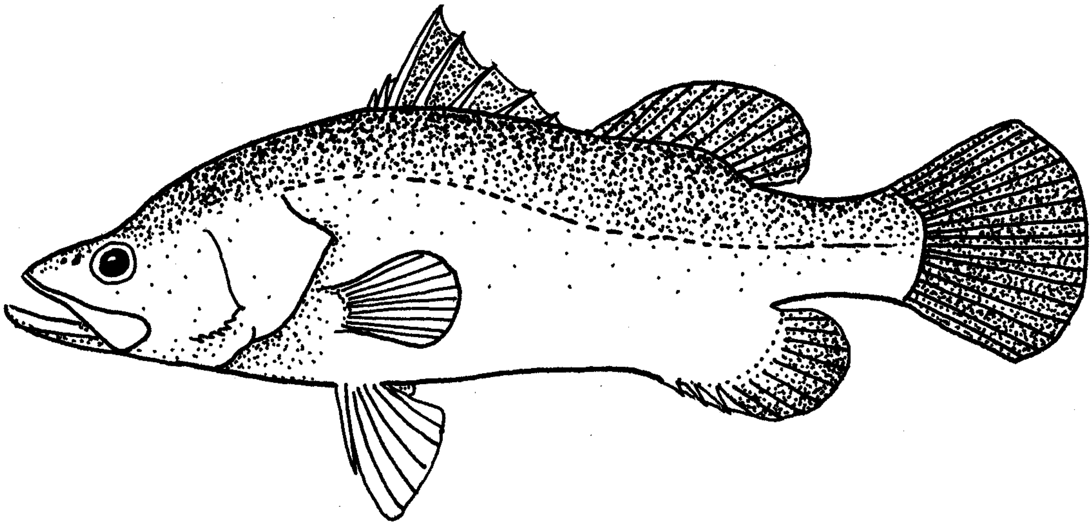
[126] Allen (1991) indicated that *O. gutturale* is known from Papua New Guinea on the basis of one specimen collected in the Bensbach River.

Family CENTROPOMIDAE

3.20 *Lates calcarifer* (Bloch)

Lates calcarifer is commonly known as the silver barramundi or giant perch. It is found in rivers and estuaries of the north-east coast, and the drainage systems of the Gulf of Carpentaria, Timor Sea and Indian Ocean (see map 3).[127] It is also found in the tropical Indo-Pacific, from China to the Persian Gulf, including Papua New Guinea. Pollard (1974) captured many specimens in corridor and floodplain billabongs in the Magela Creek catchment, and in the mainchannel and anabranches of the East Alligator River.[128] Specimens were also captured by Miller (cited in Taylor 1964) in the Oenpelli area.



Lates calcarifer

Lates calcarifer is a catadromous species[129] and a magnificent sporting fish on account of its size, strength, and its often spectacular performance when hooked. It is also probably the finest food fish in northern Australia, and supports a commercial mesh-net fishing industry in the river mouths.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found commonly in floodplain and corridor waterbodies and rarely in lowland backflow billabongs and sandy creekbed habitats. Some specimens were observed in escarpment mainchannel habitats in the Nourlangie Creek system.

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[127] Shaklee and Salini (1985) indicated that there were substantial genetic differences in *L. calcarifer* stocks across northern Australia, identifying at least three distinct stocks or subpopulations. Further work by Keenan (1994) identified 16 distinct populations. One population occurred from Darwin Harbour to the Mary River (no samples were taken from the South or East Alligator Rivers).

[128] Herbert and Peeters (1995) indicated that *L. calcarifer* can be found in all river systems of Cape York Peninsula and far northern Queensland. They can be found throughout the entire length of a river, tolerating a wide range of habitats.

[129] Based on atomic emission spectroscopy of scales, Pender and Griffin (1996) concluded that most *L. calcarifer* found in marine areas remote from freshwater parts of the Mary River system (NT), probably had no freshwater phase.

Size composition

The lengths and weights of 62 specimens were determined. Most specimens were captured by gillnets (mono- and multifilament), but many struggled free from the monofilament gillnets, which have a low breaking strain.

Length–weight relationship

The length–weight relationship for the sexes combined was described by the expression:

$W = 2.29 \times 10^{-2} L^{2.81}$ $r = 0.99$ (length in cm, weight in g)

Reynolds (1978) found that the length–weight relationship varied significantly between sexes and between specimens captured in salt and freshwaters.

Seasonal mean lengths, weights and condition factors are shown in table 73. Body condition was highest in the Late-wet–Early-dry season. It was lowest in the 1978–79 Early-wet, when adverse environmental conditions at times resulted in heavy mortalities.

Table 73 Mean length, mean weight and condition factor of *L. calcarifer*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	9	511.2	1494.80	1.04
Early-wet (1978–79)	20	656.0	2687.09	0.93
Mid-wet	5	602.4	2330.91	1.02
Late-wet–Early-dry 1979	1	640.1	3169.77	1.17
Mid-dry	2	466.7	1171.35	1.05
Overall	37	593.9	2194.92	1.00

Length-frequency distribution

The mean and modal lengths of specimens captured were 664 and 690 mm TL, respectively, with a secondary mode at 750 mm TL. Reynolds (1978) gives the LFM as 700 mm TL (fig 83), which suggests that more juveniles than adults were captured in the present study. Most specimens were in the size groups 550–640 mm and 670–800 mm TL, especially in the sample from the fish kill in Leichhardt Billabong. Fish of these sizes may be 3–4 years old (Reynolds 1978). Specimens less than 300 mm TL were rare in freshwaters; in Papua New Guinea, Reynolds (1978) found that juveniles of 150 mm TL leave the coastal swamps by March–April and disperse into freshwaters when they are one year old (or about 320 mm).

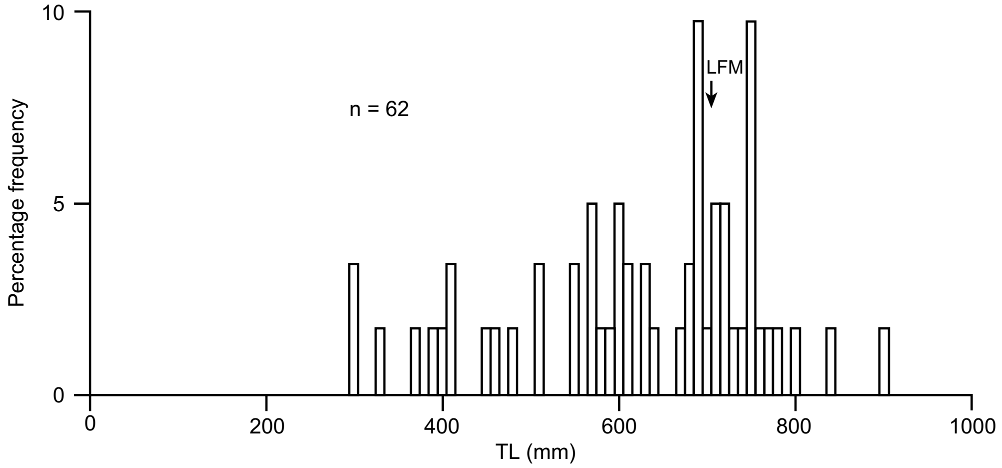

Figure 83 Length-frequency distribution of all *L. calcarifer* captured

In the Magela catchment the smallest specimen (295 mm TL) was captured in the 1978 Late-dry (fig 84), the largest (900 mm TL) in the 1978–79 Early-wet season. A 1000 mm TL specimen was caught in the East Alligator River (near Cahills Crossing) during the Mid-dry season; smaller specimens (100–150 mm TL) were caught in tidal tributaries of the East Alligator River (near Cahills Crossing) during the Late-wet–Early-dry season. *Lates calcarifer* had the greatest mean length (664 mm TL) of all the species captured in the study. Pollard (1974) reported that this species grows to 1500 mm and over 60 kg in Australian waters.[130] For Papua New Guinea specimens, Reynolds (1978) gave the L_∞ value for its von Bertalanffy growth equation as 1200 mm TL. In the Purari River, *L. calcarifer* ranged in length between 320 and 1200 mm (Haines 1979).[131]

Most specimens measured were collected after the Leichhardt Billabong fish kill in the 1978–79 Early-wet season (Bishop 1980). All other sample sizes were small.

The age–length relationship described by Davis and Kirkwood (1984) for *L. calcarifer* from the East Alligator River is superimposed on fig 84. It is apparent that specimens in the study area ranged in ages from one to seven years with most being between two and five. Reynolds (1978) stated that in Papua New Guinea most two to four years old fish are found in freshwaters, which they leave at the end of the Dry season when they are over four years old (or 700 mm TL).[132] They may return after spawning.

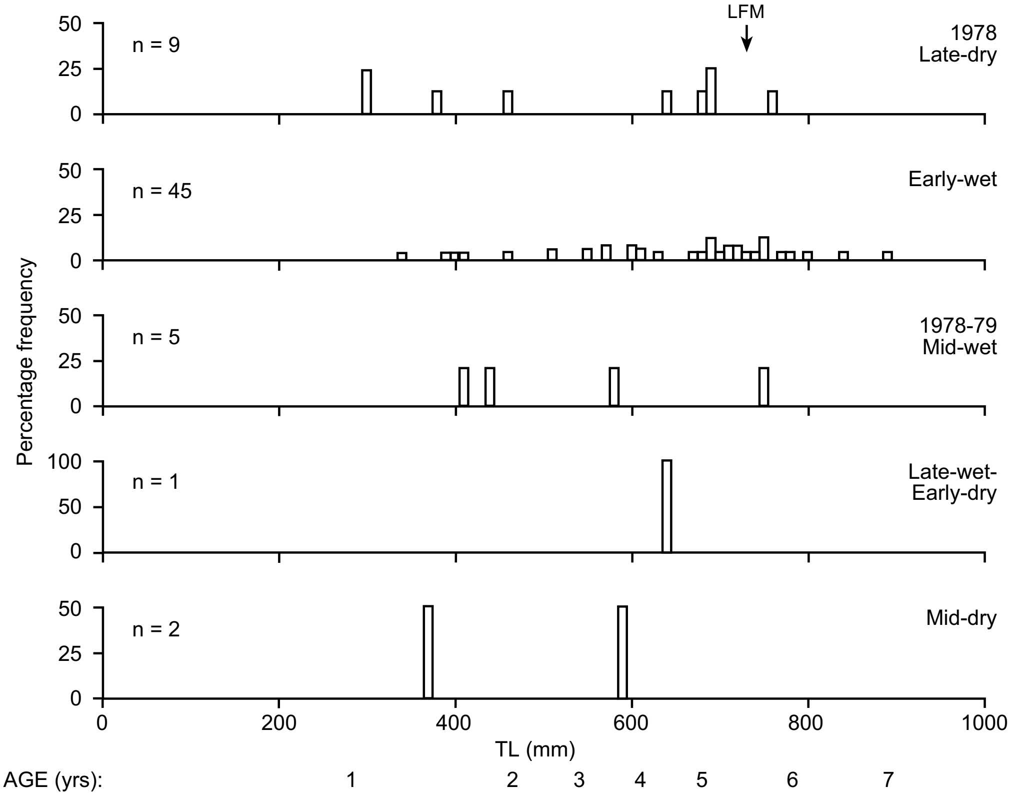

Figure 84 Seasonal length-frequency distribution of all *L. calcarifer* captured

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[130] Herbert and Peeters (1995) indicated that *L. calcarifer* grows to 1800 mm.

[131] Davis and Kirkwood (1984) gave the following L_∞ values (total length) for *L. calcarifer* for rivers within the Alligator Rivers Region: Mary, 1425 mm; West Alligator, 868 mm; South Alligator, 1604 mm; East Alligator, 1775 mm. Considerable variation in growth rates between rivers was apparent.

[132] This work on growth rates of *L. calcarifer* in PNG was later published by Reynolds and Moore (1982).

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *L. calcarifer* captured in regular sampling sites in the Magela Creek catchment are given in fig 85.

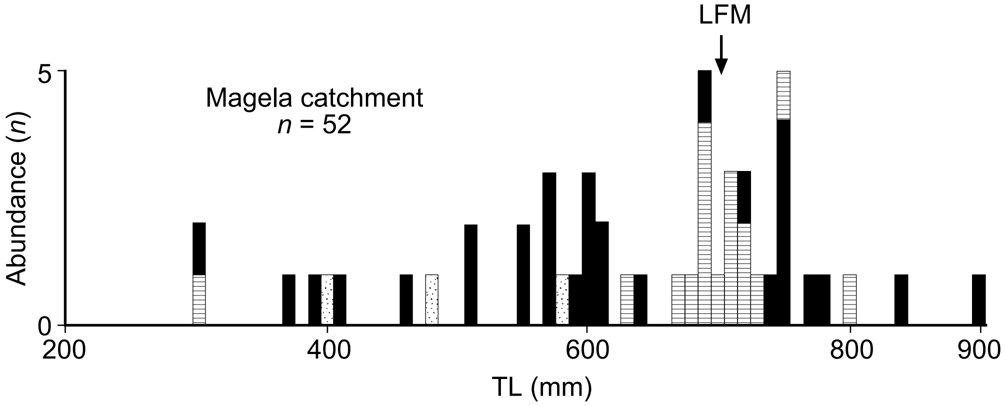

Figure 85 Length-frequency distributions and habitat preferences of *L. calcarifer* captured at regular sampling sites (see appendix 5 for key to the habitats)

The smallest juveniles were captured in floodplain and corridor anabranch billabongs. The smallest specimen captured in the Nourlangie catchment (which was close to the same size as those found in the Magela catchment) was found in a channel backflow billabong. Juveniles were occasionally observed in an escarpment mainchannel billabong in the Nourlangie catchment. Most of the juveniles captured in the Magela system were found in floodplain billabongs, with larger juveniles being found in corridor anabranch billabongs; only a few juveniles were found in lowland shallow backflow billabongs.

The smaller adults were found mainly in corridor anabranch billabongs and the larger adults mainly in floodplain billabongs. A large adult was observed in an escarpment perennial stream in the Nourlangie catchment in the Mid-wet season.

Environmental associations

Rank numbers for *L. calcarifer* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Water temperatures ranged from 26° to 35°C (mean = 30.3°C) on the surface, and from 24° to 33°C (mean 28.2°C) on the bottom. Both these means ranked in the lower-middle quarter (see fig 170). However, *L. calcarifer* tolerates a wider range of temperatures: other workers (eg Morrissy 1971; Morrissy et al 1973) found this species living in waters at 15.5°C. Hill and Grey (1979) found that water temperature affects the timing of downstream migration. They also reported that *L. calcarifer* stops feeding when the water temperature falls below 24°C.[133] As relatively few specimens were caught in the present study, the ranges and means for environmental variables may not be fully representative of the actual ranges and means.

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[133] Burke (1991) found juvenile *L. calcarifer* from Queensland to have a thermal range of 10–42°C with a zone of preference from 27.5 to 36.5°C.

Dissolved oxygen

Dissolved oxygen concentrations ranged from 3.0 to 6.8 mg/L (mean = 5.0) on the surface, and from 0 to 6.8 mg/L (mean = 3.3) on the bottom (see fig 171). A tolerance of very low DO concentrations is indicated, as might be expected for a fish typically found in lentic, turbid waters (Morrissy et al 1973). *Lates calcarifer* was amongst the species recorded in the Leichhardt Billabong fish kill (Bishop 1980), when surface DO concentrations fell to 0.1 mg/L.[134]

Visibility

Secchi depth readings ranged from 3 to 120 cm (mean = 54 cm) (see fig 172). This mean ranked in the lower-middle quarter, which accords with this fish being found in turbid lowland and floodplain billabongs. Whitley (1959) attributed the mortality of large numbers of *L. calcarifer* after a flood to clogging of the fishes' gills by silt particles. However, the range of visibilities noted in the present study indicate that this species is, in fact, tolerant of very turbid waters, as Coulter (1955) observed.

pH

The pH values ranged from 4.0 to 7.2 (mean = 6.1) on the surface, and from 5.1 to 6.3 (mean = 5.9) on the bottom. Both means ranked in the lower-middle quarter (see fig 173).

Conductivity

Conductivity values ranged from 4 to 160 µS/cm on the surface, and from 4 to 110 µS/cm on the bottom. Other workers (eg Hill & Grey 1979; Pollard 1974; Morrissy et al 1973; Rao 1964) report that this species is euryhaline, tolerant of salinities of up to at least 32 ppt in estuarine waters. An increase in salinity may trigger its migration upstream to freshwaters (Morrissy et al 1973).

Habitat–structural variables

Substrate

Mud (upper quarter) and clay (upper quarter) were the most common substrates of the waters in which *L. calcarifer* was found, as might be expected for a fish typically captured in turbid lowland and floodplain billabongs. The other substrates associated with *L. calcarifer* were, in descending order of dominance, sand, leaves and boulders; no specimens were found over rock or gravel substrates (see fig 174).

Hydrophytes

Lates calcarifer was typically found in moderately vegetated waters (vegetation-occurrence index 88.9%) with emergent (43.1%), submergent (40.3%) and floating-attached (12.5%) hydrophytes.[135] Although this species is primarily a predator, it includes plant material in its diet (Chacko 1949; Whitley 1959; Morrissy et al 1973).

Reproduction

The reproductive condition of 37 specimens was examined; 34 sexually indistinguishable fish (295–800 mm TL) and 3 males (375–1000 mm TL) were identified. The three males were all immature, with GSIs of 9.12, 0.03 and 0.18; they were captured in a floodplain billabong (Leichhardt Billabong) in the Magela Creek system and in floodplain billabongs of the East Alligator River (Cahills Crossing and Cannon Hill Billabong). As no further information on

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[134] Wells et al (1997) stated that *L. calcarifer* was an obligate water breather with blood oxygen binding properties intermediate between the saratoga and the tarpon.

[135] Herbert and Peeters (1995) indicated that in Cape York Peninsula streams their preferred habitats are aquatic plant beds, large deep-water snags and the downstream end of riffles.

the reproduction of this species was obtained from the present study, some information, mainly from research in Papua New Guinea, is summarised below.[136]

Length at first maturity

Reynolds (1978) found that males and females generally matured at 700 and 900 mm TL, respectively, although he reports that in Queensland the smallest mature female was 760 mm, while in Papua New Guinea the smallest mature fish were a 680 mm male and a 750 mm female.

Sex ratio

Lates calcarifer was found to be a protandrous hermaphrodite in Moore's 1979 study. The smaller fish were almost exclusively male; the percentage of females increased with increasing total length. The overall sex ratio was 3.8:1 in favour of males. A few primary females were found, and it is also possible that some males did not change to female. The gonads of *L. calcarifer* were strongly dimorphic, so the sex inversion requires a complete reorganisation of gonad structure as well as function. The smallest females found were 730 mm TL (five years old); few males were above 1030 mm TL. There may be a considerable variation in the size at which inversion takes place (Moore 1979).

Breeding season

The onset of the Wet season stimulates spawning behaviour but, initially, only the fish with ready access to the sea can participate. Later, as rainfall and floods allow movement of previously land-locked adult fish, there is a second spawning peak. Thus the timing, duration and intensity of the Wet season, particularly in relation to specific river systems, determines the time of spawning and, in some cases, whether some fish can spawn at all (Grey & Griffin 1979). Two main spawning seasons have been recorded: November–December and February–March (Lake 1971).

Site of spawning

The gonads begin to develop while the fish is in fresh water, and maturation is completed when the fish moves into salt water (Reynolds 1978). It spawns as the tide rises over the mudflats. Juveniles and adults migrate back into the freshwater reaches at the end of the Wet season (Pollard 1974; Reynolds 1978).

Fecundity

A very large number of small eggs are found in the ovary. Reynolds (1978) recorded 2.2–16.8 x 10^6 eggs from fish weighing 7.7–19.2 kg. The unfertilised eggs measured 0.7 x 0.8 mm and contained a single oil globule. Eggs have been reported as being demersal (Reynolds 1978) or planktonic (Lake 1978; Moore in Reynolds (1978)); according to Lake (1978) the eggs will float in water of 20–30 ppt salinity.

The larvae hatch quickly and when first hatched are about 1.5 mm long; the yolk sac is absorbed by the fifth day.

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[136] Davis (1982) examined the maturity and sexuality of *L. calcarifer* in the Northern Territory and the Gulf of Carpentaria. Davis (1985b) reported on seasonal changes in gonad maturity and the abundance of larvae and early juveniles of *Lates calcarifer* (Bloch) in Van Diemen Gulf and the Gulf of Carpentaria. Griffin (1987) examined the life history of *L. calcarifer* in the Daly River, NT. Moore (1982) described spawning and the early life history of *L. calcarifer* in Papua New Guinea.

Summary

Lates calcarifer migrates to estuaries to spawn at the onset of the Wet season. A large number of small eggs are laid as the tide rises over the mudflats. Incubation is short and tiny planktonic prolarvae emerge. Juveniles and adults move back into the freshwater reaches at the end of the Wet season.[137] No females less than about 730 mm TL have been found. Beyond this length a sex inversion occurs, and the proportion of females increases with increasing length.

Feeding habits

Overall diet

The stomachs of 35 specimens were examined; 19 contained food. The high proportion of empty stomachs may be because this species regurgitates its stomach contents as a fright response when enmeshed in gillnets (Reynolds 1978). The diet of *L. calcarifer* is summarised in fig 86; the components are listed in table 74.

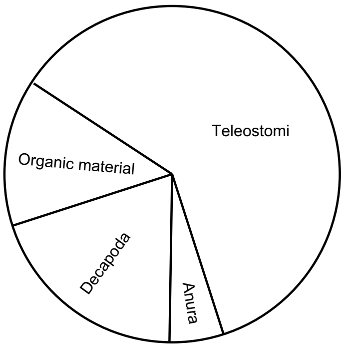

Figure 86 The main components of the diet of *L. calcarifer*

The main components were teleosts and associated unidentified organic material (65%), and macrocrustaceans (14%). The teleosts were identified as *Ambassis* spp., *Neosilurus* spp., *T. chatareus, P. rendahli, H. compressa* and *M. splendida inornata*. Anuran larvae (5%) were also found in the stomachs. *Lates calcarifer* can therefore be classified as a macrophagous piscivore/carnivore.[138] These findings are in accord with Pollard's (1974), who reported that small specimens in the Magela Creek floodplain ate *Neosilurus* and other fishes, and *Macrobrachium* and *Cherax*. Small juveniles ate some insects and occasionally some plant material in freshwaters. Larger specimens from a tidal billabong (Rock Hole) of the East Alligator River contained remains of mugilids, *Neosilurus* and other fishes.[139]

In clear water, *L. calcarifer* appears to be largely a nocturnal feeder; in turbid, estuarine waters it appears to feed during the rise and fall of the tide, following the surface movements

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[137] Russell (1987) reviewed juvenile *L. calcarifer* wildstocks in Australia and stressed the very important contributions wetlands make to fisheries and indirectly to local economies. Russell and Garrett (1985) examined the early life history of *L. calcarifer* in north-eastern Queensland, and Russell and Garrett (1983) investigated the use by juvenile barramundi of temporary supralittoral habitats in a tropical estuary in northern Australia.

[138] Based on radio tracking studies in the Mary River, NT, Griffin (1994) concluded that *L. calcarifer* is a roving predator rather than a 'lie in wait' predator. In Van Diemen Gulf rivers, Davis (1985a) concluded that *L. calcarifer* was an opportunistic predator, with an ontogenetic progression from microcrustaceans to fish. This progression was also apparent in the Gulf of Carpentaria.

[139] Herbert and Peeters (1995) indicated that in Lake Tinaroo in northern Queensland, bony bream form over 90% of the diet of the barramundi stocked there.

of small fish or crustaceans (Morrissy 1971). This fish often makes a loud noise, like a hand clap, as it chops at its prey (Whitley 1959).

Dunstan (1962) states that *L. calcarifer* is carnivorous and predacious throughout its life cycle. Generally, they will prey on any fish or crustacean smaller than themselves. In Papua New Guinea teleost remains were more common in freshwater specimens and crustacean remains in brackish-water specimens (Morrissy 1971).

Table 74 Dietary composition of *L. calcarifer*

	Season						
	1978	1978–79	1978–79	1979	1979	Overall	
Stomach contents	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Sub-mean	Main-mean
Aquatic animals							
Macrocrustacea							13.7
Macrobrachium	6.7	40.0	–	–	–	13.7	
Teleostomi							60.2
Fragmented	31.1	20.0	–	–	50.0	25.3	
Neosilurus spp.	–	–	–	100	–	5.3	
P. rendahli	–	–	–	–	37.5	4.0	
M. splendida inornata	–	–	–	–	7.5	0.8	
Ambassis spp.	–	–	20	–	5	11.1	
A. agrammus	10.0	–	80	–	–	4.7	
T. chatareus	–	20.0	–	–	–	5.3	
H. compressa	7.8	–	–	–	–	3.7	
Anura[140]							5.3
Miscellaneous (larvae)	–	20.0	–	–	–	5.3	
Parasites							
Nematoda	1.1	–	–	–	–	0.5	0.5
Organic material	43.3	–	–	–	–	20.5	20.5
Number of empty fish	–	13	3	–	–	16	16
Number of fish with food	9	5	2	1	2	19	19

Figures represent the mean percentage volume determined by the estimated volumetric method.

Seasonal changes

In sampling periods 1–5 respectively, 9 (0% empty), 18 (72% empty), 5 (60% empty), 1 (0% empty) and 2 (0% empty) stomachs of *L. calcarifer* were examined (all habitats combined). The highest proportion of empty stomachs was in the Early-wet and Mid-wet seasons.

In the 1978 Late-dry season, teleosts (the identifiable genera were *Ambassis* and *Hypseleotris*) were the main food items. The unidentified organic material in the stomachs in this season was possibly partly digested fish flesh. In the 1978–79 Early-wet season, the diet was based evenly on *Macrobrachium* and teleosts (*T. chatareus*) with a smaller component of anuran larvae. The few specimens examined in other seasons were feeding exclusively on teleosts (*Ambassis, Neosilurus, P. rendahli* and *M. splendida inornata*).

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[140] Lawler and Hero (1997) showed that, in comparison to native tadpoles, *Bufo marinus* tadpoles were unpalatable to *L. calcarifer*, particularly the later-stage tadpoles.

Family AMBASSIDAE

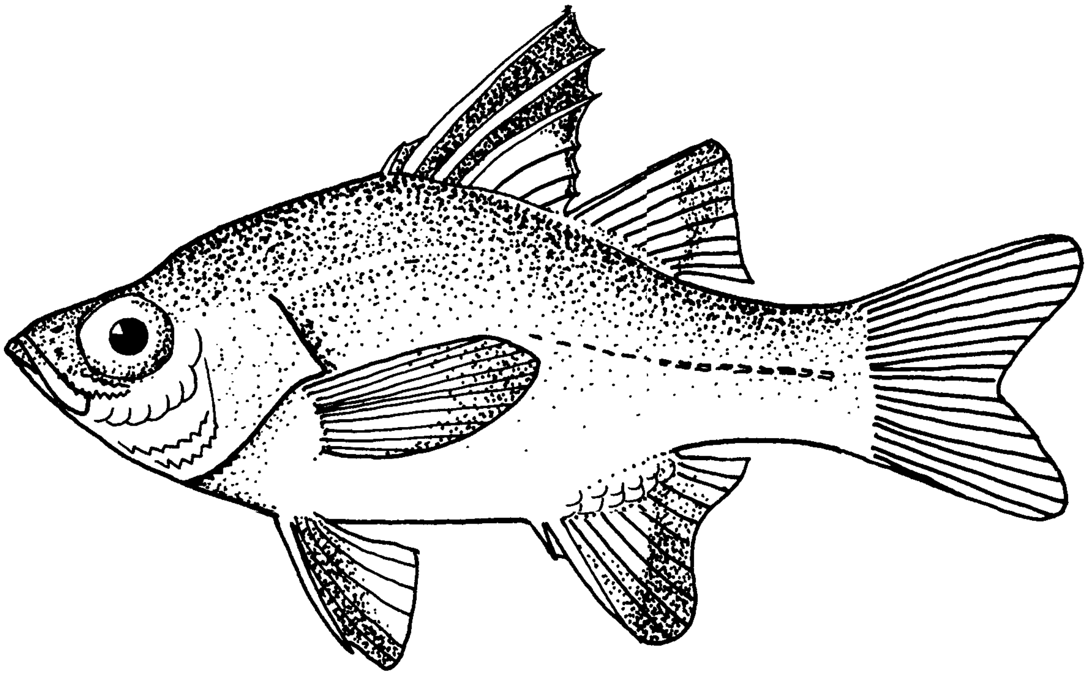
***Ambassis* spp.**

Ambassis spp. belong to a family with marine, estuarine and freshwater representatives. The taxonomic characters (mainly gill raker counts and reticulation of scales) that supposedly distinguish *Ambassis agrammus* and *A. macleayi* proved unsatisfactory with many of the specimens captured (especially the small ones), as they appeared to have intermediate or overlapping key characteristics; such specimens were recorded as *Ambassis* sp. Data on their biology for comparative use are available, though not presented in this report. Some data on *A. agrammus* and *A. macleayi* may be contaminated because of difficulties in obtaining clearcut identifications.

Family AMBASSIDAE

3.21 *Ambassis agrammus* (Gunther)

Ambassis agrammus is commonly known as the sail-fin perchlet or glassfish, or chanda perch. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (map 3), and in southern rivers of Papua New Guinea. In the Magela Creek system, Pollard (1974) found it most commonly in shallow sandy and shallow vegetated areas. In the Oenpelli area, Miller (in Taylor 1964) found this species to be abundant in large billabongs.



Ambassis agrammus

Detailed information on catches at each site and in each season is given in volume 2. In summary, *A. agrammus* was found abundantly in all floodplain,[141] corridor and backflow billabongs and commonly in some lowland sandy creekbed sites and escarpment mainchannel waterbodies. It was found in the greatest number of sites in the 1978 Late-dry season (in a pattern similar to the overall distribution), and in the fewest sites in the Late-wet–Early-dry season (in some floodplain and backflow billabongs of the Magela system and in lowland sandy creekbed habitats of the Nourlangie Creek system).

Size composition

The lengths and weights of 3381 specimens were determined. Very small juveniles were captured in the 10 mm mesh seine net when hydrophytes and filamentous algae clogged the mesh; this happened most often in the Mid-wet and Late-wet–Early-dry seasons.

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[141] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG do not use the floodplain as a preferred habitat, even in the flood season.

Length–weight relationship

The length–weight relationship for the combined sexes was described by the expression:

$$W = 1.89 \times 10^{-2} L^{3.00} \qquad r = 0.94 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 75. The condition factor was stable (near unity) between the 1978 Late-dry and Mid-wet seasons; the near-continuous breeding of this species possibly concealed any effects of spawning on body condition.[142] Body condition fell slightly in the Late-wet–Early-dry season but rose by the Mid-dry season; the fish may have been adapting to the changing environment (Wet to Dry season). By the 1979 Late-dry season body condition was nearly equal to that recorded in the 1978 Late-dry season. The few large specimens examined in the 1978–79 Early-wet season, which was very dry, had very high body condition.

Table 75 Mean length, mean weight and condition factor of *A. agrammus*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	771	31.4	0.59	0.99
Early-wet (1978–79)	355	33.1	0.69	1.00
Mid-wet	476	29.5	0.49	0.99
Late-wet–Early-dry (1979)	301	28.8	0.44	0.96
Mid-dry	675	30.6	0.57	1.03
Late-dry	226	29.8	0.50	0.98
Early-wet (1979–80)	17	39.4	1.26	1.08
Overall	2821	30.7	0.55	1.00

Length-frequency distribution

Specimens ranged in length from 11 mm to 64 mm LCF (fig 87). Lake (1978) reported that this species grows to 70 mm. The closely related *A. macracanthus, A. nalua, A. interrupta* and *A. buruensis* were, respectively, up to 100, 90, 60 and 40 mm in length in the Purari River catchment (Haines 1979).[143]

The mean length of all specimens captured was 30.7 mm LCF and the modal length 30–31 mm LCF; the distribution was fairly symmetrical around the mean length. The LFM for males was 27 mm and for females 26 mm LCF, indicating that slightly more adults than juveniles were captured.

Seasonal changes in distribution

The smallest specimens were captured during the 1978–79 Early-wet season and the Mid-wet and Mid-dry seasons (fig 88) (as were the smallest specimens of *A. macleayi*). The largest specimens were captured in the 1978 Late-dry and the 1979 Mid-dry seasons.

Length-frequency distributions were unimodal for all seasons except the Early-wet seasons and the 1979 Mid-dry season (fig 88). Juvenile peaks were strongest in the 1978–79 Early-wet and Mid-dry seasons; in the 1979–80 Early-wet season only a few small adults were captured, but large adults were abundant (the mean length [table 75] was therefore greatest at this season).

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[142] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG had a body condition which exhibited little seasonality.

[143] Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland grows to 54 mm standard length.

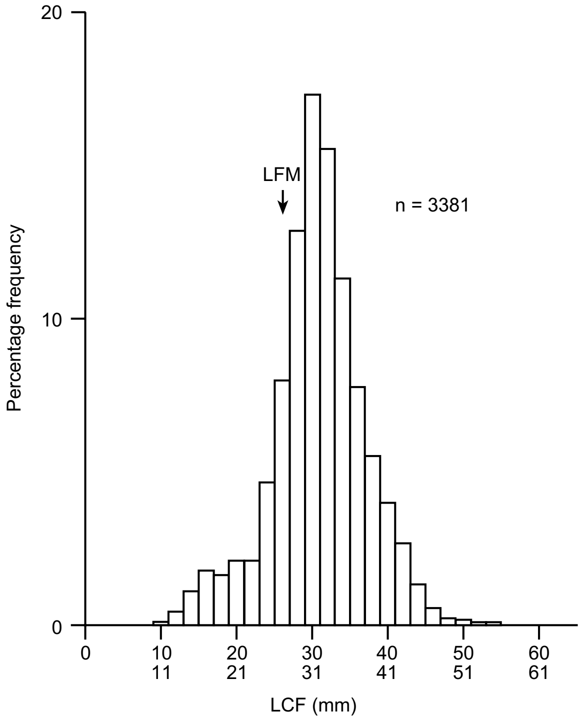

Figure 87 Length-frequency distribution of all *A. agrammus* captured

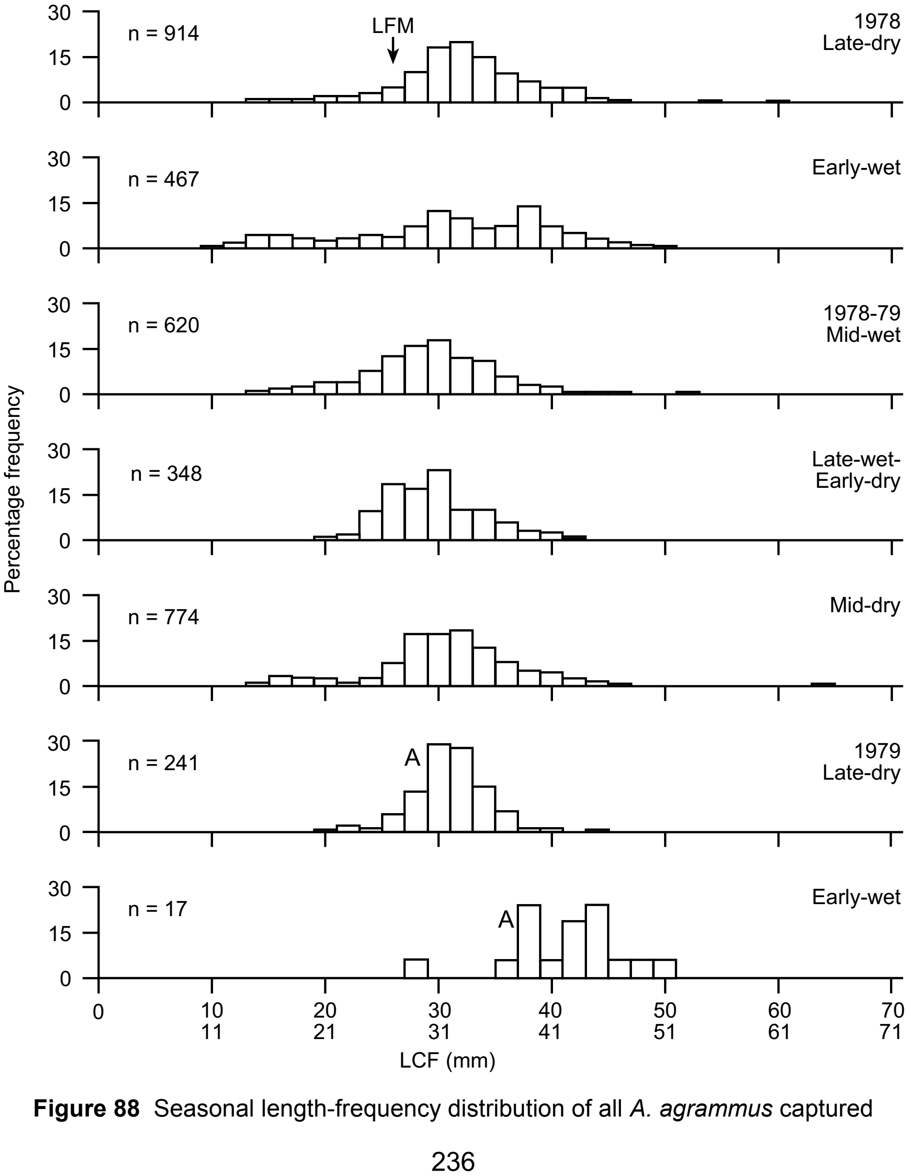

Figure 88 Seasonal length-frequency distribution of all *A. agrammus* captured

The length-frequency distributions in the two Late-dry seasons were essentially similar (with minor differences caused by sample sizes) but the 1978 mean lengths were slightly greater.

Juveniles were recruited in all seasons, except the 1979–80 Early-wet season; recruitment peaked most noticeably in the 1978–79 Early-wet and the 1979 Mid-dry season.

Growth rate

No published information on the growth of *A. agrammus* could be found. Estimation of growth rate from the seasonal length-frequency distributions is difficult due to the juveniles recruiting in most seasons and the range of habitats examined. However, between the 1979 Late-dry season and the 1979–80 Early-wet season, the length-frequency distribution shifted by approximately 10 mm (juvenile recruitment was minimal in the 1979–80 Early-wet season). If this is a true growth effect, then this species could attain its LFM within its first year of life. It is possible, therefore, that juveniles recruited in the 1979 Mid-dry season were the offspring of small adults that had been juveniles in the 1978–79 Early-wet season.[144]

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *A. agrammus* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are given in figure 89.

Magela catchment

The smallest juvenile was found in a lowland sandy creekbed. Other small juveniles were found in a variety of habitats, though most frequently in floodplain and sandy corridor waterbodies and in shallow backflow billabongs. Large juveniles were found most frequently in floodplain and backflow billabongs, and to a lesser extent in corridor waterbodies. No juveniles were found in escarpment habitats.

Small adults were found in essentially the same habitats as large juveniles. Large adults were found most commonly in shallow backflow billabongs, floodplain billabongs and lowland sandy creekbeds. The largest adult specimen was captured in a channel backflow billabong. Only a few adults were found in escarpment mainchannel waterbodies and none were observed in escarpment perennial streams.

Nourlangie catchment

Juvenile *A. agrammus* were collected in a variety of habitats, from escarpment mainchannel billabongs through lowland sandy creekbed channels to backflow billabongs. The smallest specimens were found in the escarpment mainchannel billabongs.

Small adults were most frequently found in shallow backflow billabongs and to a lesser extent in channel backflow billabongs. One small adult was observed in an escarpment perennial stream during the Mid-dry season. Large adults were mainly found in lowland sandy creekbed habitats and, to a lesser extent, in backflow billabongs (as was the case for *A. macleayi*). The largest adult (54 mm LCF) was collected in a shallow backflow billabong.

Environmental associations

Rank numbers for *A. agrammus* for the physico–chemical and habitat–structural variables are shown in table 155.

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[144] Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland grows to the following standard lengths: year 1, 31 mm; year 2, 43 mm; year 3, 51 mm. This species commences to breed at 1 year old.

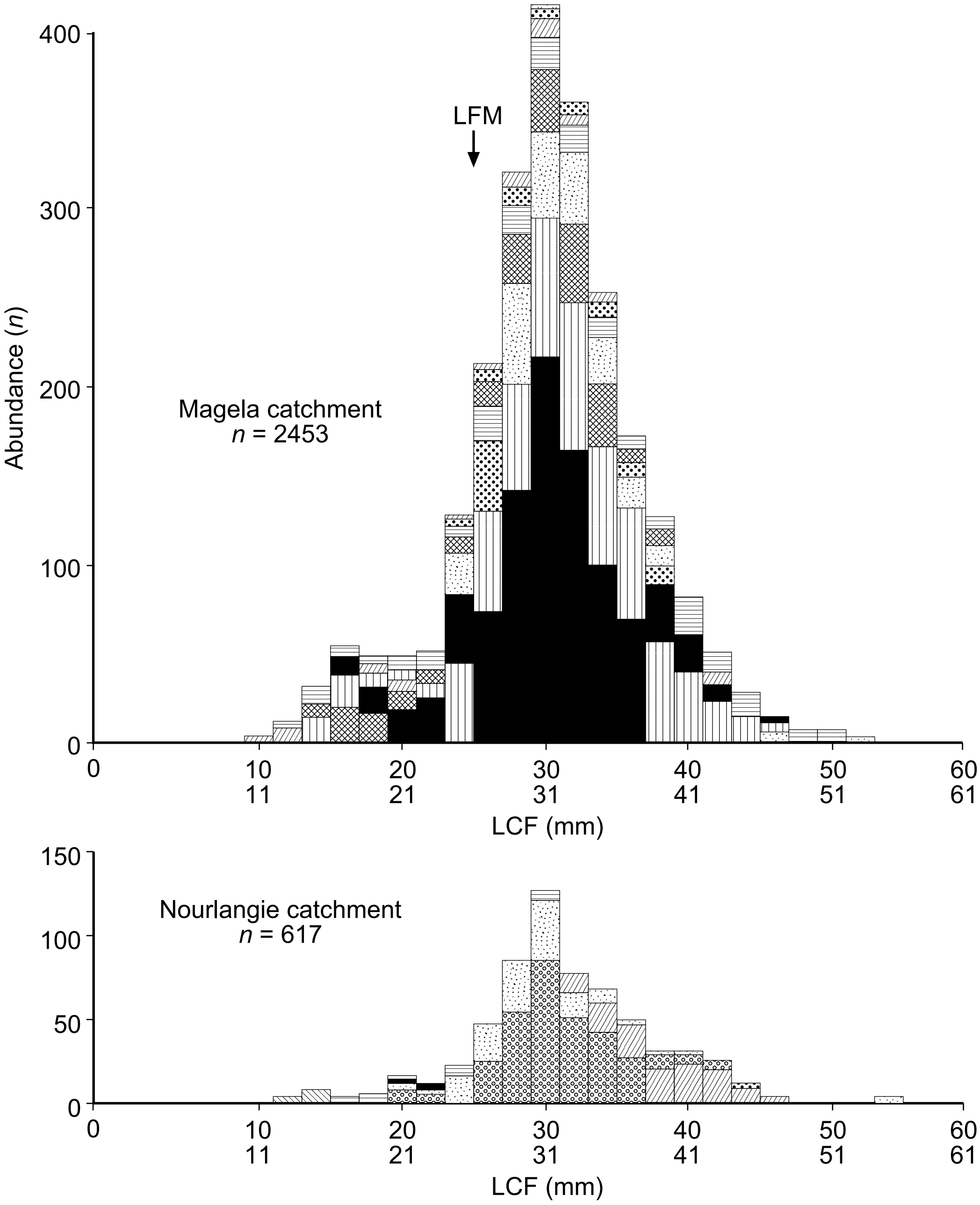

Figure 89 Length-frequency distributions and habitat preferences of *A. agrammus* captured at regular sampling sites (see appendix 5 for key to the habitats)

Physico–chemical variables

Temperature

The temperatures of waters in which *A. agrammus* was found ranged from 25° to 41°C (mean = 31.3°C) on the surface, and from 24° to 38°C (mean = 29.7°C) on the bottom. Both of these means ranked in the upper quarter (see fig 170). The tolerance of this species to a wide range of water temperatures (including some very hot surface waters) corresponds with its observed wide distribution.

Dissolved oxygen

Dissolved oxygen concentrations ranged from 1.3 to 7.8 mg/L (mean = 6.0) on the surface, and from 2.5 to 7.0 mg/L (mean = 4.4) on the bottom. Both means were placed in the lower-middle quarter (see fig 171). One hundred specimens of *A. agrammus* were found in the Leichhardt Billabong fish kill (Bishop 1980), when surface DO concentrations fell below 0.1 mg/L.

Visibility

Secchi depth readings ranged from 1 to 360 cm (mean = 32 cm). The mean depth ranked in the lower quarter (see fig 172). Specimens of *A. agrammus* were thus found in very clear to very turbid waters, but mainly in the turbid waters of the lowland and floodplain billabongs.

pH

The pH of surface waters ranged from 4.8 to 9.1 (mean = 6.4); bottom-water pH values ranged from 4.5 to 6.7 (mean = 6.0). These means ranked in the upper-middle and lower-middle quarters, respectively (see fig 173). As with other physico–chemical variables a wide tolerance is indicated.

Conductivity

Conductivity readings ranged from 4 to 220 µS/cm on the surface, and from 6 to 62 µS/cm on the bottom.

Habitat–structural variables

Substrate

As might be expected from its broad distribution, *A. agrammus* was found over the entire range of substrates defined in this study. The main one was mud (upper quarter), followed by sand (upper-middle quarter), then clay, leaf litter, gravel, boulders and rocks. Pollard (1974) commonly observed this species in shallow waters with sandy substrates.

Hydrophytes

Ambassis agrammus was usually captured in relatively heavily vegetated waters (vegetation-occurrence index 80.2%) with emergent (36.6%), submergent (35.4%) and floating-attached (24.7%) vegetation.

Reproduction

Of the 737 fish examined for reproductive condition, 153 were sexually indistinguishable, 235 were females and 349 were males. The length ranges were 18–64 mm LCF for females and 20–48 mm LCF for males.

Length at first maturity

The LFM was difficult to estimate as the percentage of mature fish in any season was between 50 and 100% (fig 90). Maturing individuals were found at 21 (female) and 27 mm LCF (male), but the LFM was estimated at 26 for females and 27 mm LCF for males.[145]

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[145] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to have a size at 50% maturity to be 70 mm for both males and females. Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland to have a minimum maturity size (females) of 32 mm standard length (it commences to breed at 1 year old).

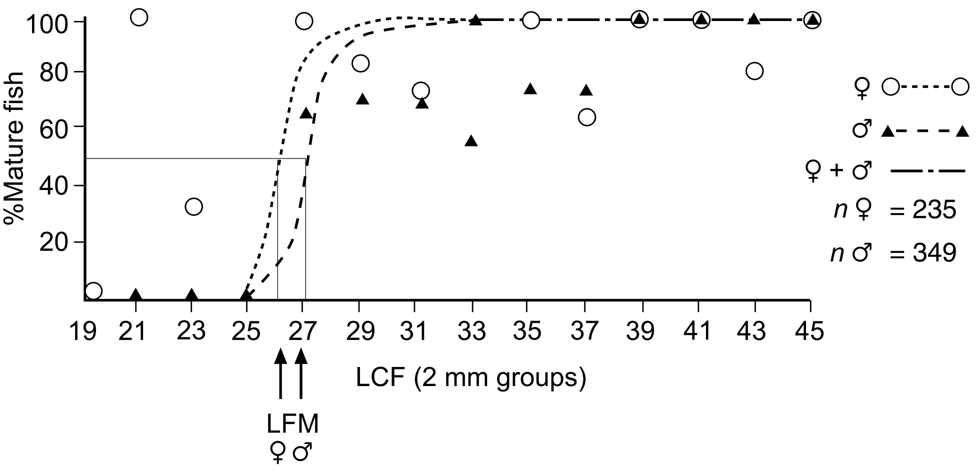

Figure 90 Estimated length at first maturity (LFM) of male and female *A. agrammus*

Sex ratio

For both juveniles + adults and adults only, the ratio of males to females was 1:1 in all seasons except the 1978 Late-dry and 1978–79 Early-wet seasons, when significantly more males were present (table 76).[146] As the unequal sex ratio occurred at the time of peak gonadal development, fish with regressed gonads are unlikely to have been misidentified as sexually indistinguishable. Localised movements within the waterbody, possibly connected with breeding behaviour, is suggested.

Breeding season

Ambassis agrammus had a well-defined breeding season: the gonads began to develop at the onset of the rains (1978 Late-dry, 1979–80 Early-wet seasons) and were fully developed in the 1978–79 Early-wet season, when the fish spawned (fig 91).[147] Rise in temperature is not thought to be a major influence on gonad development, as although the 1979 Late-dry season temperatures were higher than in the 1978 Late-dry season, the gonads were not significantly better developed. The main difference between these two seasons was that the rains were earlier and more consistent in the 1978 season, when the gonads did develop. *Ambassis agrammus* spawned at the onset of the Wet season proper; by the Mid-wet season the GSI had fallen to its lowest level.[148]

Roberts (1978) reported that *A. agrammus* in Papua New Guinea is an aseasonal breeder; however conditions are not similar to those in northern Australia.

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[146] Semple (1985) indicated that a single transient dimorphic feature was observed for gravid female *A. agrammus*. Such individuals often showed abdominal distension immediately before spawning. Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to have a sex ratio which did not differ significantly from unity during any month sampled. Similarly, Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland had an overall sex ratio which did not significantly differ from unity (some seasonal variation was apparent).

[147] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to have gonadosomatic index which remained relatively constant throughout the year in both sexes, indicating that spawning was occurring throughout the year. In contrast, Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland had highly seasonal breeding. The breeding period was October–November when water temperatures exceeded 22°C, preceding summer storms and correspondingly high and variable stream flows.

[148] Under laboratory conditions, Semple (1986) found that spawning occurred in water temperatures of 25–29°C. Smaller females spawned for a single night and larger females (> 40 mm SL) spawned up to four consecutive nights. Spent fish did not spawn again for 4–6 weeks.

Table 76 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *A. agrammus* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet– Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	38	46	36	27	61	24	3
adults	M	*n*	134	71	39	20	55	23	7
		χ^2	53.6	5.3	0.12	1.0	0.3	0.02	1.6
		P	**	*	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	36	40	34	27	58	22	3
	M	*n*	128	60	38	20	52	19	7
		χ^2	51.6	4.0	0.2	1.0	0.3	0.2	1.6
		P	**	*	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	2.9	7.0	0.7	0.9	1.4	1.3	4.1
		s.d.	2.1	1.9	0.7	1.3	0.7	0.6	1.5
	M	mean	1.1	2.7	0.4	0.9	0.4	0.6	4.2
		s.d.	0.5	1.6	0.4	0.6	0.2	0.3	0.4
	F+M	mean	2.0	4.6	0.5	0.9	0.9	1.0	4.2
		s.d.	1.7	2.8	0.6	1.0	0.7	0.6	1.0
GMSI									
Adults only	F	mean	3.2	4.8	1.9	1.8	2.0	2.5	4.0
		s.d.	0.8	0.7	0.7	1.0	0.7	0.5	0.0
	M	mean	3.6	4.5	1.8	2.7	2.6	2.5	4.9
		s.d.	0.4	0.7	0.9	1.2	0.7	0.6	0.1
	F+M	mean	3.5	4.6	1.9	2.2	2.8	2.5	4.5
		s.d	0.7	0.7	0.8	1.1	0.7	0.5	0.5

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.01$; s.d. = standard deviation.

Mature and ripe fish were found mainly in the 1978 Late-dry and 1978–79 Early-wet seasons, although one ripe fish was captured in the Mid-dry season, which indicated there may have been some aseasonal spawning.

Site of spawning

Ripe and spent fish were captured in backflow billabongs, floodplain billabongs and lowland sandy creekbed habitats (table 77).[149] These were also the habitats where *A. agrammus* was most abundant. Juvenile fish were found in all these habitats except the backflow billabongs. No ripe fish were captured in the corridor waterbodies, although juveniles were, and the species was very abundant.

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[149] Under laboratory conditions, Semple (1985) found that *A. agrammus* spawned within beds of aquatic plants. Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland laid adhesive eggs attached to aquatic plants.

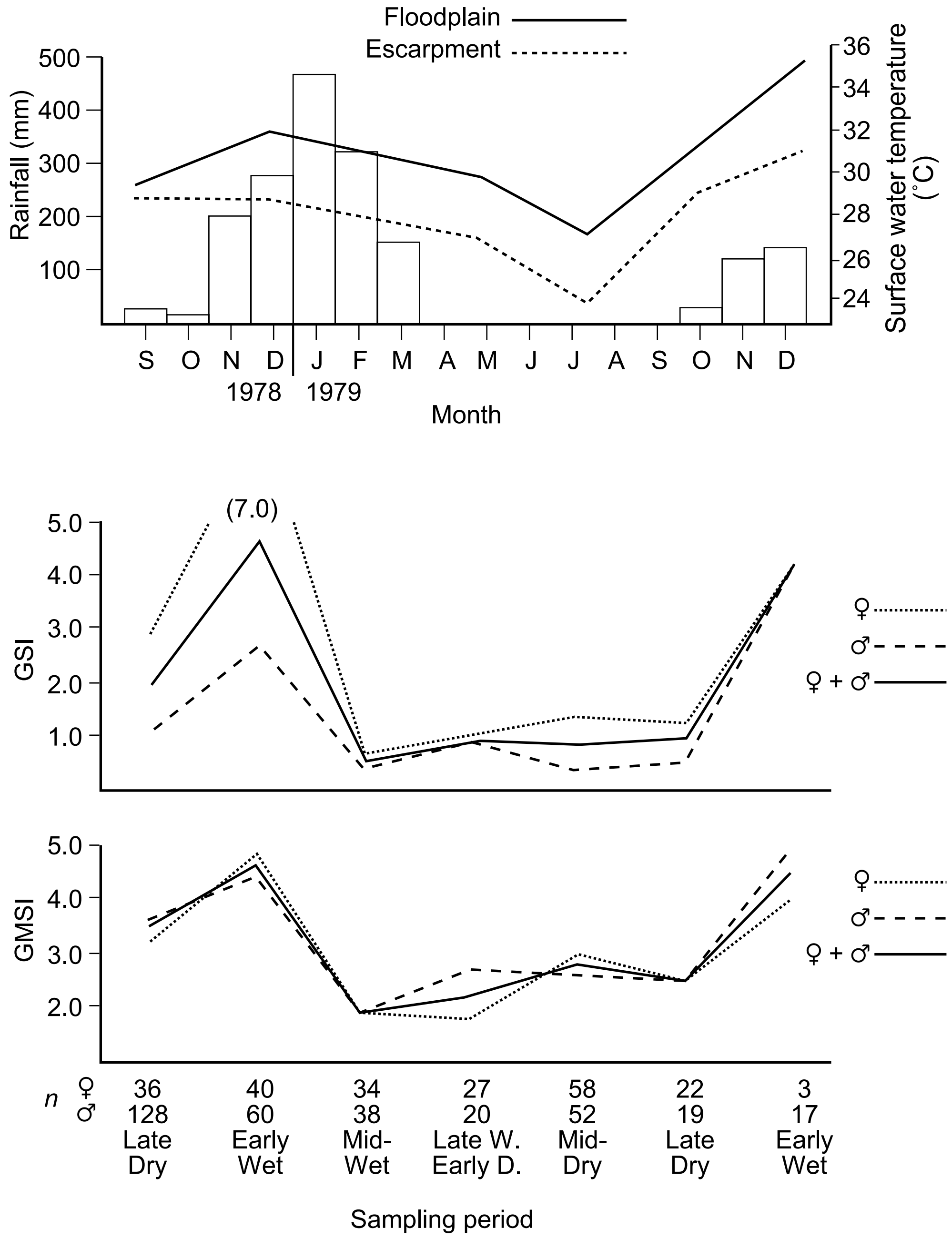

Figure 91 Seasonal fluctuations in gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *A. agrammus*

Fecundity

Sixteen ovaries were examined. The number of eggs ranged from 312 to 2905 with an average of 1614 (s.d. = 825).[150] Egg diameters were generally uniform throughout the ovary, although occasional clusters of small eggs were observed. The diameters ranged from 0.24 to 0.40 mm and were most commonly around 0.3 mm.

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[150] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to have a fecundity which varied from 29 000 to 310 000. Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland had a relatively low mean fecundity of 427 eggs per individual (mean egg size was 0.6 mm).

Table 77 Possible sites of spawning of *A. agrammus* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	–	–	–	–	–	–	1
Seasonal feeder stream	–	–	–	–	–	–	12
Perennial stream	1	–	–	–	–	–	9
Lowlands							
Sandy creekbed	–	4	2	2	–	–	45
Backflow billabong	9	30	17	8	–	–	–
Corridor	1	1	2	–	–	1	28
Floodplain billabong							
Upper	1	11	2	4	–	1	6

Very little is known about the reproduction of any species of *Ambassis*.[151] *A. castelnaui*, the western chanda perch from warmer waters of the Murray–Darling system, Queensland and the Northern Territory, has adhesive eggs about 0.7 mm in diameter. One female (49 mm LCF) contained 2350 eggs (Llewellyn 1980).

Lake (1971) described an overseas species of *Ambassis* in which the male chased the female and displayed with zig-zag motions. Small adhesive eggs were sprayed and fertilised amongst aquatic plants. Only a few eggs were shed at a time and spawning may have been repeated several times during the day, possibly for 4–5 days. Hatching was quite rapid: 12–14 hours at an unspecified temperature and 36 hours at 28°C. Breder and Rosen (1966) also suggested that *Ambassis* lays adhesive, demersal eggs amongst aquatic plants, and while distinct pairing may take place at spawning, there is no parental care.

Summary

Ambassis agrammus had a distinct breeding season, with gonads developing in the 1978 Late-dry and 1979–80 Early-wet seasons. They apparently spawned mainly in the backflow billabongs, sandy creekbeds and floodplain billabongs.

A large number of small eggs are laid. Reports on other species suggest that the adhesive, demersal eggs are scattered amongst the aquatic plants, where they hatch in 12–36 hours.

Feeding habits

Overall diet

The stomach contents of 736 specimens were examined; 679 stomachs contained food. The diet of *A. agrammus* is summarised in figure 92; the components are listed in table 78.

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[151] Semple (1985) subsequently described spawning behaviour, and embryonic development of *A. agrammus*. Under laboratory conditions, Semple found that smaller females (25 mm SL) released 5–20 eggs at one spawning, while larger females (45 mm SL) produced 200–250 per spawning.

Table 78 Dietary composition of *A. agrammus*

	Habitat						Season								
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants															
Algae															0.8
Miscellaneous	0.2	–	–	–	–	–	0.3	–	–	–	–	–	–	0.1	
Chlorophyceae															
Desmidaceae	–	–	0.4	–	–	–	–	–	0.3	–	–	–	–	0.1	
Dinophyceae	–	–	–	–	–	0.1	–	–	–	–	0.1	–	–	+	
Conjugatophyta															
Mougeotia	–	0.1	2.7	1.1	–	–	–	–	–	0.3	3.1	–	–	0.6	
Aquatic animals															
Protozoa	–	–	–	–	–	–	0.2	–	–	–	–	–	–	+	+
Porifera	–	–	–	–	–	–	+	–	–	–	–	–	–	+	+
Arachnida															4.5
Porohalacarida	–	0.1	–	–	–	–	–	–	–	0.5	–	–	–	+	
Hydracarina	19.4	2.1	6.5	3.1	33.8	0.2	2.6	7.0	2.7	5.1	6.7	1.9	–	4.5	
Microcrustacea															45.1
Conchostraca															
Miscellaneous	–	–	0.3	–	–	–	0.6	–	–	–	–	–	–	0.2	
Cyzicus	–	–	5.1	–	–	1.5	–	0.2	4.8	–	0.6	–	–	1.1	
Cladocera															
Miscellaneous	–	16.6	17.2	4.1	17.7	1.0	13.0	11.8	13.3	11.1	8.9	–	–	10.8	
Diaphanosoma	18.6	25.2	8.0	2.9	0.6	32.2	–	36.2	12.4	29.0	20.1	44.6	2.0	19.7	
Ostracoda	3.2	6.1	0.2	2.2	–	5.6	3.3	–	12.8	0.3	3.0	0.2	–	3.8	
Copepoda															
Miscellaneous	–	4.0	8.0	7.9	–	8.3	17.3	2.1	7.3	6.0	0.5	–	–	6.6	
Cyclops	–	3.4	–	0.1	–	1.6	–	–	–	–	7.9	0.2	98.0	2.9	
Macrocrustacea															0.9
Macrobrachium (adults)	–	–	–	0.8	–	–	0.6	–	–	–	–	–	–	0.2	
Macrobrachium (juv)	–	0.7	–	2.5	–	–	3.0	–	–	–	–	–	–	0.7	

Table 78 continued

	Habitat						Season								
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Insecta															25.4
Fragmented	–	0.7	0.6	0.8	–	1.0	0.4	–	2.1	–	0.8	–	–	0.6	
Ephemeroptera															
Baetidae	–	5.1	–	0.8	–	3.0	2.3	1.2	1.8	1.6	6.3	–	–	2.4	
Tasmanocoenis	–	–	–	–	–	1.0	–	–	–	–	0.8	–	–	0.1	
Hemiptera															
Anisops	–	–	–	–	–	–	1.3	–	–	–	–	–	–	0.3	
Corixidae	3.2	1.8	–	2.7	–	1.5	–	3.5	0.8	–	2.4	2.1	–	1.5	
Coleoptera															
Miscellaneous (adults)	–	0.2	–	–	–	–	–	–	0.3	–	–	–	–	0.1	
Miscellaneous (larvae)	1.1	–	–	–	–	–	0.1	0.1	–	–	–	–	–	0.1	
Dytiscidae (larvae)	–	–	–	–	–	0.7	–	–	–	–	–	1.5	–	0.1	
Rhantus	–	0.1	–	–	–	–	–	–	0.2	–	–	–	–	+	
Berosus							–	0.7	–	–	–	–	–	0.2	
Diptera															
Miscellaneous (larvae)	–	0.1	–	–	–	–	–	–	0.2	–	–	–	–	+	
Tipulidae	–	1.2	–	–	–	–	–	–	2.3	–	–	–	–	0.4	
Chaoborinae	–	4.1	–	–	–	–	–	6.8	–	–	–	–	–	1.5	
Chironomidae (larvae)	27.7	6.3	22.4	9.0	22.3	16.9	12.9	10.4	13.2	22.6	12.2	27.3	–	14.0	
Chironomidae (pupae)	0.3	1.3	3.3	1.7	–	0.5	4.1	0.1	0.1	0.2	1.6	–	–	1.3	
Ceratopogonidae	–	1.2	–	–	–	1.0	1.8	–	0.2	–	–	2.1	–	0.6	
Trichoptera															
Hydroptilidae	–	–	–	–	–	0.2	–	–	–	–	0.2	–	–	+	
Leptoceridae	–	1.5	1.1	1.0	1.8	9.1	–	0.7	2.9	1.9	7.3	–	–	2.2	
Teleostomi															0.7
Scales	–	–	0.2	–	–	0.1	0.1	–	0.2	–	–	–	–	+	
Miscellaneous (larvae)	–	–	–	–	–	1.3	–	0.8	–	–	–	–	–	0.2	
Craterocephalus sp.	3.1	–	–	–	–	–	0.6	–	–	–	–	–	–	0.1	
Egg material	–	0.4	–	–	–	–	–	0.7	–	–	–	–	–	0.2	
Anura															0.2
Miscellaneous (larvae)	–	–	–	–	–	1.0	–	0.7	–	–	–	–	–	0.2	

Table78 continued

	Habitat						Season							Overall	
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Terrestrial plants															
Angiospermae															0.1
Seed material	–	–	0.9	–	–	–	–	–	0.6	–	–	–	–	0.1	
Terrestrial animals															
Insecta															0.2
Trichoptera (adults)	–	0.4	–	–	–	–	0.4	–	0.8	–	–	–	–	0.2	
Parasites															
Trematoda	–	–	1.1	–	–	–	–	–	–	–	–	2.1	–	0.2	0.2
Nematoda	0.3	0.9	–	0.1	–	0.1	0.1	0.1	1.7	–	0.1	–	–	0.4	0.4
Microcrustacea															
Argulus	–	–	1.9	–	–	–	–	1.2	–	–	–	–	–	0.3	0.3
Detrital material	–	0.8	1.1	–	–	–	–	0.7	–	–	–	4.2	–	0.4	0.4
Inorganic material	–	1.3	0.2	1.0	–	–	1.4	1.5	0.2	0.2	–	–	–	0.7	0.7
Organic material	22.9	13.9	18.8	38.4	23.5	12.5	33.8	13.7	18.8	21.2	17.3	14.0	–	20.6	20.6
Number of empty fish	2	12	10	16	4	3	24	9	14	2	7	1	–	57	57
Number of fish with food	31	245	94	121	17	96	160	147	128	63	123	48	10	679	679

Figures represent the mean percentage volume determined by the estimated volumetric method.

Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs; Fb = floodplain billabongs

The main components were microcrustaceans (45%) (mainly cladocerans, copepods, ostracods and conchostracans) and aquatic insects (25%) (mainly chironomid, baetid and leptocerid larvae). Hydracarinids (5%) and traces of algae, macrocrustaceans, teleosts, anuran larvae, terrestrial insects and plant material were also eaten. *Ambassis agrammus* can therefore be classified as a microphagous carnivore feeding mainly in mid-waters and occasionally in benthic areas of the waterbodies.[152]

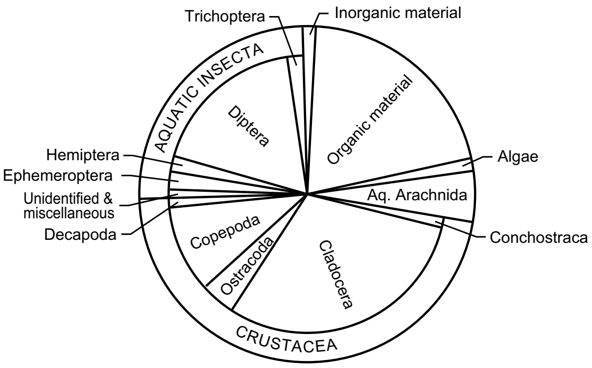

Figure 92 The main components of the diet of *A. agrammus*

Pollard (1974) suggested this species might eat small insect larvae and planktonic crustaceans. Lake (1978) noted that *A. agrammus* was similar to the inland chanda perch, *A. castelnaui*, which eats small invertebrates, particularly small crustaceans and mosquito larvae.

Sanderson (1979) noted *A. agrammus* on the Magela floodplain ate mainly small crustaceans (especially cladocerans), vegetable matter (algae and seeds) and organic detritus; in seasonal streams feeding the floodplain in the Wet season, the diet shifted to the benthic arthropod forms, especially hydracarinids, and winged terrestrial dipterans.

Seasonal changes

In sampling periods 1–7, respectively, 184 (13% empty), 156 (6% empty), 142 (10% empty), 65 (3% empty), 130 (5% empty), 49 (2% empty) and 10 (0% empty) stomachs of *A. agrammus* were examined (all habitats combined). The highest proportions of specimens with empty stomachs were found in the 1978 Late-dry and 1978–79 Mid-wet seasons.

The microcrustacean component of the diet was large throughout the study. The cladoceran component increased in importance in the 1978–79 Early-wet season, decreased during the 1979–80 Early-wet season, but remained important until the 1979 Late-dry season. The copepod component, in contrast, became markedly smaller in the 1978–79 Early-wet season, and remained relatively small, and had almost disappeared by the 1979 Late-dry season, after

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[152] Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland tends to feed within littoral vegetation and in the midwater. Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to consume mainly small insect larvae but also insects from terrestrial sources and on small crustaceans. Martin and Blaber (1983) found that 3 species of ambassids in a Natal estuary of South Africa feed mainly on a wide variety of zooplanktoners, with some fish and insects also occasionally consumed. All the species mainly fed on food suspended in the water column. Martin and Blaber (1984) concluded that the well-developed dentition and gut morphology (distensible stomach and a low relative gut length) of all the 3 species also suggested a predatory and carnivorous habit.

which it increased dramatically, to become effectively the sole food item that had been eaten by the few specimens examined in the 1979–80 Early-wet season.

The chironomid larvae were important in the diet throughout the study except in the 1979–80 Early-wet season; they were most important in the Late-wet–Early-dry season. Leptocerid and baetid larvae were most important in the diet during the 1979 Mid-dry season.

Habitat differences

Magela catchment

A total of 531 stomachs of *A. agrammus* were examined (all seasons combined): 33 (6% empty), from lowland sandy creekbeds; 257 (5% empty) from backflow billabongs; 104 (10% empty) from corridor billabongs; 137 (12% empty) from floodplain billabongs. The last two habitats had the highest proportions of specimens with empty stomachs.

The diet in the lowland sandy creekbeds was based primarily on chironomid larvae, cladocerans (*Diaphanosoma*) and hydracarinids. In the backflow billabongs, the hydracarinid component was smaller, while the microcrustacean component, particularly the cladocerans, copepods and ostracods, was larger; the aquatic insect component became more varied and included baetid, chironomid and chaoborid larvae.

The diet in the corridor waterbodies and floodplain was based on microcrustaceans. The aquatic insects were mainly chironomid larvae and pupae. Large volumes of unidentified organic material were also frequently found in the stomachs.

Nourlangie catchment

Totals of 21 (19% empty) and 99 (3% empty) stomachs of *A. agrammus* were examined (all seasons combined) from lowland sandy creekbeds and backflow billabongs, respectively. The highest proportions of specimens with empty stomachs were found in the sandy creekbed habitats (unlike the Magela catchment).

The diet in the lowland sandy creekbeds was very similar to that found in the equivalent Magela Creek habitat: mainly hydracarinids, chironomid larvae and cladocerans. The diet in the backflow billabongs was also similar to that in the Magela Creek system: mainly cladocerans, ostracods, copepods, and chironomid, baetid and leptocerid larvae.

Fullness

A summary of mean fullness indices of *A. agrammus* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 79. These data are presented on the assumption that feeding times do not vary with habitat or season.

Seasonal differences

Mean seasonal fullness indices were highest in the 1978–79 Early-wet season, fell to a low stable level, and increased again through the 1979 Mid-dry and Late-dry seasons.[153]

Habitat differences

In the Magela catchment, upstream from RUPA, mean fullness indices were highest in shallow backflow billabongs and lowest in sandy creekbeds. Downstream of RUPA, the indices, which were in the same range, were highest in backflow billabongs and lowest in corridor anabranch and floodplain billabongs.

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[153] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG had a stomach fullness index which exhibited little seasonality.

In the Nourlangie catchment mean fullness indices were also highest in the shallow backflow billabongs. The other habitats examined in this catchment had low indices typical of Magela Creek corridor anabranch and floodplain billabongs.

Table 79 Mean fullness indices of *A. agrammus* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

	Sampling period						
Habitat	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Habitat mean
Magela Creek catchment (regular sites only)							
Upstream of RUPA:							
Escarpment main-channel waterbody	2.6 (5)	n/s	3.3 (10)	n/s	n/s	n/s	3.1 (15)
Lowland sandy creekbed	n/s	n/s	1.7 (3)	n/s	n/s	n/s	1.7 (3)
Downstream of RUPA:							
Lowland sandy creekbed	3.0 (8)	2.2 (19)	n/s	n/s	1.3 (3)	n/s	2.3 (30)
Lowland channel backflow billabong	3.1 (10)	3.1 (37)	2.2 (20)	1.8 (5)	2.0 (5)	1.5 (10)	2.6 (87)
Lowland shallow backflow billabong	2.6 (24)	2.9 (28)	2.1 (49)	2.4 (10)	2.6 (35)	2.3 (9)	2.5 (155)
Corridor sandy billabong	2.1 (10)	2.2 (9)	1.5 (10)	n/s	2.1 (10)	4.4 (10)	2.1 (49)
Corridor anabranch billabong	1.6 (10)	n/s	1.1 (10)	n/s	2.6 (10)	n/s	1.8 (30)
Floodplain billabong	1.1 (41)	3.0 (30)	1.7 (20)	2.5 (24)	1.7 (37)	2.0 (10)	1.9 (162)
Nourlangie Creek catchment (regular sites only)							
Escarpment main-channel waterbody	n/s	1.8 (5)	n/s	n/s	n/s	n/s	1.8 (5)
Lowland channel backflow billabong	n/s	0 (1)	1.4 (10)	1.1 (10)	3.5 (10)	n/s	1.9 (31)
Lowland shallow backflow billabong	1.2 (6)	4.5 (17)	2.0 (10)	2.1 (10)	3.6 (10)	4.1 (10)	3.2 (63)
Lowland sandy creekbed	n/s	n/s	n/s	1.3 (6)	2.4 (10)	n/s	2.0 (16)
Seasonal mean (all sites)	2.0	2.9	2.0	2.0	2.4	2.9	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- corridor sandy billabong; 1979 Late-dry season
- escarpment mainchannel waterbody; 1978–79 Mid-wet season
- lowland channel backflow billabong; 1978 Late-dry season, 1978–79 Early-wet season

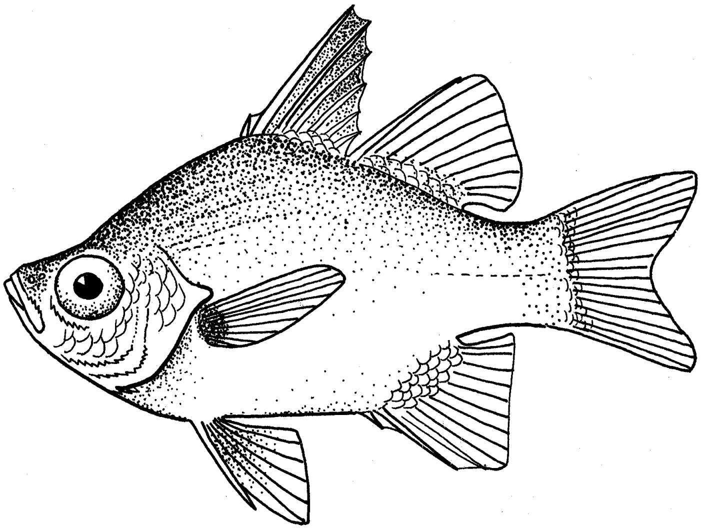
Nourlangie catchment

- lowland shallow backflow billabong; 1978–79 Early-wet season, 1979 Late-dry season.

Family AMBASSIDAE

3.22 *Ambassis macleayi* (Castelnau)

Ambassis macleayi is commonly known as the reticulated perchlet or glassfish, or chanda perch. It is distributed in the Gulf of Carpentaria and Timor Sea drainage systems (see map 3) and also occurs in rivers of southern Papua New Guinea. Pollard (1974) found it most commonly in turbid and heavily vegetated billabongs along the Magela Creek system. Miller (in Taylor 1964) reported it was abundant in large billabongs in the Oenpelli area.



Ambassis macleayi

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was moderately abundant in most corridor and backflow billabongs and common in floodplain[154] and lowland sandy creekbed sites and escarpment mainchannel waterbodies. It was found in the greatest number of sites in the Late-wet–Early-dry season and in the fewest in the 1978 Late-dry season.

Size composition

The lengths and weights of 2028 specimens were determined. The major and minor peaks in the overall length-frequency distribution correspond to the mesh selectivity of the 10 mm mesh seine net and the 26 mm mesh gillnet. Very small juveniles were captured in the seine net when hydrophytes and filamentous algae clogged the meshes.

Length–weight relationship

The length–weight relationship for the combined sexes was described by the expression:

$$W = 1.60 \times 10^{-2} L^{3.17} \qquad r = 0.98 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 80. The condition factor peaked in the 1978–79 Early-wet season, probably because of an increase in

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[154] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG not use the floodplain as a preferred habitat, even in the flood season.

reproductive condition; presumably environmental conditions and food availability were most favourable during this season.[155] However, by the Mid-wet and Late-wet–Early-dry seasons the condition went down to the 1978 Late-dry season level. It then improved in the Mid-dry and 1979 Late-dry seasons, but fell dramatically in the 1979–80 Early-wet (when conditions were comparable to an extreme Dry season). It seems, therefore, that conditions in the Wet and extreme Dry seasons lower the body condition of this species.

Table 80 Mean length, mean weight and condition factor of *A. macleayi*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	110	36.0	0.89	0.95
Early-wet (1978–79)	149	32.7	0.71	1.05
Mid-wet	221	40.8	1.34	0.97
Late-wet–Early-dry (1979)	340	37.0	0.99	0.98
Mid-dry	413	36.8	1.03	1.03
Late-dry	393	35.7	0.92	1.02
Early-wet (1979–80)	51	34.4	0.68	0.84
Overall	1677	36.6	0.98	1.00

Length-frequency distribution

The specimens captured ranged in length from 11 mm to 81 mm LCF (fig 93).

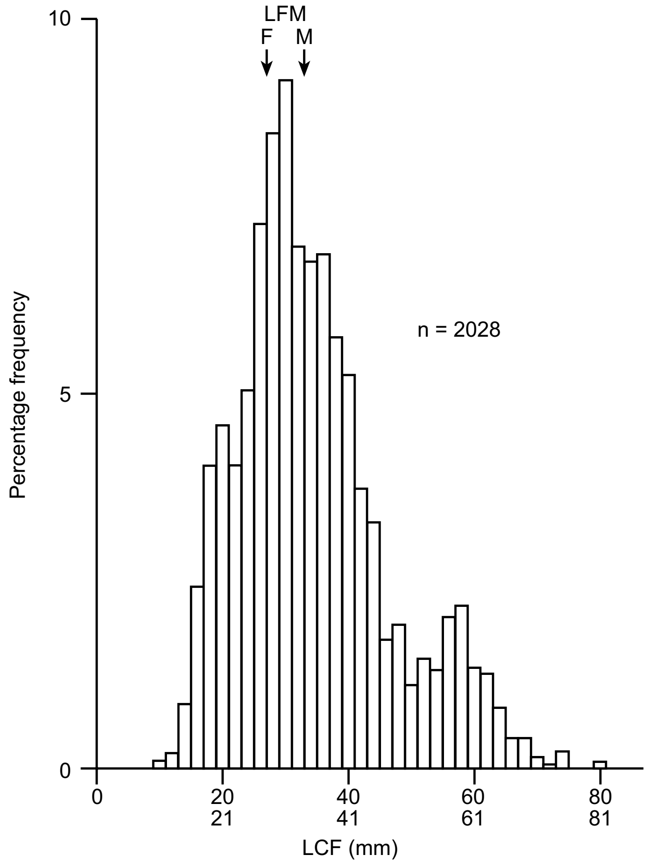

Figure 93 Length-frequency distribution of all *A. macleayi* captured

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[155] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG had a body condition which exhibited little seasonality.

Fishes of the genus *Ambassis* rarely exceed 80 mm in length (Lake 1971), however, *A. macleayi* is reputed to grow to 100 mm LCF (Pollard 1974).[156]

The mean and modal lengths of all specimens captured during the study were 36.6 and 30–31 mm LCF, respectively. The LFM for males was 33 mm LCF and for females 29 mm LCF, which indicates that most of the specimens were adults. There were two peaks in the length-frequency distribution: the larger peak (16–48 mm LCF) encompassed approximately 90% of the total number of specimens and the smaller peak (48–70 mm LCF) included most of the remainder.

Seasonal changes in distribution

The greatest number of small specimens was captured in the 1978–79 Early-wet season, followed closely by the 1978–79 Mid-wet and 1979 Mid-dry season. The greatest number of large specimens was captured in the 1978–79 Mid-wet season, followed closely by the 1978 Late-dry and 1979–80 Early-wet seasons (fig 94).

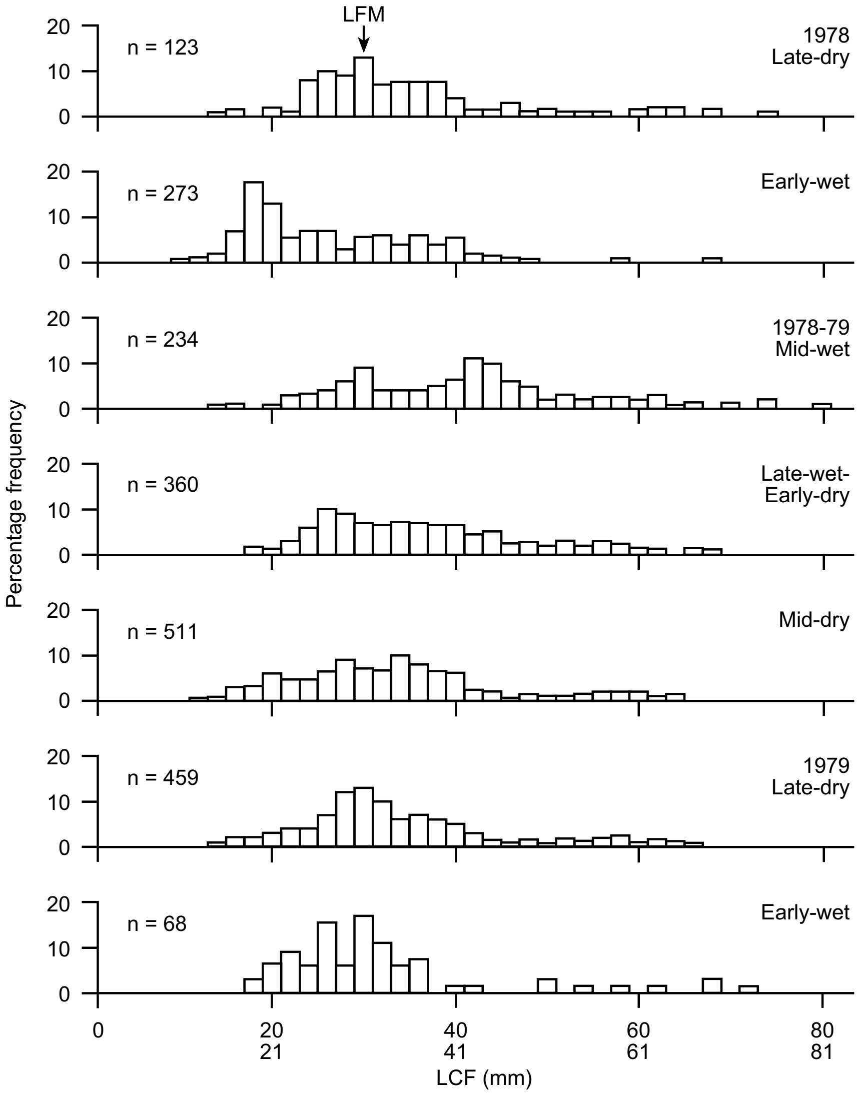

Figure 94 Seasonal length-frequency distribution of all *A. macleayi* captured

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[156] Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland grows to 54 mm standard length.

The length-frequency distributions in the Late-dry seasons were fairly similar, both being dominated by large juveniles and small adults, with smaller numbers of large adults. In the Early-wet seasons, samples were dominated by juveniles (especially in the 1978–79 season when there was a large juvenile peak) and to a lesser extent by small adults; few larger adults were found in these seasons (fig 94). The smallest mean lengths were recorded in the Early-wet seasons (table 80).

By the Mid-wet season adults dominated the samples, with greater numbers of larger adults and relatively few juveniles; as a consequence the mean lengths were the highest recorded for this species. The Late-wet–Early-dry and Mid-dry seasons had the same pattern (and therefore similar mean lengths) as the Late-dry seasons.

Continuous juvenile recruitment is indicated by the length-frequency distributions. There was a peak in recruitment in the 1978–79 Early-wet season.

Growth rate

No published information on the growth of *A. macleayi* was found. The growth rate was difficult to estimate from the seasonal length-frequency distributions due to mesh selectivity, continuous juvenile recruitment, and the range of habitats examined. A tentative estimate, based on specimens from channel backflow billabongs only, is that, like *D. bandata*, it may attain its LFM within one year.[157]

Habitat differences in distribution

Length-frequency distributions showing the habitats in which *A. macleayi* was captured in regular sampling sites in the Magela and Nourlangie Creek catchments are given in figure 95.

Magela catchment

The smallest juveniles were captured in corridor anabranch billabongs and backflow billabongs. Juveniles were found in a variety of habitats, though most commonly in corridor waterbodies, and backflow and floodplain billabongs; a few juveniles were captured in escarpment mainchannel waterbodies and lowland sandy creekbeds. No juveniles were found in escarpment perennial streams.

The largest adult was found in an escarpment mainchannel waterbody and other large specimens were captured in backflow billabongs. Intermediate-sized adults were found mainly in channel backflow billabongs and, to a lesser extent, in shallow backflow billabongs, floodplain and corridor anabranch billabongs and escarpment mainchannel waterbodies.

Small adults were mainly found in floodplain billabongs, shallow backflow billabongs upstream of RUPA, and in corridor anabranch billabongs. No adults were found in escarpment perennial streams.

Nourlangie catchment

Large juveniles were most commonly found in channel backflow billabongs, small adults in lowland sandy creekbeds, and intermediate-sized adults in escarpment mainchannel waterbodies. (Large schools were frequently observed near bedrock that overhung deep waters.) Adult *A. macleayi* were observed in escarpment perennial streams during the Mid-wet season.

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[157] Under laboratory conditions with a water temperature of 26°C, Ivantsoff et al (1988) indicated that *A. macleayi* can attain a total length of 30–34 mm in 80 days. By 150 days a total length of 36–40 mm was attained. Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland grows to the following standard lengths: year 1, 31 mm; year 2, 43 mm; year 3, 51 mm. This species commences to breed at 1 year old.

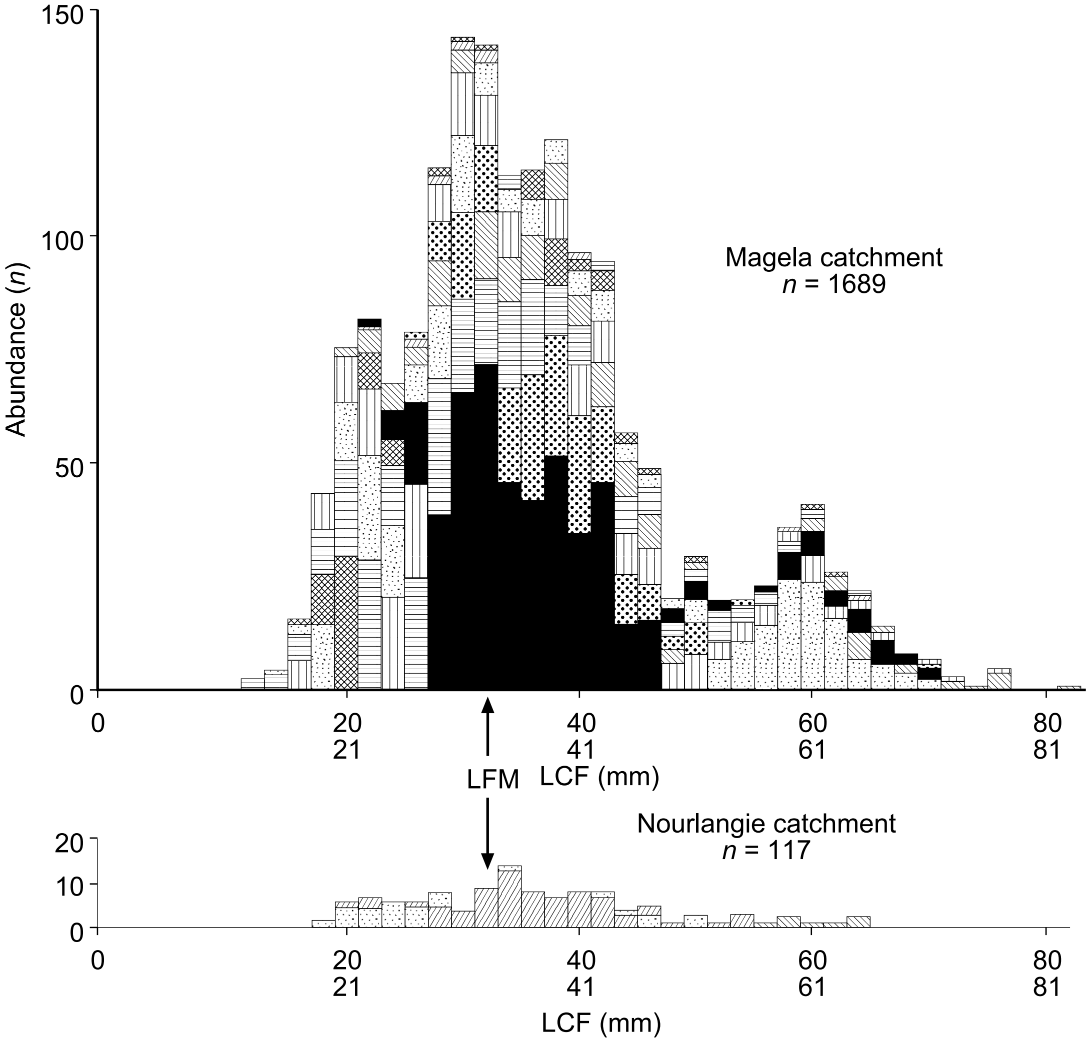

Figure 95 Length-frequency distributions and habitat preferences of *A. macleayi* captured at regular sampling sites (see appendix 5 for key to the habitats)

Environmental associations

Rank numbers for *A. macleayi* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

The water temperatures at sites where *A. macleayi* was captured ranged from 23° to 38°C (mean = 30.6°C) on the surface and from 25° to 34°C (mean = 29.3°C) on the bottom. These means ranked high in the upper and lower-middle quarters respectively (see fig 170). Apart from the lower maximum, these ranges are close to those found for *A. agrammus*.

Dissolved oxygen

Dissolved oxygen concentrations ranged from 1.0 to 9.1 mg/L (mean = 6.2) on the surface, and from 0.5 to 9.5 mg/L (mean = 4.6) on the bottom. These means both ranked in the upper-middle quarter (see fig 171). The tolerance of a wide range of DO concentrations is in accord with the distribution of *A. macleayi.* Like *A. agrammus*, it is found in habitats ranging from escarpment to floodplain.

Visibility

Secchi depth readings ranged from 1 to 150 cm (mean = 47.6 cm) (see fig 172). This mean depth was placed in the lower-middle quarter, indicating an apparent preference for less turbid waters than *A. agrammus*, although with a far narrower range.

pH

The pH values of surface waters ranged from 4.8 to 7.7 (mean = 6.2), and of bottom water from 5.3 to 7.0 (mean = 6.1). These means were placed in the lower-middle and upper-middle quarters, respectively (see fig 173). These ranges are markedly narrower than those associated with *A. agrammus*.

Conductivity

Conductivity readings ranged from 2 to 620 µS/cm on both the surface and the bottom. *A. macleayi* appears to tolerate a wider range of dissolved solids concentrations than *A. agrammus*.

Habitat–structural variables

Substrate

Like *A. agrammus, A. macleayi* was captured over the entire range of substrates, especially sand (lower-middle quarter), followed by mud (lower-middle quarter), then clay, gravel, leaves, rocks and boulders.

Hydrophytes

A. macleayi was typically captured in waters with moderate vegetation (vegetation-occurrence index 76.4%) of submergent (41.6%), emergent (34.4%) and floating-attached (19.1%) hydrophytes. *A. macleayi* was found in more sparsely vegetated waters than was *A. agrammus*, and in association with submergent rather than emergent vegetation.

Reproduction

A total of 533 fish were examined to establish reproductive condition: 53 were sexually indistinguishable, 195 were females and 285 were males. The length ranges of the male and female fish were 16–74 mm and 20–81 mm LCF, respectively.

Length at first maturity

The smallest individuals found with maturing gonads were a 31 mm LCF male and a 27 mm LCF female.[158] The estimated LFM was 33 mm LCF for males and 29 mm LCF for females (fig 96). Males of this species generally tended to be larger than the females.

Sex ratio

As with *A. agrammus*, more males than females were found in the 1978 Late-dry season; however, for *A. macleayi*, more males were also found during the 1978–79 Mid-wet (juvenile and adult fish combined) and the 1979 Mid-dry (all fish and adults only) (table 81).[159] It is unlikely that the gonads were misidentified, as females were easily recognisable and quite distinct from males.

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[158] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to have a size at 50% maturity to be 70 mm for both males and females. Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland to have a minimum maturity size (females) of 32 mm standard length (it commences to breed at 1 year old).

[159] Coates (1990) found *A. interrupta* in the Sepik River to have a sex ratio which did not differ significantly from unity during any month sampled. Similarly, Milton and Arthington (1985) indicated that *A. nigripinnis* from SE Queensland had an overall sex ratio that did not significantly differ from unity (some seasonal variation was apparent).

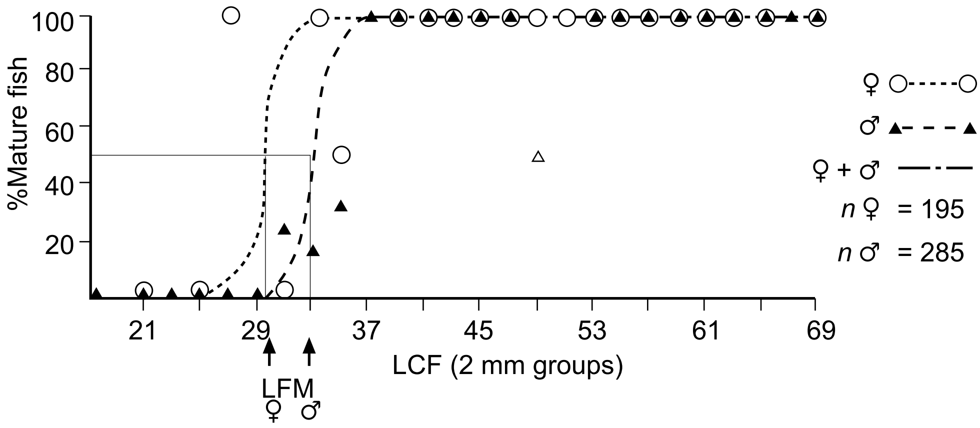

Figure 96 Estimated length at first maturity (LFM) of male and female *A. macleayi*

Table 81 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *A. macleayi* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles + adults	F	*n*	11	25	22	34	49	47	7
	M	*n*	28	30	39	41	80	59	8
		χ^2	7.4	0.5	4.7	0.7	7.5	1.4	0.1
		P	**	n.s.	*	n.s.	**	n.s.	n.s.
Adults only	F	*n*	11	20	22	34	48	46	7
	M	*n*	28	25	36	41	73	49	8
		χ^2	7.4	0.6	3.4	0.7	5.2	0.1	
		P	**	n.s.	n.s.	n.s.	*	n.s.	n.s.
GSI									
Adults only	F	mean	2.8	3.5	1.4	1.3	1.6	2.1	1.7
		s.d.	1.4	1.8	1.2	1.0	1.1	1.1	1.3
	M	mean	0.5	1.5	0.2	0.3	0.4	0.6	0.4
		s.d.	0.2	1.3	0.1	0.2	0.2	0.3	0.2
	F+M	mean	1.4	2.6	0.8	0.8	1.0	1.3	1.1
		s.d.	1.5	1.9	1.0	0.9	1.0	1.1	1.2
GMSI									
Adults only	F	mean	4.2	4.2	2.9	2.9	3.3	3.6	3.6
		s.d.	1.1	0.9	0.9	1.1	1.0	0.8	1.1
	M	mean	3.5	4.4	2.3	2.4	3.0	3.3	2.5
		s.d.	1.2	1.3	0.5	0.8	0.8	0.8	1.5
	F+M	mean	3.7	4.3	2.6	2.7	3.2	3.4	3.1
		s.d	1.2	1.1	0.8	1.0	0.9	0.8	1.4

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.01$; s.d. = standard deviation.

When the sex ratio was determined for individual habitats, it was found to be significantly different from 1:1 at a backflow billabong (Goanna Billabong) and a large escarpment-area pool (Deaf Adder Creek, Camp 1) during the 1978 Late-dry season, and at other backflow billabongs (Indium and Corndorl billabongs) during the 1979 Mid-dry season. The sex ratios were not significantly different from a 1:1 at other sites or in other seasons.

Breeding season

The GSI and GMSI were stable throughout the year, with a small peak in gonad development in the 1978–79 Early-wet season (fig 97).[160]

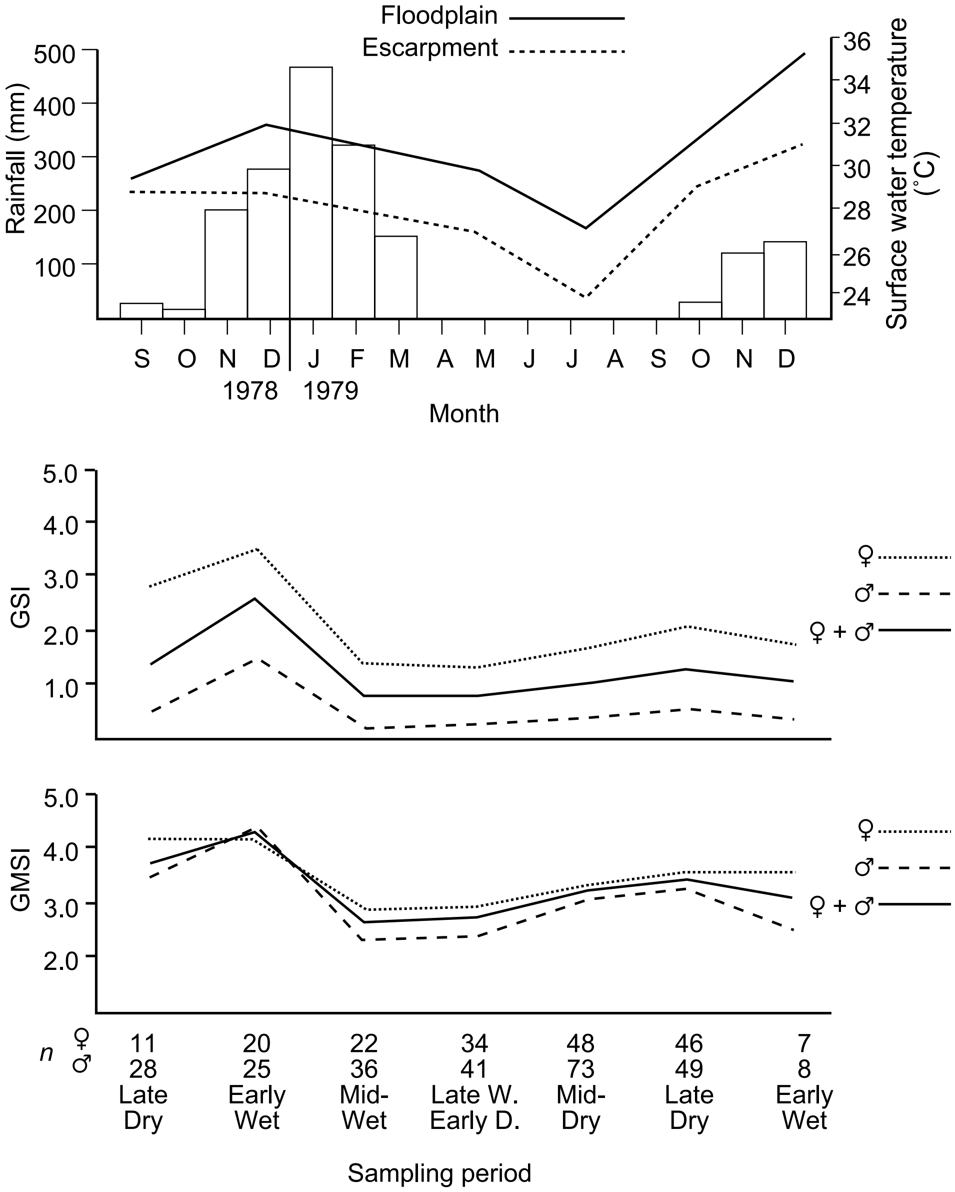

Figure 97 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *A. macleayi*

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[160] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to have gonadosomatic index which remained relatively constant throughout the year in both sexes, indicating that spawning was occurring throughout the year. Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland had highly seasonal breeding. The breeding period was October-November when water temperatures exceeded 22°C, preceding summer storms and correspondingly high and variable stream flows.

Mature fish were captured in all seasons, although ripe fish were only caught in the 1978 Late-dry and 1978–79 Early-wet seasons. The smallest juveniles were caught in the Mid-dry season, although this may reflect effort or mesh selectivity.

Spent fish were caught in many seasons, from the 1978–79 Mid-wet season through the Late-wet–Early-dry season to the 1979 Mid-dry season. This species may have a long recovery period after spawning or some fish may have spawned after the 1978–79 Early-wet season, although no ripe and few mature fish were captured after that time.

Site of spawning

Mature fish were captured in a wide range of sites (table 82), from backflow billabongs to the corridor waterbodies and floodplain billabongs. No mature fish were captured in escarpment mainchannel waterbodies. Ripe fish were caught only in a backflow billabong (Indium Billabong) and an adjacent sandy creekbed site. Ripe fish were also captured in a lowland sandy creekbed (Nourlangie Crossing 2) of the Nourlangie Creek. It appears that *A. macleayi* generally spawns in flowing sandy creeks. Juveniles were captured in the sandy creek areas and also corridor waterbodies.[161]

Table 82 Possible sites of spawning of *A. macleayi* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	–	–	–	–	1	1	–
Lowlands							
Sandy creekbed	1	–	1	7	–	–	4
Backflow billabong	13	20	1	1	–	2	–
Corridor	20	3	–	–	2	–	6
Floodplain billabong							
Upper	–	–	–	–	1	–	–
Artificial	1	–	–	–	–	–	–

Fecundity

Six ovaries were examined. The only eggs counted were in the size-class of the largest eggs, although occasional clusters of smaller eggs were noted. Egg numbers ranged from 320 (from a 45 mm LCF fish with a gonad weight of 0.06 g) to 2360 (from a 63 mm LCF fish with a gonad weight of 0.12 g); the average number of eggs was 1340. The number of eggs increased with increasing size of both fish and ovary. The mean egg diameter of 0.3 mm

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[161] Under laboratory conditions, Ivantsoff et al (1988) found that *A. macleayi* preferred dense aquatic vegetation for spawning. Eggs were laid high on the plants. Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland laid adhesive eggs attached to aquatic plants.

(± 0.07) appeared to be independent of egg number and fish size. Thus *A. macleayi* generally had a relatively large number of very small eggs.[162]

The small eggs and probably short incubation period, as observed in *A. agrammus*, suggest that the prolarvae would be poorly developed, with poor swimming ability.

Summary

Ambassis macleayi had a uniformly low level of sexual development throughout the year, although a small peak was noted in the 1978–79 Early-wet season. In some habitats at some sampling times there were significantly more males than females, which suggests a localised sexual behavioural pattern. Evidence of spawning was only found in lowland sandy anabranches of the Magela and Nourlangie creeks. The many small eggs are probably laid amongst the aquatic vegetation. The incubation period is likely to be short, so the undeveloped larvae would be dispersed by the flowing creek water.[163]

Feeding habits

Overall diet

The stomachs of 519 specimens were examined; 485 contained food. The diet of *A. macleayi* is summarised in figure 98; the components are detailed in table 83. The main items were microcrustaceans (55%) (with which large quantities [18%] of unidentified organic material were associated) and aquatic insects (19%). The microcrustaceans were mainly cladocerans (*Diaphanosoma*) and copepods; the aquatic insects were mainly chironomid larvae and pupae, and baetid larvae.

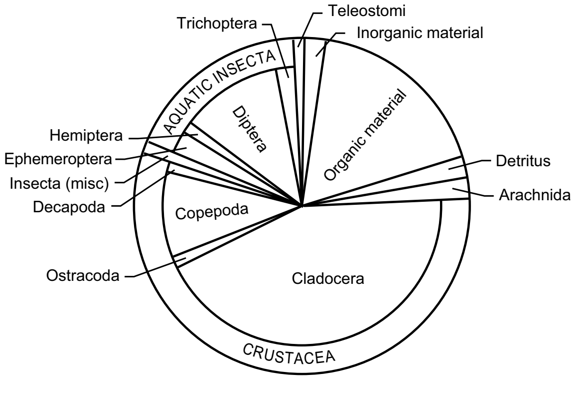

Figure 98 The main components of the diet of *A. macleayi*

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[162] Under laboratory conditions, Ivantsoff et al (1988) found that *A. macleayi* released a few eggs initially each day, but the number increased, possibly to above 200 on the second and third days. Spawning continued for about a week, followed by a period of reduced activity. Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to have a fecundity which varied from 29 000 to 310 000. Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland had a relatively low mean fecundity of 427 eggs per individual (mean egg size was 0.6 mm).

[163] Ivantsoff et al (1988) subsequently described spawning behaviour, egg surface morphology and embryonic and larval development of *A. macleayi*.

Table 83 Dietary composition of *A. macleayi*

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																	
Algae																	0.9
Miscellaneous	–	–	–	0.8	–	–	–	–	–	–	–	–	–	0.9	–	0.2	
Dinophyceae	–	–	0.7	–	–	–	–	–	–	–	–	–	1.2	–	–	0.3	
Conjugatophyta																	
Mougeotia	0.3	–	–	–	–	–	–	11.8	–	–	0.2	2.4	–	–	–	0.4	
Aquatic animals																	
Arachnida																	1.5
Hydracarina	6.6	–	1.2	–	2.3	–	2.2	–	3.0	0.8	–	–	1.5	1.4	11.1	1.5	
Microcrustacea																	54.7
Conchostraca	–	–	–	–	–	–	–	–	2.3	–	–	–	–	–	–	0.2	
Cladocera																	
Miscellaneous	19.1	16.7	8.5	4.6	5.9	–	16.5	–	40.6	7.4	13.0	8.3	7.6	2.8	–	9.9	
Diaphanosoma	5.6	41.7	51.4	29.7	24.1	–	32.8	–	–	66.2	13.6	32.5	32.3	39.5	51.6	34.4	
Ostracoda	5.3	–	–	0.9	–	–	1.3	–	–	–	5.8	–	–	0.3	–	0.6	
Copepoda																	
Miscellaneous	1.7	–	8.4	9.2	2.9	–	–	–	8.8	1.9	7.0	4.6	17.3	1.0	0.3	7.2	
Cyclops	–	–	2.7	0.6	–	–	23.0	–	–	1.2	–	–	1.3	8.7	–	2.3	
Macrocrustacea																	0.6
Macrobrachium	–	–	–	2.6	–	–	–	–	–	1.5	–	–	–	1.9	–	0.6	
Insecta																	19.0
Fragmented	7.7	–	0.2	0.9	–	16.7	–	–	–	2.0	6.4	–	–	–	2.4	1.0	
Ephemeroptera																	
Baetidae	5.5	–	2.4	3.6	2.9	–	0.9	15.9	4.6	2.0	3.6	4.5	3.2	–	9.2	3.0	
Atalophlebia	–	–	–	–	–	–	–	5.9	–	–	–	–	0.8	–	–	0.2	
Hemiptera																	
Gerridae	–	–	0.5	–	–	–	–	–	–	–	–	–	0.8	–	–	0.2	
Veliidae	–	–	–	–	–	–	–	–	2.3	–	–	–	–	–	–	0.2	
Corixidae	0.6	–	0.6	–	2.9	–	–	–	–	–	3.2	–	0.2	2.0	–	0.8	
Coleoptera	–	5.0	0.2	–	–	–	–	–	–	–	–	0.7	0.2	–	–	0.2	

Table 83 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Diptera																	
Culicidae (larvae)	7.2	–	–	–	–	–	–	–	–	–	–	–	–	–	12.1	0.5	
Culicidae (pupae)	–	–	0.5	–	–	–	–	–	–	–	–	–	–	1.0	–	0.2	
Chaoborinae	–	–	1.0	–	–	–	–	–	–	–	–	–	1.6	–	–	0.4	
Chironomidae (larvae)	3.9	0.8	3.2	10.1	8.8	–	5.4	5.9	9.6	2.7	3.4	7.3	8.0	3.9	6.6	5.9	
Chironomidae (pupae)	7.8	2.5	1.6	5.8	2.9	16.7	3.9	11.8	3.9	0.2	4.7	2.7	7.7	2.3	–	3.7	
Ceratopogonidae	0.9	–	–	2.0	–	–	0.9	–	–	0.3	–	–	–	2.2	1.6	0.6	
Trichoptera																	
Hydroptilidae	–	–	0.5	–	–	–	–	–	–	–	–	–	0.8	–	–	0.2	
Leptoceridae	3.1	–	0.5	–	–	–	–	35.3	–	–	2.1	–	5.7	–	–	1.7	
Lepidoptera																	
Pyralidae	3.1	–	–	–	–	–	–	–	–	–	2.1	–	–	–	–	0.2	
Teleostomi																	1.0
Fragmented	–	–	–	0.9	–	–	–	–	–	–	2.1	–	–	–	–	0.2	
Scale	3.1	–	0.9	–	–	–	–	–	–	–	2.1	–	0.8	0.8	–	0.6	
Miscellaneous (larvae)	–	–	–	–	–	–	–	–	–	–	–	1.2	–	–	–	0.2	
Terrestrial plants																	
Angiospermae																	0.3
Fragmented	–	–	+	–	–	–	4.3	–	–	1.5	–	–	+	–	–	0.2	
Seed material	1.6	–	–	–	–	–	–	–	–	–	1.1	–	–	–	–	0.1	
Terrestrial animals																	
Insecta																	0.2
Hymenoptera																	
Formicidae	–	–	0.5	–	–	–	–	–	–	–	–	1.2	–	–	–	0.2	
Parasites																	
Nematoda	–	–	+	–	–	–	–	–	0.1	–	–	–	–	–	–	+	+
Detrital material	–	6.7	4.7	–	–	–	4.4	–	–	2.8	–	–	–	9.3	–	2.3	2.3
Inorganic material	–	4.2	2.4	0.6	–	16.7	–	–	–	0.8	2.1	–	0.1	5.4	–	1.5	1.5
Organic material	16.9	22.5	7.4	27.6	47.1	50.0	4.3	13.5	25.0	8.8	27.5	34.5	8.9	16.9	5.3	18.1	18.1
Number of empty fish	–	–	8	11	11	–	–	1	1	4	5	2	11	10	1	34	34
Number of fish with food	32	12	202	110	34	6	23	17	44	65	47	84	124	102	19	485	485

Figures represent the mean percentage volume determined by the estimated volumetric method. + = present, but in very small proportions

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs Cb = corridor billabongs; Fb = floodplain billabongs

Traces of algae, aquatic arachnids, macrocrustaceans, teleosts, terrestrial plant material and insects, detritus and inorganic material were also found in the stomachs. *Ambassis macleayi* can therefore be classified as a microphagous carnivore feeding mainly in midwater and occasionally from the benthic areas of the waterbodies.[164]

Pollard (1974) thought it was likely that the diet of this species would include small insects occurring in aquatic vegetation. Haines (1979) classified the closely related *Ambassis interruptus* as an insectivore in the Purari River.

Seasonal changes

In sampling periods 1–7, respectively, 45 (2% empty), 69 (6% empty), 52 (10% empty), 86 (2% empty), 135 (9% empty), 112 (9% empty) and 20 (5% empty) stomachs of *A. macleayi* were examined (all habitats combined). The highest proportion of specimens with empty stomachs occurred in the Mid-wet, Mid-dry and 1979 Late-dry seasons.

The microcrustacean component of the diet was important throughout the study. The cladocerans component increased and the copepod component decreased during the 1978–79 and the 1979–80 Early-wet seasons.

Aquatic insects were less important in the diet. Chironomid larvae and pupae were common in the stomachs during the 1978 Late-dry season, then became less common until the Late-wet–Early-dry and the Mid-dry seasons, when they increased in importance again. Most unidentified organic material was found in the stomachs in the 1978 Late-dry, 1978–79 Mid-wet and Late-wet–Early-dry seasons.

Habitat differences

Magela catchment

A total of 420 stomachs of *A. macleayi* were examined (all seasons combined): 32 (0% empty) from escarpment mainchannel waterbodies, 12 (0% empty) from lowland sandy creekbeds, 210 (4% empty) from lowland backflow billabongs, 121 (9% empty) from corridor billabongs, and 45 (24% empty) from floodplain billabongs.

In escarpment mainchannel waterbodies, aquatic insects (chironomid, culicid and baetid larvae) were the main component in the diet, although considerable numbers of cladocerans, ostracods and hydracarinids were found in the stomachs. There were large volumes of unidentified organic material in the stomachs in both this habitat and in lowland sandy creekbeds where large numbers of cladocerans, particularly *Diaphanosoma*, were also eaten. There was a large cladoceran component in the diet in the backflow billabongs. Copepods were also present in the diet in the backflow billabongs, as well as in the corridor waterbodies. The microcrustacean component of the diet was generally smaller in the corridor and floodplain billabongs, while chironomid larvae and pupae were more important, and so there was a large unidentified organic material component.

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[164] Milton and Arthington (1985) indicated that the closely related *A. nigripinnis* from south-eastern Queensland tends to feed within littoral vegetation and in the midwater. Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG to consume mainly small insect larvae but also insects from terrestrial sources and on small crustaceans. Martin and Blaber (1983) found that 3 species of ambassids in a Natal estuary of South Africa feed mainly on a wide variety of zooplanktoners, with some fish and insects also occasionally consumed. All the species mainly fed on food suspended in the water column. Martin and Blaber (1984) concluded that the well-developed dentition and gut morphology (distensible stomach and a low relative gut length) of all the 3 species also suggested a predatory and carnivorous habit.

Nourlangie catchment

A total of 47 stomachs of *A. macleayi* were examined (all seasons combined): 6 from escarpment mainchannel waterbodies, 23 from lowland sandy creekbeds and 18 from backflow billabongs. Only one specimen, from a backflow billabong, had an empty stomach.

The few specimens in the escarpment waterbodies that were examined were feeding mainly on aquatic insects (chironomid pupae), as in the equivalent habitat in the Magela Creek catchment. There were no microcrustaceans but large amounts of unidentified organic material in their stomachs. The diet in the lowland sandy creekbeds was based mainly on cladocerans and copepods, as in the Magela catchment. However, unlike the Magela catchment, the diet in the backflow billabongs did not include microcrustaceans; the main items were aquatic insects (leptocerid larvae, baetid, *Atalophlebia* larvae and chironomid larvae and pupae) and smaller quantities of incidentally ingested algae.

Fullness

The mean fullness indices of *A. macleayi* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments are summarised in table 84. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 84 Mean fullness indices of *A. macleayi* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	0 (1)	n/s	2.8 (20)	n/s	0 (1)	n/s	2.8 (10)	2.6 (32)
Lowland sandy creekbed	n/s	n/s	n/s	n/s	2.4 (10)	2.6 (10)	1.0 (2)	1.0 (2)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	2.7 (7)	n/s	2.0 (5)	n/s	n/s	n/s	2.2 (13)
Lowland channel backflow billabong	2.0 (8)	2.0 (9)	n/s	1.8 (5)	2.8 (40)	3.1 (31)	3.1 (4)	2.7 (97)
Lowland shallow backflow billabong	0 (1)	3.8 (12)	0 (1)	2.8 (11)	2.9 (20)	2.1 (30)	n/s	2.6 (75)
Corridor sandy billabong	2.4 (5)	3.4 (5)	n/s	3.0 (2)	n/s	n/s	n/s	2.9 (12)
Corridor anabranch billabong	n/s	2.7 (10)	1.7 (11)	1.5 (13)	2.1 (10)	2.6 (10)	n/s	2.1 (54)
Floodplain billabong	2.5 (2)	2.3 (6)	n/s	2.1 (20)	1.9 (43)	1.6 (25)	n/s	1.9 (96)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	n/s	n/s	1.6 (5)	n/s	0 (1)	n/s	n/s	1.3 (6)
Lowland channel backflow billabong	n/s	n/s	2.0 (2)	1.8 (6)	3.0 (9)	n/s	n/s	2.5 (17)
Lowland sandy creekbed	n/s	3.9 (17)	n/s	n/s	n/s	4.0 (6)	n/s	3.9 (23)
Seasonal mean (all sites)	2.2	3.2	2.2	2.3	2.5	2.5	3.3	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Seasonal changes

In the main, seasonal fullness indices were stable throughout most of the year, except for peaks in the Early-wet seasons.[165]

Habitat differences

In the Magela catchment, upstream of RUPA, the mean fullness indices were comparable with those recorded in downstream habitats. Downstream of RUPA they were highest in the sandy corridor waterbodies and lowest in the floodplain billabongs.

In the Nourlangie catchment the mean fullness indices were highest in the lowland sandy creekbed habitats and lowest in the escarpment mainchannel waterbodies.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- escarpment mainchannel waterbody; 1978–79 Mid-wet season, 1979–80 Early-wet season
- lowland shallow backflow billabongs; 1978–79 Early-wet season
- lowland channel backflow billabongs; 1979 Late-dry season, 1979–80 Early-wet season

Nourlangie catchment

- lowland sandy creekbed; 1978–79 Early-wet season, 1979 Late-dry season.

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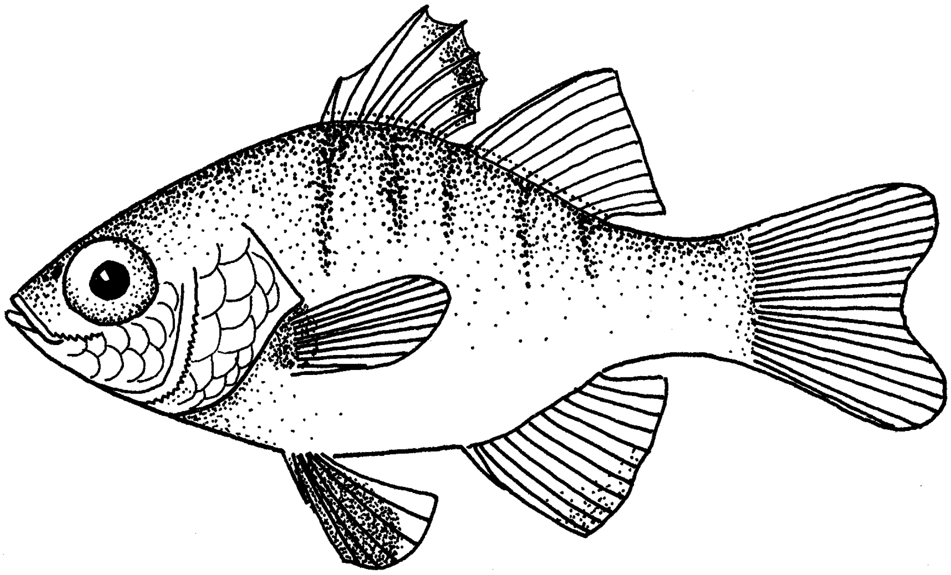
[165] Coates (1990) found the closely related *A. interrupta* in the Sepik River of PNG had a stomach fullness index which exhibited little seasonality.

Family AMBASSIDAE

3.23 *Denariusa bandata* (Whitley)

Denariusa bandata is commonly known as the pennyfish. It is found in the Timor Sea and Gulf of Carpentaria drainage systems (see map 3) and southern rivers of Papua New Guinea. Midgley (1973) collected this species in floodplain and lowland backflow billabongs in the Magela Creek system. Miller (cited in Taylor 1964) found it in a large billabong in the Oenpelli area and in (Eastern) Red Lily Billabong. Little is known about its biology.



Denariusa bandata

Detailed information on catches at each site and in each season is given in volume 2. In summary, *D. bandata* was moderately abundant in all floodplain, corridor and lowland backflow (mainly shallow) billabongs. It was also found commonly in some lowland sandy creekbeds. It was found in the greatest number of sites in the Late-wet–Early-dry season (mainly in lowland backflow and floodplain billabongs); it was found in the fewest sites in the Mid-wet season (mainly in corridor waterbodies).

Size composition

The lengths and weights of 1340 specimens were determined. The slight positive skew of the overall distribution was probably an artefact of the mesh size (10 mm) of the seine net.

Length–weight relationship

The length–weight relationship for the sexes combined was:

$$W = 2.44 \times 10^{-2} L^{2.75} \qquad r = 0.91 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 85. The seasonal condition factor was highest in the 1978 Late-dry and fell markedly by the 1978–79 Early-wet season; this fall may have been caused by a peak in spawning activity (as evidenced by the presence of juvenile recruits), changing environmental conditions caused by the onset of water flow, or both. The condition factor then gradually increased through the Wet season to reach a stable level (near unity) by the Late-wet–Early-dry season, where it remained for the remainder of the study. The condition attained by the 1979 Late-dry season was slightly less than that recorded in the same season in 1978.

Table 85 Mean length, mean weight and condition factor of *D. bandata*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	212	28.7	0.46	1.03
Early-wet (1978–79)	17	28.5	0.44	0.95
Mid-wet	74	26.7	0.36	0.98
Late-wet–Early-dry (1979)	206	27.6	0.39	1.01
Mid-dry	296	29.0	0.45	0.98
Late-dry	33	27.6	0.40	1.00
Overall	838	28.2	0.42	1.00

Length-frequency distribution

The smallest specimen captured was 9 mm LCF; the largest was 42 mm LCF. This species may grow to 35 mm (Lake 1978), though it is reputed to attain 50 mm (Pollard 1974).

The mean and modal lengths of *D. bandata* were 28.2 and 28–29 mm LCF respectively. The LFM for males was 31 mm LCF and for females 25 mm LCF (fig 99), indicating that fairly equal proportions of juveniles and adults were captured. A slight positive skew was apparent in the overall length-frequency distribution, possibly because many young specimens would not be captured by the 10 mm mesh seine net. A very low survival rate is indicated for specimens greater than 31 mm LCF.

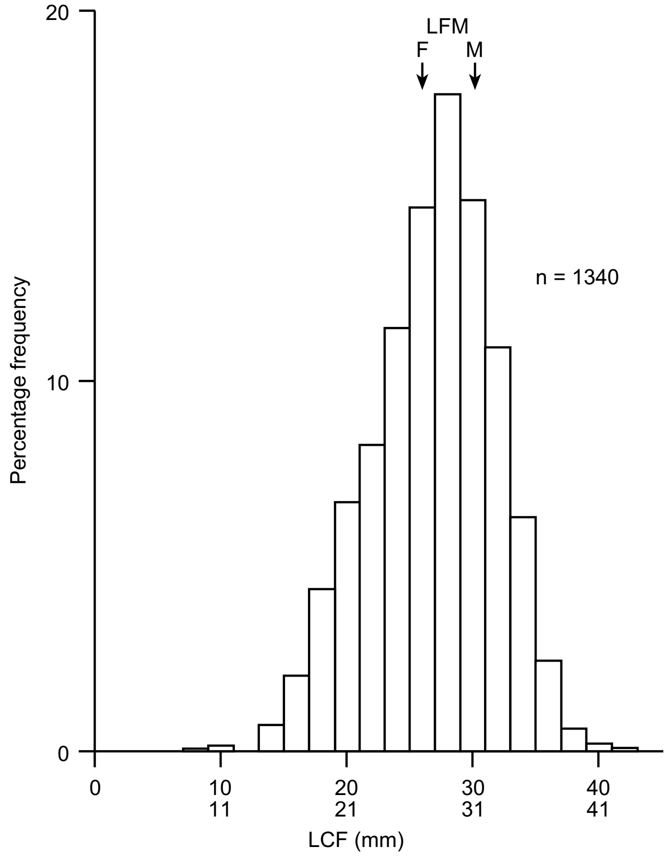


Figure 99 Length-frequency distribution of all *D. bandata* captured

Seasonal changes in distribution

The smallest specimens were captured in the 1978–79 Early-wet and 1979 Mid-dry seasons (fig 100). As small specimens were also captured in all other seasons except the 1979 Late-dry and 1979–80 Early-wet seasons, juveniles apparently recruited during most of the study period. The largest specimen was captured in the 1979 Mid-dry season.

The length-frequency distributions were unimodal in all sampling periods except the 1978–79 Early-wet season, when the distribution was bimodal, owing to the recruitment of large numbers of juveniles. The unimodal peaks indicate continuous recruitment in all other seasons except the 1979 Late-dry, which had a truncated, narrow size-range of specimens. The mean lengths (table 85) were greatest in the 1978 Late-dry and 1979 Mid-dry seasons; in between these seasons they were shorter because of the greater proportion of juveniles. The decrease in mean length in the 1979 Late-dry season may be attributable to higher mortality of large adults during this season.

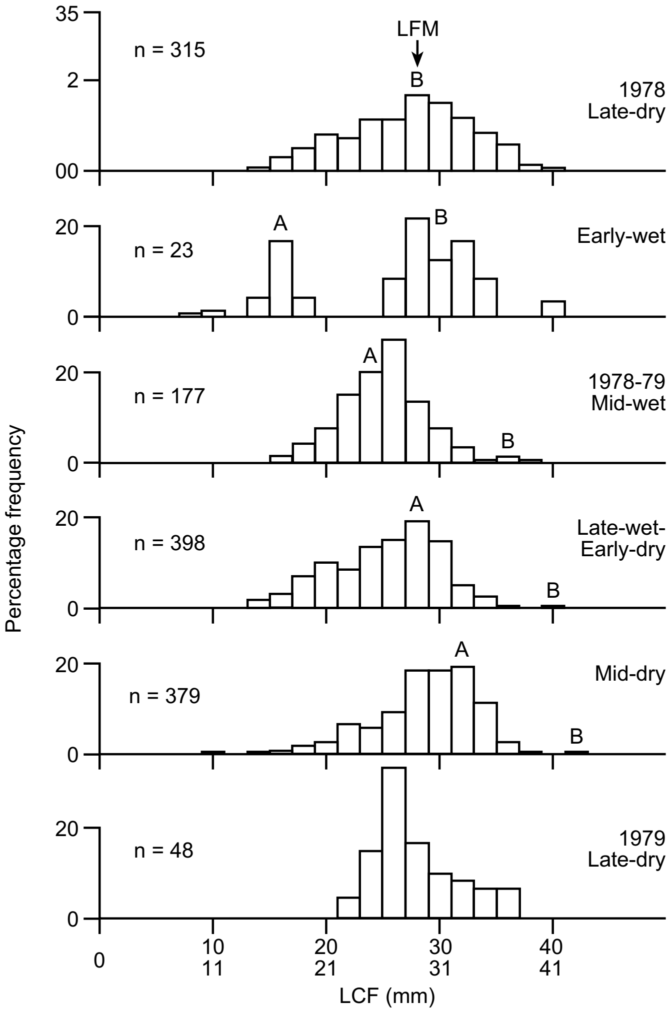


Figure 100 Seasonal length-frequency distribution of all *D. bandata* captured

Growth rate

No published information on the growth of *D. bandata* was found. It is difficult to estimate the growth rate from the seasonal length-frequency distributions because juvenile recruitment was almost continuous, and a wide range of habitats was sampled. However, the growth of

D. bandata may be described by following the seasonal modal progression of juveniles present in the 1978–79 Early-wet season (modal length 16–17 mm LCF; A on fig 100) until the 1979 Mid-dry season. The juveniles, which apparently grew fastest in the Early-wet season, may have grown 15 mm in the eight months.

A similar progression may be described for small adults (modal length 28–29 mm LCF; B on fig 100) which grew approximately 15 mm in the ten months between the 1978 Late-dry season and the 1979 Mid-dry season. The juveniles that were recruited in the 1978–79 Early-wet season had therefore reached their LFM within their first year of life.

Habitat differences in distribution

The habitat preferences of *D. bandata* captured in regular sampling sites of the Magela and Nourlangie Creek catchments are given in figure 101.

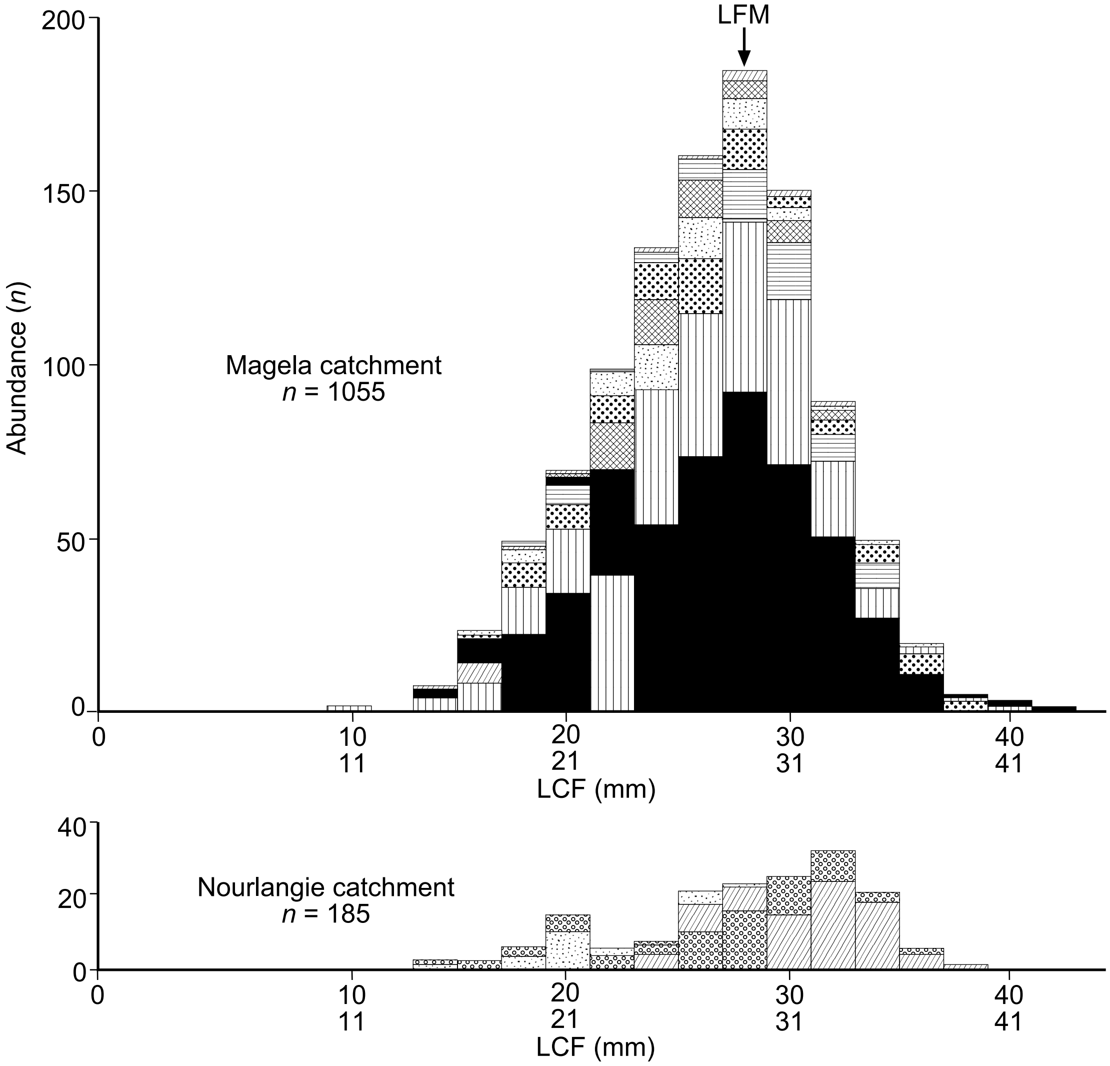


Figure 101 Length-frequency distributions and habitat preferences of *D. bandata* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment

The LFM for males and females differed by 5 mm LCF. For ease of presentation, juvenile *D. bandata* are defined as those fish less than 28–29 mm LCF (the mean LFM and mode of the overall length-frequency distribution), and the adults are defined as those fish greater than this length.

The smallest juveniles were captured in lowland shallow backflow billabongs. Most juveniles were captured in these and floodplain billabongs up- and downstream of RUPA. Small numbers were found in channel backflow lowland billabongs and corridor waterbodies. A few specimens were captured in lowland sandy creekbeds (and then only amongst hydrophytes over clay banks). None were captured in escarpment habitats.

Small adults were captured in similar habitats, ie mainly in floodplain and lowland shallow backflow billabongs, but in larger numbers in anabranch corridor waterbodies and smaller numbers in channel backflow lowland billabongs. The largest adults were found in floodplain and lowland shallow backflow billabongs. No adults were found in escarpment habitats.

Nourlangie catchment

Most juveniles were found in lowland backflow billabongs. Small numbers of the larger juveniles and most adults were found in lowland sandy creekbeds. (The sandy creekbed had hydrophytes present throughout the study). Adults were also found in lowland shallow backflow billabongs, but no juveniles or adults were found in escarpment habitats.

Environmental associations

Rank numbers for *D. bandata* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Surface-water temperatures ranged from 25° to 38°C (mean = 31.0°C); bottom-water temperatures ranged from 25° to 38°C (mean = 29.7°C). The mean temperatures were both ranked high in the upper-middle quarter (see fig 170). *Denariusa bandata* was captured in the billabongs of the lowlands, corridor and floodplain, in which high water temperatures were common.

Dissolved oxygen

Dissolved oxygen concentrations ranged from 3.7 to 7.8 mg/L (mean = 5.9) on the surface, and from 2.9 to 6.2 mg/L (mean = 4.3) on the bottom. Both of these means ranked in the lower-middle quarter (see fig 171).

Visibility

Secchi depth readings ranged from 1 to 110 cm (mean = of 35 cm) (see fig 172). This mean ranked in the lower quarter, indicating that this species prefers quite turbid conditions.

pH

The pH values ranged from 4.8 to 8.1 (mean = 6.4) on the surface, and from 4.5 to 6.7 (mean = 6.1) on the bottom. These means ranked in the lower-middle and upper-middle quarters respectively (see fig 173).

Conductivity

Conductivities ranged from 4 to 220 µS/cm on the surface, and from 8 to 60 µS/cm on the bottom. This range is close to the average range for all species.

Habitat–structural variables

Substrate

Denariusa bandata was most often captured over mud (upper quarter) followed by clay (lower-middle quarter), then sand, leaves and gravel (see fig 174). This apparent preference for muddy substrates corresponds with the high turbidities of waters in which this species is found.

Hydrophytes

Waters in which *D. bandata* was captured were generally heavily vegetated (vegetation-occurrence index 93.2%), with submergent (43.5%), emergent (30.6%) and floating-attached (20.7%) hydrophytes.[166]

Reproduction

A total of 505 gonads was examined; 45 fish were sexually indistinguishable, 205 were female and 255 were male. The length range for males was 12–41 mm LCF and for females 18–38 mm LCF.

Length at first maturity

The LFM was difficult to estimate, particularly for females, as in most seasons there were few mature fish of a given length. The estimated LFM was 25 mm LCF for females and 31 mm LCF for males (fig 102); only one female (23 mm LCF) and two males (29 and 30 mm LCF) were maturing below that length. One mature, one spent and no ripe males were recorded.

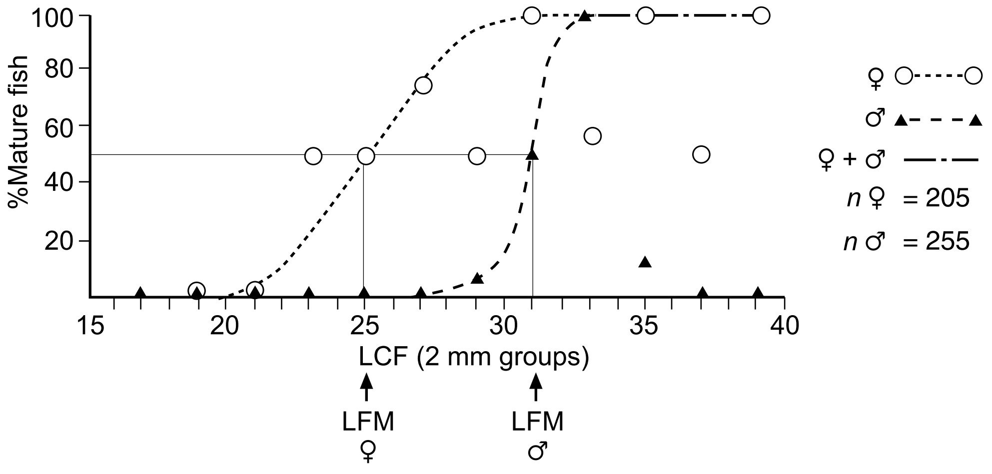


Figure 102 Estimated length at first maturity (LFM) of male and female *D. bandata*

Sex ratio

The 1978–79 Early-wet season (when the number of fish captured was low) was the only season to show no significant difference from a 1:1 sex ratio for both juvenile + adult fish and adult fish only (table 86). The 1978 Late-dry season had significantly more males in the juvenile + adult group, but an equal ratio for the adult group. A large number of juvenile males were identified (as this did not happen in later samples, errors in identification may have been the cause). From the 1978–79 Mid-wet season onwards, excluding the 1979–80 Early-wet when no *D. bandata* were captured, there were significantly more females in the

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[166] Herbert and Peeters (1995) indicated that in streams of Cape York Peninsula *D. bandata* are only found in areas with heavy aquatic vegetation.

adult group, although sex ratios for juveniles + adults were equal. Although amongst the few adult males there were some up to 48 mm LCF, only six had stage IV gonads and only two had gonads beyond this stage.

Table 86 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *D. bandata* over all habitats

			Sampling period					
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry
Sex ratio								
Juveniles	F	*n*	27	7	27	65	64	15
+ adults	M	*n*	64	9	43	75	51	13
		χ^2	15.0	0.3	3.7	0.7	1.5	0.1
		P	***	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	27	7	23	57	60	15
	M	*n*	23	4	6	10	32	3
		χ^2	0.3	0.8	10.0	33.0	8.5	8.0
		P	n.s.	n.s.	**	***	**	**
GSI								
Adults only	F	mean	2.2	5.3	4.0	1.9	2.1	2.7
		s.d.	1.2	1.6	1.8	0.7	0.6	0.9
	M	mean	0.4	0.8	0.6	0.5	0.4	1.1
		s.d.	0.2	0.1	0.1	0.0	0.3	0.2
	F+M	mean	1.5	4.0	2.5	1.5	1.4	2.3
		s.d.	1.3	2.6	2.2	0.9	1.0	1.1
GMSI								
Adults only	F	mean	3.3	4.2	3.4	2.4	2.9	3.0
		s.d.	0.6	1.3	0.7	0.5	0.5	0.4
	M	mean	2.3	4.0	1.7	2.5	2.2	3.0
		s.d.	0.4	0.0	0.5	0.8	0.7	0.0
	F+M	mean	2.9	4.1	2.6	2.4	2.6	3.0
		s.d	0.7	1.0	1.1	0.5	0.7	0.4

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); ** = $0.001 < P < 0.01$; *** = $P < 0.001$; s.d. = standard deviation.

Breeding season

Analysis of the GSI of *D. bandata* for each season indicated that gonad development peaked in the 1978–79 Early-wet season and that development extended through to the 1978–79 Mid-wet season (fig 103). While females showed significant changes in GSI during the reproductive period, the male GSI hardly varied throughout the year. Fish in breeding condition were rare (table 87), which was unexpected, as 460 sexually distinguishable fish were captured. This could have been due to fish moving out of the study area to breed, localised breeding behaviour resulting in mature and spawning fish not being captured by our fishing methods, or sexually mature fish showing very little change in their gonads and therefore being classed at a lower gonad stage.

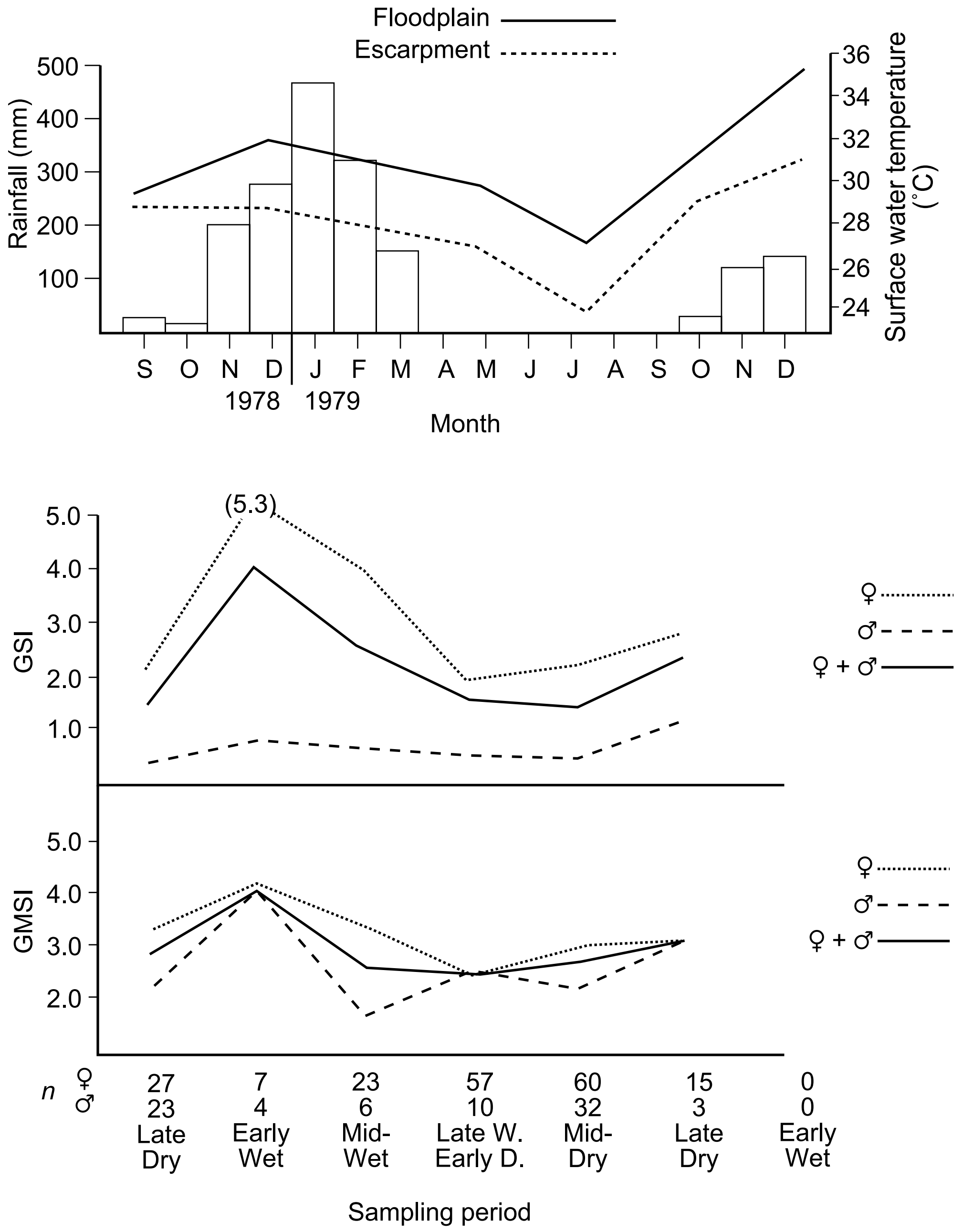


Figure 103 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *D. bandata*

Site of spawning

Only a few (8) mature, ripe or spent fish were identified amongst the 460 sexually distinguishable fish captured. Possibly *D. bandata* migrated out of the study area to spawn; however, at least some appear to have spawned in backflow billabongs such as Djalkmara Billabong and Fishless Billabong, and also in floodplain billabongs (table 87). Both the smallest fish (9 mm LCF) and a spent male were captured in a backflow billabong (Djalkmara Billabong) in the 1979 Mid-dry season, which suggests that spawning had occurred at this site some time before. Most of the small fish were captured during the 1979 Late-wet–Early-dry season from floodplain and corridor waterbodies and backflow billabongs. A small fish (12 mm LCF) was captured with a smaller than usual (2 mm) mesh seine net from the Magela Creek in the 1978–79 Early-wet season.

Table 87 Possible sites of spawning of *D. bandata,* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	F	M	
Lowlands							
Sandy creekbed	–	–	–	–	–	–	6
Backflow billabong	1	–	–	–	–	1	51
Corridor	2	1	1	–	–	–	11
Floodplain billabong							
Upper	2	–	–	–	–	–	21

Summary

Many anomalies appeared in the data on this species: the unequal sex ratios, the very low number of sexually maturing fish of both sexes, and the small number of adult males recorded. Possibly a spawning migration occurred, either to areas outside the study area or to areas of the waterbody we did not sample. Generally, the gonad development of the males changed very little throughout the year, although one GSI of 5.00 was recorded. In contrast, females showed significant seasonal changes in GSI over the seasons, with a peak in development around the 1978–79 Early-wet season. The breeding season is probably extended, as the GSI was still relatively high in the following season (1978–79 Mid-wet season). Nothing is known of egg numbers, egg size or breeding strategy of this species.

Feeding habits

Overall diet

The stomachs of 506 specimens were examined; 477 contained food. The diet of *D. bandata* is summarised in figure 104; the components are listed in table 88.

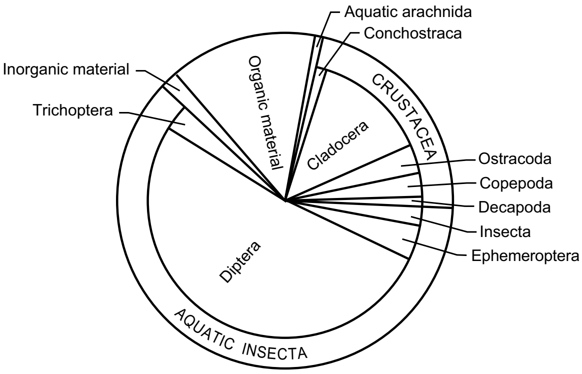


Figure 104 The main components of the diet of *D. bandata*

Table 88 Dietary composition of *D. bandata*

	Habitat						Season							
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Aquatic plants														
Algae														0.3
Miscellaneous	–	–	–	0.4	–	–	–	–	–	–	0.5	–	0.1	
Conjugatophyta														
Mougeotia	–	–	–	0.6	–	–	–	–	–	0.5	–	–	0.2	
Aquatic animals														
Arachnida														0.6
Porohalacaridae	–	0.7	–	–	0.3	1.2	–	–	1.4	0.5	–	–	0.4	
Hydracarina	–	0.7	–	–	–	–	1.0	–	–	–	–	–	0.2	
Microcrustacea														20.8
Conchostraca														
Miscellaneous	–	0.7	–	–	–	–	1.0	–	–	–	–	–	0.2	
Cyzicus	–	0.2	3.7	–	–	–	–	4.2	–	–	–	–	0.7	
Cladocera														
Miscellaneous	–	2.4	5.7	7.5	–	3.5	8.7	10.7	0.1	5.5	–	6.7	4.3	
Diaphanosoma	–	12.6	8.6	12.4	8.1	8.4	–	–	6.6	15.5	13.4	21.0	10.2	
Ostracoda	–	3.2	2.6	1.0	1.6	7.3	4.4	–	8.7	0.9	0.7	–	2.8	
Copepoda	–	2.2	1.2	2.4	–	4.6	4.5	–	3.3	2.1	–	6.7	2.6	
Macrocrustacea														0.6
Macrobrachium (juveniles)	–	–	–	0.8	–	–	–	6.7	–	–	–	–	0.2	
Macrobrachium (adults)	–	–	1.2	–	–	1.8	1.0	–	–	0.7	–	–	0.4	
Insecta														59.5
Fragmented	–	0.7	–	2.1	–	1.8	6.1	–	–	–	–	5.7	1.6	
Ephemeroptera														
Baetidae	–	4.5	3.1	1.3	–	1.1	3.0	–	4.1	0.2	6.8	–	2.8	
Atalophlebia	–	–	–	–	–	1.8	–	–	–	–	1.0	–	0.2	
Tasmanocoenis	–	–	–	–	6.5	–	–	–	–	1.3	–	–	0.4	
Hemiptera														
Corixidae	–	0.1	–	0.5	–	1.8	1.0	–	0.3	–	0.6	–	0.4	

Table 88 continued

	Habitat						Season						Overall	
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979		
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Coleoptera														
Miscellaneous (larvae)	–	–	–	–	–	1.3	1.0	–	1.0	–	–	–	0.4	
Hydrophilidae	–	–	–	0.3	–	–	–	–	0.5	–	–	–	0.1	
Diptera														
Chironomidae (larvae)	100.0	40.5	60.1	40.8	65.2	55.0	21.3	40.0	64.1	57.5	48.6	41.7	47.6	
Chironomidae (pupae)	–	5.3	0.5	2.6	–	–	1.9	6.7	–	–	8.9	0.7	2.6	
Ceratopogonidae	–	0.7	–	0.8	3.2	–	1.0	–	1.3	0.3	0.7	–	0.7	
Trichoptera														
Hydroptilidae	–	1.8	–	–	–	–	–	–	–	–	2.6	–	0.6	
Leptoceridae	–	–	1.2	2.6	15.2	–	–	6.7	1.3	–	5.6	4.3	1.9	
Lepidoptera														
Pyralidae	–	0.5	–	–	–	–	–	–	–	–	0.8	–	0.2	
Teleostomi														0.2
Scales	–	0.1	–	–	–	–	0.2	–	–	–	–	–	+	
Egg material	–	–	–	0.8	–	–	1.0	–	–	–	–	–	0.2	
Terrestrial plants														0.2
Fragmented	–	–	0.5	–	–	–	–	2.7	–	–	–	–	0.1	
Seed material	–	–	–	0.2	–	–	–	–	0.4	–	–	–	0.1	
Terrestrial animals														+
Insecta														
Trichoptera	–	0.1	–	–	–	–	–	–	0.3	–	–	–	+	
Parasites														
Nematoda	–	0.1	–	0.1	–	–	0.1	–	–	–	0.1	–	+	+
Detrital material	–	0.7	–	–	–	–	–	–	–	–	1.0	–	0.2	0.2
Inorganic material	–	4.0	–	0.7	–	–	5.4	–	0.8	–	1.0	–	1.5	1.5
Organic material	–	18.5	10.7	23.0	–	10.5	37.4	26.7	2.7	15.1	7.8	13.3	16.4	16.4
Number of empty fish	–	6	4	17	–	1	6	1	2	5	15	29	29	29
Number of fish with food	10	148	81	127	31	57	99	15	79	152	102	30	477	477

Figures represent the mean percentage volume determined by the estimated volumetric method.

Ls = lowland sandy creek bed; Bb = lowland backflow billabongs Cb = corridor billabongs; Fb = floodplain billabongs

The main components were small aquatic insects (60%) and microcrustaceans (21%), which were possibly associated with the considerable quantities of unidentified organic material. The aquatic insects consisted mainly of chironomid larvae, and the microcrustaceans mainly of cladocerans. Traces of algae, terrestrial plant material, aquatic arachnids, teleosts, detrital and inorganic matter were also found in the stomachs. *Denariusa bandata* can therefore be classified as a meiophagous carnivore feeding opportunistically, mainly in benthic littoral areas and frequently in the mid-water areas of the waterbodies. Pollard (1974) suggested that adults probably consumed small dipteran insect larvae. In Magela Creek floodplain habitats, *D. bandata* ate mainly *Chaoborus* larvae, ostracods (*Cypretta, Candonocypris* and *Newnhamia*), cladocerans (*Chydorus, Pleuroxus* and *Alona*) and organic detritus (Sanderson 1979).

Seasonal changes

In sampling periods 1–6, respectively, 105 (6% empty), 16 (6% empty), 86 (2% empty), 157 (3% empty), 117 (13% empty) and 30 (0% empty) stomachs of *D. bandata* were examined (all habitats combined). The highest proportion of specimens with empty stomachs was found in the 1979 Mid-dry season and the lowest in the Mid-wet to Late-wet–Early-dry seasons and the 1979 Late-dry season.

Chironomid larvae in the diet increased from a minimum in the 1978 Late-dry season through the Early-wet season to peak in the Mid-wet season, and then fall steadily to another low in the 1979 Late-dry season, but at roughly twice the level of the 1978 Late-dry season. Chironomid pupae appeared to be most important in the diet during the 1978–79 Early-wet season and the 1979 Mid-dry season. Baetid larvae were most important in the diet in the 1979 Mid-dry season.

The cladoceran component of the diet became slightly smaller in the Mid-wet season and then returned to a higher level during the rest of the study, to peak in the 1979 Late-dry season. Ostracods were most common in the diet in the 1978 Late-dry and Mid-wet seasons, as were copepods, which had an additional peak in the 1979 Late-dry season. Conchostracans were most common in the stomachs in the Mid-wet season.

Habitat differences

Magela catchment

A total of 393 stomachs of *D. bandata* were examined (all seasons combined) from the Magela Creek: 10 (0% empty) from lowland sandy creekbeds, 154 (4% empty) from lowland backflow billabongs, 85 (5% empty) from corridor billabongs, and 144 (12% empty) from floodplain billabongs. The highest proportion of empty stomachs was found in floodplain billabongs and the lowest proportion in lowland sandy creekbeds.

The few specimens caught in sandy pools were feeding only on chironomid larvae. In the lowland backflow billabongs, the diet was much more varied, although this may reflect the larger sample size. Chironomid larvae were the main food items in all habitats, and especially in the corridor waterbodies. Chironomid pupae were also important in the lowland backflow billabongs, as were baetids in corridor waterbodies. The largest microcrustacean component was found in the stomachs of fish from the floodplain billabongs; these stomachs also contained large quantities of unidentified organic material.

Nourlangie catchment

The stomach contents of 31 (0% empty) specimens from lowland sandy creekbeds and 58 (2% empty) specimens from backflow billabongs were examined. Very few fish had empty stomachs.

Chironomid larvae were the main food items in both habitats, as in the Magela catchment. Higher proportions of microcrustaceans (cladocerans, ostracods and copepods) and unidentified organic material were found in fish from the backflow billabongs, as in the Magela catchment. Mayfly larvae, *Tasmanocoenis*, were also important in the diet in the sandy creekbeds.

Fullness

The mean fullness indices of *D. bandata* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments are summarised in table 89. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 89 Mean fullness indices of *D. bandata* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Habitat mean
Magela Creek catchment (regular sites only)							
Upstream of RUPA:							
Lowland shallow backflow billabong	2.4 (5)	n/s	2.7 (10)	n/s	2.9 (10)	n/s	2.7 (25)
Downstream of RUPA:							
Lowland sandy creekbed	n/s	n/s	n/s	3.1 (10)	n/s	n/s	3.1 (10)
Lowland channel backflow billabong	2.7 (3)	n/s	4.3 (4)	2.7 (28)	0 (1)	n/s	2.8 (36)
Lowland shallow backflow billabong	1.5 (25)	0 (1)	3.7 (3)	2.7 (37)	2.6 (24)	2.0 (4)	2.3 (94)
Corridor sandy billabong	0 (1)	n/s	1.7 (10)	n/s	2.0 (3)	n/s	1.6 (14)
Corridor anabranch billabong	2.0 (5)	4.0 (2)	2.0 (2)	1.8 (10)	2.2 (10)	n/s	2.1 (29)
Floodplain billabong	1.8 (33)	2.5 (13)	2.8 (25)	1.8 (42)	2.1 (49)	3.0 (25)	2.2 (187)
Nourlangie Creek catchment (regular sites only)							
Lowland channel backflow billabong	n/s	n/s	2.0 (2)	2.3 (10)	0 (1)	n/s	2.1 (13)
Lowland shallow backflow billabong	2.3 (10)	n/s	3.1 (14)	2.1 (10)	1.9 (10)	0 (1)	2.4 (45)
Lowland sandy creekbed	n/s	n/s	3.0 (11)	2.7 (10)	3.0 (10)	n/s	2.9 31)
Seasonal mean (all sites)	2.0	1.5	2.8	2.3	2.3	2.8	

Numbers examined are given in parenthesis; n/s = not sampled in the habitat

Seasonal changes

The mean seasonal index (all habitats combined) fell during the 1978–79 Early-wet season and then increased to peak in the Mid-wet season, after which it fell and remained stable in the Late-wet–Early-dry and the Mid-dry season. It rose again in the 1979 Late-dry season.

Habitat differences

In the Magela catchment, upstream of RUPA, *D. bandata* was found mainly in lowland shallow backflow billabongs, where the mean fullness index appeared to be slightly higher than in same habitats downstream. Downstream of RUPA, the highest mean fullness indices were recorded in lowland sandy creekbeds and channel backflow billabongs; the lowest mean indices were found in the corridor sandy billabongs.

In the Nourlangie catchment, the mean fullness indices were similar to those recorded in the Magela catchment; however, the mean index from the channel backflow billabong was the lowest recorded.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland channel backflow billabongs; 1978–79 Mid-wet season
- corridor anabranch billabong; 1978–79 Early-wet season
- lowland shallow backflow billabongs (downstream of RUPA); 1978–79 Mid-wet season
- lowland sandy creekbeds; 1979 Late-wet–Early-dry season

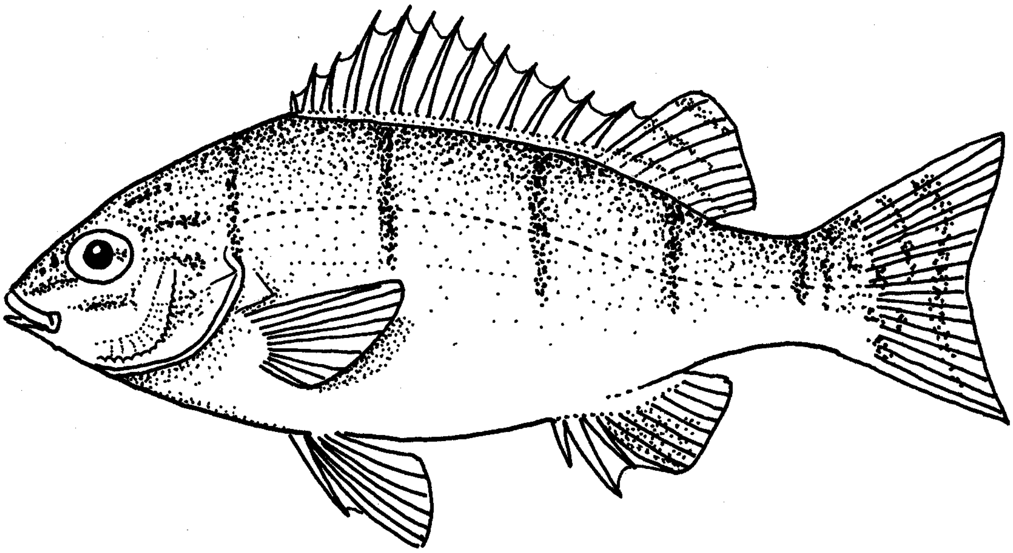
Nourlangie catchment

- lowland shallow backflow billabong; 1978–79 Mid-wet season
- lowland sandy creekbed; 1978–79 Mid-wet season, 1979 Mid-dry season.

Family TERAPONTIDAE

3.24 *Amniataba percoides* (Gunther)

Amniataba percoides (syn. *Terapon percoides*) is commonly known as the black-striped grunter or banded grunter. It is found in the drainage basins of the north-east coast, Gulf of Carpentaria, Timor Sea, Indian Ocean and Lake Eyre (see map 3). In the Magela Creek system, this species is generally found together with *L. unicolor*, but usually in smaller numbers (Pollard, 1974). It was abundant in a large billabong in the Oenpelli area (Miller [in Taylor 1964]).



Amniataba percoides

Although it belongs to a family with marine, estuarine and freshwater representatives, *A. percoides* is strictly an inhabitant of freshwaters.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was moderately abundant in lowland sandy creekbed sites and escarpment mainchannel billabongs, and common in lowland backflow billabongs, corridor and floodplain billabongs. Small numbers were observed in escarpment perennial streams in the Nourlangie Creek system. It was found in the greatest number of sites during the Late-wet–Early-dry season and in the fewest in the 1978 Late-dry season.

Size composition

The lengths and weights of 581 specimens were determined. The main peak in the overall length-frequency distribution was probably caused by selectivity of the 26 mm mesh gill net and the cumulative effect of specimens of this size also being captured by seine net. The smaller peak in the juvenile size range may have been exaggerated by the mesh of the seine net being clogged by filamentous algae.

Length–weight relationship

The length–weight relationship for the sexes combined was described by the following expression:

$W = 1.85 \times 10^{-2} L^{3.06}$ $r = 1.00$ (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors are shown in table 90. The seasonal condition factor dropped slightly between the 1978 Late-dry and 1978–79 Early-wet seasons, probably due to spawning activity. It improved steadily through the Wet season to peak in the Late-wet–Early-dry season; it then dropped throughout the 1979 Dry season, and was lower in the Early-wet than in the previous year. The environmental conditions, food availability or both were therefore apparently more favourable to *A. percoides* in the Wet season than in the Dry, and more favourable in the 1978 Dry than the 1979.

Table 90 Mean length, mean weight and condition factor of *A. percoides*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	143	93.0	16.78	1.00
Early-wet (1978–79)	14	54.2	3.06	0.95
Mid-wet	95	94.0	17.82	1.02
Late-wet–Early-dry (1979)	113	87.2	14.76	1.07
Mid-dry	124	83.4	11.61	0.96
Late-dry	44	98.4	18.93	0.94
Early-wet	7	79.1	9.02	0.88
Overall	540	88.6	14.54	1.00

Length-frequency distribution

Specimens ranged in length from 11 mm to 188 mm LCF (fig 105). Lake (1978) reported that this species may grow up to 250 mm.

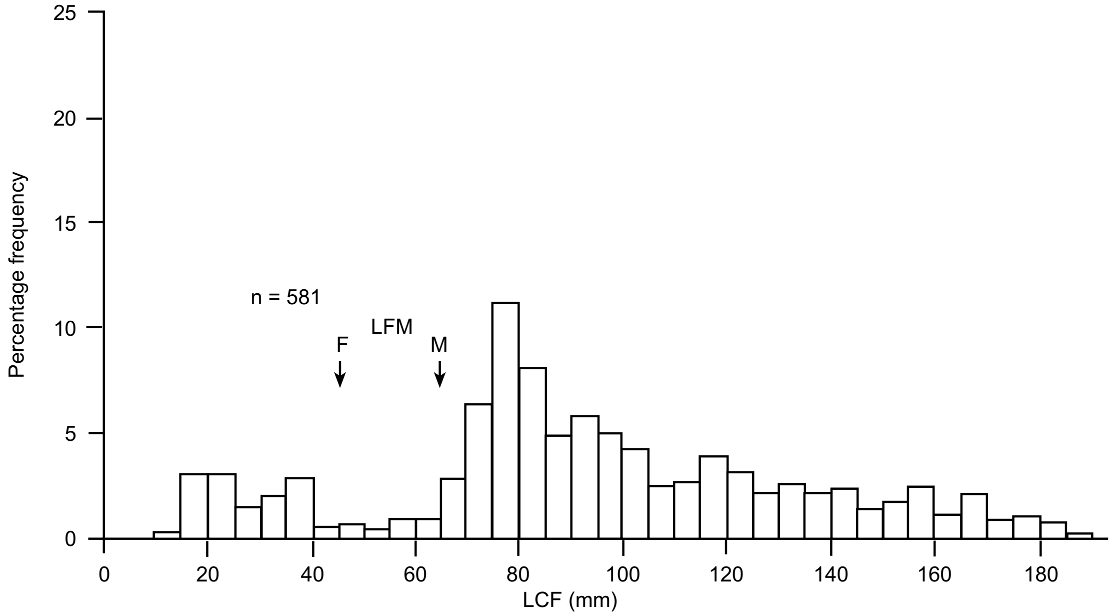


Figure 105 Length-frequency distribution of all *A. percoides* captured during study period

The mean and modal lengths of all specimens captured were 88.6 and 75–80 mm LCF, respectively. The LFM for males was 65 mm LCF and for females 45 mm LCF, which indicates that most of the specimens captured were adults.

There were two clear peaks in the length-frequency distribution: a small peak of specimens between 15 and 40 mm LCF, and a much larger peak (mode = 75–80 mm) showing negative skew.

Seasonal changes in distribution

The smallest specimen was captured in the 1978 Late-dry season; slightly larger specimens were found in the 1978–79 Early-wet, Late-wet–Early-dry and 1979 Mid-dry seasons. Most small juveniles were captured in the 1978–79 Early-wet season, indicating a peak in juvenile recruitment during this period. The largest specimens were captured in the Mid-wet and both Late-dry seasons.

The mean length of specimens (table 90) of *A. percoides* captured during the 1978 Late-dry season was relatively high, as there were large numbers of adults (mainly small adults). By the 1978–79 Early-wet season a large juvenile peak appeared and fewer adults were captured (the same applied to the related *L. unicolor*); the mean length was the lowest recorded. In the Mid-wet, the mean length increased as more adults (of similar sizes to those in the previous Late-dry season) were captured, while few juveniles were found.

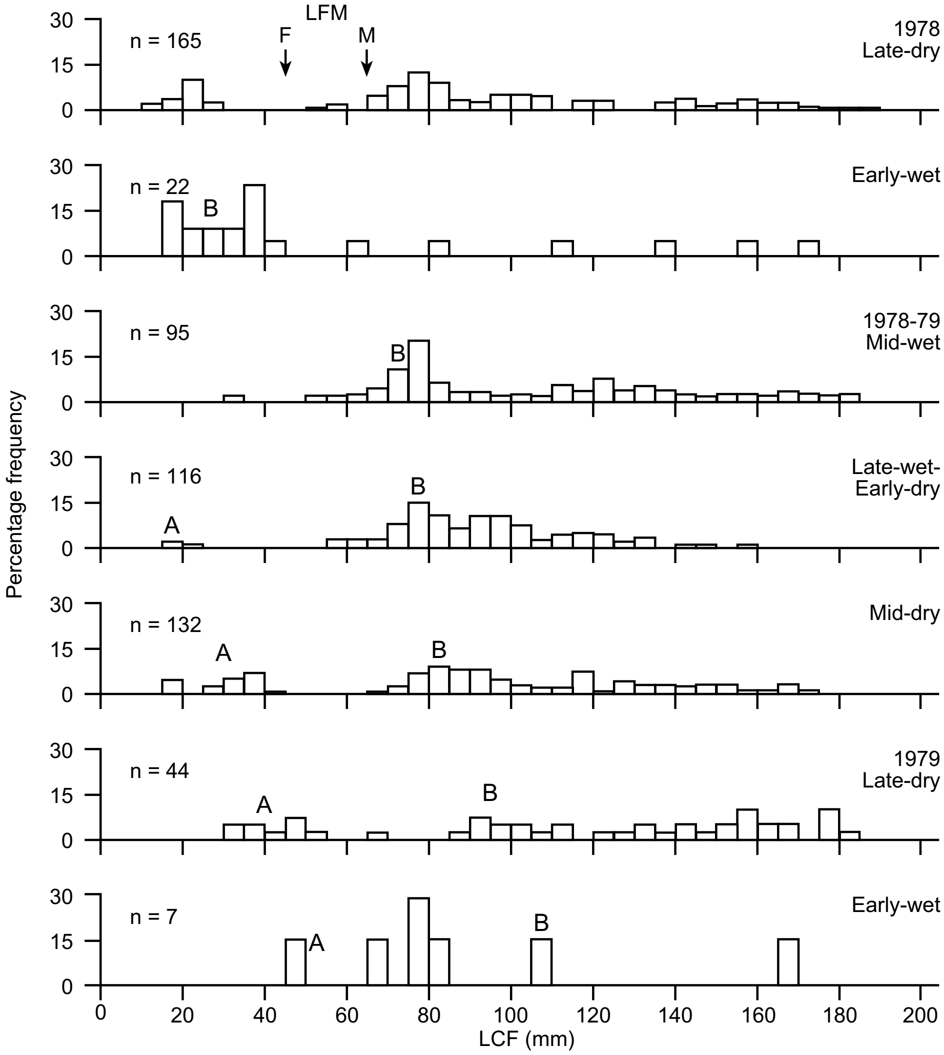


Figure 106 Seasonal length-frequency distributions of all *A. percoides* captured

Mean lengths in the Late-wet–Early-dry and Mid-dry seasons were lower, as few larger adults were captured and the numbers of juveniles increased. By the 1979 Late-dry season many more large adults were present in the population and fewer small adults; a wide and nearly continuous size range of specimens was recorded in this season (as in the equivalent season in 1978) and the mean length was the greatest recorded for this species during the study. During the 1979–80 Early-wet season few specimens were collected; the mean length was less than in other seasons, as the collection was dominated by small adults. No juveniles were present in this sample, unlike in the sample from the 1978 Early-wet season (probably because of the extreme nature of the 1979 Dry season and the fact that the creeks had not yet started to flow).

Growth rate

No published information on the growth of *A. percoides* was found. The growth rate of *A. percoides* was difficult to estimate from seasonal length-frequency distributions because of mesh selectivity, the near-continuous recruitment of juveniles and the range of habitats sampled.

However, the growth rate of *A. percoides* may be described by following the progression of juveniles (length range 15–25 mm) present in the Late-wet–Early-dry season (A on fig 106) until the 1979–80 Early-wet season. These specimens appeared to grow 25–30 mm in the six months.[167]

The growth of small adults present in the Mid-wet season (B on fig 106) can be followed until the 1979–80 Early-wet season. They appeared to grow 30–35 mm in the eight months (possibly these small adults were members of the large-juvenile group (B on fig 106) present in the 1978–79 Early-wet season).

It therefore appears that *A. percoides* (especially females) may attain the LFM by the end of their first year of life.

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *A. percoides* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are given in figure 107.

Magela catchment

The LFM of males and females differed by 20 mm LCF. This difference in length corresponded to a trough in the overall length-frequency distribution; for ease of presentation juveniles are defined as those fish less than 60 mm LCF (centre of trough) and adults as those greater than 60 mm LCF.

Juvenile *A. percoides* were most frequently captured in sandy corridor waterbodies and, to a lesser extent, in lowland backflow and floodplain billabongs. Very small juveniles were also found in escarpment mainchannel waterbodies; these specimens were first observed grazing on periphyton on partly submerged *Pandanus aquaticus* branches during the 1978 Late-dry season.

Small adult *A. percoides* were captured mainly in lowland sandy creekbeds and lowland backflow billabongs; small numbers were also captured in corridor and floodplain billabongs and escarpment mainchannel waterbodies. Larger adults were mainly captured in deeper and more permanent waters such as escarpment mainchannel waterbodies and corridor and floodplain billabongs; these habitats probably function as Dry season refuge areas for the breeding populations of most species in the catchment.

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[167] Data from Wise et al (1994) on the estuarine relative *A. caudavittata* in the Swan River estuary in WA indicated the following growth rate: 1 year, 110–115 mm total length; 2 years, 175–180 mm; 3 years, 215–235 mm.

Nourlangie catchment

Juvenile *A. percoides* were found mainly in lowland sandy creekbeds, escarpment mainchannel waterbodies and channel backflow billabongs (fig 107). They also appeared in escarpment perennial streams during the Wet season.

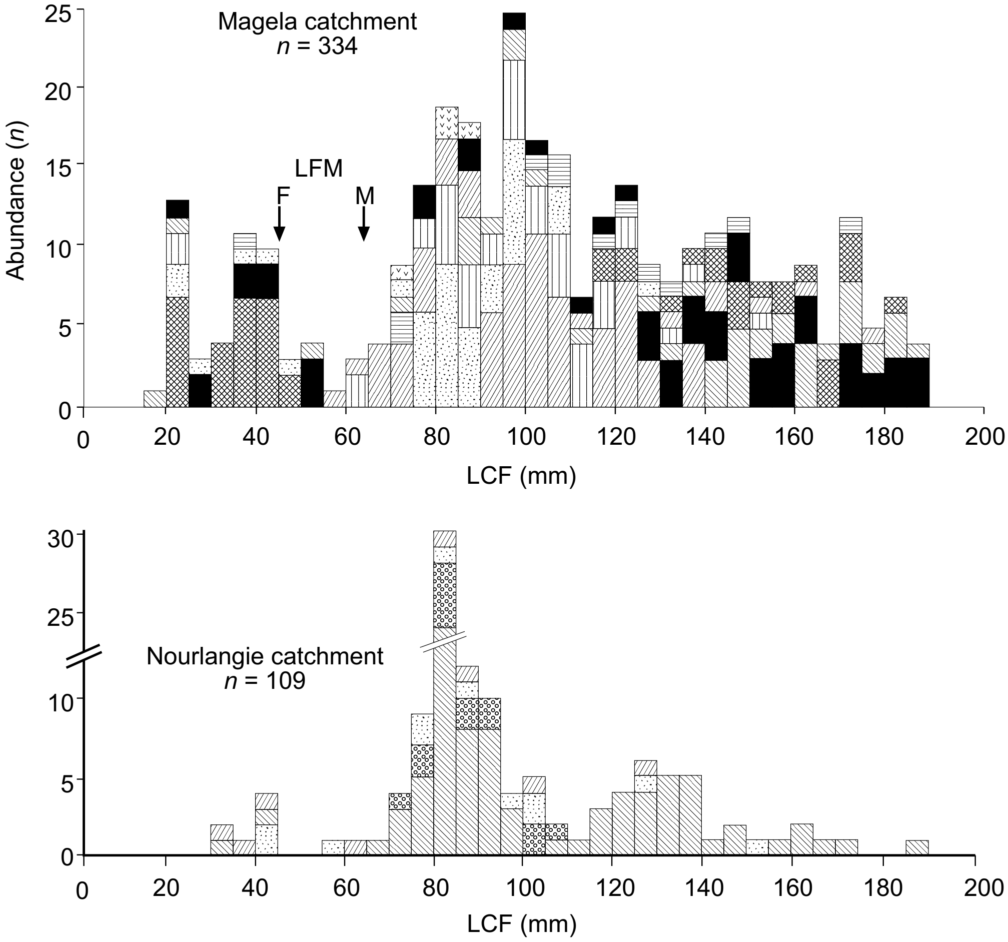


Figure 107 Length-frequency distributions and habitat preferences of *A. percoides* captured at regular sampling sites (see appendix 5 for key to the habitats)

Adult *A. percoides* were mainly captured in escarpment mainchannel waterbodies; however, a few of the small adults were found in lowland backflow billabongs and in lowland sandy creekbed. Small adults appeared in escarpment perennial streams during the Mid-wet season and persisted there for the remainder of the study.

Environmental associations

Rank numbers for *A. percoides* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Water temperatures at sites where *A. percoides* was captured ranged from 23° to 40°C (mean = 30.2°C) on the surface, and from 23° to 35°C (mean = 28.9°C) on the bottom. Both means ranked in the lower-middle quarter. These ranges are similar to those found for the closely related *Leiopotherapon unicolor*, with which *A. percoides* was often associated (see fig 170).

Dissolved oxygen

Dissolved oxygen concentrations in waters in which this species was found ranged from 3.9 to 9.7 mg/L on the surface (mean = 6.2), and from 0.2 to 9.5 mg/L (mean = 4.8) on the bottom. These means both ranked in the upper-middle quarter (see fig 171). As for *L. unicolor,* a wide range of tolerance to DO concentrations (including some very low concentrations) is indicated.

Visibility

Secchi depths ranged from 1 to 360 cm, with a mean depth of 112 cm (fig 172). This mean ranked at the top of the upper-middle quarter. Although this indicates *A. percoides* tolerates turbidity, it is usually found in clearer waters.

pH

The pH values of waters in which *A. percoides* was captured ranged from 5.0 to 8.6 (mean = 6.25) on the surface, and from 4.5 to 7.3 (mean = 6.0) on the bottom. These means both ranked in the upper-middle quarter (see fig 173). This range of pH values is similar to that for *L. unicolor.*

Conductivity

Amniataba percoides was taken from waters with conductivities ranging from 2 to 160 µS/cm on the surface, and from 2 to 230 µS/cm on the bottom. This range is not as broad as for *L. unicolor.*

Habitat–structural variables

Substrate

As expected from its wide distribution, *A. percoides* was captured over a variety of substrates. The main one was sand (lower-middle quarter) followed by mud (lower-middle quarter), clay, leaves, rocks, gravel and boulders. This range of substrates was nearly identical to that for *L. unicolor.*

Hydrophytes

Amniataba percoides was found in waters with moderate to low vegetation (vegetation-occurrence index 54.2%). Submergent hydrophytes were dominant (45.6%), followed by emergent (26.4%) and then floating hydrophytes (25.7%). Both *A. percoides* and *L. unicolor* feed on the submergent hydrophyte *Najas tenuifolia* and show a similar preference for other hydrophytes.

Reproduction

In all, 501 *A. percoides* were examined for reproductive condition: 94 were sexually indistinguishable (12–149 mm LCF), 188 were females (40–180 mm LCF) and 219 were males (50–180 mm LCF).

Length at first maturity

The length at first maturity (LFM) was calculated from 10-mm-length groups. Unfortunately, very few fish were captured during the apparent breeding season (1978–79 Early-wet). The LFM was estimated to be 65 mm for males and 45 mm LCF for females (fig 108), as maturing fish were found at these lengths and at all lengths above them. This estimate may to some extent be a reflection of the size range of fish captured, as only three identifiable males less than 65 mm LCF and two identifiable females less than 45 mm LCF were captured during the study, and all of these were caught outside the breeding period.

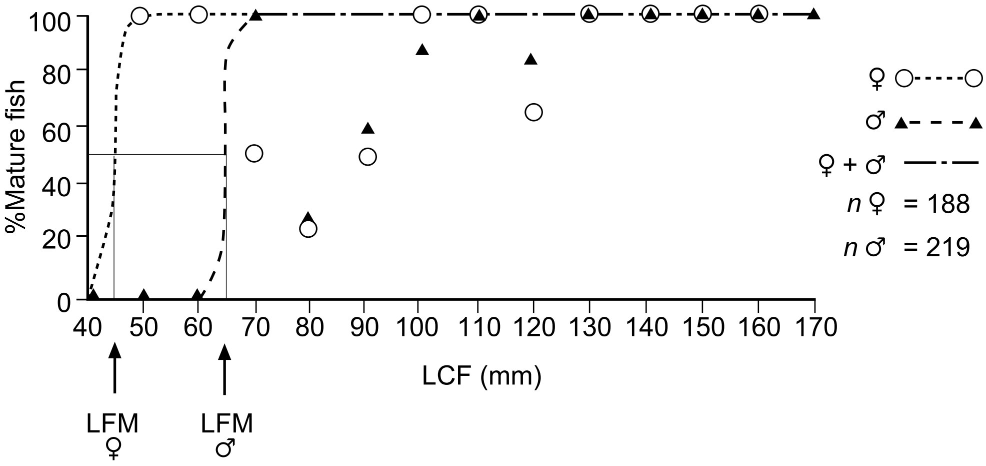


Figure 108 Estimated length at first maturity for male and female *A. percoides*

Sex ratio

Chi-squared tests on the sex ratios for adults + juveniles and adults only indicated no significant difference from 1:1 ratios in any season (table 91).

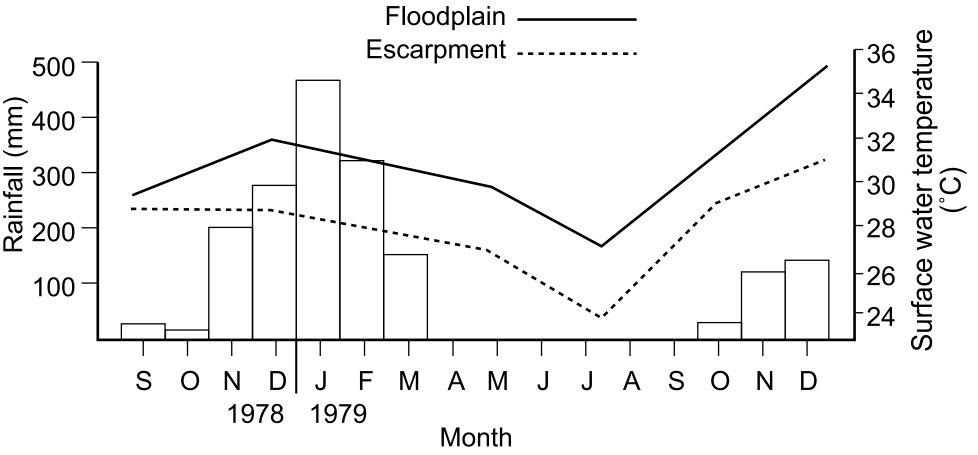
Table 91 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *A. percoides* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	48	2	36	35	39	23	5
+ adults	M	*n*	66	3	42	45	49	13	1
		χ^2	2.8	0.2	0.5	1.25	1.1	2.8	2.7
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	48	2	36	35	38	22	5
	M	*n*	66	3	40	45	49	12	1
		χ^2	2.8	0.2	0.2	1.25	1.4	2.9	2.7
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
(Adults only)	F	mean	1.4	5.2	0.4	0.5	6.7	2.7	1.8
		s.d.	1.0	4.4	0.4	0.3	0.4	2.0	1.2
	M	mean	0.7	1.7	0.2	0.1	0.3	0.7	3.0
		s.d.	0.4	0.6	0.1	0.1	0.2	0.7	–
	F+M	mean	1.1	3.1	0.3	0.4	0.5	1.8	2.0
		s.d.	0.6	3.0	0.2	0.5	0.4	1.8	1.2
GMSI									
(Adults only)	F	mean	3.7	5.0	2.6	2.0	2.4	3.8	3.0
		s.d.	0.7	1.4	0.9	0.5	0.7	1.3	0.7
	M	mean	3.5	6.0	2.6	2.3	2.5	3.8	5.0
		s.d.	1.2	0.0	0.8	1.3	1.2	1.6	–
	F+M	mean	3.7	5.6	2.6	2.2	2.5	3.8	3.3
		s.d	0.7	0.9	0.8	1.0	0.9	1.4	1.1

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant (P > 0.05); s.d. = standard deviation.

Breeding season

Of the 407 sexually distinguishable fish examined, only 5 were captured in the 1978–79 Early-wet season; however, the GSI and GMSI values for these five were significantly higher than for the rest (fig 109). Figure 109 also indicates that the gonads regressed very quickly after the breeding season and remained at a low level of development from the 1978–79 Mid-wet season through to the 1979 Mid-dry season; by the 1979 Late-dry season the gonads had begun to develop. Further confirmation that *A. percoides* had bred during the 1978–79 Early-wet is that most of the mature fish were found in the 1978 Late-dry season, just before the 1978–79 Early-wet season, and that most of the spent fish were found in the following season (table 91). Some fish may have spawned in the 1978 Late-dry season, as running-ripe males were captured in this season.



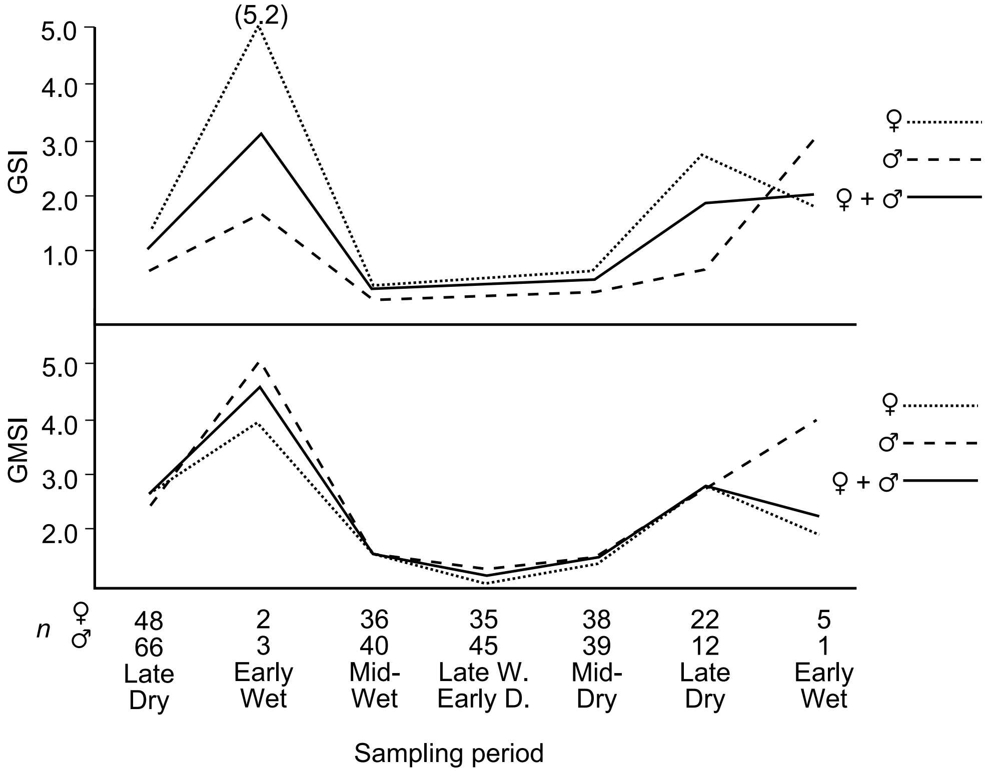


Figure 109 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *A. percoides*

Because few fish were captured in the 1979–80 Early-wet season, it is difficult to determine whether spawning had occurred before the creeks began to flow (with the true onset of the Wet season, which did not happen until January). It appears that there may have been some spawning as early as the 1979 Late-dry, as running-ripe fish were found in this season.[168]

Midgley (1980) collected running-ripe *A. percoides* from the Magela Creek system in January after the onset of the Wet season.

Most of the juvenile fish (11–40 mm LCF) were captured in the 1978–79 Early-wet season. The smallest of these were most likely progeny from the 1978 Late-dry season spawning. Interestingly, only one juvenile was captured in the 1978–79 Mid-wet season, when the progeny of the 1978–79 Early-wet season spawning would be most likely to be found.

Site of spawning

Examination of the sites where ripe fish were captured (table 92) indicated that spawning may have occurred over a wide range of habitats: from escarpment mainchannel waterbodies through lowland backflow billabongs and the lowland sandy creekbed sites to corridor waterbodies and floodplain billabongs.

Table 92 Possible sites of spawning of *A. percoides,* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	2	–	–	3	1	6	3
Lowlands							
Sandy creekbed	2	1	1	2	–	–	3
Backflow billabong	3	3	–	2	–	2	9
Corridor	11	11	1	3	–	–	58
Floodplain billabong							
Upper	–	–	1	–	3	6	1
Lower	–	–	–	–	–	–	1
Artificial	3	1	–	–	–	–	–

Fecundity

Nine ovaries, ranging in weight from 0.29 g (GSI = 6.04) to 5.44 g (GSI not recorded), were examined. Fecundity was generally higher for the heavier gonads, although not directly proportional. Fecundities ranged from 800 (a running-ripe fish that had probably spawned most of its eggs) to 400 000 the mean egg count for the nine ovaries was 125 000 (s.d. = 120 500).[169] Oocyte diameters were variable, but most commonly around 0.24 to 0.32 mm; however, diameters ranged from 0.16 to 0.4 mm. Midgley (1980) recorded eggs

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[168] Herbert & Peeters (1995) indicated the banded grunters breed in northern Queensland from August to March, that is, during the warmer months of the year.

[169] Herbert & Peeters (1995) indicate that an average size female (75–85 g) lays around 50 000 to 60 000 eggs.

from a spawning female as having a diameter of 0.4 mm when hardened in water. The eggs were demersal and non-adhesive.

Summary

Amniataba percoides did not exhibit any secondary sexual dimorphism. No significant difference from a 1:1 sex ratio was found in any season (it is believed that the family Terapontidae generally pair during breeding [Breder & Rosen 1966]). Breeding occurred during the Late-dry season, with most spawning activity most likely taking place around the onset of the Wet season. Running-ripe fish were captured in a wide range of habitats, from the escarpment to the floodplain. Members of the family Terapontidae are believed to spawn in shallow places in rivers, often in holes or under stones (Breder & Rosen 1966); however, *A. percoides* has also been recorded as breeding in dams (Lake 1971; Midgley, pers comm). A large number (around 125 000) of small (0.16–0.4 mm) demersal, non-adhesive eggs are laid. Male terapontids of some species may guard and aerate the eggs (Breder & Rosen 1966).

Feeding habits

Overall diet

The stomach contents of 484 specimens were examined; 479 contained food. The diet of *A. percoides* is summarised in figure 110; the components are listed in table 93. The main components of the diet were aquatic insects (44%), algae (13%), terrestrial plant material (11%), hydrophytes (11%) and microcrustaceans (8%). The aquatic insects were mainly chironomid larvae and baetids. The identifiable algae were mainly green filamentous species such as *Mougeotia* and *Spirogyra;* the most common hydrophyte was *Najas.* The microcrustaceans were mainly cladocerans (*Diaphanosoma*). Macrocrustaceans (*Macrobrachium* and *Caridina*), teleosts (including *C. stercusmuscarum* and *G. giuris*) and traces of gastropods, oligochaetes, hydracarinids, terrestrial insects, detrital material and inorganic and unidentified organic material were also found in the stomachs. *Amniataba percoides* can therefore be classified as a meiophagous omnivore feeding in benthic and midwater areas of the waterbodies.[170] The significant herbivorous component in the diet of this species in the present study was not found in Pollard's (1974) study; he considered its diet was similar to *L. unicolor*'s, but with few or no small fishes.

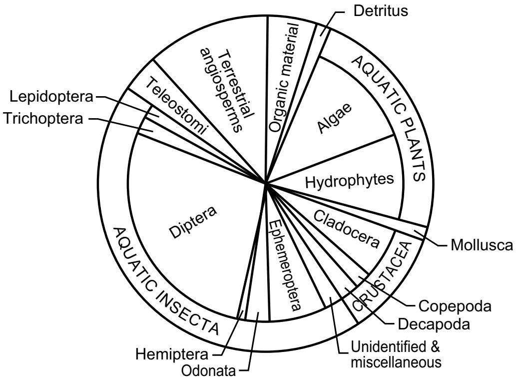

Figure 110 The main components of the diet of *A. percoides*

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[170] Wise et al (1994) indicated the estuarine relative *A. caudavittata* in the Swan River estuary in WA is a benthic omnivore.

Table 93 Dietary composition of *A. percoides*

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Lb	Cb	Fb	Em	Ls	Lb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																	
Algae																	13.4
Miscellaneous	12.6	7.7	0.5	0.5	–	2.7	10.0	–	5.1	–	1.7	7.0	1.8	0.7	–	3.4	
Conjugatophyta																	
Mougeotia	19.1	3.4	4.3	4.0	–	32.1	1.3	–	–	–	24.1	4.5	11.0	2.1	–	7.8	
Spirogyra	–	2.9	1.2	0.3	–	3.2	2.5	1.1	–	–	2.0	0.2	1.3	5.9	–	2.2	
Hydrophytes																	10.5
Hydrilla	–	–	1.2	–	12.9	–	–	–	–	–	4.5	–	0.6	–	–	0.9	
Najas	–	7.2	29.9	24.1	–	–	–	13.4	–	4.2	0.7	31.5	5.9	18.1	–	9.4	
Vallisneria	–	1.1	–	–	–	–	–	–	–	2.6	–	0.4	–	–	–	0.2	
Aquatic animals																	
Oligochaeta	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	+	+
Gastropoda																	1.2
Miscellaneous	–	–	3.3	0.1	11.9	–	–	0.8	–	–	4.2	2.1	0.2	–	–	1.2	
Segnitila	–	–	–	–	–	–	–	0.5	–	–	–	–	0.1	–	–	+	
Arachnida																	+
Hydracarina	–	–	–	0.1	–	–	–	–	–	–	–	–	–	0.2	–	+	
Microcrustacea																	8.1
Conchostraca																	
Cyzicus	–	2.0	0.3	–	–	–	–	0.3	–	–	0.1	0.2	1.4	–	–	0.4	
Cladocera																	
Miscellaneous	0.6	0.1	–	0.6	3.5	10.3	–	–	0.2	7.6	–	0.1	6.4	–	–	1.9	
Diaphanosoma	–	9.3	16.4	1.3	–	–	–	–	–	7.9	–	10.1	3.3	–	66.7	3.9	
Ostracoda	–	–	0.8	0.3	–	0.6	–	0.5	–	4.0	0.5	–	0.1	–	–	0.3	
Copepoda																	
Miscellaneous	–	0.7	–	0.8	–	–	–	–	–	5.5	–	–	–	–	–	0.2	
Cyclops	–	–	0.2	8.8	–	–	–	–	–	–	–	–	6.2	–	–	1.4	
Macrocrustacea																	1.7
Macrobrachium (juv)	–	–	0.8	–	–	–	–	–	0.7	–	–	–	–	–	–	0.2	
Macrobrachium (adults)	2.9	0.7	1.7	4.9	0.5	–	1.3	–	2.1	2.6	0.4	0.3	1.2	5.3	–	1.5	

Table 93 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Lb	Cb	Fb	Em	Ls	Lb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Insecta																	43.5
Fragmented	0.3	1.6	0.7	1.6	–	3.0	–	4.7	1.9	1.1	3.6	0.3	2.1	0.7	–	1.8	
Ephemeroptera																	
Baetidae	2.9	5.8	5.6	2.2	0.2	3.4	23.8	16.8	5.8	9.5	5.1	6.6	4.8	1.6	11.7	5.4	
Atalophlebia	–	2.3	–	–	–	1.5	12.5	–	–	15.3	–	–	0.9	–	–	0.8	
Tasmanocoenis	–	1.8	–	1.2	–	–	–	–	–	–	–	0.8	2.1	–	–	0.7	
Tasmanophlebia	–	–	–	0.5	–	–	–	–	–	–	–	–	0.4	–	–	0.1	
Odonata																	
I. heterosticta	–	–	0.2	–	–	–	–	2.1	–	–	–	0.5	–	–	–	0.1	
Gomphidae	–	1.0	–	–	0.9	–	–	–	0.7	–	0.3	–	–	–	–	0.2	
Libellulidae	–	2.0	1.5	2.6	26.2	–	–	7.9	0.6	–	12.4	1.1	2.5	–	–	3.1	
Hemiptera																	
Naucoridae	–	–	–	0.4	–	1.5	–	–	0.8	–	–	–	0.3	–	–	0.3	
Corixidae	–	0.4	1.3	1.3	1.0	0.4	–	–	0.3	4.0	0.4	–	0.3	2.3	–	0.6	
Coleoptera																	
Miscellaneous (adults)	–	0.5	–	–	–	0.3	–	–	+	–	0.2	–	–	0.9	–	0.1	
Miscellaneous (larvae)	–	–	–	–	–	0.3	–	–	0.2	–	–	–	–	–	–	+	
Diptera																	
Miscellaneous (larvae)	–	1.2	–	–	–	–	–	–	–	5.3	–	–	–	–	–	0.2	
Tipulidae	–	–	1.4	–	–	–	–	–	–	–	1.0	–	–	–	–	0.2	
Chaoborinae	–	0.1	1.3	–	–	–	–	–	–	–	–	–	0.1	1.8	–	0.2	
Chironomidae (larvae)	14.0	19.6	17.4	15.7	14.8	17.9	11.2	40.2	39.4	15.8	14.2	19.3	23.0	21.0	19.2	24.7	
Chironomidae (pupae)	–	0.1	1.5	0.9	–	0.4	2.5	4.2	0.2	2.4	0.5	0.5	1.2	0.9	–	0.7	
Ceratopogonidae	0.3	1.7	0.5	2.0	–	2.1	–	–	1.2	–	1.8	–	2.6	0.7	0.8	1.3	
Simuliidae	–	–	–	–	–	–	10.0	–	–	4.2	–	–	–	–	–	0.2	
Trichoptera																	
Hydroptilidae	–	1.0	–	–	–	–	–	0.5	–	–	–	0.9	0.1	–	–	0.2	
Leptoceridae	1.4	2.9	–	2.2	9.0	1.3	2.5	1.6	0.3	1.1	3.4	1.2	2.9	2.3	1.7	1.9	
Miscellaneous (pupae)	–	–	0.1	–	–	–	–	–	–	–	–	0.1	–	–	–	+	
Lepidoptera																	
Pyralidae	–	–	–	1.0	13.3	–	–	–	–	–	5.6	–	–	–	–	1.0	
Teleostomi																	3.7
Fragmented	4.9	1.2	–	1.7	1.2	0.9	2.5	–	0.6	–	1.6	0.2	1.8	2.1	–	1.1	

Table 93 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Lb	Cb	Fb	Em	Ls	Lb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Scales	10.7	1.8	–	0.3	–	2.1	–	–	4.0	1.6	1.7	–	0.6	2.3	–	1.7	
Miscellaneous (larvae)	–	0.6	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	
C. stercusmuscarum	–	1.1	–	–	–	–	–	–	–	–	–	2.0	–	–	–	0.4	
G. giuris	–	0.6	–	–	–	–	–	–	–	2.6	–	–	–	–	–	0.1	
Egg material	–	–	–	–	–	0.2	11.2	–	0.2	–	0.2	1.0	–	–	–	0.3	
Terrestrial plants																	
Angiospermae																	11.2
Fragmented	9.4	9.1	1.5	13.2	–	6.1	8.8	–	19.8	1.1	3.7	6.4	5.0	14.6	–	9.3	
Root material	11.3	4.4	–	–	–	–	–	–	–	–	–	–	4.0	7.8	–	1.7	
Seed material	–	0.2	1.1	–	–	–	–	–	–	–	–	0.7	0.1	–	–	0.2	
Terrestrial animals																	
Arachnida	–	–	–	–	0.7	–	–	–	–	–	0.2	–	–	–	–	+	+
Insecta																	0.7
Fragmented	–	0.7	–	0.5	–	–	–	–	–	–	0.5	–	–	2.3	–	0.3	
Odonata																	
Zygoptera (adults)	–	–	–	0.1	–	–	–	–	0.1	–	–	–	–	–	–	+	
I. heterosticta	–	–	–	0.8	–	–	–	–	–	–	–	–	–	1.4	–	0.1	
Anisoptera (adults)	–	–	–	0.5	–	–	–	–	0.6	–	–	–	–	0.9	–	0.2	
Neuroptera																	
Sisyridae	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	
Trichoptera																	
Leptoceridae (adults)	–	0.3	–	–	–	–	–	–	–	–	–	–	0.2	–	–	0.1	
Parasites																	
Trematoda	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	+	+
Nematoda	0.6	–	0.7	0.6	–	0.1	–	–	0.7	1.8	0.1	0.4	–	0.2	–	0.4	0.4
Microcrustacea																	+
Argulus	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	+	
Detrital material	4.3	–	–	–	–	0.6	–	–	0.8	–	–	–	1.7	–	–	0.6	0.6
Inorganic material	2.3	1.2	0.6	0.5	–	4.0	–	–	0.7	–	–	–	–	–	–	0.2	0.2
Organic material	2.6	2.4	3.4	4.4	4.8	5.2	–	5.3	12.8	–	4.5	1.7	3.3	2.3	–	4.6	4.2
Number of empty fish	1	–	–	1	1	–	–	1	2	–	1	–	1	–	1	5	5
Number of fish with food	35	60	82	77	29	68	8	19	123	19	83	92	112	44	6	479	479

Figures represent the mean percentage volume determined by the estimated volumetric method.
Em = escarpment mainchannel; Ls = lowland sandy creekbed; Lb = lowland backflow billabong; Cb = corridor billabong; Fb = floodplain billabong; + = present (<0.1%)

Seasonal changes

In sampling periods 1–7, respectively, 125, 19, 84, 92, 113, 44 and 7 stomachs of *A. percoides* were examined (all habitats combined). Very few specimens had empty stomachs.

The diet in the 1978 Late-dry season was based primarily on aquatic insects (mainly chironomid and baetid larvae) and terrestrial plant material. During the 1978–79 Early-wet season the terrestrial plant component became much smaller and the microcrustacean component larger. There was a new hydrophyte component and a new mayfly species, *Atalophlebia,* became important in the diet. By the Mid-wet season algae had increased in the diet and microcrustaceans decreased; libellulid larvae had replaced *Atalophlebia* mayfly larvae, but chironomid larvae remained important.

The algal component of the diet decreased during the Late-wet–Early-dry season, while the hydrophyte (mainly *Najas*) component increased dramatically. During the Dry season, microcrustaceans (mainly *Diaphanosoma*) and terrestrial plants increased in importance and the aquatic insects (except for chironomid and baetid larvae) became less common in the stomachs. The hydrophyte component decreased in the 1979 Mid-dry season as the variety and abundance of all the other components increased.

During the 1979 Late-dry season the algal component and an increased hydrophyte component persisted (unlike in the previous year); however, aquatic insects (chironomid larvae) and terrestrial plants were still common in the stomachs.

During the 1979–80 Early-wet season the few specimens examined had eaten mainly *Diaphanosoma,* which corresponded to the increased microcrustacean component recorded in the 1978–79 Early-wet season; similarly, aquatic insects (chironomid and baetid larvae) were found in the stomachs but were of only secondary importance.

Habitat differences

Magela catchment

A total of 286 stomachs of *A. percoides* were examined (all seasons combined): 36 from escarpment mainchannel waterbodies, 60 from lowland sandy creekbeds, 82 from lowland backflow billabongs, 78 from corridor billabongs and 30 from floodplain billabongs. Very few stomachs were empty.

In the escarpment mainchannel waterbodies *A. percoides* was mainly eating algae, and also aquatic insects (mainly chironomid larvae), terrestrial plant material and teleost remains (mainly scales). The diet in the lowland sandy creekbeds had smaller algae, teleost and terrestrial plant material components, and additional hydrophyte (*Najas*) and microcrustacean (*Diaphanosoma*) components; aquatic insects (especially chironomid and baetid larvae) were still the main food.

In the lowland shallow backflow billabongs, hydrophytes (mainly *Najas*) were eaten most frequently, followed by aquatic insects (mainly chironomid and baetid larvae) and microcrustaceans (mainly *Diaphanosoma*). The diet in corridor waterbodies was also based on *Najas,* chironomid and baetid larvae, and microcrustaceans (with a shift from cladocerans to copepods); in this habitat *Macrobrachium* and terrestrial plant material were also found in the stomachs, along with traces of terrestrial insects. No algae were found in the stomachs of specimens captured in the floodplain billabongs; hydrophytes (*Hydrilla*) and adherent gastropods appeared regularly in the diet. Aquatic insects (mainly libellulid, chironomid, pyralid and leptocerid larvae) were the main component in the floodplains.

Nourlangie catchment

A total of 96 specimens were examined from the Nourlangie Creek catchment: 68 from escarpment mainchannel waterbodies, 8 from lowland sandy creekbeds, and 20 from lowland backflow billabongs (where the one specimen with an empty stomach was captured).

The diet in the escarpment mainchannel waterbodies was based on algae, as in the Magela catchment, but microcrustaceans and terrestrial plant material were more common, and teleosts less common (chironomid and baetid larvae were still the main aquatic insects). Aquatic insects were by far the largest component of the diet in the sandy creekbeds, with baetid larvae, *Atalophlebia* and chironomid and simuliid larvae being the main items. The teleost (especially egg material) and terrestrial plant material components were more important in the sandy creekbeds of the Nourlangie catchment than in the Magela catchment, while microcrustaceans and hydrophytes did not appear in the diet, unlike in the Magela catchment.

In the 1979 Mid-dry season, one *A. percoides* specimen in an escarpment mainchannel waterbody (Twin Falls, Jim Jim Creek catchment) was observed apparently cleaning an *Anodontiglanis dahli* (TL approx. 50 cm). The bigger fish was lying motionless on sandy substrate when an *A. percoides* approached and appeared to feed around the head and particularly around the gill cavity. *Anodontiglanis dahli* moved away, followed by *A. percoides,* which resumed its cleaning behaviour. *Amniataba percoides* is the only fish known to eat *Argulus* (a brachiuran ectoparasite).

In the backflow billabongs, aquatic insects (mainly chironomid, baetid and libellulid larvae) dominated the diet. Hydrophytes were also eaten, but few microcrustaceans (unlike in the equivalent Magela catchment habitat).

Fullness

A summary of mean fullness indices of *A. percoides* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchment is shown in table 94. These data are presented on the assumption that feeding times do not vary with habitat or season.

Seasonal changes

Mean fullness indices were generally high throughout the study, though slightly lower in the 1978–79 Early-wet and 1979 Mid-dry seasons and higher in the 1978–79 Mid-wet and Late-wet–Early-dry seasons.

Habitat differences

Mean fullness indices were high throughout the Magela catchment. Upstream of RUPA the index was highest in the lowland sandy creekbeds. Downstream of RUPA the index was highest in the lowland shallow backflow billabongs and floodplain billabongs.

The mean fullness indices in the Nourlangie catchment were generally similar to those in the Magela Creek catchment.

Table 94 Mean fullness indices of *A. percoides* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	3.8 (16)	n/s	n/s	n/s	3.0 (14)	3.8 (4)	3.0 (3)	3.4 (37)
Lowland sandy creekbed	n/s	n/s	n/s	n/s	n/s	n/s	4.0 (4)	4.0 (4)
Downstream of RUPA:								
Lowland sandy creekbed	4.5 (6)	3.8 (5)	0 (1)	3.7 (30)	2.7 (27)	3.4 (10)	n/s	3.3 (79)
Lowland channel backflow billabong	0 (1)	0 (1)	0 (1)	4.5 (15)	3.6 (7)	3.0 (2)	n/s	3.4 (27)
Lowland shallow backflow billabong	0 (1)	3.5 (2)	0 (1)	4.2 (23)	4.5 (6)	n/s	n/s	4.0 (33)
Corridor sandy billabong	4.5 (2)	n/s	n/s	n/s	3.2 (32)	4.3 (6)	n/s	3.4 (40)
Corridor anabranch billabong	n/s	n/s	5.0 (3)	3.3 (4)	0 (1)	4.3 (4)	n/s	3.8 (12)
Floodplain billabong	3.5 (6)	2.5 (4)	4.3 (31)	n/s	n/s	3.8 (17)	n/s	3.9 (58)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	2.6 (8)	3.0 (2)	4.0 (39)	n/s	3.1 (20)	n/s	n/s	3.5 (69)
Lowland channel backflow billabong	n/s	n/s	5.0 (3)	0 (1)	3.7 (3)	0 (1)	n/s	3.3 (8)
Lowland shallow backflow billabong	1.5 (2)	n/s	n/s	4.0 (7)	3.8 (4)	n/s	n/s	3.6 (13)
Lowland sandy creekbed	n/s	3.3 (3)	n/s	3.8 (5)	n/s	n/s	n/s	3.6 (8)
Seasonal mean (all sites)	3.9	3.3	4.1	4.0	3.2	3.7	3.6	

Numbers examined are given in parentheses; n/s = not sampled in the habitat.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- corridor anabranch billabong; 1978–79 Mid-wet season
- lowland sandy creekbed (downstream of RUPA); 1978 Late-dry season
- lowland channel backflow billabong; 1979 Late-wet–Early-dry season
- lowland shallow backflow billabong; 1979 Mid-dry season
- corridor sandy billabong; 1978 Late-dry season

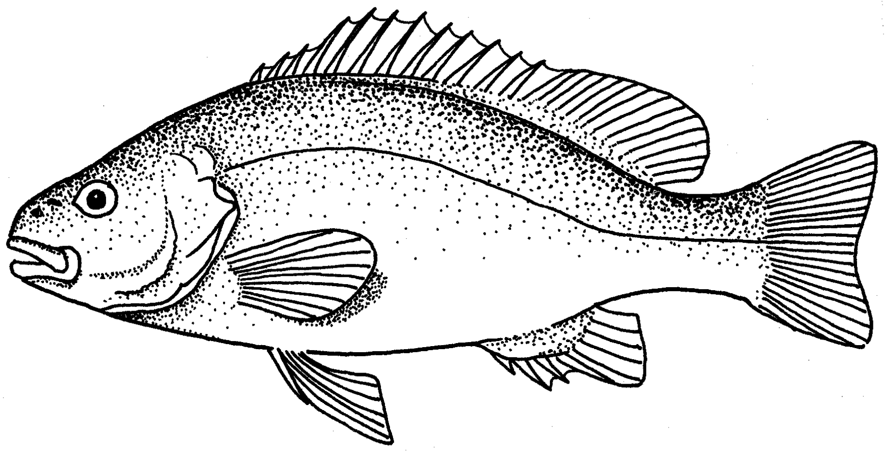
Nourlangie catchment

- lowland channel backflow billabongs; 1978–79 Mid-wet season
- escarpment mainchannel waterbody; 1978–79 Mid-wet season
- lowland shallow backflow billabong; 1979 Late-wet–Early-dry season.

Family TERAPONTIDAE

3.25 *Hephaestus fuliginosus* (Macleay)

Hephaestus fuliginosus is commonly known as the black bream or sooty grunter. It is found in drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3), and in Papua New Guinea. Pollard (1974) found this species mainly in the upper reaches of streams in rocky upland waterbodies, and he also observed some juveniles under and around submerged tree roots in lowland sandy creekbeds near Jabiru.



Hephaestus fuliginosus

Hephaestus fuliginosus is a strictly freshwater species, usually found in the rocky upper reaches of coastal rivers,[171] where it provides excellent sport when fished on light tackle; its flesh is good eating. However, overfishing of *H. fuliginosus* in escarpment mainchannel habitats could threaten existing populations of this species if such amateur fisheries are not properly managed.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found abundantly in escarpment terminal mainchannel waterbodies, moderately abundantly in escarpment perennial streams, and commonly in escarpment mainchannel waterbodies and seasonal streams. It was found rarely in lowland sandy creekbeds.

Hephaestus fuliginosus was found in the greatest number of sites during the Mid-wet season and in the fewest in the 1978 Late-dry season.

Size composition

The lengths and weights of 54 specimens were determined. Most of the specimens were caught by baited hook, but a few were by caught gill and seine nets. The series of peaks found in the overall length-distribution was not, therefore, due to mesh selectivity.

Length–weight relationship

The length–weight relationship for the combined sexes was described by the following expression:

$$W = 1.38 \times 10^{-2} L^{3.10} \qquad r = 1.00 \text{ (length in cm, weight in g)}$$

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[171] Herbert and Peeters (1995) indicated that *H. fuliginosus* are often found at the headwaters of streams in Cape York Peninsula, particularly in the spawning season.

Seasonal mean lengths, weights and condition factors are shown in table 95. The condition factor was highest in the 1978 Late-dry season and lowest in the 1979 Mid-dry and Late-dry seasons. By the end of the 1979 Dry season, the condition appeared to be poorer than that recorded in the 1978 Dry season.

Table 95 Mean length, mean weight and condition factor of *H. fuliginosus*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	10	185.4	126.56	1.08
Mid-wet (1978–79)	29	205.4	162.92	1.01
Mid-dry (1979)	8	252.9	281.72	0.92
Late-dry	7	224.3	199.11	0.94
Overall	54	210.2	173.05	1.00

Length-frequency distribution

The smallest specimen was 57 mm LCF and the largest was 340 mm LCF (fig 111). In the Purari River catchment, Papua New Guinea (Haines 1979), *H. fuliginosus* ranged in length from 120 to 350 mm. This species might grow to 500 mm (Lake 1978).

The mean length of all specimens captured was 210 mm LCF; there were modes at the 190 and 220-mm-length intervals. The LFM for males was 200 mm and for females was 250 mm, indicating that fairly equal proportions of juveniles and adults were captured.

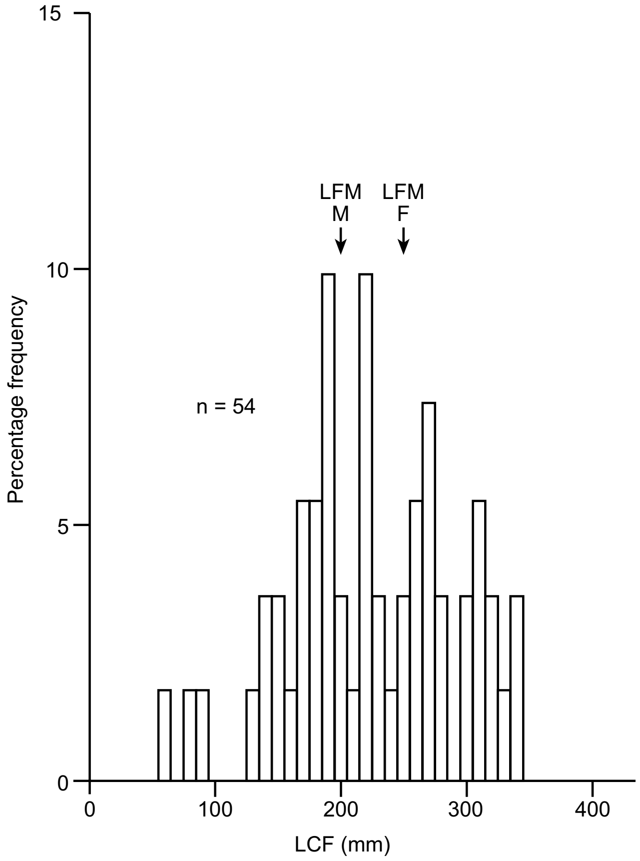

Figure 111 Length-frequency distribution of all *H. fuliginosus* captured

Seasonal changes in distribution

The smallest specimens were captured in the Mid-wet season in escarpment mainchannel waterbodies and were observed in the Late-wet–Early-dry season and 1979–80 Early-wet seasons in escarpment perennial streams of the Magela Creek system (fig 112). The main periods of juvenile recruitment appear to be the Mid-wet and Late-wet–Early-dry seasons; however, this may not be the case in the escarpment perennial streams.

The largest specimens were captured in the Mid-wet and 1979 Mid-dry seasons in the escarpment mainchannel billabongs; in the escarpment perennial streams the largest specimens were observed in the 1979 Late-dry and Late-wet–Early-dry seasons in the Magela and Nourlangie catchments, respectively.

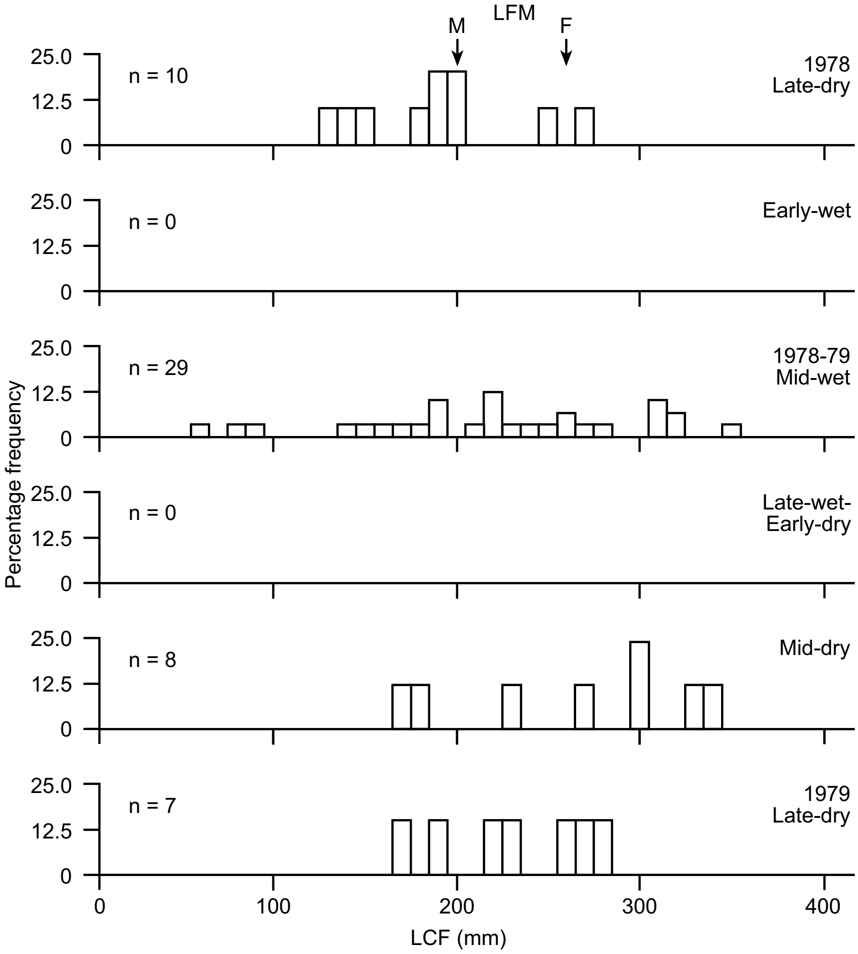

Figure 112 Seasonal length-frequency distribution of all *H. fuliginosus* captured

Habitat differences in distribution

Magela catchment

Most specimens (encompassing a wide size-range) were captured in escarpment mainchannel waterbodies. A few small juveniles were captured in rapidly flowing lowland sandy creekbed channels in the 1978–79 Mid-wet season. Adults were also captured as far downstream as the corridor waterbodies. They are regularly fished from deep sandy creekbeds in RUPA (see *Jabiru Journal*, February 1980) during the Mid-wet season. These adults and juveniles no doubt came from escarpment populations during the Mid-wet season, when high floodwaters would have displaced them downstream from their Dry season refuges. A wide size-range of specimens was observed in escarpment perennial streams throughout the study.

Nourlangie catchment

All *H. fuliginosus* were captured in escarpment mainchannel waterbodies. Their size-range was wide, as was that of specimens observed in escarpment perennial streams throughout the study.

Environmental associations

Rank numbers for *H. fuliginosus* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Both surface and bottom water temperatures ranged from 23° to 34°C (surface mean = 28.2°C; bottom mean = 27.7°C). Both means ranked at the base of the lower quarter (see fig 170). These generally low water temperatures reflects this species' distribution in the cooler escarpment streams and rocky waterbodies (Pollard 1974, Mees & Kailola 1977).

Dissolved oxygen

Dissolved oxygen concentrations in waters in which *H. fuliginosus* was captured ranged from 3.8 to 7.4 mg/L (mean = 6.0) on the surface, and from 5.0 to 7.4 mg/L (mean = 6.4) on the bottom. These mean DO concentrations were ranked in the lower-middle and upper quarters respectively (see fig 171). The relatively high bottom-water DO concentrations are indicative of well-mixed, cooler waters, such as may be found in escarpment streams.

Visibility

Secchi depth readings ranged from 90 to 360 cm (mean = 180 cm) (see fig 172). This mean ranked at the top of the upper quarter, indicating that *H. fuliginosus* is often found in very clear waters. Its apparent preference for clear waters was also noted by Pollard (1974) and Mees and Kailola (1977).

pH

Surface and bottom water pH readings at sites where *H. fuliginosus* was captured ranged from a low 4.0 to 6.7 (mean = 5.6) and 4.5 to 6.5 (mean = 5.7), respectively (see fig 173). Both means ranked at the base of the lower quarter; thus *H. fuliginosus* was captured in relatively acidic waters.

Conductivity

Surface water conductivity readings ranged from 6 to 80 µS/cm; corresponding bottom water conductivities ranged from 6 to 12 µS/cm. Such low conductivities suggest low concentrations of dissolved solids, as might be expected in escarpment waters. Pollard (1974) regarded *H. fuliginosus* as a strictly freshwater species.[172]

Habitat–structural variables

Substrate

Most specimens of *H. fuliginosus* were captured over sandy substrates, followed closely by boulders,[173] then rocks and leaf-litter substrates. The percentage dominance values for sand and boulders ranked in the upper-middle and upper quarters, respectively (see fig 174). This agrees with Mees and Kailola's (1977) report that this species lives over sand and gravel

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[172] Hogan and Nicholson (1987) showed that the sperm of *H. fuliginosus* was most active in salinities of 0 ppt and 5 ppt, and not motile in salinities above 15 ppt.

[173] Hogan (1994) found *H. fuliginosus* spawned in small caverns underneath boulders within rapids in the Tully River in north-eastern Queensland. Herbert and Peeters (1995) indicated that this species spawns at selected sites among rocks and boulders at the edge of rapids at dusk.

substrates in southern Papua New Guinea, and Pollard's (1974) that it is usually found in the rocky upper-reaches of coastal rivers.

Hydrophytes

Hephaestus fuliginosus was found in exceptionally sparsely vegetated waters (vegetation-occurrence index 14.6%). In waters with hydrophytes, emergent vegetation was dominant (43.5%), followed by a comparatively low reading for submergent vegetation (26.1%). Pollard (1974) noted that this species has a high proportion of plant material, including algae and the fruits of terrestrial plants, in its diet; bank vegetation may thus be of some importance to this species.

Reproduction

Hephaestus fuliginosus was caught mainly by handline. As only 54 specimens were captured, the information on this species is sparse. They were captured in only four of the seven seasons sampled. The sex of four fish (length range 57–143 mm LCF) could not be determined; the remainder comprised 16 females (length range 170–340 mm LCF) and 34 males (80–320 mm LCF).

Length at first maturity

No mature or ripe females were captured; however, no fishing for this species was undertaken during the 1978–79 Early-wet season, which is when spawning is most likely. The smallest female with spent gonads was 261 mm LCF. The LFM, using data from five spent fish only, was estimated to be around 250 mm LCF. If the smallest spent fish was a precocious spawner, then the LFM would be closer to 320 mm LCF (fig 113). Fifteen males with developing or spent gonads (stages IV and VII) were captured. The estimated LFM was around 200 mm LCF, but if the two smallest fish (150 and 183 mm LCF) were not precocious spawners, the LFM could be around 150 mm LCF.

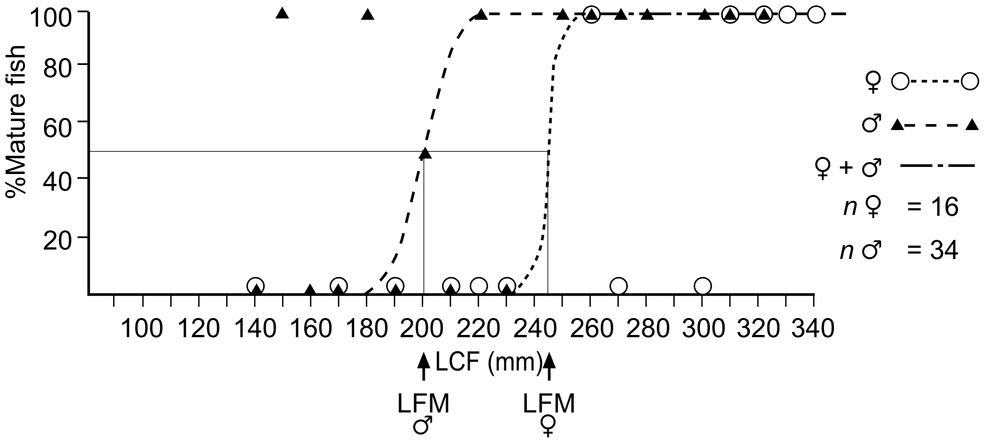

Figure 113 Estimated length at first maturity of *H. fuliginosus*

The numbers of mature fish were too low to be more certain of the LFM, but the GSI and GMSI were calculated on 200 mm LCF as the LFM for males and 250 mm LCF for females. Lake (1978) suggested that *H. fuliginosus* females probably do not mature until over 260 mm in length.

Sex ratio

Although generally more males than females were captured in each season, only in the 1978 Late-dry season was the difference significant ($0.001 < P < 0.01$ for adults + juveniles and

0.01 < P < 0.05 for adult fish; table 96). This unequal sex ratio may be a result of the difficulty in distinguishing between immature female and male gonads.

Table 96 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *H. fuliginosus* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	0	–	9	–	4	3	–
+ adults	M	*n*	9	–	17	–	4	4	–
		χ^2	9.0	–	2.5	–	0.0	0.1	–
		P	**	–	n.s.	–	n.s.	n.s.	–
Adults only	F	*n*	0	–	4	–	4	1	–
	M	*n*	4	–	11	–	2	4	–
		χ^2	4.0	–	3.3	–	0.7	1.8	–
		P	*	–	n.s.	–	n.s.	n.s.	–
GSI									
Adults only	F	mean	–	–	0.5	–	0.6	0.5	–
		s.d.	–	–	0.1	–	0.4	–	–
	M	mean	0.5	–	0.2	–	0.4	0.4	–
		s.d.	0.5	–	0.1	–	0.1	0.3	–
	F+M	mean	–	–	0.3	–	0.5	0.4	–
		s.d.	–	–	0.1	–	0.3	0.2	–
GMSI									
Adults only	F	mean	–	–	2.0	–	2.0	2.0	–
		s.d.	–	–	0.0	–	0.0	–	–
	M	mean	4.3	–	2.0	–	3.5	5.3	–
		s.d.	1.5	–	0.0	–	0.7	1.5	–
	F+M	mean	–	–	2.0	–	2.5	4.6	–
		s.d	–	–	0.0	–	0.8	1.9	–

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant (P > 0.05); * = 0.01 < P < 0.05; ** = 0.001 < P < 0.01; s.d.= standard deviation.

Breeding season

Although data are sparse, the GMSI does suggest that the male gonads started to develop (without much increase in weight) towards the end of the Dry season, while the females were still in a resting state (fig 114). Mature and ripe gonads were found only in the 1978 Late-dry season (two males) and all but one spent fish were from the 1978–79 Mid-wet season sample; spawning thus appears to have occurred during the early part of the 1978–79 Wet season.

Midgley (1980) found running-ripe males in escarpment streams during the 1979–80 Early-wet season; the females were not ready for spawning. When stream flow began (January 1980) the fish were no longer to be found in escarpment streams; in February, individuals with large gonads were captured (by angling) from Magela Creek downstream of the escarpment area and in lowland sandy creekbed streams.

Specimens were also caught in corridor waterbodies (Magela Crossing) and where Gulungul Creek crosses the Arnhem Highway. Thus, from of Midgley's and our data, it appears that

H. fuliginosus spawns during the Early-wet to Mid-wet seasons and that females do not start maturing until around the start of stream flow.[174] Lake (1978) recorded that this species spawned in the Wet season following an increase (and subsequent fall) in water level.

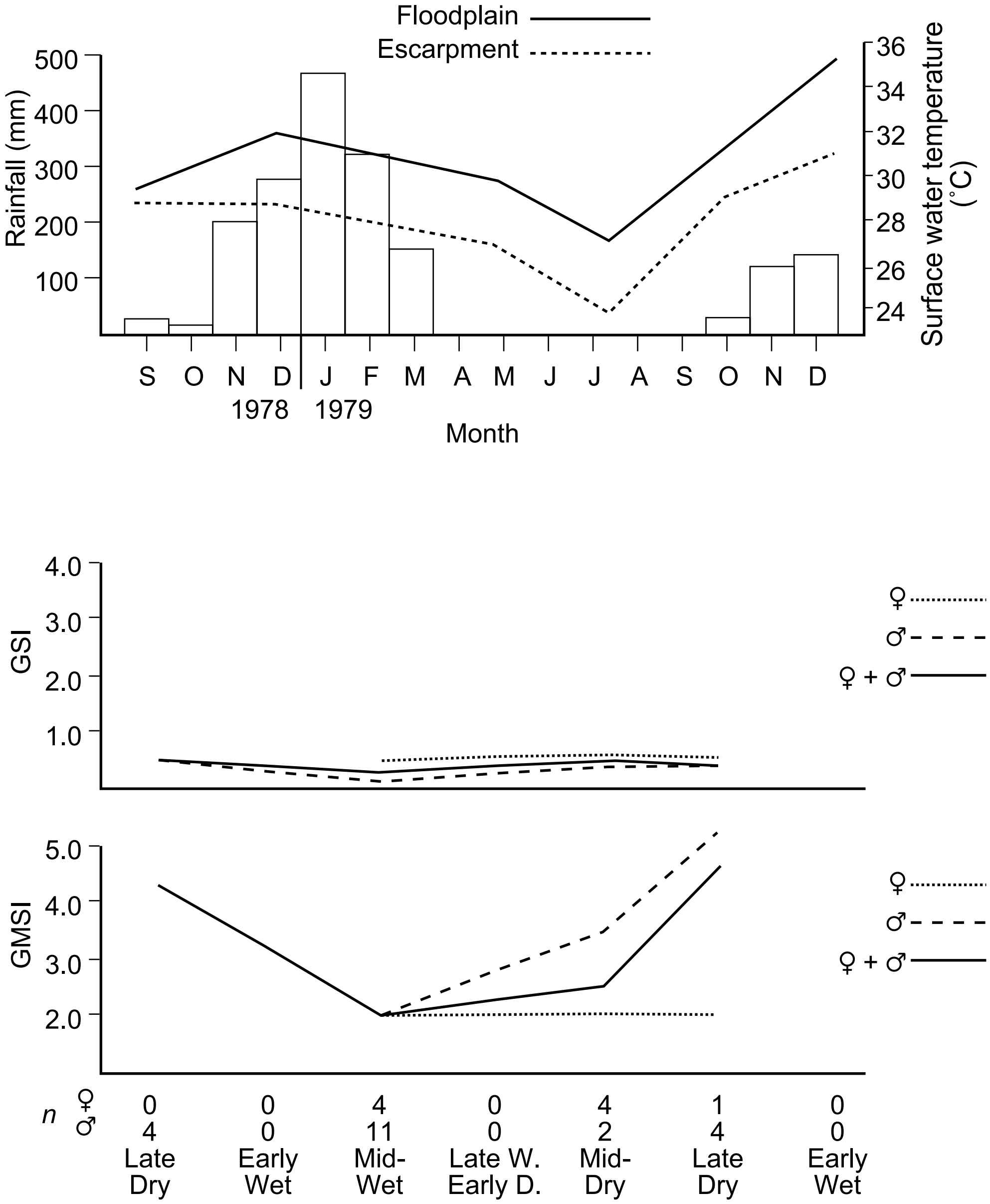

Figure 114 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *H. fuliginosus*

Site of spawning

Although one maturing and one ripe male and all spent fish (five females and 10 males) were captured from the mainchannel waterbody in the escarpment area, Midgley (1980) records that some *H. fuliginosus* move down Magela Creek towards the corridor areas to spawn.

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[174] Herbert and Peeters (1995) indicated that *H. fuliginosus* spawning activity peaks in October–November in far northern Queensland.

However, there are no records of angling in corridor waterbodies and lowland sandy creekbeds during the Wet season to determine how far downstream the fish migrates to its spawning sites. This species reputedly does not spawn in dams (Lake 1971).[175]

Fecundity

Hephaestus fuliginosus produces tens of thousands of eggs, depending on the size of the fish. The eggs are golden, demersal, non-adhesive and up to 3 mm in diameter; two or more partial spawnings may occur over a period of days (Lake 1978). The only ovaries available for examination during this study were spent. They contained between 200 000 and 800 000 eggs of 0.08 mm diameter; most likely they were developing for the next year's breeding.[176]

Specimens from north Queensland spawn at the heads of stony rapids. Their eggs are apparently distributed into gravel crevices by water currents (Midgley, pers comm). The eggs hatch in 24 hours at 26°C, and the larvae begin feeding at about 96 hours.

Summary

Hephaestus fuliginosus was generally captured in escarpment mainchannel waterbodies. Male gonads mature towards the end of the Dry season; however, female gonads do not ripen until the Wet season starts and the creeks begin to flow. Early in the Wet season some mature fish leave the escarpment area and probably migrate downstream towards the corridor waterbodies, though it is not known how far downstream they go to spawn. Queensland specimens lay a very large number of eggs (up to 3 mm in diameter) in gravel beds at the heads of stony rapids when the flood peak subsides; however, such stony gravel beds are generally found only in escarpment areas in the Alligator Rivers Region. Adults that spawn downstream of the escarpment area may have a different breeding strategy from populations that spawn over gravel.

The eggs have a very short incubation period (24 hours at 26°C) and the larvae begin feeding after 96 hours. Spawning in groups of up to 50 individuals has been observed (Lake 1978).

Feeding habits

Overall diet

The stomachs of 52 specimens were examined; 51 contained food. The diet of *H. fuliginosus* is summarised in figure 115; the components are listed in table 97.

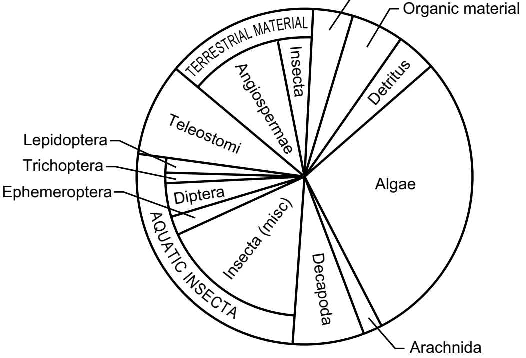

Figure 115 The main components of the diet of *H. fuliginosus*

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[175] Hogan (1994) found *H. fuliginosus* spawned in rapids in the Tully River in north-eastern Queensland. Small caverns under boulders were the specific microhabitat.

[176] Hogan (1994) found that six female *H. fuliginosus* from north-eastern Queensland produced at least 429 000 eggs following induced spawning.

Table 97 Dietary composition of *H. fuliginosus*

	Habitat			Seasons				Overall	
	Magela system		Nourlangie system	1978	1978–79	1979	1979		
Stomach contents	Em	Ep	Em	Late-dry	Mid-wet	Mid-dry	Late-dry	Sub-mean	Main-mean
Aquatic plants									
Algae									27.5
Miscellaneous	3.1	–	–	–	–	7.1	–	1.0	
Conjugatophyta									
Mougeotia	–	–	25.8	–	25.7	10.0	–	15.5	
Spirogyra	–	–	18.0	–	20.0		–	11.0	
Aquatic animals									
Arachnida									1.5
Hydracarina	4.7	–	–	–	–	10.7	–	1.5	
Macrocrustacea									7.9
Macrobrachium	2.5	25.0	5.2	5.0	4.6	4.3	6.7	4.9	
Euastacoides	–	50.0	–	10.0	–	–	–	2.0	
Insecta									25.2
Fragmented	18.1	–	16.9	4.0	18.9	8.6	35.0	16.4	
Ephemeroptera									
Baetidae	0.6	–	3.2	–	3.9	–	–	2.2	
Diptera									
Chironomidae	1.6	–	5.6	10.5	3.4	–	–	3.9	
Ceratopogonidae	–	–	0.2	–	0.2	–	–	0.1	
Trichoptera									
Leptoceridae	2.5	–	–	–	–	5.7	–	0.8	
Lepidoptera									
Pyralidae	5.6	–	–	–	3.2	–	–	1.8	
Teleostomi									8.6
Fragmented	–	–	8.7	–	7.5	8.6	–	5.3	
Scales	5.9	–	2.4	3.0	2.7	2.1	8.3	3.3	
Terrestrial plants									
Angiospermae									10.2
Fragmented	10.0	25.0	1.6	19.0	1.1	5.7	–	5.1	
Bark material	1.3	–	–	–	–	–	3.3	0.4	
Flower material	1.9	–	–	–	–	–	5.0	0.6	
Root material	1.9	–	–	–	–	–	5.0	0.6	
Seed material	10.6	–	–	–	–	–	28.3	3.3	
Pandanus seeds	–	–	0.3	–	0.4	–	–	0.2	
Terrestrial animals									
Insecta									4.1
Fragmented	–	–	2.6	–	2.9	–	–	1.6	
Odonata									
Zygoptera (adults)	–	–	0.2	–	0.2	–	–	0.1	
Orthoptera	–	–	0.3	–	0.4	–	–	0.2	
Lepidoptera									
Miscellaneous (larvae)	–	–	3.2	–	–	14.3	–	2.0	
Hymecoptera									
Oecophylia	0.6	–	–	1.0	–	–	–	0.2	
Parasites									
Nematoda	–	–	0.2	–	0.2	–	–	0.1	0.1
Detrital material	1.9	–	–	14.0	–	4.3	–	3.3	3.3
Bait material	18.4	–	–	29.5	–	–	–	5.8	5.8
Inorganic material	4.4	–	2.9	4.0	1.8	8.6	8.3	3.9	3.9
Organic material	4.4	–	5.5	–	6.1	10.0	–	4.7	4.7
Number of empty fish	1	–	–	–	–	1	–	1	1
Number of fish with food	16	2	31	10	28	7	6	51	51

Figures represent the mean percentage volume determined by the estimated volumetric method.
Em = escarpment mainchannel; Ep = escarpment perennial stream

The main components were algae (28%), aquatic insects (25%), terrestrial plant material (10%) and some teleost remains (9%). The algae were mainly filamentous green species such as *Mougeotia* and *Spirogyra*. The main identifiable aquatic insects were chironomid larvae. The terrestrial plant material consisted of scrapings of bark and root (possibly from submerged tree trunks and roots, eg of *Pandanus*) as well as numerous seeds and flowers that had fallen into the water. Macrocrustaceans (8%), mainly *Macrobrachium* and *Euastacoides,* were also eaten. Traces of terrestrial animals, aquatic arachnids, detritus and inorganic material were also found in the stomachs. *Hephaestus fuliginosus* can therefore be classified as a macrophagous omnivore. Pollard (1974) also considered this species to be an omnivore, eating plant material (including algae and often the small fruits or berries of terrestrial plants) as well as crustaceans and insects. This species is reputedly not a fish eater; however, teleost remains were found in several stomachs. Haines (1979) classified *Terapon* (= *Hephaestus*) *fuliginosus* from the Purari River, Papua New Guinea as a herbivore (its diet including other plant material).[177]

Seasonal changes

In sampling periods 1, 3, 5 and 6, respectively, 10, 28, 8 and 6 stomachs were examined (all habitats combined). Only one specimen (from the 1979 Mid-dry season) had an empty stomach.

The diet in the 1978 Late-dry season was based fairly evenly on terrestrial plant material, aquatic insects (mainly chironomid larvae), macrocrustaceans (*Euastacoides* and *Macrobrachium*), and detritus. During the Mid-wet season the emphasis shifted towards algae, with less terrestrial plant material, detritus and macrocrustaceans; terrestrial insects appeared in the diet during this season.

By the 1979 Mid-dry season the diet had shifted from algae to aquatic and terrestrial food items and teleosts. The inorganic and unidentified organic material components were larger in the Mid-dry season. In the 1979 Late-dry season, *H. fuliginosus* ate mainly aquatic insects, terrestrial plant material, teleosts, aquatic arachnids and macrocrustaceans. Algae were not eaten in this or the 1978 Late-dry season.

Habitat differences

Magela catchment

Totals of 17 and 2 stomachs of *H. fuliginosus* were examined (all seasons combined) from escarpment mainchannel waterbodies and perennial streams, respectively. Only one specimen (in the mainchannel habitat) had an empty stomach.

The main dietary items (other than the bait used to catch the specimens in the mainchannel habitat) were aquatic insects (mainly pyralid larvae) and terrestrial plant material (mainly seeds); macrocrustaceans, fish scales, aquatic arachnids, algae, inorganic and detrital material were also found in the stomachs. The few specimens examined from perennial streams had eaten only macrocrustaceans (*Euastacoides* and *Macrobrachium*) and terrestrial plant material.

Many juvenile and adult specimens were observed feeding in lowland sandy creekbeds during the Mid-wet season.

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[177] Pusey et al (1995b) found *H. fuliginosus* to consume large quantities of vegetable matter, either as terrestrial material, aquatic macrophytes or particularly filamentous alga in two rivers of the Australian wet tropics, north-eastern Queensland.

Nourlangie catchment

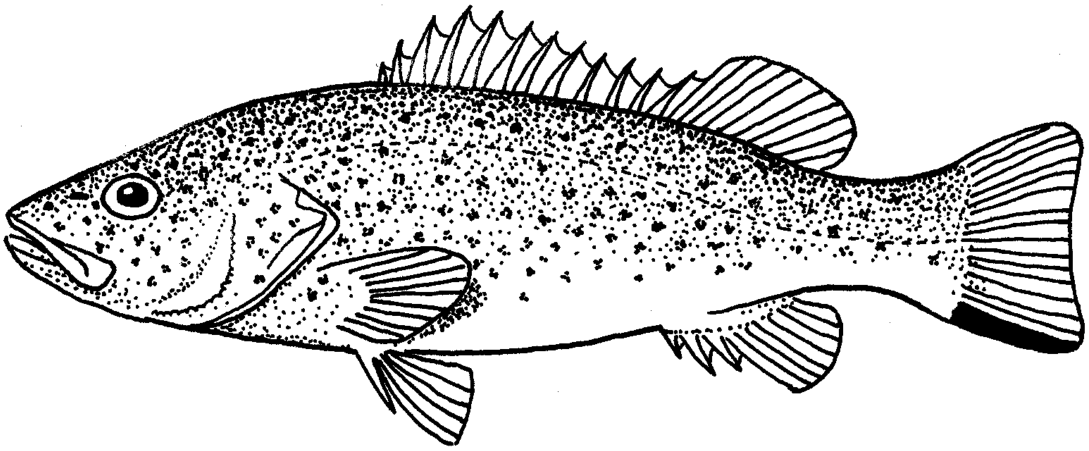
A total of 31 stomachs of *H. fuliginosus* were examined (all seasons combined) from an escarpment mainchannel waterbody. All contained food.

The diet encompassed a variety of food items, with the main components being algae (*Mougeotia* and *Spirogyra*), aquatic insects (mainly chironomids identifiable), teleost remains, macrocrustaceans (*Macrobrachium*) and traces of terrestrial insects and plants and inorganic material. In this catchment the diet appeared to be based more on algae than in the specimens examined in the Magela catchment.

Family TERAPONTIDAE

3.26 *Leiopotherapon unicolor* (Gunther)

Leiopotherapon unicolor is commonly known as the spangled grunter or perch. It is a wide-ranging species, found in the drainage systems of the north-east coast, Gulf of Carpentaria, Timor Sea, Indian Ocean, Lake Eyre, Bulloo and Murray–Darling (see map 3). Pollard (1974) reported it was common in almost all waterbodies in the Magela Creek system, and Miller (in Taylor 1964) that it was abundant in large billabongs and creeks in the Oenpelli area. The black marking on the tail is only found in specimens of less than 90 mm.



Leiopotherapon unicolor

Leiopotherapon unicolor (syn. *Madigania unicolor*) belongs to a family with marine, estuarine and freshwater representatives, but it is strictly an inhabitant of freshwaters. It is a good eating fish, although generally small.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was abundant in escarpment terminal mainchannel waterbodies, moderately abundant in escarpment perennial and seasonal streams, and common in all escarpment mainchannel waterbodies, lowland sandy creekbeds, lowland backflow billabongs and corridor waterbodies. It was found in only a few floodplain billabongs. It was found in the greatest number of sites in the Late-wet–Early-dry season and in the fewest in the 1978 Late-dry season.

Size composition

The lengths and weights of 439 specimens were recorded. Peaks apparent in the overall length-frequency distribution were caused to some extent by the mesh selectivity of the gillnets (mainly 26, 44 and 58 mm mesh); however, the large overlap in sizes of fish caught by the various nets, and of those caught by seine net, suggests mesh selectivity did not disguise trends in growth of this species.

Length–weight relationship

The length–weight relationship for the combined sexes was described by the expression:

$$W = 2.04 \times 10^{-2} L^{2.95} \qquad r = 0.99 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 98. The seasonal condition factor was stable (near unity) between the 1978 Late-dry and 1978–79 Mid-wet seasons; it is surprising that condition was not depressed during the Early-wet season spawning. By the Late-wet–Early-dry season, condition peaked, due to extensive feeding in the Wet. After the Wet season, a change in environmental conditions, food supply or both caused condition to deteriorate through the 1979 Dry season.[178] The condition of specimens in the 1979 Late-dry and 1979–80 Early-wet seasons was considerably poorer than in the same seasons the previous year. Specimens with especially poor body condition (k = 0.75–0.80) were found in escarpment perennial streams (mainly Baroalba Springs) during both Late-dry seasons.

Table 98 Mean length, mean weight and condition factor of *L. unicolor*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	25	129.5	38.79	1.00
Early-wet (1978–1979)	44	32.6	0.68	1.02
Mid-wet	55	98.3	17.28	1.00
Late-wet–Early-dry (1979)	49	124.2	38.71	1.13
Mid-dry	122	124.6	34.11	0.98
Late-dry	44	114.1	24.63	0.92
Early-wet (1979–80)	10	123.8	30.87	0.91
Overall	349	100.4	18.38	1.00

Length-frequency distributions

Specimens ranged in length from 11 mm to 236 mm LCF (fig 116). The largest was near the reputed maximum size (250 mm; Pollard 1974) attained by this species, but specimens up to 260 mm LCF were observed in escarpment perennial streams in the Magela Creek catchment.

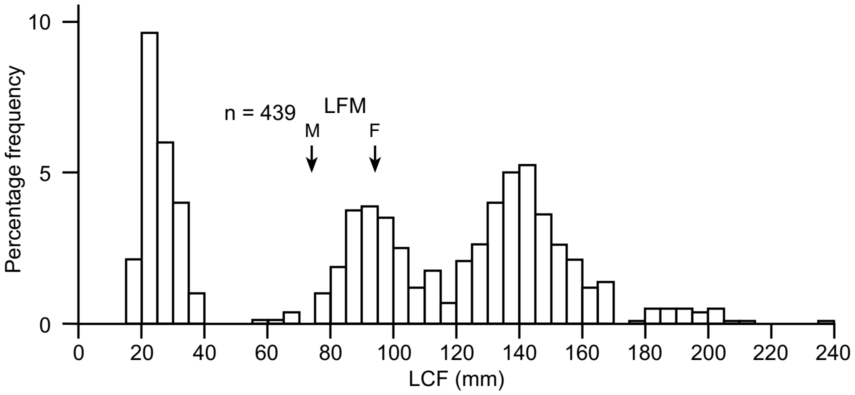


Figure 116 Length-frequency distribution of *L. unicolor*

The mean length of all specimens captured was 100 mm LCF. The LFM (fig 116) for males was 74 and for females 94 mm LCF, indicating that most of the specimens were adults. There were three peaks with modal sizes of 20–25, 90–95 and 140–145 mm in the length-frequency

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[178] Gehrke (1988b) recorded reduced condition for *L. unicolor* during winter in south-east Queensland.

distribution. A strongly kurtosed size group occurred between 175 and 215 mm LCF. Few specimens were captured between 40–75 mm LCF.

Seasonal changes in distribution

The smallest specimens were captured in the 1978–79 Early-wet season (fig 117), indicating that juveniles recruit during this period; no juveniles were found in the 1979–80 Early-wet season, probably because the 1979 Dry season was extreme and the flow had not started in the catchments. In escarpment perennial streams, small juveniles were found mainly in the Mid-wet and Late-wet–Early-dry seasons, and again in the 1979 Late-dry season.

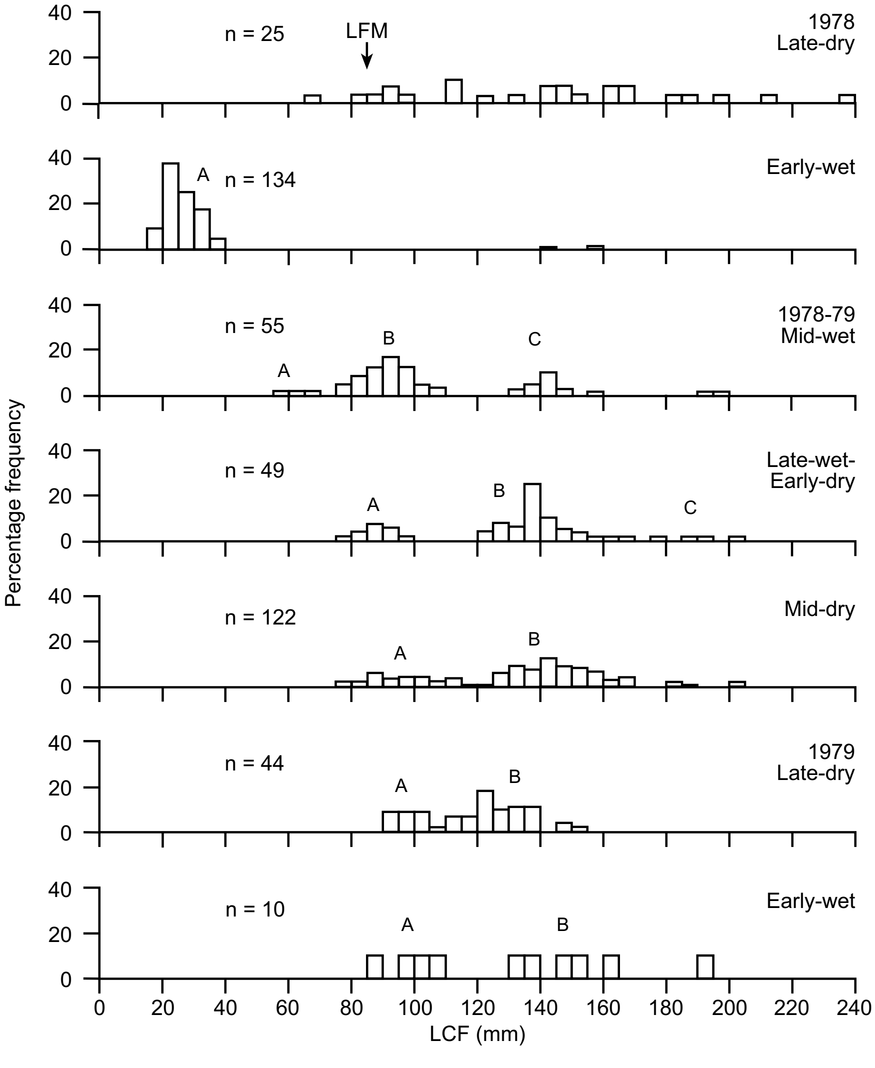

Figure 117 Seasonal length-frequency distribution of *L. unicolor*

The largest specimen was captured in the 1978 Late-dry season. The largest adults were observed in escarpment perennial streams in the 1978–79 Mid-wet and 1979–80 Early-wet seasons.

The mean seasonal lengths of specimens, shown in table 98, were greatest in the 1978 Late-dry season, when a wide range of sizes of predominantly adult fish was captured (fig 117). The mean lengths fell dramatically by the 1978–79 Early-wet season, when large numbers of juvenile recruits entered the populations of apparently few adults. By the Mid-wet season mean length had increased, as large juveniles and small adults dominated the populations; intermediate-sized and large adults had also reappeared. The mean lengths continued to increase until the 1979 Late-dry season, when the peaks of small and intermediate-sized adults almost merged and growth appeared to slow. The reduction of mean length may be an artefact of sampling, an indication of increased mortality, or result from larger-sized specimens moving out of sampling sites. The mean lengths and size ranges in the season were much less than those recorded in the 1978 season.

By the 1979–80 Early-wet season the small and intermediate-sized adult peaks had again separated and mean lengths were comparable with those in the 1979 Mid-dry season; the length-frequency distribution resembled that recorded in the 1978 Late-dry season, with small discrepancies due to differences in sample sizes.

Growth rate

Male and female specimens of *L. unicolor* can attain their LFM (58 and 78 mm LCF) within one year if kept in drastically understocked ponds with an abundant food supply (Llewellyn 1973).

Growth in *L. unicolor* may be described from the seasonal length-frequency distributions by following the progression of small juveniles (modal length 20–25 mm) from the 1978–79 Early-wet season (A on fig 117). The fastest growth appeared to be in the six months between the Mid-wet and the Late-wet–Early-dry seasons, when a modal length of 85–90 mm LCF was attained. These large juveniles/small adults appeared to grow through the Dry season to a mean length of 95–100 mm LCF by the 1979–80 Early-wet season (ie 10 mm in six months).

The growth of *L. unicolor*, therefore, appears to be faster than that noted by Llewellyn (1973): our study suggests it reaches its LFM in the six months over the Wet season. The environment may be described (as Llewellyn described his growth ponds) as drastically understocked, with an abundant food supply.[179]

Habitat differences in distributions

Length-frequency distributions showing habitat preferences of *L. unicolor* captured in regular sampling sites of the Magela and Nourlangie Creek catchments are given in figure 118.

Magela catchment

The smallest juveniles were most abundant in lowland sandy creekbeds and to a lesser extent in lowland shallow backflow billabongs and sandy corridor waterbodies; a few specimens were captured in channel backflow, corridor anabranch and floodplain billabongs. The larger juveniles were captured less often in sandy creekbeds and more usually in lowland backflow billabongs upstream and downstream of RUPA. A few specimens were found in escarpment mainchannel waterbodies. Juveniles were present in escarpment perennial streams throughout the study.

The small and intermediate-sized adults were found mainly in lowland backflow billabongs up- and downstream of RUPA; small numbers were also found in escarpment mainchannel waterbodies, sandy creekbeds, and corridor and floodplain billabongs. Intermediate-sized adults were captured more frequently in lowland sandy creekbeds.

Large adults were found mainly in backflow billabongs (especially in channel types) as well as in sandy creekbed and escarpment mainchannel waterbodies. Adults of all sizes (including the largest specimens observed) were found in escarpment perennial streams throughout the study.

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[179] Gehrke (1988b) held *L. unicolor* weighing 54–96 g in aquaria at 16.8°C and found no significant growth over a period of 180 days, whereas individuals held at 22.6°C showed a weight increase of 32.8% over the same period.

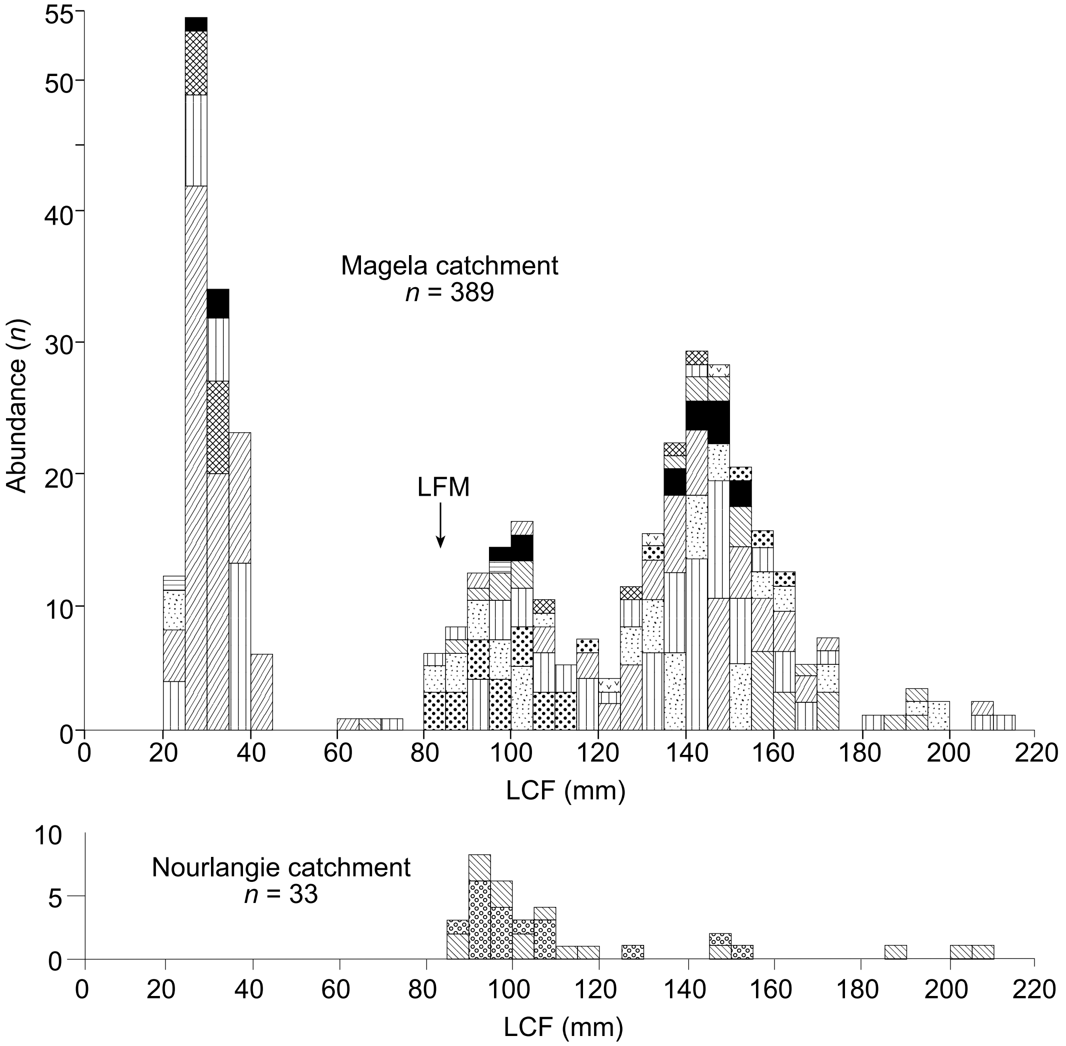

Figure 118 Length-frequency distributions and habitat preferences of *L. unicolor* captured at regular sampling sites (see appendix 5 for key to the habitats)

Nourlangie catchment

No juveniles were captured in this catchment; however, sampling in this catchment was limited. Small adults were found in shallow backflow billabongs and escarpment mainchannel waterbodies, as were intermediate-sized adults. Large adults were captured in the escarpment mainchannel waterbodies.

Juveniles and adults were found in escarpment perennial streams throughout this study, and adults were frequently observed in seasonal escarpment streams.

Environmental associations

Rank numbers for *L. unicolor* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Temperatures of waters from which *L. unicolor* was captured ranged from 23° to 40°C (mean = 30.2°C) on the surface, and from 23° to 35°C (mean = 28.9°C) on the bottom. Both means were placed in the lower-middle quarter (see fig 170). *Leiopotherapon unicolor* was commonly found in escarpment waters, but was also found in smaller numbers in almost all other habitats sampled. The broad local (and continental; Pollard [1974]) distribution of this species is reflected in its tolerance of a range of water temperatures. Other workers (eg Beumer 1979a, Llewellyn 1973) have also found that *L. unicolor* can tolerate extremely high water temperatures (up to 41.8°C for adult fish).[180]

Dissolved oxygen

Dissolved oxygen concentrations in waters in which *L. unicolor* was found ranged from 0.9 to 9.1 mg/L (mean = 6.3) on the surface, and from 0.2 to 9.5 mg/L (mean = 4.5) on the bottom. These mean DO concentrations were placed in the upper-middle and lower-middle quarters respectively (see fig 171). This species apparently tolerates a wide range of DO concentrations, as might be expected of a fish with a broad local and continental distribution.[181]

Visibility

Secchi depths ranged widely from 1 to 360 cm with a mean depth of 62 cm, which ranked in the lower-middle quarter (fig 172). This species was thus found in both very turbid and very clear waters.

pH

The pH of surface waters ranged from 4.0 to 8.6 (mean = 6.1), and of bottom waters from 4.5 to 7.3 (mean = 5.8). These means ranked in the upper-middle and lower-middle quarters respectively (see fig 173).

Conductivity

The conductivity of waters in which this species was found ranged from 6 to 620 µS/cm on the surface and from 4 to 620 µS/cm on the bottom. Both ranges are extremely wide, which is in accord with *L. unicolor*'s wide distribution from the upper to the lower reaches of the catchment. Pollard (1974) stated that this species, although a member of a family with marine and estuarine representatives, is a strictly freshwater fish. However, Beumer (1979a) found that *L. unicolor* could tolerate salinities of up to 36 ppt.

Habitat–structural variables

Substrate

Leiopotherapon unicolor was found over a wide range of substrates, predominantly sand (lower-middle quarter), followed by mud (lower-middle quarter), then clay, leaf litter and boulders/rocks (see fig 174). This species is reputed to be able to aestivate in the mud of dried watercourses (Llewellyn 1973). After heavy rains and floods, it rapidly disperses into areas that were previously dry and apparently devoid of fish (Beumer 1979a, Llewellyn 1973).

Hydrophytes

Leiopotherapon unicolor was found in waters with relatively little vegetation (vegetation-occurrence index 62.7%): the order of dominance was submergent, emergent then floating-attached hydrophytes. This species eats considerable quantities of hydrophytes.

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[180] Gehrke (1988b) investigated the feeding energetics of *L. unicolor* and found in aquaria their daily food consumption reduced as water temperature decreased. Fish held at 16.8°C did not grow significantly over a period of 180 days, whereas individuals held at 22.6°C showed a weight increase of 32.8% over the same period. Gehrke (1988c) examined cardio-respiratory responses of *L. unicolor* to temperature. Gehrke and Fielder (1988) examined the effects of temperature on the heart rate, ventilation rate and oxygen consumption of *L. unicolor*.

[181] Gehrke (1988c) examined cardio-respiratory responses of *L. unicolor* to dissolved oxygen. Gehrke and Fielder (1988) examined the effects of dissolved oxygen on the heart rate, ventilation rate and oxygen consumption of *L. unicolor*.

Reproduction

Of the 383 *L. unicolor* examined to determine reproductive state, 113 were sexually indistinguishable (length range 11–189 mm LCF), 138 were females (64–231 mm LCF) and 132 were males (61–205 mm LCF).

Length at first maturity

The smallest identifiable maturing female (gonad stage approx. III) was 94 mm LCF; the smallest identified maturing male was 81 mm LCF. Beumer (1979b) found females of 33 mm LCF and males of 34 mm LCF, with the smallest maturing female at 58 and the smallest maturing male at 66 mm. The largest female was 194 mm and the largest male 151 mm, (compare 231 and 205 mm from the Alligator Rivers Region). Llewellyn (1973) found mature females and males at 78 and 58 mm, respectively, amongst fish collected from southern Queensland.

The estimated LFM was around 94 mm LCF for females and 74 mm LCF for males. Calculations for the LFM were based on 10-mm-length groups (fig 119). The length at first maturity of fish collected in north Queensland was 60 mm for both sexes (Beumer 1979b), which is smaller than in the Alligator Rivers Region. The largest specimen was also smaller.

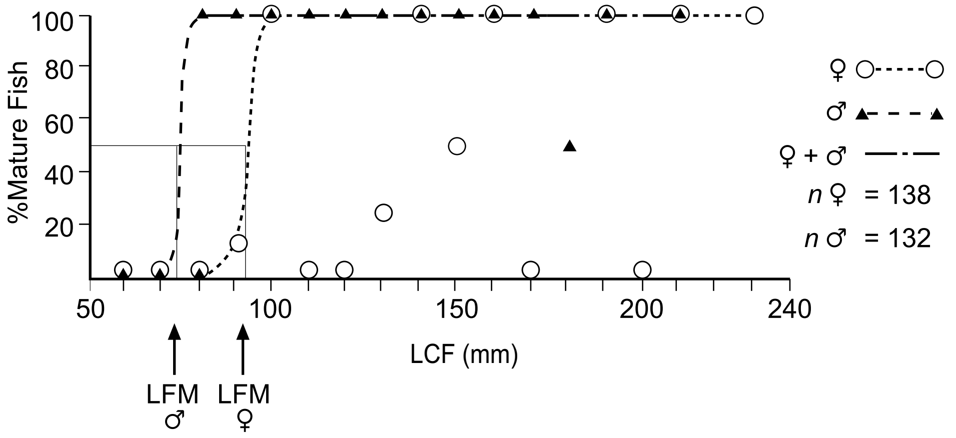

Figure 119 Estimated length at first maturity (LFM) of male and female *L. unicolor*

Sex ratio

During the 1978 Late-dry season significantly more males than females were captured ($0.001 < P < 0.01$), and significantly more adult males than adult females ($0.01 < P < 0.05$); however, there was no significant difference from a 1:1 ratio in any other season (table 99). The 1979 Late-wet–Early-dry season showed a slight increase in the proportion of females, although the difference was not significant. Beumer (1979*b*) found that the ratio was generally 1:1 throughout the system, with a slight increase in the number of males in the pre-flood, and of females in the post-flood, periods.

Breeding season

Leiopotherapon unicolor had a well-defined breeding season during the 1978–79 and 1979–80 Early-wet seasons, although the highest GSIs found in the 1978–79 Early-wet season were higher than in the previous year (fig 120). This may have been because the Wet season proper (ie heavy and frequent rains with stream flow) did not begin until after the 1979–80 Early-wet season sample was taken. The GSI was constant and low for all other seasons, with a slight increase in the Late-dry seasons, which precede spawning.

Table 99 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *L. unicolor* over all habitats

Parameter	Sex	Statistic	Sampling period						
			Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	5	2	20	29	59	29	3
+ adults	M	*n*	18	2	22	17	42	24	7
		χ^2	7.3	0.0	0.1	3.1	2.9	0.4	1.6
	P	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	5	2	15	26	55	20	3
	M	*n*	17	2	21	17	42	24	7
		χ^2	6.5	0.0	1.0	1.9	1.7	0.4	1.6
		P	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	0.9	4.3	0.3	0.2	0.4	0.8	3.1
		s.d.	0.5	1.5	0.1	0.1	0.1	0.3	2.3
	M	mean	0.8	5.8	0.1	0.1	0.7	4.5	4.7
		s.d.	0.5	2.7	0.1	0.0	0.1	0.6	1.3
	F+M	mean	0.8	5.1	0.2	0.2	0.2	0.7	3.9
		s.d.	0.5	2.0	0.1	0.1	0.2	0.3	1.7
GMSI									
Adults only	F	mean	3.2	5.5	2.0	2.1	2.1	2.3	4.0
		s.d.	1.1	0.7	1.0	0.2	0.3	0.5	1.0
	M	mean	3.6	4.0	2.2	1.7	1.6	3.8	5.0
		s.d.	1.0	2.8	0.5	0.6	0.7	1.4	0.0
	F+M	mean	3.5	4.8	2.1	1.9	1.9	3.0	4.6
		s.d	1.0	1.9	0.6	0.4	0.5	1.3	0.7

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.001$; s.d. = standard deviation.

Mature fish were captured only in the Late-dry and Early-wet seasons (table 100). Two ripe fish were found in the 1978–79 Early-wet season and three males in the 1979 Late-dry season. As with *H. fuliginosus, L. unicolor* males were found running-ripe before the floods but females were not yet ready to spawn.

Most of the spent females were caught in the 1978–79 Mid-wet and Late-wet–Early-dry seasons, with one spent female being caught in the 1979–80 Early-wet, indicating there may have been some spawning before the floods. Juveniles (11–35 mm LCF) were captured only during the 1978–79 Early-wet season.

Other studies on *L. unicolor* support these results. Llewellyn (1973) found running-ripe fish in south-eastern Queensland during September–October. In ponds at Narrandera, this fish spawned from November through to mid-February, when water temperatures rose to about 26°C at the surface and 22°C at the bottom. An increase in water level seemed to trigger spawning if the temperatures were suitable.

In north Queensland, both sexes mature rapidly between September and October (Beumer 1979b), and spawn around December–February, depending on the time of onset of Wet season flooding. Ripe specimens were found only before and during floods, and spent fish were found during the floods. No juveniles were captured before the floods.

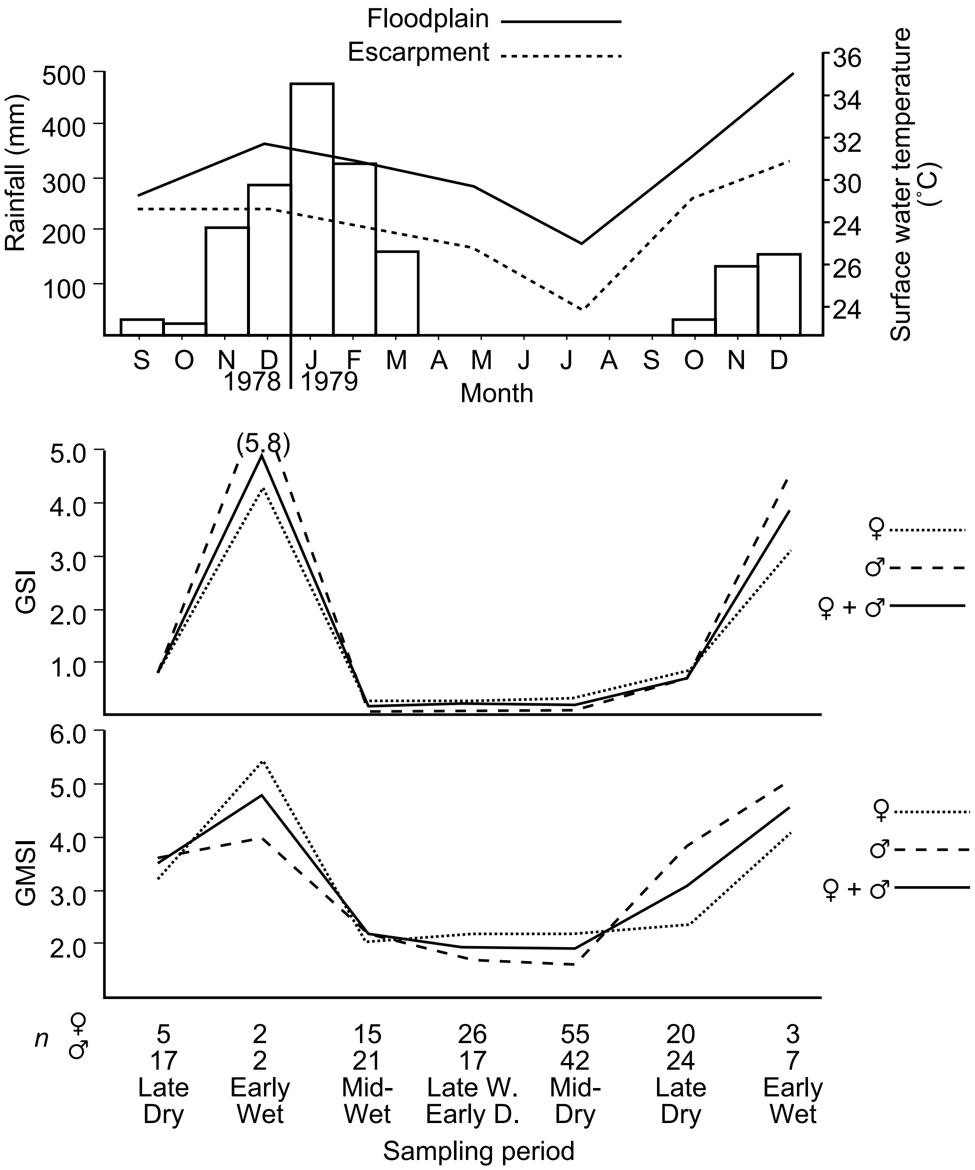

Figure 120 Seasonal fluctuations in the gonadosomatic index (GSI) and the gonad maturing stage index (GMSI) of male and female *Leiopotherapon unicolor*

Table 100 Possible sites of spawning of *Leiopotherapon unicolor,* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juveniles
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	–	2	–	–	1	4	–
Lowlands							
Sandy creekbed	1	3	–	–	2	1	79
Backflow billabong	–	9	1	4	8	6	32
Corridor	–	–	–	–	–	1	17
Floodplain billabong							
Upper	–	–	–	–	–	1	–

Site of spawning

Mature, ripe, spent and juvenile fish were captured from lowland shallow backflow billabongs. Although running-ripe fish were not captured from any other habitat, mature, spent and juvenile fish were captured from sandy creekbeds, spent and juvenile fish from corridor waterbodies, and spent fish from floodplain billabongs (table 100).

The fish was probably spawning in the backflow billabongs and possibly the sandy creekbeds, and the eggs, larvae or juveniles were washed down into the corridor waterbodies.

Beumer (1979b) recorded a spawning migration for this species in coastal north Queensland with fish moving towards the upper reaches during floods.

Although *L. unicolor* does not readily spawn in small bodies of water (Llewellyn 1973), it will breed in dams (Merrick 1980). Spawning is believed to take place at night (Llewellyn 1973, Merrick 1980) in the shallows of lentic waterbodies (Llewellyn 1973).

Since *L. unicolor* breeds during the Wet season, the above information suggests that it could be spawning in backwaters and still pools of the billabongs and sandy creekbeds.

Fecundity

Two ovaries only were examined. One weighed 0.92 g and contained 15 600 eggs with diameters ranging from 0.24–0.32 mm, while the other weighed 3.36 g and contained about 80 000 eggs with a mean diameter of 0.27 mm (± 0.03). The mean fecundity was therefore around 48 000, and the mean egg diameter around 0.27 mm.

Llewellyn (1973) found that the fecundity increased with the increasing weight of the fish: fish of 24 and 64 g contained 24 000 and 113 200 eggs, respectively. Beumer (1979b) recorded fecundities ranging from 1727 to 81 755, and means for two consecutive breeding seasons of 16 030 and 23 978.

The egg diameters reported in the literature are larger than those found in the present study; probably these eggs were not fully mature. Llewellyn (1973) records a diameter of 0.68 mm when fresh and 0.71 mm when water-hardened. Beumer (1979b) records the average egg diameter from ripe fish as 0.6 mm, with egg diameters from all parts of the ovary generally showing a unimodal distribution.

The eggs are demersal, spherical, transparent and non-adhesive. They contain a single oil globule and have a thin perivitelline space. The eggs are spawned and randomly dispersed as the fish swims through the shallows, where they settle on the bottom. They hatch 45–55 hours after fertilisation at 23–26.4°C and the newly hatched prolarvae are small (2.2 mm) and generally not well developed (Llewellyn 1973). The yolk sac is completely resorbed in about three days (Llewellyn 1971).

Summary

Leiopotherapon unicolor had a well-defined breeding period during the Early-wet season, and probably spawned in the shallows of still backwaters and pools in the lowland backflow billabongs and sandy creekbed. Spawning probably occurred at night and the eggs were randomly dispersed over the bottom as the fish swam through the shallows (Llewellyn 1973). A large number of tiny, demersal, non-adhesive eggs are scattered over the substrate. After a very short (less than 50 hours) incubation period, they hatch into small (2.2 mm), poorly developed prolarvae (Llewellyn 1973). The yolk sac is resorbed after about three days. Our results suggest growth is rapid, with fish attaining at least 11 mm within a few weeks. *Leiopotherapon unicolor* have grown to greater than the LFM within one year in good conditions (Llewellyn 1973).

The LFM was estimated at 90 mm for females and 80 mm for males. Llewellyn (1973) and Beumer (1979b) recorded that the species was sexually dimorphic at breeding: female urinogenital papillae are enlarged and bulbous and exceed the anus in diameter, whereas those of males are smaller than the diameter of the anus.

Feeding habits

Overall diet

The stomachs of 371 specimens were examined; 342 contained food. The diet of *L. unicolor* is summarised in figure 121; the components are listed in table 101. The main components were aquatic insects (46%), hydrophytes (12%) and teleosts (9%). The aquatic insect component consisted mainly of baetid and chironomid larvae. *Najas* was the main hydrophyte eaten and *C. marianae* and *Ambassis* spp. were the most common identifiable teleosts. A wide variety of other plants and animals was eaten, including algae (5%) (mainly green filamentous species), terrestrial plant material (6%), microcrustaceans (6%, mainly cladocerans), macrocrustaceans (3%) and traces of oligochaetes, gastropods, arachnids, terrestrial insects, detritus and unidentified organic material. *Leiopotherapon unicolor* can therefore be classified as an opportunistic meiophagic omnivore taking food items from mid-water and benthic areas of the waterbodies.[182]

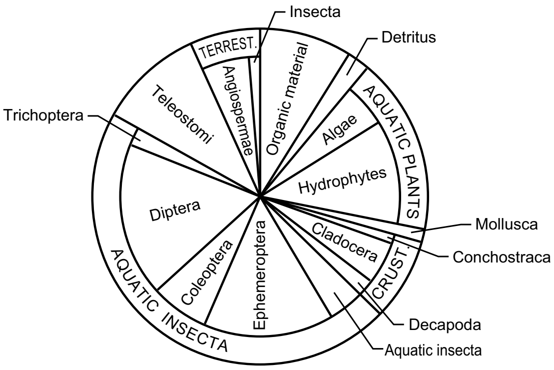

Figure 121 The main components of the diet of *L. unicolor*

Lake (1978) reported that the food of this species was mainly small invertebrates, including aquatic insects, crustaceans, molluscs and some plant material. Pollard (1974) noted that this species feeds principally on freshwater shrimps and insects, but will readily eat smaller fishes. Merrick (1974) concluded from examining the stomach contents of nine specimens that *Madigania* (syn. *L. unicolor*) was primarily a carnivore, but due to 'accidental uptake', the terrestrial plant content was high in some specimens. However, the herbivorous component of the diet in the Alligator Rivers Region appears to be an important part of this species' food.

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[182] Gehrke (1988a) investigated the gut morphology of *L. unicolor* and concluded that the small conical teeth on the jaws and pharynx, a simple Y-shaped stomach and a short gut were characteristic of an opportunistic carnivorous fish. Gehrke further found that the capture of prey small enough to swallow whole was assisted by suction created as the mouth opened to engulf prey. Crustaceans to large to ingest whole were broken into smaller pieces against the substrate. Directional and oscillatory movement were the most effective sensory cues in eliciting feeding behaviour. The frequency with which *L. unicolor* responded to cues increased with hunger.

Table 101 Dietary composition of *L. unicolor*

	Habitat								Season							Overall	
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Lb	Cb	Fb	Em	Ep	Lb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																	
Algae																	4.8
Miscellaneous	–	0.4	1.1	–	–	–	–	–	–	–	–	0.6	1.8	–	–	0.6	
Conjugatophyta																	
Mougeotia	2.6	–	0.3	–	9.1	14.6	–	–	4.8	–	6.8	–	0.5	–	–	1.5	
Spirogyra	10.2	0.4	1.4	–	–	29.2	–	1.6	–	–	12.8	–	2.7	–	–	2.7	
Hydrophytes																	12.0
Eriocaulon	–	0.4	1.7	–	–	–	–	–	–	–	3.9	2.5	–	–	–	0.9	
Najas	–	10.3	14.7	–	–	–	–	5.0	–	0.8	3.7	39.7	12.7	–	–	9.1	
Vallisneria	–	2.1	2.4	–	9.1	–	–	–	–	–	–	11.9	1.0	–	–	2.0	
Aquatic animals																	
Oligochaeta	–	–	0.5	–	–	–	–	–	–	–	1.6	–	–	–	–	0.2	0.2
Gastropoda																	0.9
Amerianna	–	–	1.5	–	–	–	–	2.5	–	–	–	0.4	2.8	–	–	0.9	
Segnitilia	–	–	–	–	–	–	–	6.3	–	–	–	–	0.1	–	–	+	
Arachnida																	0.2
Hydracarina	–	–	0.3	–	–	–	–	–	–	–	–	–	–	1.3	–	0.2	
Microcrustacea																	6.4
Conchostraca																	
Cyzicus	–	1.2	1.4	2.2	–	–	–	–	–	3.5	0.1	–	–	2.4	–	1.0	
Cladocera																	
Miscellaneous	–	–	2.2	19.4	–	–	–	–	–	6.8	–	0.8	–	–	–	1.6	
Diaphanosoma	–	3.7	3.7	10.6	–	–	–	6.3	–	6.2	–	–	1.3	5.0	27.8	3.0	
Ostracoda	–	1.0	0.2	2.8	–	–	–	0.3	–	2.0	–	–	0.1	–	–	0.4	
Copepoda																	
Miscellaneous	–	–	–	–	–	–	–	–	4.8	–	–	–	–	–	–	0.3	
Cyclops	–	–	0.2	–	–	–	–	–	–	–	–	–	–	1.0	–	0.1	
Macrocrustacea																	2.6
Macrobrachium	–	3.8	1.9	–	3.6	8.3	–	–	4.8	–	5.7	0.1	3.5	–	4.4	2.3	
Hymanosomatidae																	
P. transversa	–	–	0.6	–	–	–	–	–	–	–	–	2.0	–	–	–	0.3	

Table 101 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Lb	Cb	Fb	Em	Ep	Lb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Insecta																	45.7
Fragmented	11.9	5.9	0.6	–	8.2	10.8	40.0	3.7	14.3	1.4	6.3	–	5.3	4.5	–	4.2	
Ephemeroptera																	
Baetidae	0.2	20.3	13.7	10.6	–	0.4	–	17.5	1.0	38.4	2.8	9.1	9.9	–	–	12.9	
Atalophlebia	–	1.2	1.9	–	–	–	–	–	–	5.8	–	–	–	–	–	1.3	
Odonata																	
Coenagrionidae	–	3.2	–	–	–	–	–	–	–	3.5	–	–	–	–	–	0.8	
I. heterosticta	–	–	2.5	–	–	–	–	26.9	–	–	7.5	5.9	1.9	–	–	2.5	
Gomphidae	–	0.7	0.6	–	–	–	–	–	4.8	0.8	–	–	–	–	–	0.5	
Libellulidae	0.2	2.6	3.0	–	9.1	6.7	–	–	0.5	0.7	8.0	1.6	3.6	0.3	–	2.7	
Aeshnidae	–	–	–	–	7.3	–	–	–	–	–	1.6	–	–	–	–	0.2	
Hemiptera																	
Miscellaneous	–	–	0.2	–	9.1	–	–	–	–	–	–	0.8	–	–	–	0.1	
Naucoridae	–	–	1.8	–	–	–	–	–	–	0.5	2.3	2.7	1.2	–	–	1.2	
Anisops	–	–	–	–	–	1.3	–	–	–	–	–	–	0.2	–	–	+	
Corixidae	–	6.2	2.1	11.1	–	–	–	0.9	0.5	7.4	0.1	0.6	2.4	4.2	–	2.9	
Coleoptera																	
Miscellaneous (adults)	1.3	5.2	0.2	–	–	–	–	–	9.8	–	–	–	1.8	5.5	–	1.8	
Miscellaneous (larvae)	–	1.8	1.3	–	–	–	–	–	–	5.0	–	–	–	–	–	1.1	
Diptera																	
Miscellaneous (larvae)	–	–	0.4	–	–	–	–	–	–	–	–	1.3	–	–	–	0.2	
Culicidae	0.2	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	+	
Chaoborinae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	21.1	0.3	
Chironomidae (larvae)	10.4	12.2	8.3	7.8	–	6.7	–	–	6.2	12.5	0.3	1.4	19.1	10.3	–	10.1	
Chironomidae (pupae)	–	1.0	0.8	3.3	–	–	–	–	–	2.0	–	0.6	0.1	1.8	–	0.7	
Ceratopogonidae	–	0.5	–	–	–	–	–	–	–	–	–	–	0.4	–	–	0.1	
Tabanidae	–	0.6	–	–	–	–	–	–	–	–	–	–	–	1.3	–	0.2	
Trichoptera																	
Hydroptilidae	–	–	0.1	–	–	–	–	–	–	–	–	–	0.2	–	–	0.1	
Leptoceridae	2.2	0.9	2.4	–	–	–	–	3.1	–	0.2	6.6	0.4	2.2	–	–	1.7	
Lepidoptera																	
Pyralidae	–	–	0.2	–	–	–	–	–	–	–	–	–	0.3	–	–	0.1	
Teleostomi																	9.0
Fragmented	–	2.4	4.9	10.0	10.9	2.5	–	1.3	–	–	4.9	4.3	3.2	11.5	6.7	3.8	

Table 101 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Lb	Cb	Fb	Em	Ep	Lb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Scales	3.7	0.2	0.1	–	–	11.7	–	–	–	–	2.6	0.4	1.0	0.5	1.1	0.8	
Scleropages (scale)	–	–	0.1	–	–	–	–	–	–	–	–	0.4	–	–	–	0.1	
Neosilurus spp.	–	–	0.6	–	–	–	–	–	–	–	–	–	1.0	–	–	0.3	
M. splendida	–	–	0.4	11.1	–	–	–	–	–	–	2.0	1.2	–	–	–	0.5	
C. marianae	3.5	4.5	–	–	–	–	–	–	2.9	–	–	–	–	9.3	10.6	1.5	
Ambassis spp.	–	–	2.2	–	–	–	–	–	1.4	–	–	1.5	3.0	–	–	1.2	
D. bandata	–	–	–	11.1	–	–	–	–	–	–	2.0	–	–	–	–	0.3	
G. giuris	–	–	0.5	–	–	–	–	–	–	–	–	–	0.9	–	–	0.3	
M. mogurnda	–	–	0.4	–	–	–	–	–	–	–	1.4	–	–	–	–	0.2	
Terrestrial plants																	
Angiospermae																	6.3
Miscellaneous	18.2	1.7	8.3	–	–	–	–	–	11.0	1.3	2.0	6.5	4.9	21.0	5.0	5.2	
Seed material	–	–	0.2	–	–	–	–	–	–	–	–	0.4	0.1	–	–	0.1	
Terrestrial animals																	
Insecta																	1.2
Fragmented	7.0	0.2	0.5	–	–	–	–	–	–	–	–	0.2	0.7	0.5	21.1	0.9	
Orthoptera																	
Miscellaneous	3.7	–	–	–	–	–	–	–	–	–	–	–	1.0	–	–	+	
Egg material	–	–	0.5	–	–	–	–	–	–	–	1.8	–	–	–	–	0.1	
Hymenoptera																	
Miscellaneous	–	–	0.2	–	–	–	–	–	–	–	–	–	–	1.0	–	0.1	
Formicidae	1.7	–	–	–	–	–	–	–	–	–	–	–	0.4	–	0.6	0.1	
Parasites																	0.5
Cestoda	–	–	0.6	–	–	–	–	–	–	–	–	–	–	–	11.7	0.3	
Nematoda	0.4	0.2	0.2	–	–	–	–	–	–	0.1	0.5	0.6	0.1	–	–	0.2	
Detrital material	–	–	3.2	–	–	–	–	–	–	–	–	–	–	13.8	–	1.6	1.6
Bait material	10.9	–	–	–	–	–	–	–	14.1	–	–	–	–	–	–	0.9	0.9
Inorganic material	–	0.1	–	–	–	0.4	–	–	–	–	0.1	–	0.1	–	–	+	+
Organic material	11.9	5.2	3.0	–	33.6	7.5	60.0	24.6	19.5	1.4	11.5	1.8	8.5	5.0	–	6.5	6.5
Number of empty fish	3	4	14	–	1	3	3	1	4	2	4	–	14	4	1	29	29
Number of fish with food	27	82	171	9	11	5	2	16	21	74	51	49	98	40	9	342	342

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ep = escarpment perennial stream; Ls = lowland sandy creekbed; Lb = lowland backflow billabong; Cb = corridor billabong; Fb = floodplain billabong; + = present (<0.1%)

Seasonal changes

In sampling periods 1–7, respectively, 25 (16% empty), 76 (3% empty), 55 (7% empty), 49 (0% empty), 112 (13% empty), 44 (9% empty) and 10 (10% empty) stomachs of *L. unicolor* were examined (all habitats combined). The highest proportions of specimens with empty stomachs was in the 1979 Late-dry season and the lowest in the 1979 Late-wet–Early-dry season.

The diet in the 1978 Late-dry season was based primarily on aquatic insects, terrestrial plant material, and smaller teleost, micro- and macrocrustacean and algal components; large amounts of unidentified organic material were also found in the stomachs. During the 1978–79 Early-wet season the aquatic insect component of the diet strengthened (shifting to mainly baetid larvae) as did the microcrustacean (mainly cladoceran) component. The diet in the Mid-wet season had a more varied but slightly less important aquatic insect component, and filamentous green algae, hydrophytes and teleosts became more important.

By the Late-wet–Early-dry season the hydrophyte component of the diet had increased dramatically (mainly *Najas* and *Vallisneria*), as had the terrestrial plant material.

The diet in the 1979 Mid-dry season was varied and still had a strong aquatic insect (mainly chironomid and baetid larvae) component and a smaller hydrophyte component.

During the 1979 Late-dry and 1979–80 Early-wet seasons the algal and hydrophyte components had disappeared from the diet, as was more or less apparent during the same seasons in 1978. During the 1979 Late-dry season, teleosts (mainly *Ambassis* spp.) and terrestrial plant material were important in the diet, together with aquatic insects (mainly chironomid larvae) and detritus. The few specimens examined in the 1979–80 Early-wet season had eaten microcrustaceans (*Diaphanosoma*), aquatic insects (chaoborinid larvae), teleosts (mainly *C. marianae* from sandy creeks) and terrestrial insects. Many cestode parasites were found in the stomachs in this season.

Habitat differences

Magela catchment

A total of 322 stomachs of *L. unicolor* were examined (all seasons combined): 30 (10% empty), 86 (5% empty), 185 (8% empty), 9 (0% empty) and 12 (8% empty), 30 (10% empty) from escarpment mainchannel waterbodies, 86 (5% empty) from lowland sandy creekbeds 185 (8% empty) from lowland backflow billabongs, 9 (0% empty) from corridor billabongs and 12 (8% empty) from floodplain billabongs. The highest proportions of specimens with empty stomachs were in escarpment waterbodies and the lowest proportions in corridor waterbodies (sample sizes were small).

In the escarpment mainchannel waterbodies, *L. unicolor* ate terrestrial plant material and fairly equal proportions of green filamentous algae, aquatic insects (mainly chironomid larvae), teleosts (many *C. marianae*) and terrestrial insects. In the lowland sandy creekbeds it ate more aquatic insects (baetid and chironomid larvae). Few terrestrial insects and little plant material were eaten, though more micro- and macrocrustaceans were eaten and the algal component was replaced by hydrophytes.

The diet in the backflow billabongs was again based primarily on aquatic insects, but with more hydrophytes and a greater variety of teleosts (plotosids, *M. splendida inornata, Ambassis* spp., *G. giuris* and *M. mogurnda*). In the corridor waterbodies *L. unicolor* had not eaten algae or hydrophytes, but had eaten fairly equal proportions of microcrustaceans (mainly cladocerans), aquatic insects (baetid and chironomid larvae and corixids) and teleosts (*M. splendida inornata* and *D. bandata*). The diet in the floodplain habitats had a large organic component (presumably digested fish flesh) and fairly equal proportions of aquatic insects, algae, hydrophytes and teleosts.

Nourlangie catchment

A total of 31 stomachs of *L. unicolor* were examined (all seasons combined): 8 (38% empty) from escarpment mainchannel waterbodies and 5 (60% empty) from perennial streams, and 18 (6% empty) from backflow billabongs. The highest proportions of specimens with empty stomachs were in escarpment perennial streams and the lowest proportions in backflow billabongs. The proportion of empty fish in the escarpment mainchannel waterbody was much higher than in the equivalent Magela Creek habitat.

The green filamentous algae and aquatic insects components in the diet in the escarpment mainchannel waterbody were large; macrocrustaceans were also found in the stomachs though, unlike the Magela Creek catchment, no terrestrial insects or plant material. The diet of the few specimens examined in the escarpment perennial stream was based mainly on aquatic insects, together with large volumes of unidentified organic material. In the lowland backflow billabongs the diet was again based mainly on aquatic insects (*I. heterosticta* and baetid larvae) with smaller hydrophyte and gastropod components.

Fullness

A summary of mean fullness indices of *L. unicolor* in different sampling periods and habitat types is shown in table 102. These data are presented on the assumption that feeding times do not vary with habitat or season.

Seasonal changes

After the 1978 Late-dry season the mean fullness index (all habitats combined) peaked in the 1978–79 Early-wet season. It then fell during the Mid-wet season, increased in the Late-wet–Early-dry season, and gradually fell through the Mid-dry season to reach a low in the 1979 Late-dry season (close to the level of the 1978 Late-dry season). The index increased dramatically in the 1979–80 Early-wet season, as it had done the previous year.[183]

Habitat differences

In the Magela catchment upstream from RUPA, mean fullness indices were highest in the shallow backflow billabongs and lowest in the lowland sandy creekbeds (and much lower than in equivalent downstream habitats; however, sample sizes were small). Downstream of RUPA the mean indices were highest in shallow backflow billabongs and sandy creekbeds and lowest in corridor waterbodies.

In the Nourlangie catchment, fullness indices were also highest in the shallow backflow billabongs. The fullness indices in escarpment mainchannel habitats were lower than those recorded in the equivalent Magela Creek habitat.

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[183] Gehrke (1988b) found that *L. unicolor* caught by angling in winter has less food in their stomachs (0.31% body weight) than fish caught in other seasons (4.9% in spring to 3.1% in autumn).

Table 102 Mean fullness indices for *Leiopotherapon unicolor* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	4.3 (4)	n/s	1.8 (6)	n/s	2.1 (18)	0 (1)	4.0 (3)	2.5 (32)
Lowland shallow backflow billabong	0 (1)	n/s	3.5 (15)	n/s	4.0 (6)	3.3 (6)	n/s	3.4 (28)
Lowland sandy creekbed	n/s	0 (1)	n/s	n/s	2.0 (2)	n/s	n/s	0.7 (3)
Downstream of RUPA:								
Lowland sandy creekbed	4.0 (2)	3.3 (36)	2.7 (7)	3.4 (8)	1.8 (17)	2.8 (13)	n/s	2.9 (83)
Lowland channel backflow billabong	0 (1)	2.0 (4)	0 (1)	3.3 (11)	2.4 (27)	2.3 (7)	2.8 (4)	2.5 (55)
Lowland shallow backflow billabong	n/s	4.2 (31)	0 (1)	3.0 (24)	3.3 (29)	1.3 (15)	4.5 (2)	3.1 (102)
Corridor sandy billabong	n/s	n/s	3.0 (2)	n/s	n/s	1.0 (2)	n/s	1.0 (4)
Corridor anabranch billabong	n/s	0 (1)	0 (1)	n/s	n/s	n/s	n/s	0 (2)
Floodplain billabong	n/s	3.7 (3)	1.8 (9)	3.5 (2)	0 (1)	n/s	n/s	2.3 (15)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	n/s	n/s	1.4 (12)	n/s	1.7 (3)	n/s	n/s	1.5 (15)
Lowland shallow backflow billabong	0.5 (2)	n/s	n/s	3.8 (4)	3.8 (11)	n/s	n/s	3.4 (17)
Seasonal mean (all sites)	2.2	3.5	2.5	3.2	2.7	2.1	3.6	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland shallow backflow billabongs (downstream of RUPA); 1979–80 Early-wet season
- lowland shallow backflow billabongs; 1978–79 Early-wet season
- escarpment mainchannel waterbody; 1978 Late-dry season

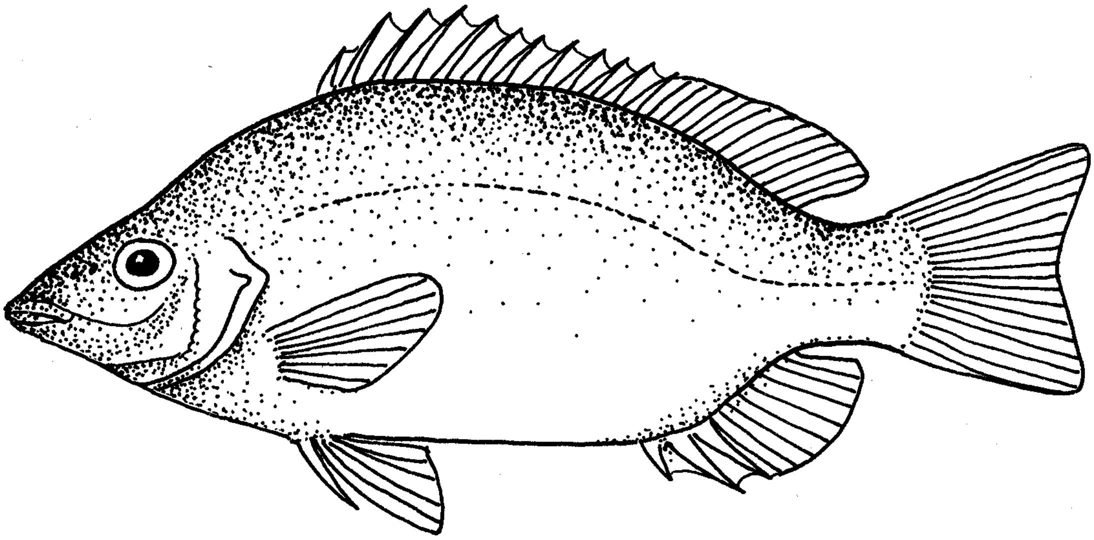
Nourlangie catchment

- lowland shallow backflow billabongs; 1978–79 Late-wet–Early-dry season
- lowland shallow backflow billabongs; 1979 Mid-dry season.

Family TERAPONTIDAE

3.27 *Syncomistes butleri* (Vari)

Syncomistes butleri is commonly known as Butler's grunter, or the sharp-nose grunter, as Lake (1978) called it before it was described. It is endemic to Australia. Its known distribution is from the Bow River in northern Western Australia to the East Alligator River in the Northern Territory. Pollard (1974) and Midgley (1973), who referred to this species as *Mesopristes* sp. and *Therapon* sp., respectively, collected them from Tin Camp and Magela Creeks (East Alligator River system) and from Deaf Adder and Hickey Creeks (South Alligator River system).



Syncomistes butleri

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found commonly in all escarpment mainchannel waterbodies and perennial streams, and in sandy corridor waterbodies. It was found rarely in lowland sandy creekbeds. It was found in the greatest number of sites in the Mid-wet season and in the fewest in the 1978 Late-dry season.

Size composition

The lengths and weights of 43 specimens were determined.

Length–weight relationship

The length–weight relationship for the combined sexes was described by the expression:

$$W = 7.38 \times 10^{-3} L^{3.29} \qquad r = 0.86 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 103. The few specimens captured in the 1978–79 Early-wet, 1979 Mid-dry and 1979 Late-dry seasons had very high condition factors, in contrast to those captured in the Mid-wet and 1979–80 Early-wet seasons. Poor condition in the Mid-wet season may be attributable to spawning activity. Annual variation in condition between the Late-dry and Early-wet seasons was high.

Table 103 Mean length, mean weight and condition factor of *S. butleri*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	12	253.6	315.19	1.03
Early-wet (1978–79)	3	267.2	429.12	1.18
Mid-wet	11	206.0	126.13	0.82
Mid-dry(1979)	10	241.8	312.16	1.19
Late-dry	2	288.5	556.08	1.19
Early-wet (1979–80)	5	187.1	96.60	0.86
Overall	43	238.1	227.48	1.00

Length-frequency distribution

Specimens captured ranged in size from 122 mm to 320 mm LCF (fig 122). Lake (1978) noted that this species grows to only 120 mm, while Vari (1978) said that it reaches 200 mm TL. The specimens captured in the study area are therefore considerably larger than the largest previously recorded.

The mean length of all specimens captured was 232 mm LCF. The LFM for males and females was estimated to be 125 and 235 mm LCF, respectively, indicating that most of the specimens captured were adults. The peaks in the overall distribution can be attributed to the mesh selectivity of the gillnets in which most *S. butleri* were captured. The absence of juveniles in the samples is puzzling; however, small unidentified theraponids were observed in escarpment and lowland sandy creekbeds in the Mid-wet season.

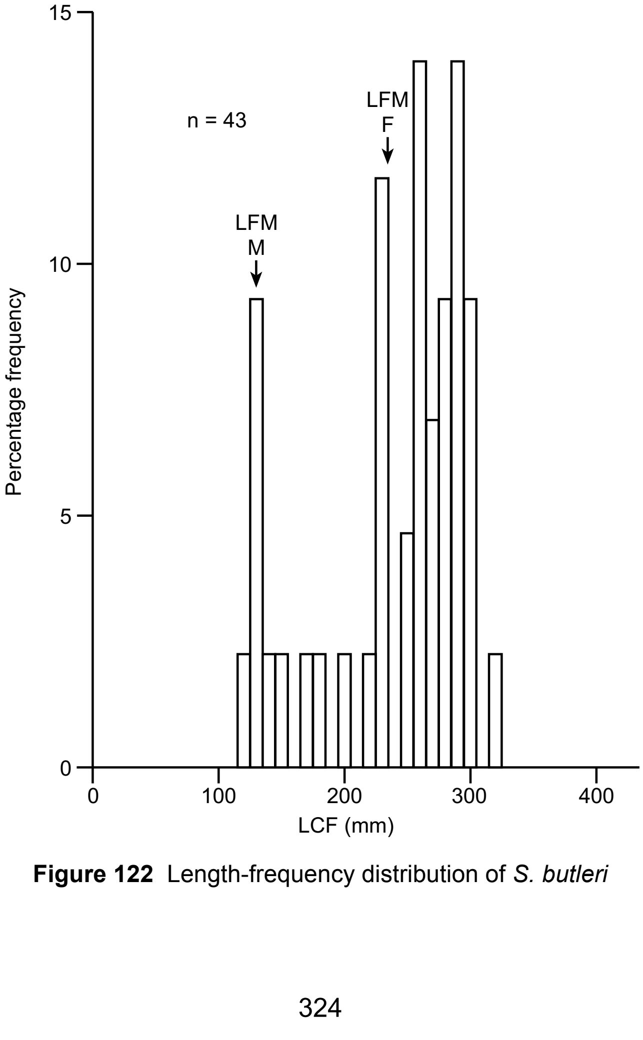


Figure 122 Length-frequency distribution of *S. butleri*

Seasonal changes in distribution

The smallest specimen was captured in the Mid-dry season and the largest in the 1979 Late-dry season. The mean seasonal lengths were highest during the 1979 Late-dry season and lowest in the 1979–80 Early-wet season (table 103); low mean lengths were also recorded in the Mid-wet season. The period of juvenile recruitment to the populations is unknown, as few small specimens were captured.

Habitat differences in distribution

Length-frequency distributions showing habitat preferences of *S. butleri* captured in regular sampling sites in the Magela catchments are given in figure 123.

Magela catchment

The smallest specimens were captured mainly in escarpment mainchannel waterbodies and to a lesser extent in lowland sandy creekbeds. Most of the larger specimens captured were in sandy corridor waterbodies; however, large specimens were also captured in escarpment mainchannel waterbodies, and some appeared in the lower reaches of escarpment perennial streams during the Late-wet–Early-dry season.

Nourlangie catchment

A wide size range of *S. butleri* were observed in escarpment mainchannel waterbodies. A similar size range was found in escarpment perennial streams in the Mid-wet season and during the remainder of the study. A few large specimens were captured in occasionally sampled sandy corridor waterbodies.

Environmental associations

Rank numbers for *S. butleri* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Both surface and bottom temperatures ranged from 23° to 34°C, with means of 28.9°C and 28.4°C, respectively. These means were ranked in the lower and lower-middle quarters (see fig 170). Most *S. butleri* captured in this study were found in cooler escarpment streams, although a few were taken from corridor waterbodies in the lower reaches.

Dissolved oxygen

Dissolved oxygen concentrations in waters in which *S. butleri* was captured ranged from 5.0 to 7.4 mg/L (mean = 6.2) on the surface, and from 3.8 to 7.2 mg/L. (mean = 5.7) on the bottom. These means ranked in the upper-middle and upper quarters, respectively (see fig 171). As with other generally escarpment-dwelling fish (eg *H. fuliginosus*), the high bottom water DO is indicative of the cooler, well-mixed waters of escarpment streams.

Visibility

Secchi depths ranged from 50 to 360 cm, with a mean of 171 cm (see fig 172). This mean was placed in the upper quarter, indicating the clear waters in which *S. butleri* was typically found (see also Vari 1978).

pH

Surface and bottom pH values had the same range (4.5–6.7) and mean (5.9). The mean surface water pH was placed in the lower quarter, whilst the mean bottom water pH was placed in the lower-middle quarter (see fig 173).

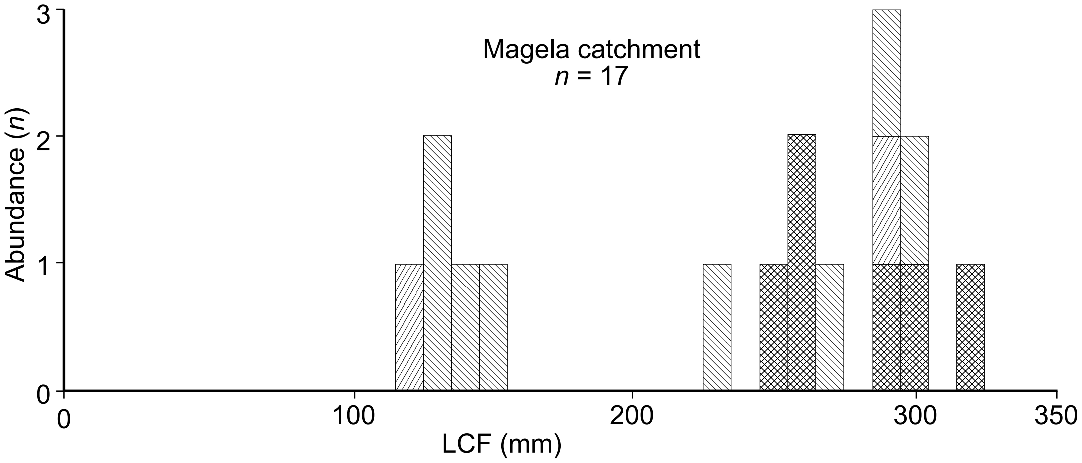


Figure 123 Length-frequency distributions and habitat preferences of *S. butleri* captured at regular sampling sites (see appendix 5 for key to the habitats)

Conductivity

Conductivity readings on the surface were between 2 and 50 µS/cm, and on the bottom between 2 and 60 µS/cm. Such low conductivities suggest that this species is associated with perennially flowing waters, which is confirmed by its distribution in escarpment streams.

Habitat–structural variables

Substrate

Syncomistes butleri was most commonly found in waters with a sand substrate, followed in descending order of dominance by rock, clay, and boulder substrates. The percentage dominance values for sand and boulders both ranked in the upper quarter (see fig 174). Sandy, rocky or boulder substrates are characteristic of the escarpment streams in which this species was commonly found (see also Vari 1978).

Hydrophytes

As with other primarily escarpment-dwelling species, *S. butleri* was found in waters with a very low hydrophyte content (vegetation-occurrence index 40%). The most abundant vegetation was emergent, followed distantly by submergent and then floating unattached hydrophytes.

Reproduction

A total of 42 *S. butleri* were examined for reproductive condition: 21 females (length range 122–304 mm LCF), 19 males (125–320 mm LCF) and 2 that were sexually indistinguishable (129 and 166 mm LCF).

Length at first maturity

Because the sample is small, the usual method for estimating the LFM could not be used. Estimation of the LFM is further complicated by the length range of fish captured, particularly of females. No female fish were captured between 150 mm (all to this size were immature) and 225 mm LCF (one spent female) (fig 124). The LFM may be somewhere between these two lengths; it is taken here to be 235 mm LCF. The smallest males captured were mature, and the LFM was taken as that length (125 mm LCF); the actual LFM could be smaller.

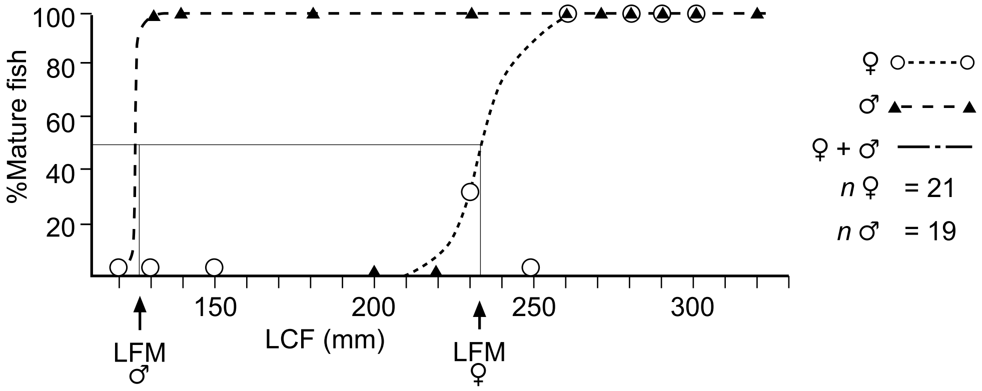


Figure 124 Estimated length at first maturity (LFM) of *S. butleri*

Sex ratio

No significant differences from a 1:1 ratio of males to females were found for either juvenile + adult fish or adult fish only in any season (table 104).

Table 104 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *S. butleri* over all habitats

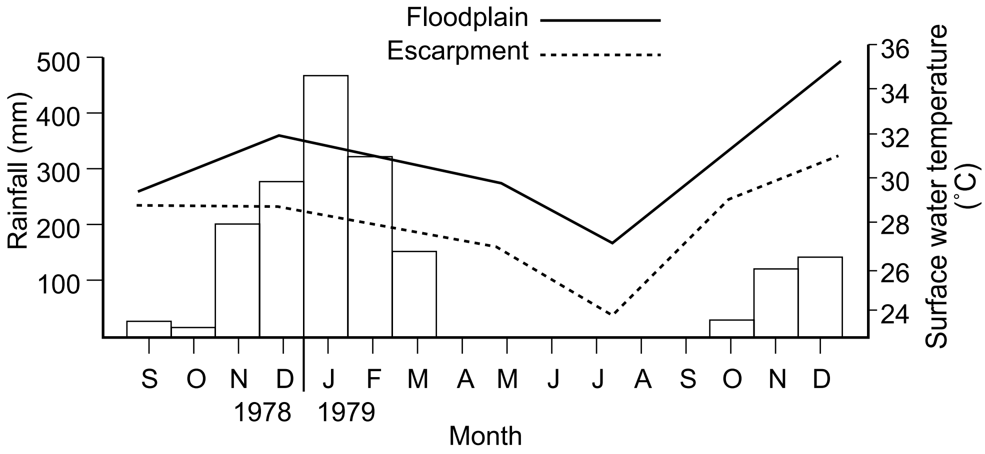
			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	5	2	4	0	7	1	2
+ adults	M	*n*	4	1	7	0	3	1	3
		χ^2	0.1	0.3	0.8	–	1.6	0.0	0.2
		P	n.s.	n.s.	n.s.	–	n.s.	n.s.	n.s.
Adults only	F	*n*	5	2	3	0	6	1	1
	M	*n*	4	1	7	0	3	1	3
		χ^2	0.1	0.3	1.6	–	1.0	0.0	1.0
		P	n.s.	n.s.	n.s.	–	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	4.8	4.2	1.8	–	0.2	1.5	10.7
		s.d.	1.5	1.4	2.3	–	0.2	–	–
	M	mean	2.7	2.7	0.2	–	0.2	2.5	2.1
		s.d.	0.7	–	0.1	–	0.2	–	3.0
	F+M	mean	4.0	3.5	0.6	–	0.2	2.0	4.25
		s.d.	1.5	1.1	1.3	–	0.2	0.7	4.9
GMSI									
Adults only	F	mean	5.8	2.0	1.0	–	1.1	3.0	5.0
		s.d.	0.4	0.0	0.0	–	0.4	0.0	0.0
	M	mean	6.0	6.0	2.1	–	2.7	6.0	5.3
		s.d.	0.0	0.0	0.9	–	1.2	0.0	0.6
	F+M	mean	5.9	4.0	2.1	–	2.3	4.5	5.3
		s.d	0.2	2.8	0.7	–	0.7	2.1	0.5

n = number ; χ^2 = Chi-squared value; P = probability; n.s. = not significant; s.d. = standard deviation.

Breeding season

Although not many fish were captured, the data indicate an extended breeding season from the Late-dry through to the Early-wet season for both 1978 and 1979 (fig 125). The gonads were in a resting state from the Mid-wet until the Mid-dry (assuming there was no activity during the Late-wet–Early-dry when no *S. butleri* were captured).

The seasons when mature, ripe and spent fish were captured (table 104) confirm a Late-dry–Early-wet breeding season although no ripe fish were captured during the 1979 Late-dry season, possibly because there had been very little rain, unlike the previous year.



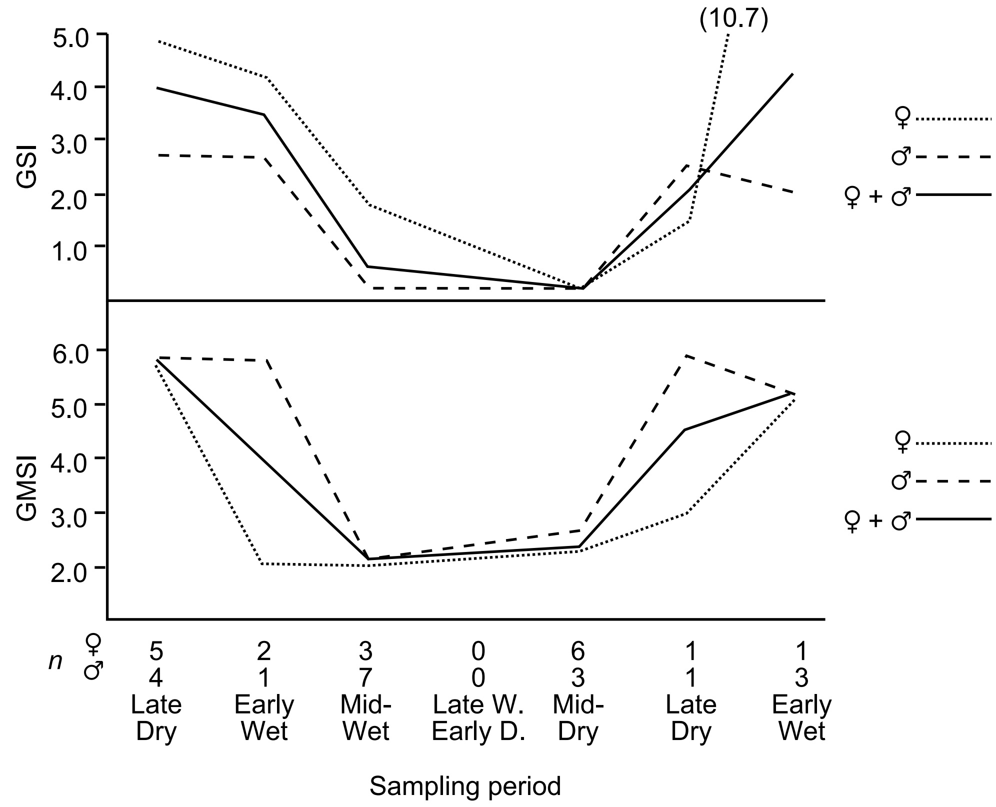


Figure 125 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *S. butleri*

Table 105 Possible sites of spawning of *S. butleri,* as indicated by the abundance (*n*) of mature, ripe and spent fish

	Gonad stage					
	Mature (V)		Ripe (VI)		Spent (VII)	
Habitat	F	M	F	M	F	M
Escarpment						
Mainchannel waterbody	2	2	4	5	–	–
Lowlands						
Sandy creekbed	–	–	–	1	–	–
Corridor	–	–	–	1	4	4

It is interesting to note the presence of spent fish during the Mid-dry season; these may be very late spawners or slow recoverers from the previous spawning period (Late-dry–Early-wet season) or they may indicate that there are occasional aseasonal spawnings.

Site of spawning

Evidence of spawning (ie ripe or spent fish) was found at all habitats where this species was collected (table 105).

Fecundity

Two gonads only were examined. One fish (285 mm LCF, GSI = 10.74) had approximately 40 000 eggs with a mean diameter of 0.88 mm (± 0.089); the other (304 mm LCF, GSI = 3.79) had approximately 17 000 eggs with a mean diameter of 0.84 mm (± 0.13). A few clusters of very tiny eggs (1.1 ± 0.1 mm) were found amongst the ripe eggs.

Summary

Syncomistes butleri has an extended breeding period, from the Late-dry through to the Early-wet season, and may breed throughout in all its habitats. It spawns a large number of small eggs.

Feeding habits

Overall diet

The stomachs of 41 specimens were examined; 40 contained food. The diet of *S. butleri* is summarised in figure 126; the components are listed in table 106.

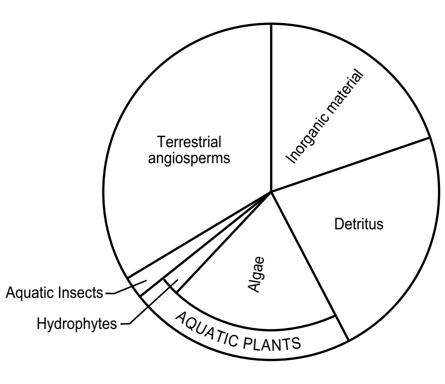


Figure 126 Main dietary components of *S. butleri*

Table 106 Dietary composition of *S. butleri*

	Habitat			Seasons						Overall	
	Magela system		Nourlangie system	1978	1978–79	1978–79	1979	1979	1979–80		
Stomach contents	Em	Cb	Em	Late-dry	Early-wet	Mid-wet	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants											
Algae											19.7
Miscellaneous	1.1	30.0	9.2	–	66.7	–	14.4	–	–	8.1	
Desmidacea	–	–	–	–	–	–	–	–	–	0.5	
Conjugatophyta											
Mougeotia	7.2	–	7.7	–	–	15.0	–	–	–	4.0	
Spirogyra	21.1	–	–	–	–	11.8	–	–	32.0	7.1	
Hydrophytes											1.7
Najas	–	–	–	–	6.7	–	–	–	–	0.5	
Vallisneria	–	–	–	–	16.7	–	–	–	–	1.2	
Aquatic animals											
Insecta											2.5
Fragmented	–	–	6.9	–	–	8.2	–	–	–	2.2	
Diptera											
Chironomidae	–	1.0	–	–	–	1.8	–	–	–	0.1	
Ceratopogonidae	–	–	0.8	–	–	0.9	–	–	–	0.2	
Terrestrial plants											
Angiospermae											33.7
Fragmented	26.1	20.0	45.0	1.8	6.7	60.5	11.1	–	–	1.5	
Bark material	–	12.0	–	–	–	–	–	60.0	12.0	6.8	
Root material	6.7	24.0	3.9	–	–	–	21.1	30.0	47.0	25.4	
Parasites											0.1
Nematoda	–	1.0	–	–	–	–	–	–	–	0.1	
Detrital material	20.0	12.0	12.7	55.5	–	–	30.6	5.0	4.0	23.3	23.3
Inorganic material	17.8	–	13.9	42.7	3.3	1.8	23.3	5.0	5.0	19.5	19.5
Number of empty fish	–	–	–	1	–	–	–	–	–	1	1
Number of fish with food	9	5	13	11	3	11	9	1	5	40	40

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Cb = corridor billabong

The main components were terrestrial plant material (34%), detritus (23%) and algae (20%). The terrestrial plant material consisted mainly of scrapings of bark and root material, possibly from submerged tree trunks and roots (eg *Pandanus*). The identifiable algae were mainly filamentous green species such as *Mougeotia* and *Spirogyra* as well as desmids. Traces of aquatic hydrophytes and aquatic animals were also found in the stomachs along with substantial quantities of inorganic material. *Syncomistes butleri* can therefore be classified as a herbivore/detritivore feeding over hard substrates such as wood and rocks, as well as on sand. H. Midgley (pers comm) classifies this species as a 'scunge' eater. The related species *Syncomistes rastellus* and *S. trigonicus* have been observed together swimming in schools (Vari & Hutchins 1978) and grazing on algae-covered rocks in the Drysdale River, North Kimberley, Western Australia.

Syncomistes butleri has an elaborate intestinal morphology, modified jaws (Plate 2) and teeth that appear to be adapted to eating filamentous algae, which Vari (1978) considers the staple diet of the adults. However, our study suggests Vari underestimated the variety of items it eats. Both the specialised dentition and alimentary tract would also be useful for scraping and digesting plant material, detritus and algae.

Habitat differences

Magela catchment

The stomachs of nine fish from escarpment mainchannel waterbodies and of five from corridor waterbodies were examined (all seasons combined). No specimens had empty stomachs.

In the escarpment mainchannel waterbody *S. butleri* were eating fairly equal proportions of green filamentous algae (*Spirogyra* and *Mougeotia*), terrestrial plant material (including root material) and detritus; the large inorganic component of the diet indicates they ate mainly over sandy substrates. The diet in the corridor waterbodies had a large algal component with an even larger terrestrial plant material component. The absence of inorganic material in the stomachs indicates that it was feeding by scraping bark and protruding roots from terrestrial vegetation (eg *Pandanus*) submerged by the billabong waters.

Nourlangie catchment

A total of 13 stomachs of *S. butleri* were examined (all seasons combined) from escarpment mainchannel waterbodies. None had empty stomachs. The diet consisted mainly of terrestrial plant material, algae, detritus and inorganic material. It appeared that in this habitat *S. butleri* was feeding over sand, as well as scraping algae, bark and root material from submerged terrestrial plants.

Seasonal changes

In sampling periods 1 to 3 and 5 to 7, respectively, 11, 3, 11, 9, 1 and 5 stomachs of *S. butleri* were examined. One specimen with an empty stomach was found in the 1978 Late-dry season.

The diet in the 1978 Late-dry season consisted of detritus and inorganic material. By the 1978–79 Early-wet season there was a large algal component and a significant hydrophyte component. In the Mid-wet season large quantities of terrestrial plant material and some aquatic insects also appeared in the stomachs while the algal component was smaller. In the 1979 Mid-dry season, the detrital and inorganic component was bigger, with a sizeable terrestrial plant material component, and less algae. The single specimen analysed in the 1979 Late-dry season had eaten mainly bark and root material from submerged terrestrial plants. The latter component persisted into the 1979–80 Early-wet season and the algal component increased, as in the previous Early-wet season.

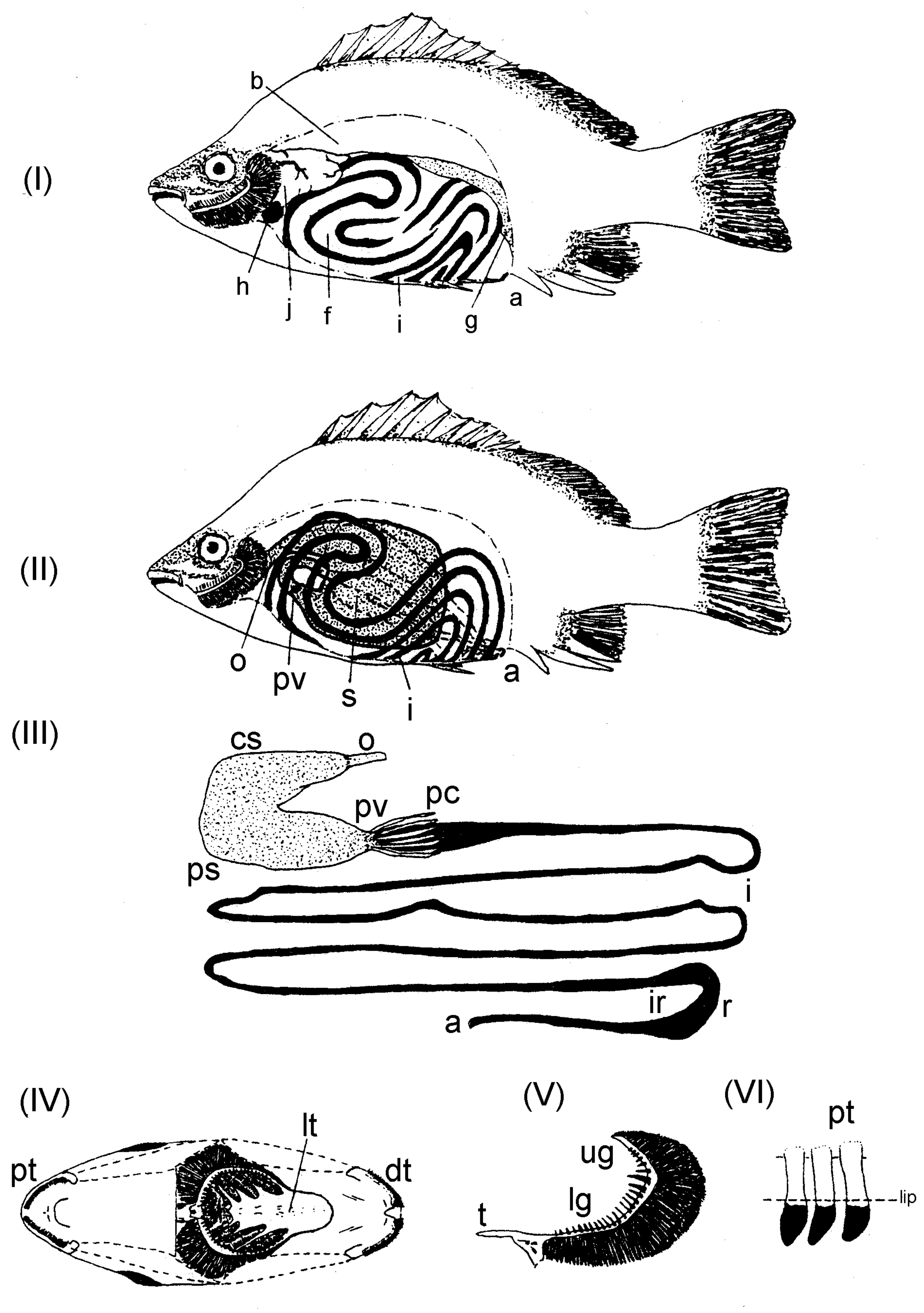


Plate 2 Details of various sections of the alimentary tract of *S. butleri* (LCF 230mm). (I) Viscera in situ. (II) Alimentary tract in situ. (III) Alimentary tract dissected out. (IV) Buccopharyngeal cavity. (V) First gill arch. (VI) Premaxillary teeth. a) anus b) air bladder cs) cardiac region of stomach dt) dentary teeth (flattened) f) fat tissue g) gonad h) heart i) intestine (five loops) ir) intestino-rectal valve l) liver lg) lower gillrakers (n=19) lt) lingual teeth o) oesophagus pt) premaxillary teeth (curved slightly inwards, flattened, depressible and brown tipped) pc) pyloric caecum (n=11), 25–35 mm in length) ps) pyloric region of stomach (thinwalled) pv) pyloric valve r) rectum t) tongue ug) upper gillrakers (n=6). Overall dimensions (mm): oesophagus 15, stomach 105, intestine 500, rectum 120.

Fullness

A summary of mean fullness indices of *S. butleri* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 107. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 107 Mean fullness indices of *S. butleri* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

	Sampling period							
Habitat type	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	0 (1)	n/s	0 (1)	n/s	0 (1)	0 (1)	4.8 (5)	1.9 (9)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	0 (1)	n/s	n/s	0 (1)	n/s	n/s	0 (2)
Corridor sandy billabong	n/s	5.0 (2)	n/s	n/s	4.7 (3)	0 (1)	n/s	4.0 (6)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	n/s	n/s	4.8 (8)	n/s	4.2 (5)	n/s	n/s	4.6 (13)
Seasonal mean (all sites)	4.5	4.7	4.8	n/s	4.4	4.0	4.8	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Seasonal changes

Syncomistes butleri appeared to have very high mean fullness indices throughout the study.

Habitat differences

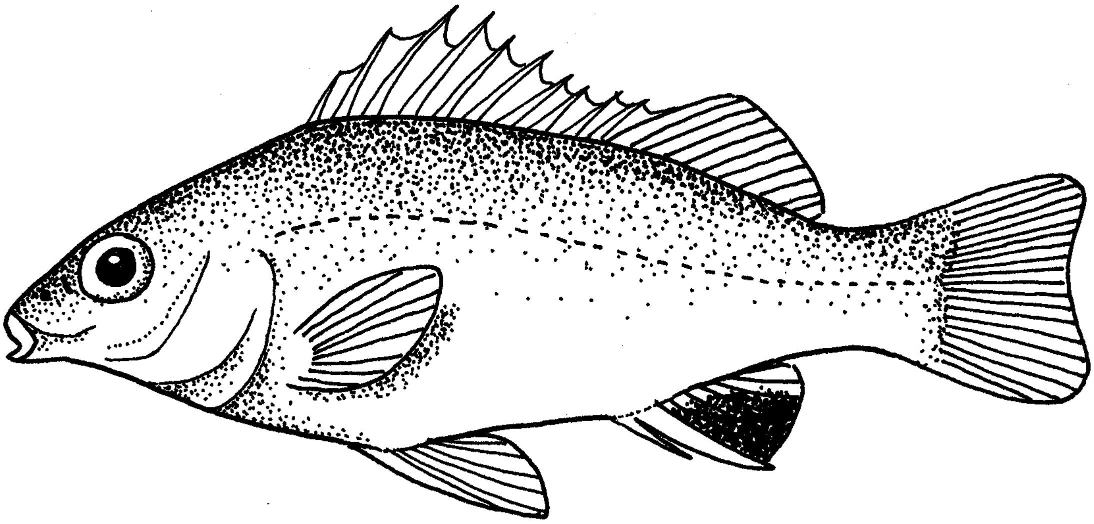
In the Magela catchment mean fullness indices were highest in the sandy corridor waterbodies. Indices were lower in the escarpment mainchannel waterbody upstream of RUPA, while the few specimens captured in lowland sandy creekbeds downstream of RUPA had no food in their stomachs; however, during the Mid-wet season many juveniles were observed feeding in these habitats.

In the Nourlangie catchment all *S. butleri* captured in the escarpment mainchannel waterbodies had very high fullness indices, as had specimens captured at occasional sites in similar habitats and in sandy corridor waterbodies.

Family TERAPONTIDAE

3.28 *Pingalla midgleyi* (Allen & Merrick 1984)

Pingalla midgleyi is also known as the black-blotched anal fin grunter. An Australian endemic, it is found in the Timor Sea drainage system of the Northern Territory and Western Australia (see map 3). It was collected in the small escarpment tributaries of the East and South Alligator Rivers by Pollard (1974) and by Midgley (1973), who referred to it as *Mesopristes cancellatus* (?) and *Therapon* sp., respectively. Lake (1978) noted that the sub-terminal mouth, like a tapir's snout, is also seen in Gilbert's grunter (*P. gilberti*); however, Lake thought it was almost certainly a new species, whereas Vari (1978) misidentified specimens from the South Alligator River catchment as *P. gilberti.*



Pingalla midgleyi

Detailed information on catches by site and season is given in volume 2. In summary, this species was moderately abundant in escarpment mainchannel waterbodies and perennial streams of the Nourlangie Creek system and slightly less abundant in the Magela Creek system. It was also common in escarpment mainchannel terminal waterbodies and in some seasonal streams; it was found rarely in lowland sandy habitats downstream of the RUPA. In the 1978 Late-dry season it was found in only three sites and in the Mid-wet season in four sites (in both seasons, mainly in escarpment perennial streams); by the Late-wet–Early-dry season it was found in five sites (some downstream from escarpment reaches in lowland sandy creekbeds).

Size composition

The lengths and weights of 85 specimens were recorded.

Length-weight relationship

The length-weight relationship for the combined sexes was described by the following expression:

$W = 1.46 \times 10^{-2} L^{3.16}$ $r = 0.98$ (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors are shown in table 108. The condition factor was highest between the 1978–79 Early-wet and the Late-wet–Early-dry seasons, and lowest in the 1979 Mid-dry. The condition of the single specimen examined in the 1979 Late-dry season was close to the mean condition of all specimens examined in the equivalent 1978 season.

Table 108 Mean length, mean weight and condition factor of *P. midgleyi*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	27	84.2	12.14	1.00
Early-wet (1978–79)	1	80.0	12.20	1.18
Mid-wet	32	80.9	10.98	1.03
Late-wet–Early-dry (1979)	1	69.0	7.70	1.19
Mid-dry	23	81.1	10.29	0.95
Late-dry	1	78.0	9.50	1.00
Early-wet (1979–80)		–	–	–
Overall	85	81.8	11.09	1.00

Length composition

The smallest specimen captured was 68 mm LCF, and the smallest observed was approximately 40 mm LCF. The largest specimen captured was 120 mm LCF and the largest observed was approximately 130 mm LCF (fig 127).

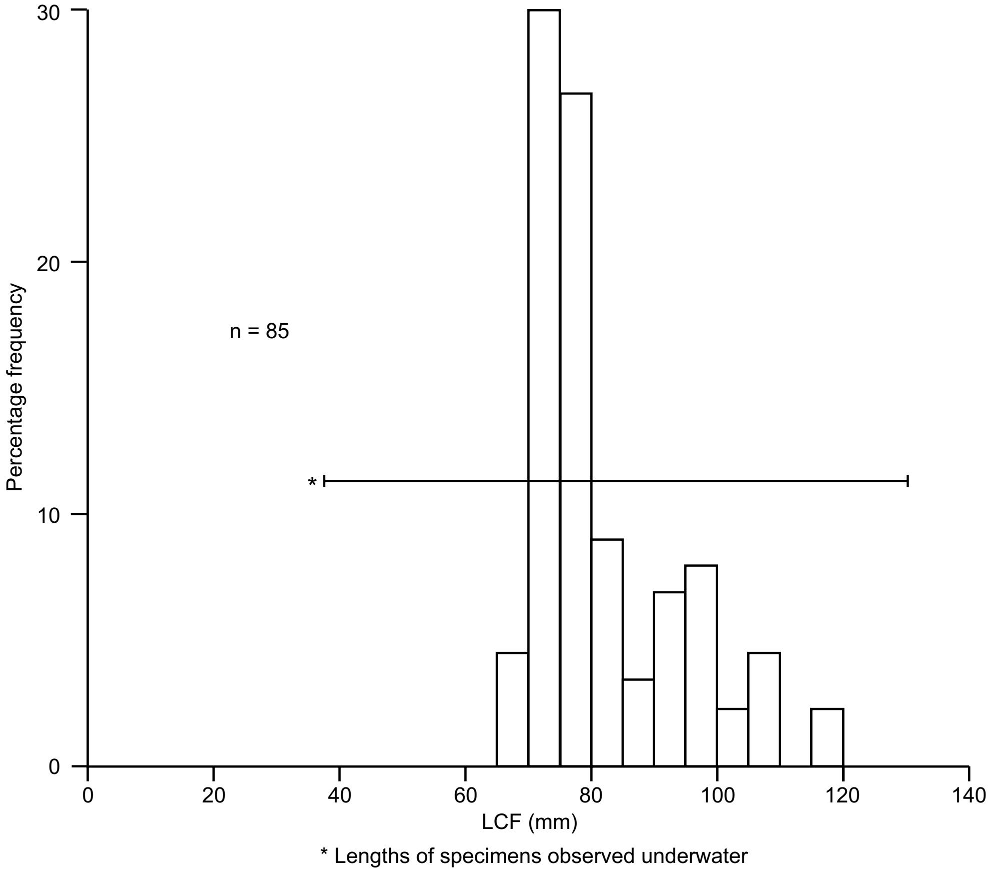


Figure 127 Length-frequency distribution of all *P. midgleyi* captured

Lake (1978) reported that the 'black blotched anal fin' grunter (presumably *P. midgleyi*) grows to 145 mm and the closely related *P. gilberti* grows to 105 mm. Mees and Kailola (1977), when describing the closely related *Therapon lorentzi,* examined specimens up to 162 mm TL.

Length-frequency distribution

The mean and modal lengths of specimens examined were 81.8 mm and 70 mm LCF, respectively (fig 127). The distribution showed negative skew, indicating lower survival rates for larger specimens. The absence of specimens less than 64 mm long is puzzling, as they were observed in interstitial waters of rock and gravel substrates. This species was captured mainly by gillnets, so the major and minor peaks in the length-frequency distribution is caused by selectivity of the 26 and 44 mm mesh, respectively. A few of the smallest specimens were captured by 10 mm mesh seine net.

The smallest specimens were captured in the Mid-dry season, and the next smallest in the Late-wet–Early-dry and 1979 Late-dry seasons (fig 128).

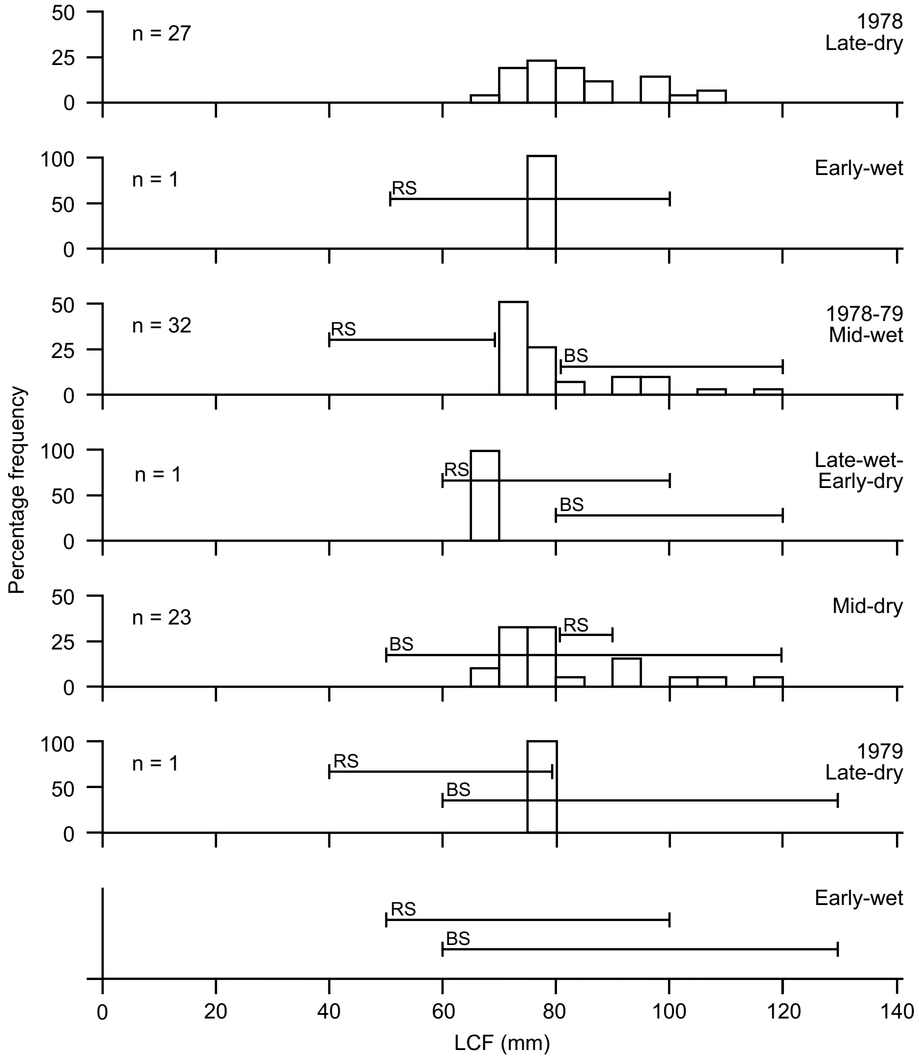


Figure 128 Seasonal length-frequency distribution of all *P. midgleyi* captured

The smallest specimens observed in escarpment perennial streams were at Radon Springs (RS) in the Mid-wet and 1979 Late-dry seasons and at Baroalba Springs (BS) in the 1979 Mid-dry season. The model of juvenile recruitment into the populations is therefore likely to be complex.

The largest specimens were captured in the Mid-wet and Mid-dry seasons. In the escarpment perennial streams the largest specimens were observed in the 1979 Late-dry and 1979–80 Early-wet season. The seasonal mean lengths of all specimens captured was highest in the 1978 Late-dry season.

The seasonal length-frequency distributions of *P. midgleyi* captured during the study are shown in figure 128.

Habitat differences in distribution

Magela catchment

This species was found in most escarpment habitats, with the widest range of sizes being captured in perennial streams. Specimens that presumably came from escarpment populations were occasionally found in lowland sandy creekbeds downstream of the RUPA. Unidentified juvenile theraponids were observed in these habitats in the Mid-wet season.

Nourlangie catchment

Pingalla midgleyi was only found in escarpment habitats in the Nourlangie Creek catchment; however, some fish may move to the lowland during the Wet season. The widest size range of specimens was observed in escarpment perennial streams.

Environmental associations

Rank numbers for *P. midgleyi* for the physico–chemical and habitat–structural variables during the study period are shown in table 155.

Physico–chemical variables

Temperature

Both surface and bottom water temperatures at sites where *P. midgleyi* was captured ranged from 23 to 35°C, with means of 27.6°C for surface waters and 27.4°C for bottom waters. These means were both ranked at the base of the lower quarter (see fig 170). These low water temperatures are characteristic of the escarpment waterbodies in which *P. midgleyi* was generally found. This species is related to *H. fuliginosus* and *S. butleri,* which had markedly similar ranges of associated water temperatures (and other environmental parameters).

Dissolved oxygen

Dissolved oxygen concentrations in waters at sites where *P. midgleyi* was found ranged from 3.8 to 8.3 mg/L (mean = 5.9 mg/L) on the surface, and from 5.0 to 7.4 mg/L (mean = 5.9 mg/L) on the bottom (see fig 171). The mean for surface waters was ranked in the upper-middle quarter, and the mean for bottom water was ranked in the upper quarter. As with other primarily escarpment-dwelling fish, the DO concentration in the bottom waters in which the species was captured was generally high.

Visibility

Secchi depths recorded for waters where *P. midgleyi* was caught ranged from 100 to 360 cm (mean = 188 cm) (see fig 172). This mean ranked high in the upper quarter, as might be expected for a fish commonly found in clear escarpment streams.

pH

The pH values of water in which this species was captured ranged at the surface from 4.0 to 7.1 (mean = 5.4) and at the bottom from 4.5 to 7.0 (mean = 5.7). Both means were placed in the lower quarter (fig 173). As with other mainly escarpment-dwelling species, its aquatic environment is relatively acidic.

Conductivity

Pingalla midgleyi was captured in waters with conductivities ranging from 2 to 80 µS/cm on the surface, and from 2 to 64 µS/cm on the bottom. The low levels of dissolved solids are typical of escarpment channels.

Habitat–structural variables

Substrate

Pingalla midgleyi was most often found in waters with a sandy bottom, and to a lesser extent in waters with boulder, rock, leaf litter and gravel substrates. The percentage dominance values for sandy substrates were ranked in the upper quarter, and that for boulders at the apex of the upper quarter (see fig 174).

Hydrophytes

This species is usually found in sparsely vegetated waters (vegetation-occurrence index 27.9%). Thus *P. midgleyi* showed similar ranges of habitat–structural parameters to other primarily escarpment-dwelling fish species.

Reproduction

A total of 81 *P. midgleyi* were examined for reproductive condition: 25 females (length range 71–116 mm LCF), 34 males (70–120 mm LCF) and 22 sexually indistinguishable fish (68–84 mm LCF).

Length at first maturity

The LFM could not be determined for females as, apart from three spent fish, no females were captured with a gonad maturity stage greater than III. No females were captured during the 1978–79 Early-wet season, which the capture of one running-ripe male suggests was the breeding season. The highest GSI for a female was only 0.66.

The LFM for males was estimated to be around 75 mm LCF (fig 129). Since no LFM was determined for females, the ratio of adult males to adult females was not tested; also, GSI and GMSI were calculated from the data on all male and female fish.

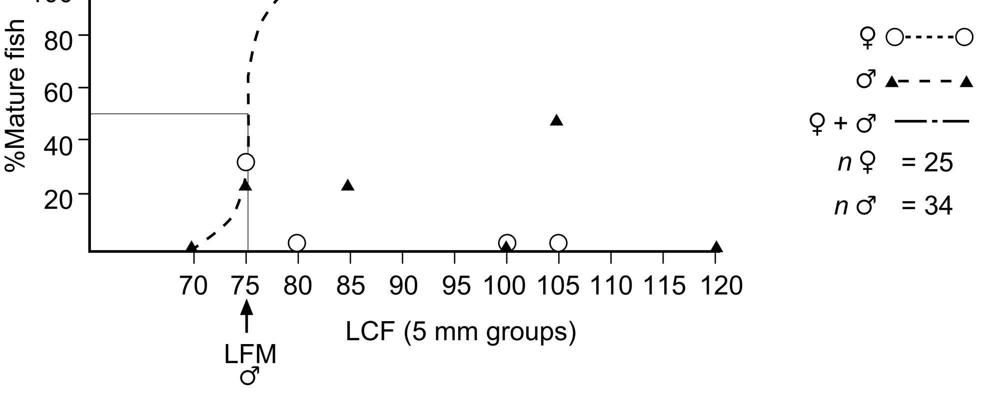


Figure 129 Estimated length at first maturity of *P. midgleyi*

Sex ratio

Only the ratio of males to females over the entire length range was tested, as the LFM for females was not adequately determined and therefore adult fish could not be defined. No significant difference from 1:1 was found except in the 1978 Late-dry season when more males than females (0.01 > P > 0.05) were captured (table 109). However, the small samples were, in the other seasons, too small to draw firm conclusions.

Table 109 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *P. midgleyi* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	5	0	11	–	9	0	–
adults	M	*n*	18	1	9	–	5	1	–
		χ^2	6.0	1.0	0.2	–	1.1	1.0	–
		P	*	n.s.	n.s.	–	n.s.	n.s.	–
GSI									
Adults only	F	mean	0.4	–	0.2	–	0.2	–	–
		s.d.	0.2	–	0.1	–	0.1	–	–
	M	mean	0.6	5.9	0.1	–	0.1	0.13	–
		s.d.	0.6	–	0.1	–	0.03	–	–
	F+M	mean	0.5	–	0.1	–	0.2	–	–
		s.d.	0.5	–	0.1	–	0.1	–	–
GMSI									
Adults only	F	mean	2.6	–	1.5	–	1.8	–	–
		s.d.	0.5	–	1.5	–	1.8	–	–
	M	mean	3.3	6.0	1.7	–	1.8	2.0	–
		s.d.	1.1	–	0.5	–	0.4	–	–
	F+M	mean	3.1	–	1.6	–	1.8	–	–
		s.d	1.0	–	0.5	–	0.4	–	–

n= number; χ^2 = Chi-squared value; P = probability; n.s. = not significant (P > 0.05); * = 0.01 < P < 0.05; s.d. = standard deviation.

Breeding season

Only one fish, a ripe male, was captured during the 'most likely' reproductive season (the 1978–79 Early-wet). Mature and maturing males were identified in the preceding 1978 Late-dry season and spent males and females in the following 1978–79 Mid-wet season. Figure 130 also indicates that males may have bred over the 1978–79 Early-wet season; however, these conclusions are based on only very few fish.

Site of spawning

Due to the extremely small numbers of mature and ripe males and the absence of females at these stages, the site of spawning cannot be determined; however, a mature fish was found in an escarpment perennial stream (Baroalba Springs), and a ripe fish was found in a lowland sandy creekbed (Magela bed) (table 110). Spent fish were captured in two escarpment area habitats: Baroalba Springs and Bowerbird Billabong.

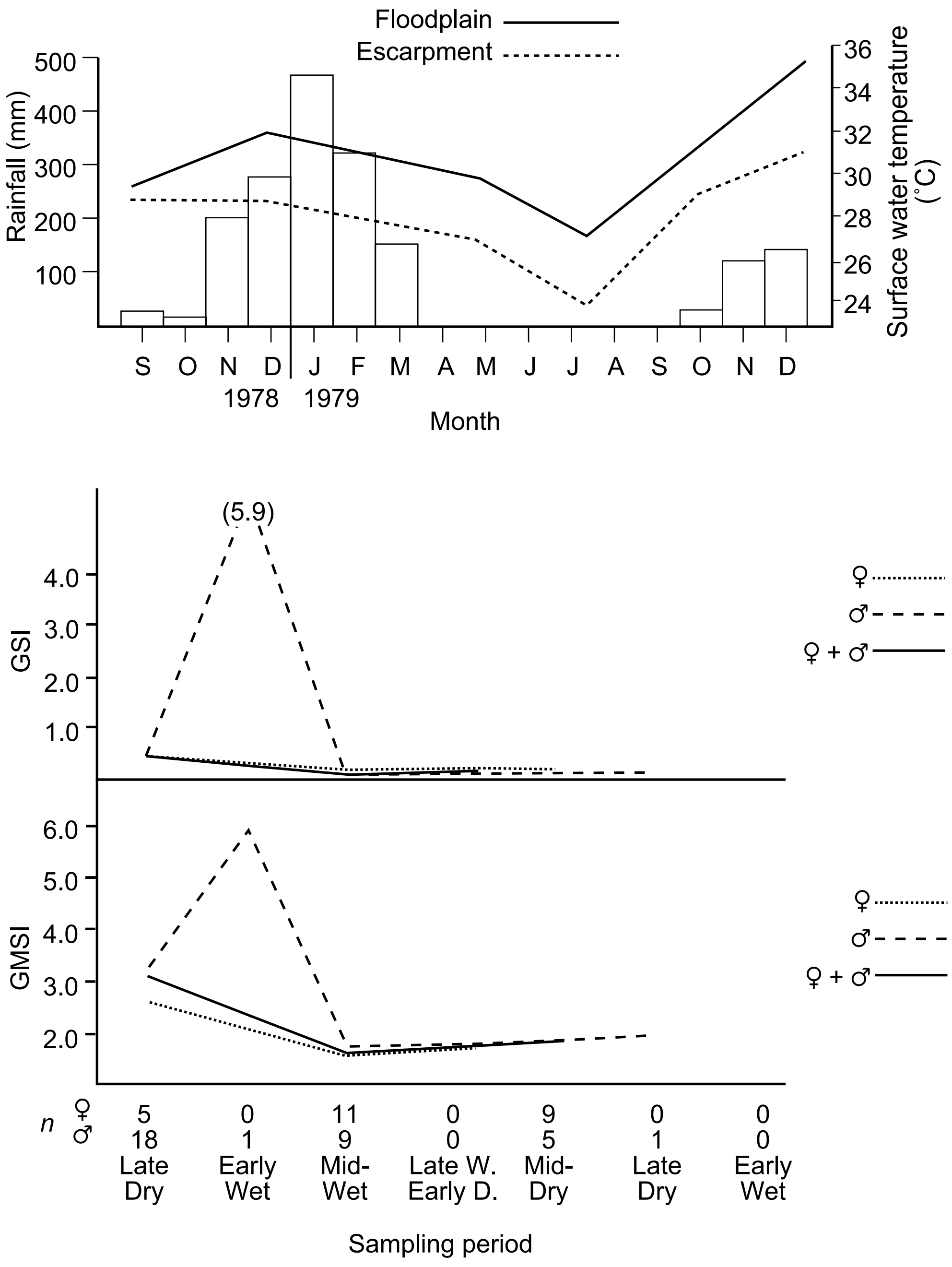


Figure 130 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *P. midgleyi*

Table 110 Possible sites of spawning for *P. midgleyi* as indicated by the abundance (*n*) of mature, ripe and spent fish

	Gonad stage					
	Mature (V)		Ripe (VI)		Spent (VII)	
Habitat	F	M	F	M	F	M
Escarpment						
Perennial stream	–	1	–	–	4	4
Lowlands						
Sandy creekbed	–	–	–	1	–	–

Summary

Data on this previously undescribed species were extremely scarce. No maturing females were captured and therefore no female LFM could be determined. Males were found at both mature and ripe stages and their LFM was estimated to be 75 mm LCF. Significantly more males than females were captured during the 1978 Late-dry season; however, too few fish were caught in most other seasons to adequately determine the sex ratios.

Breeding most likely occurred in the 1978–79 Early-wet season; however, only one fish was captured in that season and no fish were captured in the 1979–80 Early-wet season. Mature and ripe fish were captured in Baroalba Springs, and Magela bed on Magela Creek, which suggests the fish may spawn both in the escarpment area habitats and in the Magela Creek downstream of the escarpment.

Feeding habits

Overall diet

The stomachs of 82 specimens were analysed; 80 contained food. The diet of *P. midgleyi* is summarised in figure 131; the components are listed in table 111. The main components were algae (49%) and detritus (25%), and considerable amounts of incidentally ingested inorganic material (14%). The identifiable algae were mainly filamentous green species such as *Mougeotia* and *Spirogyra*; desmids were also found abundantly in the stomachs on a few occasions. Aquatic insects (mainly chironomids, 7%) were also eaten, as well as terrestrial plant material (4%). *Pingalla midgleyi* can therefore be classified as a herbivore (mainly algae) and detritivore, and occasionally an omnivore, feeding over sand and rocky substrates and sometimes over submerged tree trunks and other plant material. H. Midgley (pers comm) classified this species as a 'scunge' eater. Lake (1978) noted that the main food of the 'black-blotched anal fin grunter' (the *P. midgleyi* pictured in Lake's book is a specimen from Magela Creek) was benthic algae, which supports our results.

The very small mouth, protruding upper jaw (giving the mouth a sub-terminal snout like a tapir), strongly curved maxilla, and very flattened noncuspidate teeth that distinguish the genus *Pingalla* are adaptations to graze on the algae that grow on a variety of substrates.

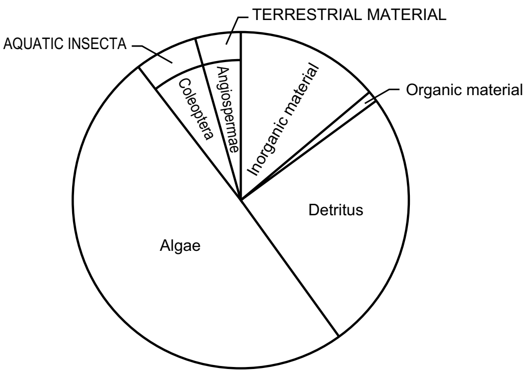


Figure 131 The main components of the diet of *P. midgleyi*

Habitat differences

A total of 25 stomachs of *P. midgleyi* were analysed (all seasons combined): 5 from the Magela Creek catchment escarpment mainchannel waterbodies and 16 from its perennial streams, and 4 from lowland sandy creekbeds. No fish had empty stomachs.

Table 111 Dietary composition of *P. midgleyi*

	Habitat					Seasons							
	Magela system			Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Em	Ep	Ls	Em	Ep	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Aquatic plants													
Algae													48.8
Miscellaneous	–	87.8	7.5	4.9	22.5	60.0	–	–	–	7.9	30.0	22.1	
Desmidaceae	–	–	–	–	14.2	–	–	5.9	–	–	–	2.1	
Conjugatophyta													
Mougeotia	10.0	–	8.8	24.3	–	–	30.0	34.0	5.0	9.6	–	15.4	
Spirogyra	68.0	–	–	11.0	–	–	–	25.3	–	–	–	9.2	
Aquatic animals													
Insecta													6.6
Fragmented	–	1.3	–	–	–	0.8	–	–	–	–	–	0.2	
Hemiptera													
Corixidae	–	–	5.0	–	–	–	–	–	–	–	20.0	0.3	
Coleoptera	–	–	–	0.1	–	–	–	0.2	–	–	–	0.1	
Diptera													
Chironomidae	1.0	6.3	21.3	2.2	5.0	8.3	25.0	2.9	20.0	4.6	–	5.6	
Ceratopogonidae	–	–	3.8	–	1.7	–	5.0	0.7	–	0.5	–	0.4	
Terrestrial Plants													
Angiospermae													4.1
Miscellaneous	11.0	–	20.0	–	5.8	4.6	30.0	4.3	–	–	50.0	4.1	
Detrital material	8.0	3.1	26.3	37.9	17.5	18.9	–	3.4	75.0	60.7	–	25.0	25.0
Inorganic material	2.0	1.6	7.5	17.6	30.8	7.5	10.0	19.8	–	16.8	–	14.4	14.4
Organic material	–	–	–	1.9	2.5	–	–	3.5	–	–	–	1.3	1.3
Number of empty fish	–	–	–	1	1	–	–	2	–	–	–	2	2
Number of fish with food	5	16	4	36	12	26	1	29	1	22	1	80	80

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ep = escarpment perennial; Ls = lowland sandy creekbed

Specimens in the escarpment habitats were feeding mainly on algae and a small amount of detritus. In the mainchannel waterbodies, terrestrial plant material was eaten, and in the perennial streams, chironomid larvae. The small inorganic material component in the stomachs indicated that *P. midgleyi* was feeding mainly over hard substrates in these habitats. The inorganic component was higher in the sandy creekbed lowland billabongs, where the fish ate fairly equal portions of detritus, terrestrial plant material, chironomid larvae and algae.

Catchment differences

A total of 50 stomachs of *P. midgleyi* were analysed (all seasons combined) from the Nourlangie Creek catchment: 37 from escarpment mainchannel waterbodies and 13 from perennial streams. Only one fish from each of the above habitats had an empty stomach. In both habitats the diet included a large inorganic material component, indicating that this species was feeding predominantly over sandy substrates. Algae were the main food item with detritus of secondary importance. A few chironomid larvae and some terrestrial plant material were eaten at both sites. Algae appeared to be less important in the diet in the Nourlangie Creek habitats than in the Magela Creek system.

Seasonal changes

In sampling periods 1–6, respectively, 26, 1, 31, 1, 22 and 1 stomachs of *P. midgleyi* (all habitats combined) were analysed. Only during the Mid-wet season were a few fish found with empty stomachs.

The diet in the 1978 Late-dry season was dominated by algae, as was the case in the Mid-wet season. Chironomids were present in the diet in both seasons though they were more abundant in the former. Terrestrial plant material was also present in both seasons. During the Mid-dry season detritus was the main food item, followed by algae and chironomid larvae.

Fullness

A summary of mean fullness indices of *P. midgleyi* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 112. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 112 Mean fullness indices of *P. midgleyi* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

	Sampling period						
Habitat	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry 1979	Habitat mean
Magela Creek catchment (regular sites only)							
Upstream of RUPA:							
Escarpment main-channel waterbody	n/s	n/s	3.5 (4)	n/s	0 (1)	n/s	2.8 (5)
Escarpment perennial stream	4.5 (16)	n/s	n/s	n/s	n/s	n/s	4.5 (16)
Downstream of RUPA:							
Lowland sandy creekbed	n/s	0 (1)	n/s	0 (1)	0 (1)	0 (1)	0 (4)
Nourlangie Creek catchment (regular sites only)							
Escarpment main-channel waterbody	n/s	n/s	3.4 (16)	n/s	3.6 (20)	n/s	3.5 (36)
Escarpment perennial stream	4.3 (13)	n/s	n/s	n/s	n/s	n/s	4.3 (13)
Seasonal mean (all sites)	4.4	0	3.8	0	3.6	0	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment upstream of RUPA, the mean fullness indices for *P. midgleyi* were highest in the escarpment perennial streams and lowest in the escarpment mainchannel waterbody. No specimen captured downstream of RUPA had food in its stomach.

In the Nourlangie catchment the mean fullness indices were also highest in the escarpment perennial streams and lowest in the mainchannel habitat, although they were generally higher than in the equivalent Magela habitat.

Seasonal changes

Interpretation of seasonal changes of mean fullness indices is difficult owing to small sample sizes and inconsistent sampling of habitats, eg the high levels in the 1979 Late-dry season were due to sampling exclusively in escarpment perennial streams.

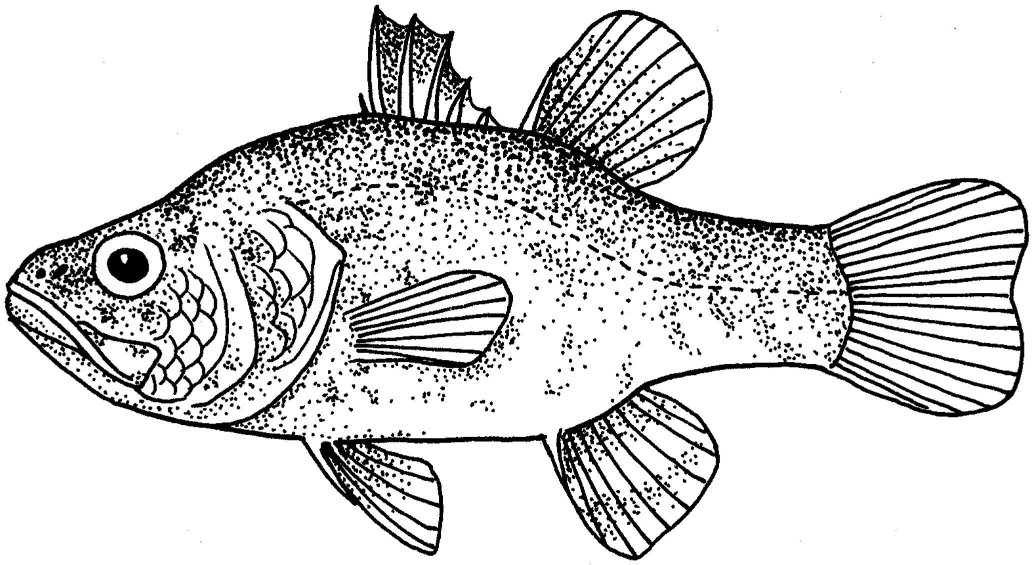
Summary

Mean fullness indices were highest in escarpment habitats and particularly in perennial escarpment streams of both catchments.

Family APOGONIDAE

3.29 *Glossamia aprion* (Richardson)

Glossamia aprion is commonly known as the mouth almighty or Queensland mouthbrooder. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3). It also occurs in southern rivers of Papua New Guinea. Pollard (1974) found this species to be common in lowland backflow billabongs and sandy creekbeds. Miller (in Taylor 1964) found it to be abundant in large billabongs in the Oenpelli area.



Glossamia aprion

Glossamia aprion is a strictly freshwater species, in a predominantly marine family. It is reputedly a good eating fish, though generally small.

Detailed information on catches by site and season is given in volume 2. In summary, *G. aprion* was moderately abundant in all floodplain, corridor and lowland backflow billabongs, less abundant in lowland sandy creekbeds (mainly downstream of the RUPA) and rare in escarpment perennial streams and mainchannel waterbodies. In the 1978 Late-dry season it was found at 15 sites (mainly lowland backflow and floodplain billabongs); during the Mid-wet season it was found in only 10 sites (mainly lowland channel backflow billabongs). By the Late-wet–Early-dry season it was found in 19 sites (mainly lowland backflow and floodplain billabongs but also sandy creekbeds downstream of RUPA), presumably becoming more catchable as Wet season waters subsided.

Size composition

The lengths and weights of 1020 specimens were recorded. The smallest juveniles were captured with seine (10 mm mesh) nets and the very smallest specimens were captured when hydrophytes clogged the net and effectively reduced the mesh size. The smallest specimen captured by gillnets was 60 mm LCF. The slight peaks in the overall distribution of larger fish may be the result of mesh selectivity.

Length–weight relationship

The length–weight relationship was described by the following expression:[184]

$W = 1.09 \times 10^{-2} L^{3.17}$ r = 1.00 (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors are shown in table 113. The seasonal condition factor was fairly stable throughout most of the study;[185] however, a slight peak was apparent in the Late-wet–Early-dry season and troughs were apparent in the Early-wet season, especially in the 1979–80 season after the extreme Dry season.

Table 113 Mean length, mean weight and condition factor of *G. aprion*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition (K)
Late-dry (1978)	250	43.2	1.12	0.99
Early-wet (1978–79)	58	42.0	1.00	0.97
Mid-wet	53	49.0	1.66	0.99
Late-wet–Early-dry (1979)	221	47.2	1.53	1.02
Mid-dry	263	65.1	4.13	1.00
Late-dry	72	63.1	3.75	1.00
Early-wet (1979–80)	19	67.3	4.29	0.93
Overall	936	51.7	1.99	1.00

Length composition

Range

The specimens ranged in length from 11 mm to 175 mm LCF (fig 132). Lake (1971) reported that this species grows to 200 mm.

Most of the smallest specimens were captured in the Late-wet–Early-dry season and some in the Mid-wet and Mid-dry seasons (fig 133). The largest specimens were captured in the 1979 Mid-dry season and also in the Late-wet–Early-dry season. Large adults were frequently observed in escarpment perennial streams of the Nourlangie catchment during the 1979 Mid-dry season.

Length-frequency distribution

The mean and modal lengths of all specimens captured were 52 mm and 30–35 mm LCF, respectively. The length composition of the populations had a negatively skewed distribution, which reflected the decreasing survival rate of larger specimens. Very small specimens were not abundant in the samples, due partly to gear selectivity and partly to this species being a mouth brooder. The length at first sexual maturity (LFM on fig 132) was approximately 60 to 70 mm LCF, indicating that most of the specimens captured were juveniles.

The seasonal length-frequency distributions of all *G. aprion* captured during the study are shown in figure 133.

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[184] van Zweiten (1995) gave the following length-weight relationship for *G. gjellerupi* from the Sepik-Ramu basin in PNG:
$W = 8.21 \times 10^{-6} L^{3.14}$ (r=0.97, p=0.001) (L is standard length in mm, W is total weight in g)
The relationship did not vary significantly between males and females.

[185] van Zweiten (1995) found the body condition of *G. gjellerupi* from the Sepik-Ramu basin in PNG to be generally stable and showing no particular seasonality. Condition was negatively correlated to current speeds, with populations from floodplain margin streams having the highest averages.

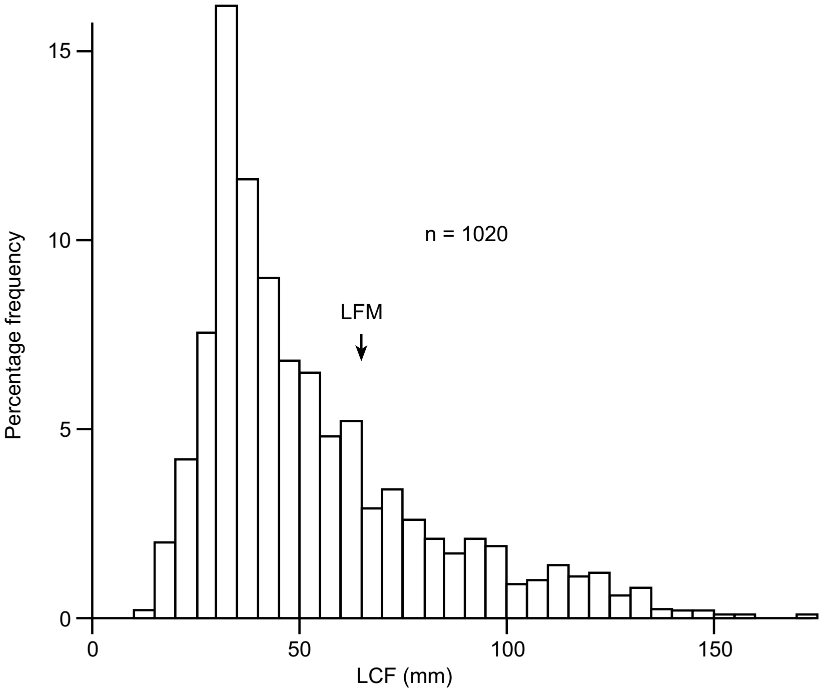

Figure 132 Length-frequency distribution of all *G. aprion* captured

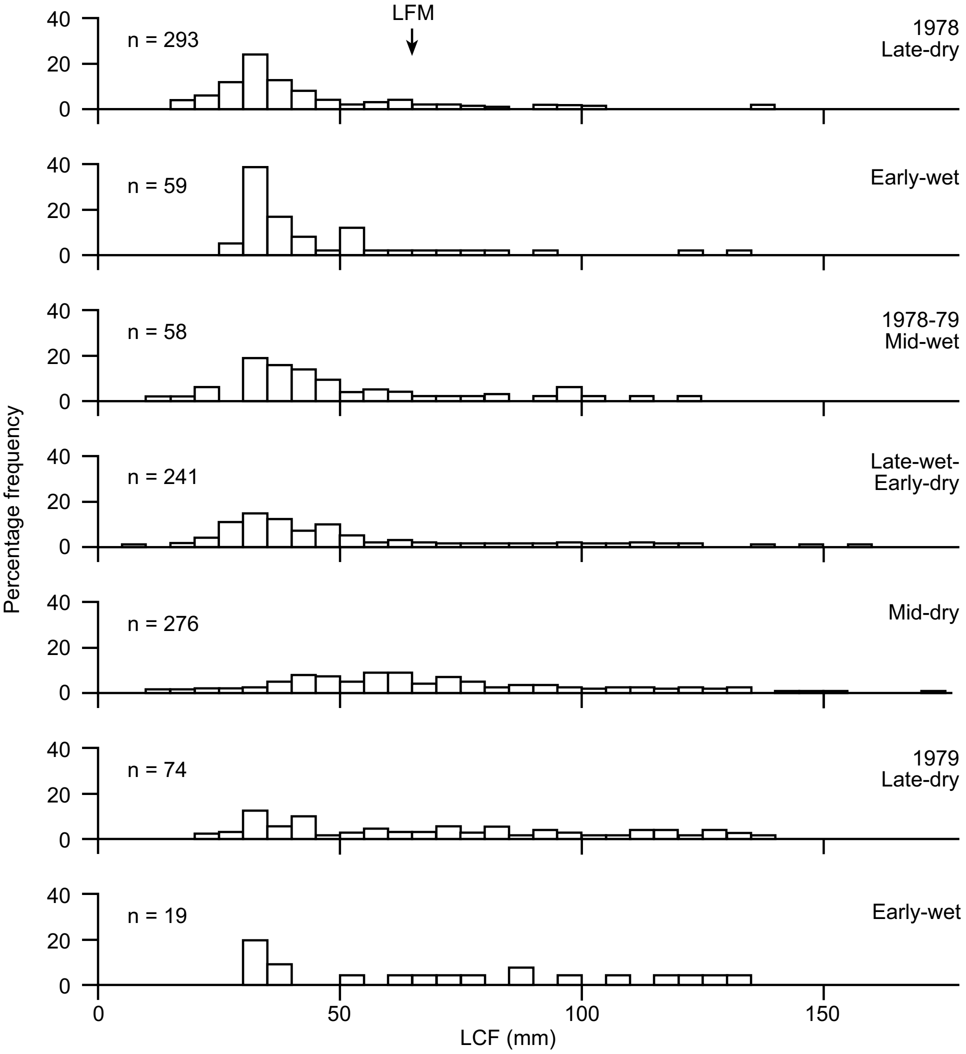

Figure 133 Seasonal length-frequency distribution of all *G. aprion* captured

The mean seasonal lengths are shown in table 113. They were shortest during the 1978 Late-dry and 1978–79 Early-wet seasons and then increased slightly during the Mid-wet and Late-wet–Early-dry seasons. By the Mid-dry season the mean lengths had increased dramatically but remained at much the same level to the end of the study.

The initial low mean lengths were primarily due to the many juveniles in the samples; in the following seasons the juvenile component remained strong, though more adults were found. By the 1979 Mid-dry season there were fewer small juveniles and more larger juveniles and adults (fig 133). This did not change in the 1979 Late-dry and 1979–80 Early-wet seasons, unlike the previous year. The environmental conditions in the 1979 Dry season were apparently less favourable for producing large numbers of juveniles than the 1978 season. The presence of juveniles in all sampling seasons indicates that the fish bred in the billabongs during these times; however, the length-frequency distributions indicate that this activity was greatest between the 1978 Late-dry season and the Late-wet–Early-dry season.

Growth rate

Estimation of the growth rate of *G. aprion* from the seasonal length-frequency distributions was difficult because of mesh selectivity, the range of habitats sampled, and especially the nearly continuous recruitment of juveniles.

Habitat differences in distribution

The habitats in which *G. aprion* was captured in regular sampling sites in the Magela and Nourlangie Creek catchments are shown in figure 134.

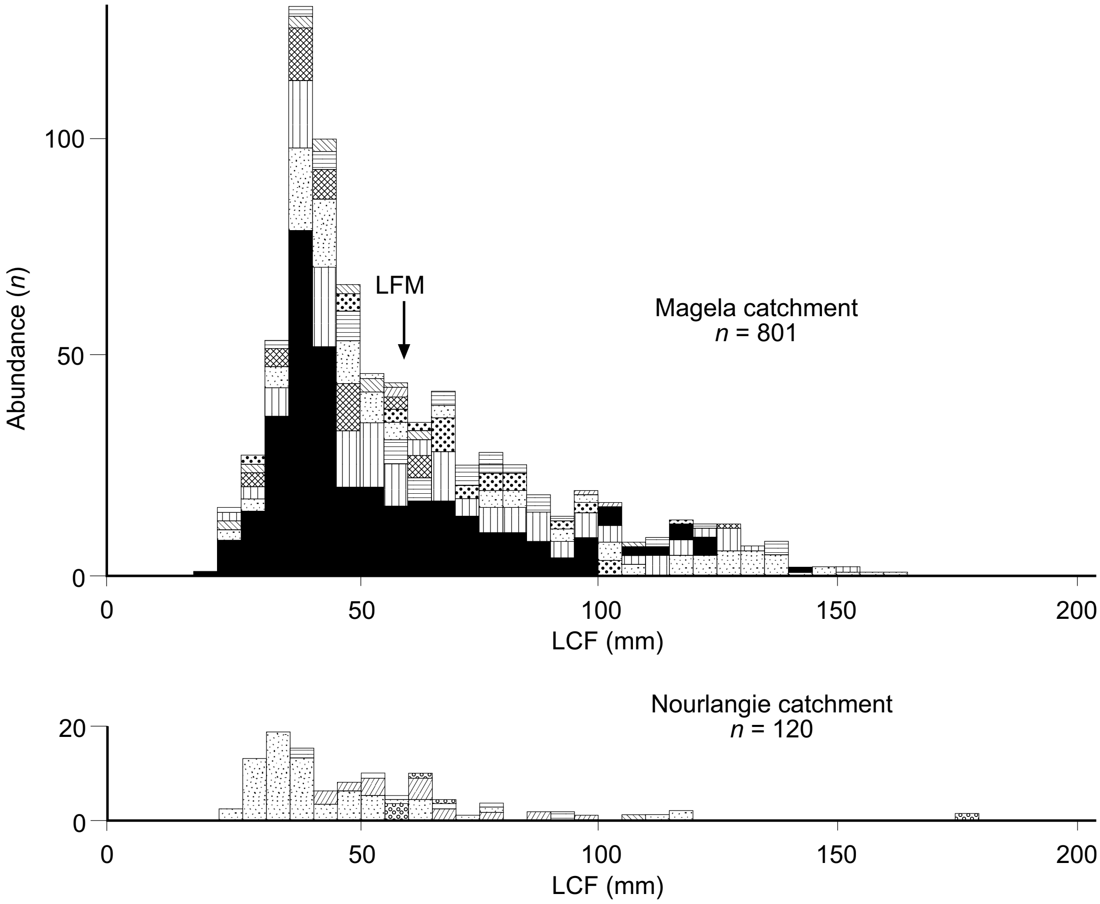

Figure 134 Length-frequency distribution and habitat preferences of *G. aprion* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment

Most juveniles were captured in floodplain billabongs and secondarily in lowland backflow billabongs, and to a lesser extent in corridor waterbodies. Very few juveniles were found in sandy creekbeds. Juveniles were frequently captured upstream of RUPA in escarpment mainchannel waterbodies (though not in perennial streams) and backflow billabongs.

Smaller adults were found in a variety of habitats, but most frequently in floodplain billabongs and to a lesser extent in backflow billabongs. Considerable numbers of these small adults were also found in corridor waterbodies and lowland sandy creekbeds (unlike the juveniles) as well as in habitats upstream of RUPA. The presence of small adults in lowland sandy creekbeds may indicate dispersion of this size group to spawning or feeding areas or both.

The large adults were mainly found in backflow billabongs, and infrequently in floodplain billabongs, lowland sandy creekbeds, corridor waterbodies and habitats upstream of RUPA.

Nourlangie catchment

Both small and larger juveniles were mainly captured in channel backflow billabongs. The larger juveniles were also captured in lowland sandy creekbeds and shallow backflow billabongs. No juveniles were observed in escarpment habitats.

A large proportion of small adults captured in the Nourlangie catchment were found in lowland sandy creekbeds (as was the case in the Magela catchment) and to a lesser extent in backflow billabongs. The largest adult was captured in a shallow backflow billabong. Large adults were also frequently observed in escarpment perennial streams and in mainchannel waterbodies.

Environmental associations

Rank numbers for *G. aprion* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

The water temperatures of sites where *G. aprion* was found ranged from 25 to 38°C (mean = 30.6°C) on the surface and from 23 to 35°C (mean = 29.0°C) on the bottom. Both means ranked high in the lower-middle quarter (see fig 170). The larvae of this species died when kept in water at 22 to 24°C (over five days). Although some specimens of *G. aprion* were found in cooler escarpment streams, it was more commonly captured in warmer lowland waterbodies.

Dissolved oxygen

Dissolved oxygen concentrations in waters inhabited by *G. aprion* ranged from 1.3 to 9.7 mg/L (mean = 6.2 mg/L) on the surface, and from 0.2 to 9.5 mg/L (mean 4.8 mg/L) on the bottom. Both means were ranked in the upper-middle quarter (see fig 171). *Glossamia aprion* thus apparently tolerates very low DO concentrations; however, a specimen of *G. aprion* was found in the Leichhardt Billabong fish kill (Bishop 1980) in which surface DO levels fell to 0.1 mg/L.[186]

Visibility

Secchi depth readings in waters in which *G. aprion* was caught ranged from 1 to 200 cm (mean = 41 cm). This mean ranked at the top of the lower quarter, indicating this species' association with moderately turbid waters (see fig 172).

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[186] van Zweiten (1995) suggested that mouth-brooding in *G. gjellerupi* from the Sepik-Ramu basin in PNG may restrict the species to well-oxygenated waters.

pH

The pH values of waters in which *G. aprion* was caught ranged from 4.9 to 8.1 (mean = 6.3) on the surface, and from 4.5 to 7.3 (mean = 5.9) on the bottom. These means were ranked in the upper-middle and lower-middle quarters, respectively (see fig 173).

Conductivity

Conductivity readings for waters in which *G. aprion* were captured ranged widely from 2 to 620 µS/cm on the surface, and from 2 to 110 µS/cm on the bottom. The closely related *G. wichmonni* is found in brackish to freshwaters in Papua New Guinea (Roberts 1978); however, Pollard (1974) stated that *G. aprion* is a purely freshwater species.

Habitat–structural variables[187]

Substrate

Glossamia aprion was most commonly found over muddy substrates (upper-middle quarter) followed by clay (upper-middle quarter), then sand, leaves, gravel, rocks and boulders (see fig 174). Such a wide range of types of substrate is in accord with the species' wide distribution.

Hydrophytes

This species was typically captured in heavily vegetated waters (vegetation-occurrence index 86.8%): the order of dominance was submergent followed by emergent and then floating-attached hydrophytes).

Reproduction

A total of 559 *G. aprion* was examined for reproductive condition: 255 were sexually indistinguishable (length range 11–115 mm TL); 146 were females (33–157 mm TL) and 158 were males (33–140 mm TL). Only males were observed incubating eggs in their mouths.

Length at first maturity

The LFM, determined by 10-mm-length groups, was found to be 63 mm for males and 67 mm for females (fig 135). The smallest maturing fish were 61 mm LCF (males) and 70 mm LCF (females).[188]

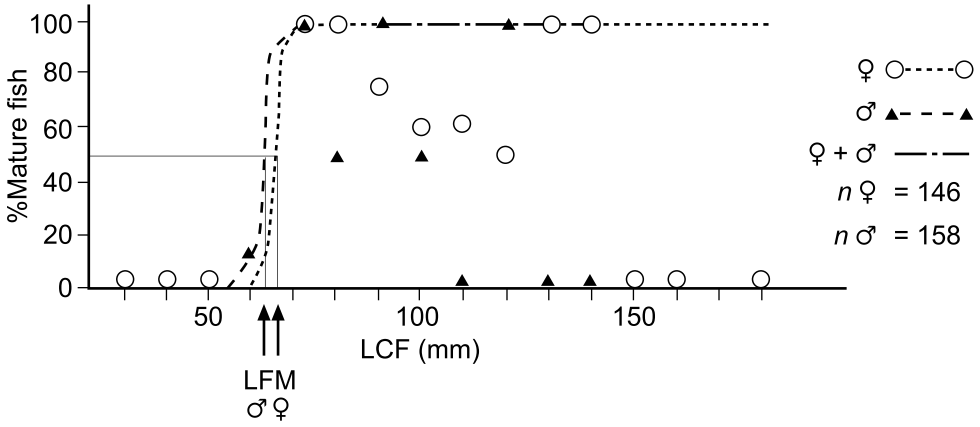

Figure 135 Estimated length at first maturity of *G. aprion*

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[187] van Zweiten (1995) found *G. gjellerupi* from the Sepik-Ramu basin in PNG to prefer slow flow rates: pools, alongside banks, under cover of vegetation, etc. Biomass and density decreased with increasing current speeds. Fluctuations in population size appeared to be related to the irregular occurrence of spates.

[188] Data presented by van Zweiten (1995) indicated that LFM for *G. gjellerupi* from the Sepik-Ramu basin in PNG was 70–80 mm SL for females and 60 mm for males.

Sex ratio

A chi-squared test on adult fish only indicated no significant difference from a 1:1 sex ratio for each season; however, significantly more males were identified in the entire sample during the 1978 Late-dry ($0.01 < P < 0.05$), 1978–79 Early-wet ($0.001 < P < 0.01$) and the following Mid-wet ($0.01 < P < 0.05$) seasons (table 114).

Thus more juvenile males than females were identified (possibly some immature females were misidentified as males).

Breeding season

The breeding season was not well defined.[189] Roberts (1978) found that in Papua New Guinea, *G. aprion* reproduced aseasonally, while Lake (1978) found it spawned when water temperatures reached about 22°C. The information from figure 136 and table 114 indicates *G. aprion* may have bred over a range of seasons.

Table 114 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *G. aprion* over all habitats

Parameter	Sex	Statistic	Sampling period						
			Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979-80
Sex ratio									
Juveniles	F	*n*	16	4	4	28	66	22	6
+ adults	M	*n*	34	18	14	21	48	18	5
		χ^2	6.5	8.9	5.6	1.0	2.8	0.4	0.09
		P	*	**	*	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	13	1	3	18	47	16	6
	M	*n*	19	6	8	14	42	16	4
		χ^2	1.1	3.6	2.3	0.5	0.3	0	0.4
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	7.6	1.8	3.9	1.1	1.9	1.4	1.4
		s.d.	7.3	–	5.8	1.0	1.0	0.5	1.3
	M	mean	0.3	0.2	0.2	0.1	0.1	0.1	0.1
		s.d.	0.3	0.2	0.1	0.1	0.1	0.1	0.1
	F+M	mean	3.5	0.5	1.6	0.7	1.1	0.8	0.9
		s.d.	5.9	0.7	3.7	0.9	1.2	0.8	1.2
GMSI									
Adults only	F	mean	4.1	4.0	3.0	2.3	2.9	2.3	2.2
		s.d.	0.7	–	2.0	0.9	0.8	0.4	1.0
	M	mean	2.8	2.9	2.3	1.8	2.1	2.1	2.0
		s.d.	0.4	1.0	0.9	0.6	0.6	0.7	0.8
	F+M	mean	3.8	3.1	2.5	2.1	2.5	2.2	2.1
		s.d	0.8	1.0	1.3	0.8	0.8	0.6	0.9

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.01$; s.d. = standard deviation.

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[189] van Zweiten (1995) found that *G. gjellerupi* from the Sepik-Ramu basin in PNG had no seasonality in its reproduction, although peaks occurred due to local conditions. Reproductive activity and/or survival was considered to be directly related to floods: prolonged periods of environmental stability, such as those occurring during periods with less rainfall, seemed to be conditional for the survival of juveniles.

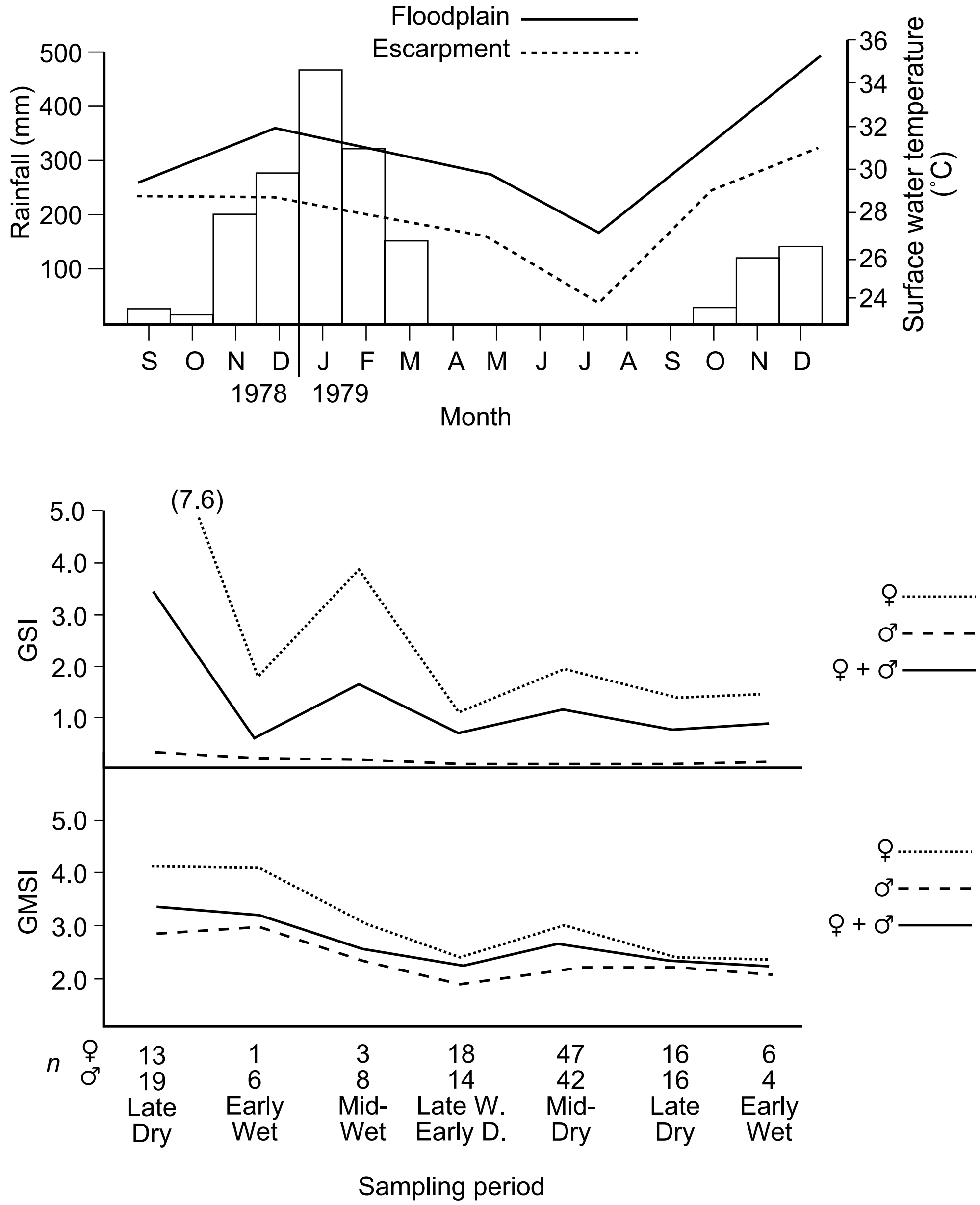

Figure 136 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *G. aprion*

GSI peaked in the 1978 Late-dry and 1978–79 Mid-wet seasons, while the GMSI was slightly high from the 1978 Late-dry season through to the 1978–79 Mid-wet season with a very small peak during the 1979 Mid-dry season. Incubating eggs and spent fish were found during the 1978–79 Early-wet and 1979 Mid-dry seasons. Mature fish were found in four seasons from the 1978 Late-dry to the 1979 Mid-dry seasons, excluding the 1978–79 Early-wet season. Juvenile fish, 11–15 mm LCF, were captured during the 1978–79 Mid-wet and 1979 Mid-dry seasons. The minimum temperature of 22°C described by Lake (1978) would not affect spawning activity in the Alligator Rivers Region, as surface water temperatures did not fall below 23°C during the study.

Site of spawning

Male *G. aprion* incubating eggs were found in two lowland backflow billabongs (Coonjimba Billabong and Baroalba Crossing) and in a floodplain billabong (Island Billabong); however, mature and juvenile fish were found over a far wider range of habitats, from escarpment mainchannel waterbodies (Bowerbird Billabong) down to the East Alligator floodplain billabongs (Cannon Hill Billabong). The evidence suggests *G. aprion* may breed throughout its entire preferred range (table 115). One environmental requirement may be lentic conditions where the females can spawn and the males can gather the eggs into its mouth.

Table 115 Possible sites of spawning of *G. aprion* as indicated by the abundance (*n*) of mature, ripe, spent fish, of males buccally incubating eggs, and of small (11–25 mm) juvenile fish

	Gonad stage							
	Mature (V)		Ripe (VI)		Spent (VII)		Males with eggs	Juveniles
Habitat	F	M	F	M	F	M		
Escarpment								
Mainchannel waterbody	–	–	–	–	–	–	–	4
Lowlands								
Backflow billabong	4	–	–	–	–	–	2	33
Corridor	4	–	–	–	–	–	4	24
Floodplain billabong								
Upper	2	1	–	–	1	1	–	–
Lower	1	–	–	–	–	–	–	2

Fecundity

The ovaries of *G. aprion* were bilobed and contained eggs in many stages of development (Plate 3). The ovary was long, and rounded and broader at the anterior end (ie pear-shaped). The most mature eggs were at the anterior end, grading down to tiny undeveloped eggs at the posterior end.

Only the largest size-class of eggs from 6 ovaries were counted. They averaged 250 eggs (range: 136–430; s.d. 98).[190] The number of eggs incubating in the mouths of male fish were 378 (fish length 123 mm LCF, weight 39.3 g) and 188 (108 mm LCF, 20 g) and 416 (no size available);[191] these numbers were not included in the determination of average fecundity as eggs may have been lost into the water upon capture, and males possibly collect eggs from more than one female, as recorded for a marine Apogonid by Ebine (1932, cited in Breder & Rosen 1966).

The diameters of the largest size-class of eggs ranged between 0.8 and 1.78 mm, with most being around 1.5 mm.[192] The diameter range of a less-developed stage of eggs was 0.16–0.25 mm. Eggs are laid in a bundle that appears to be enveloped in a very fine membrane; the eggshell is transparent (Lake 1978). Lake recorded that the eggs have a diameter of about 3 mm, and that they are incubated in the buccal cavity of the male for around two weeks, depending on temperature. Rudel (1934, cited by Breder & Rosen 1966) observed the spawning of *Glossamia gilli* (Steindachner), possibly a subspecies of *G. aprion* (Pollard

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[190] van Zweiten (1995) found the fecundity (F) of *G. gjellerupi* from the Sepik-Ramu basin in PNG to be correlated with fish size:

$F = -220.0 + 4.59*SL$ ($r=0.95$, $p<0.001$) (SL is standard length in mm)

[191] van Zweiten (1995) found the number of eggs in broods held by male *G. gjellerupi* from the Sepik-Ramu basin in PNG varied from 62 to 94 (mean 85.3, n = 8) for fish ranging in length from 72 to 87 mm. Brood size appeared to be related fish size.

[192] van Zweiten (1995) found *G. gjellerupi* from the Sepik-Ramu basin in PNG to have ripe eggs with a mean size 3.33 ± 0.54 mm. Eggs in a ripe ovary were all at the same stage of development.

1974), which he collected from a river near Brisbane and kept in a freshwater aquarium. At the time of spawning the male became a light golden colour on the body except below, where it was purple. The first dorsal and pectoral fins were intense black, and the operculum had a black edging. The eye bar was prominent. The female was golden, with dark spots on the body and dusky white fins. The male danced around the female, trembling with head inclined downwards, and finally the female deposited her eggs in one effort. The eggs were in a thin sac-like membrane about 20 mm x 10 mm. The male tore the egg sac apart and took each egg into his mouth separately. Young fishes were seen in the aquarium five weeks later. The male paid no attention to them.

During underwater observations in escarpment perennial streams, fish were seen with very different colouration from that normally seen in netted fish. Distinct orange and black stripes extended from the top of the head anteriorly to the snout, and there were other differences in colour. No ripe fish were captured to verify this as a breeding colouration.

A breeding study of *G. aprion* eggs was attempted; 416 eggs were removed from the mouth of a male fish and placed in a small aquarium in the open air. No heat or air was provided in the tank. The eggs (plate 4a) hatched after a day in the tank (the previous incubation period in the buccal cavity was not known). After an initially high mortality (30% died), to which an early morning temperature of 23°C was most likely a contributing factor, the prolarvae survived and grew from 7 mm when first hatched to over 10 mm in 8 days. The remaining larvae all died during one particularly cold night (the temperature at 7.30 a.m. the next morning was 22°C). Island Billabong, where the eggs were collected, had surface and bottom temperatures of 28 and 27°C, respectively, and thus the eggs had experienced quite a reduction in temperature when initially placed in the tank. The prolarvae were well developed at hatching, with well-formed fins and mouth structure. Vertical bands of pigmentation were visible along the body wall and around the head (plate 4b). The newly hatched fish were quite efficient swimmers and would often swim to the surface of the tank.

Summary

Glossamia aprion exhibits aseasonal reproduction. It may spawn throughout the year, and probably throughout all its preferred habitats. Areas of lentic water for the transfer of eggs from the female to the buccal cavity of the male is most likely an important environmental requirement.

Approximately 250 eggs (diameter around 1.5 mm) are spawned at a time (Breder & Rosen 1966). However, Lake (1978) cites a diameter of 3 mm. Recorded incubation times vary from two weeks (Lake 1978) to five weeks (Breder & Rosen 1966). The prolarvae are well developed at hatching, are about 7 mm long, and do not appear to be guarded by the male (Breder & Rosen 1966). Growth is rapid and the yolk sac is almost completely absorbed after a few days.

The bilobed ovaries of *G. aprion* contained eggs grouped into different stages of development. Those most developed were at the anterior end of the ovary. This characteristic may enable each female to spawn more than once a year. Colour differences in the sexes were observed in this species.

Feeding habits

Overall diet

The stomachs of 557 specimens were examined; 425 contained food. The diet of *G. aprion* is summarised in figure 137; the components are listed in table 116. The main components were aquatic insects (36%), macrocrustaceans (23%) and teleosts (17%). The aquatic insects were mainly baetid mayfly larvae, chironomid larvae and pupae, and chaoborinid larvae. The macrocrustaceans were mainly *Macrobrachium* and some *Caridina*.

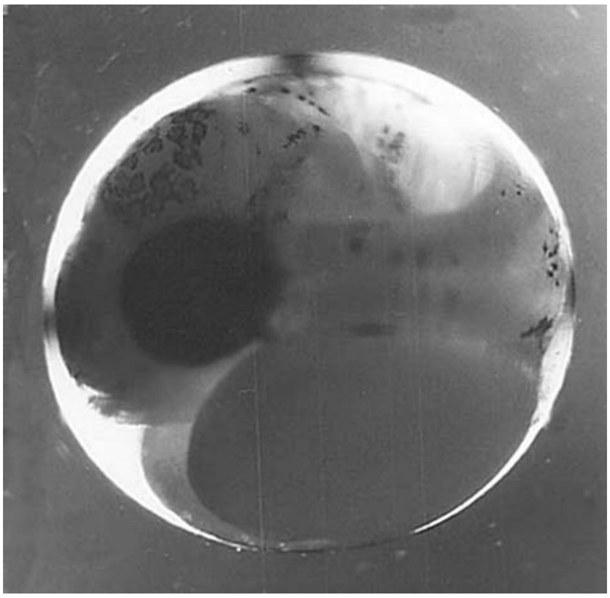
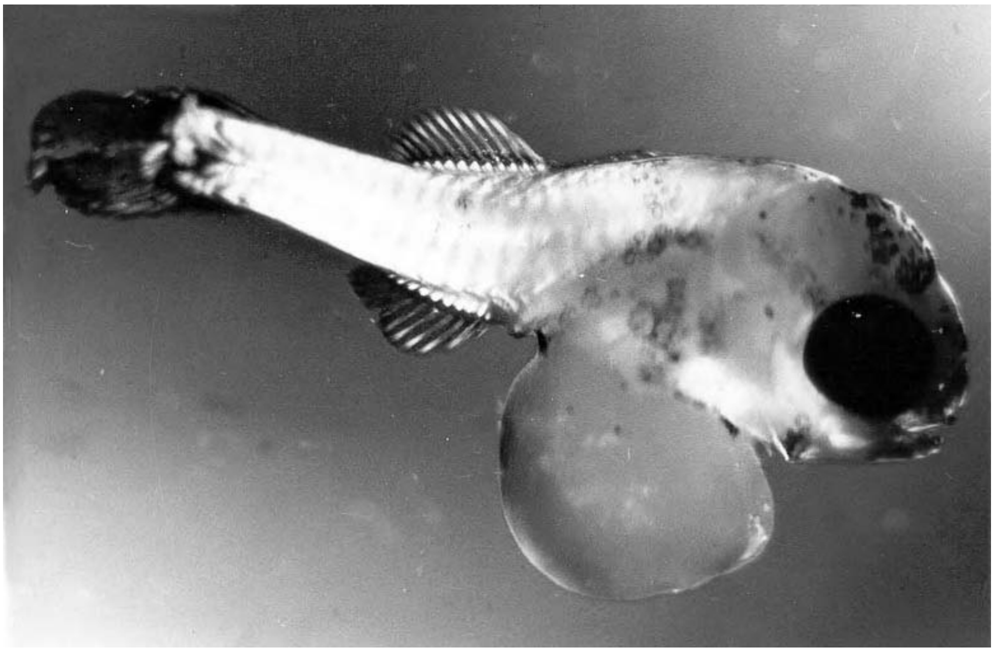


Plate 3 (above) Mature (stage v) ovary from *G. aprion* showing sequential stages of oocyte maturation. Diameter of largest oocytes 1.5 mm; of smallest oocytes 0.2 mm.

a

Plate 4 Stages in the embryonic and larval development of *G. aprion*: (a) fertilised egg x 25, diameter 3.5 mm; (b) newly hatched larva x 25, TL 6.5 mm



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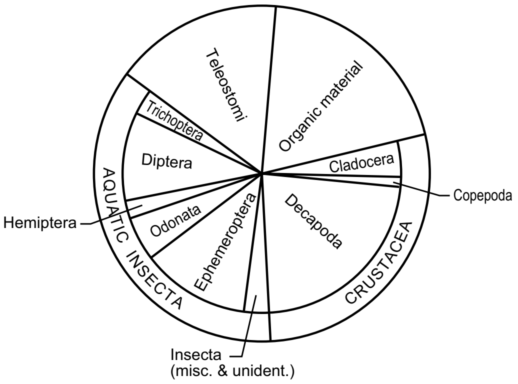

Figure 137 The main component of the diet of *G. aprion*

The three main teleosts of the seven identifiable species were *Ambassis* spp., *M. splendida inornata* and *Craterocephalus* spp. Microcrustaceans (mainly *Diaphanosoma*) were also eaten, as well as traces of algae, hydrophytes, terrestrial plants and animals. Large volumes of unidentifiable organic material, which may have been partly digested fish flesh, were frequently found in the stomachs.[193, 194]

Glossamia aprion can therefore be classified as a macrophagic carnivore feeding opportunistically on benthos and in the midwaters of the waterbodies. Pollard (1974) also noted that it was carnivorous, probably feeding upon small fish, crustaceans and aquatic insects. Lake (1978) commented that this species is carnivorous, and in an aquarium will eat all other fish smaller than itself and any other small moving animals.

Habitat differences [195]

A total of 443 stomachs of *G. aprion* were analysed (all seasons combined) from the Magela Creek catchment: 20 (5% empty) from escarpment mainchannel waterbodies, 10 (40% empty) from lowland sandy creekbeds, 235 (25% empty) from shallow backflow billabongs, 115 (25% empty) from corridor billabongs, and 63 (27% empty) from floodplain billabongs. The highest proportion of fish with empty stomachs were from lowland sandy creekbeds and the lowest proportion from escarpment waterbodies.

Glossamia aprion in the escarpment waterbodies were feeding mainly on aquatic insects (mainly baetids, libellulids and chlorolestids) and small portions of teleosts, microcrustaceans (cladocerans and ostracods) and terrestrial insects. In lowland sandy creekbeds they were also eating mainly aquatic insects (the same odonatans as above plus the mayfly larvae *Atalophlebia* and chironomid pupae), but more teleosts; *M. splendida inornata* was the main identifiable species.

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[193] Barlow et al. (1987) indicated that the piscivorous feeding habits of *G. aprion*, which had been translocated to Lake Eacham in north-eastern Queensland, are likely to be responsible for the local extinction of the Lake Eacham rainbowfish *Melanotaenia eachamensis* (*G. aprion* did not occur in the lake beforehand).

[194] van Zweiten (1995) found the diet of the closely related *G. gjellerupi* from the Sepik-Ramu basin in PNG to vary in relation to the size of individuals. Fish up to 30 mm fed predominantly on small benthic insect larvae. Fish larger than 60 mm were carnivorous top predators, feeding predominantly on crabs, bottom dwelling fish and large terrestrial insects. Fish of all sizes, except the largest, fed on caridinid prawns.

[195] van Zweiten (1995) found the diet of *G. gjellerupi* from the Sepik-Ramu basin in PNG to vary between habitats depending on the local conditions. The most obvious differences occurred between large rocky streams with high flow rates and small muddy streams with lower flow rates. In this habitat order, the proportions of food from terrestrial sources decreased and caridinid prawns increased.

Table 116 Dietary composition of *G. aprion*

	Habitat							Season								
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																
Algae																0.1
Conjugatophyta																
Mougeotia	–	–	–	–	1.3	–	–	–	–	–	–	0.6	–	–	0.1	
Hydrophytes																+
Najas	–	–	–	–	–	–	0.3	–	–	–	–	0.1	–	–	+	
Aquatic animals																
Microcrustacea																4.4
Conchostraca																
Cyzicus	–	–	–	–	–	–	2.6	–	–	–	–	–	2.3	–	0.2	
Cladocera																
Miscellaneous	–	–	0.2	2.8	–	–	–	0.5	6.0	–	–	–	–	–	0.7	
Diaphanosoma	2.1	–	1.9	7.8	0.3	–	–	–	16.8	0.8	0.5	2.8	–	–	2.5	
Ostracoda	2.1	–	–	–	–	–	–	–	–	1.3	–	–	–	–	0.1	
Copepoda	0.3	–	0.6	0.8	–	–	5.3	–	1.8	2.2	2.3	–	–	–	0.9	
Macrocrustacea																22.8
Phreatoicidea	–	–	–	–	–	5.7	–	–	–	–	–	0.8	–	–	0.2	
Macrobrachium (juv)	–	–	9.9	41.6	34.8	14.3	21.1	2.4	1.0	6.3	–	–	–	–	1. 3	
Macrobrachium (adults)	–	–	2.3	0.4	2.2	–	–	45.9	22.5	10.2	9.2	17.9	21.9	6.3	21.3	
Insecta																36.1
Fragmented	7.9	–	3.0	1.2	3.7	–	–	4.5	2.5	3.1	3.5	0.9	4.0	–	2.8	
Ephemeroptera																
Baetidae	17.6	–	16.7	6.2	0.1	20.0	17.4	6.8	2.3	18.4	16.2	19.7	–	5.6	12.1	
Atalophlebia	4.7	16.7	–	–	–	–	–	–	2.5	–	–	–	–	5.6	0.5	
Tasmanocoenis	–	–	–	–	–	4.3	–	–	–	–	–	0.6	–	–	0.1	
Odonata																
Chlorolestidae	9.0	–	–	–	–	–	–	–	–	3.5	–	–	–	–	0.4	
Coenagrionidae	–	16.7	–	1.2	–	–	–	–	5.0	–	–	–	–	–	0.5	
I. heterosticta	4.7	–	3.3	–	2.5	–	–	–	–	8.1	3.6	–	–	5.6	1.9	
Libellulidae	10.5	16.7	1.4	0.5	–	8.6	–	–	2.5	7.1	3.5	0.6	–	–	1.9	

Table 116 continued

	Habitat							Season							Overall	
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Hemiptera																
Naucoridae	–	–	0.6	–	–	–	0.3	–	–	–	–	1.0	–	–	0.3	
Corixidae	6.8	–	2.5	0.5	5.0	2.1	–	0.7	0.3	6.9	4.0	1.2	–	6.3	2.3	
Coleoptera																
Miscellaneous (adults)	–	–	0.7	–	–	–	–	–	–	–	0.2	–	2.3	–	0.3	
Miscellaneous (larvae)	4.5	–	0.2	–	–	–	–	–	1.0	1.8	–	–	–	–	0.3	
Diptera																
Tipulidae	0.3	–	–	–	–	–	–	–	–	–	–	–	–	0.3	+	
Culicidae	–	–	0.6	–	–	–	–	–	–	2.1	–	–	–	–	0.2	
Chaoborinae	–	–	1.3	–	–	–	–	–	5.0	1.7	0.3	–	–	50.0	2.6	
Chironomidae (larvae)	4.7	–	1.6	7.4	4.5	2.9	7.9	8.9	2.3	3.3	4.7	1.3	6.3	1.9	4.4	
Chironomidae (pupae)	5.3	16.7	1.7	4.2	1.9	8.6	7.9	3.1	–	–	2.1	6.8	4.7	–	3.2	
Ceratopogonidae	–	–	0.3	–	–	–	–	0.2	–	–	–	–	0.7	–	0.1	
Trichoptera																
Leptoceridae	–	–	3.2	1.2	–	–	3.7	–	3.3	1.9	0.8	3.2	4.7	–	3.2	
Teleostomi																16.9
Fragmented	9.0	16.7	12.6	6.5	10.8	14.3	10.5	5.9	12.5	9.4	10.4	12.3	14.0	–	10.0	
Scale	–	–	0.1	–	–	–	–	–	–	–	–	1.0	0.5	–	0.1	
Miscellaneous (larvae)	5.0	–	0.6	1.2	–	–	–	–	–	–	1.2	1.0	–	5.9	0.7	
N. erebi	–	–	0.5	–	–	–	–	–	2.0	–	–	–	–	–	0.2	
M. splendida inornata	–	16.7	0.6	1.2	–	–	2.6	–	5.0	–	1.2	0.9	–	–	0.9	
Craterocephalus spp.	–	–	0.6	0.5	4.4	–	–	3.5	1.0	–	–	–	–	–	0.8	
C. marianae	–	–	–	–	–	–	–	1.2	–	–	–	–	–	–	0.2	
P. tenellus	–	–	–	–	1.7	–	2.4	–	–	1.9	0.9	–	–	–	0.4	
Ambassis spp.	–	–	5.1	1.2	–	–	2.4	4.7	–	–	3.5	4.6	–	–	2.8	
A. agrammus	–	–	0.6	–	–	–	–	1.2	–	–	–	–	–	–	0.2	
Glossogobius spp.	–	–	0.6	–	–	–	–	–	–	–	–	–	–	6.3	0.2	
Egg material	–	–	–	1.1	–	–	–	–	–	–	–	–	2.1	–	0.2	
Glossamia spp. eggs	–	–	0.6	–	–	–	–	–	2.5	–	–	–	–	–	0.2	

Table 116 continued

	Habitat							Season							Overall	
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Terrestrial plants																
Angiospermae																0.3
Miscellaneous	–	0.5	–	–	–	–	–	0.6	–	–	–	–	1.9	–	0.3	
Terrestrial animals																
Insecta																0.4
Fragmented	5.3	–	–	–	–	–	–	–	–	–	–	–	–	6.3	0.2	
Trichoptera	–	–	–	–	–	5.0	–	–	–	–	–	0.7	–	–	0.2	
Parasites																0.5
Cestoda	–	–	0.5	–	–	–	–	–	–	1.7	–	–	–	–	0.2	
Nematoda	–	–	–	–	–	–	–	1.3	–	–	–	–	–	–	0.3	
Inorganic material	0.3	–	0.6	–	–	–	–	1.2	–	0.1	–	–	–	–	0.2	0.2
Organic material	–	–	25.1	12.8	27.0	14.3	15.8	7.5	2.5	8.3	32.2	22.9	34.9		18.5	18.5
Number of empty fish	1	4	58	29	17	3	12	18	7	10	26	49	19	3	132	132
Number of fish with food	19	6	177	86	46	14	38	85	40	48	87	106	43	16	425	425

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs; Fb = floodplain billabongs

In the lowland backflow billabongs the diet was more varied (possibly due to the larger sampling effort), with mainly equal proportions of aquatic insects (mainly baetids) and teleosts (mainly *Ambassis* spp., but also *N. erebi, M. splendida inornata, Craterocephalus* spp.and *Glossogobius* spp.), and some macrocrustaceans (*Macrobrachium* and *Caridina*) and microcrustaceans. Partly digested *Glossamia* eggs, which had been buccally incubating, were also found in the stomachs along with large volumes of unidentified organic matter. In the corridor waterbodies the diet was based mainly on macrocrustaceans (mainly *Caridina* and *Macrobrachium*) and fairly equal proportions of aquatic insects (mainly chironomid larvae and pupae), microcrustaceans (mainly the cladoceran *Diaphanosoma*) and teleosts (*Ambassis* spp., *M. splendida inornata* and *Craterocephalus* spp. were identifiable). In the floodplain billabongs the diet was similar, with the main differences being the larger proportions of unidentified organic matter, and the lack of microcrustaceans. *Craterocephalus* spp. and *Pseudomugil* spp. were the main identifiable teleosts eaten.

Catchment differences

The stomach contents of 67 specimens were analysed (all seasons combined) from Nourlangie Creek catchment: 17 (18% empty) from lowland sandy creekbeds and 50 (24% empty) from shallow backflow billabongs. These levels of emptiness were similar to those of fish in the Magela system.

In the lowland sandy creekbeds the diet was based primarily on aquatic insects (mainly baetids, libellulids and chirinomid larvae and pupae) and significant portions of macrocrustaceans (mainly *Caridina* and phreatoicids), teleosts and terrestrial insects. This diet is most similar to that in the backflow billabongs in the Magela catchment. In the backflow billabongs of the Nourlangie catchment the diet was also similar to that in the Magela catchment, but was more varied. It included aquatic insects (mainly baetids and chironomids), macrocrustaceans (*Caridina*), teleosts (*M. splendida inornata, P. tenellus* and *Ambassis* spp.), microcrustaceans, and traces of incidentally ingested hydrophytes (*Najas*).

Seasonal changes

In sampling periods 1 to 7, respectively, 103 (17% empty), 47 (15% empty), 58 (17% empty), 113 (23% empty), 155 (32% empty), 62 (31% empty) and 18 (17% empty) stomachs were analysed (all habitats combined). The highest proportion of fish with empty stomachs were found in the 1979 Mid- and Late-dry seasons, while all other seasons had fairly equal proportions of fish with empty stomachs.

In the 1978 Late-dry season the diet was based mainly on macrocrustaceans (*Macrobrachium* and *Caridina*), with aquatic insects (mainly chironomids and baetids), teleosts (mainly *Ambassis* spp. and *Craterocephalus* spp.) and traces of microcrustaceans and terrestrial plant material. During the 1978–79 Early-wet season *G. aprion* ate fewer macrocrustaceans but ate microcrustaceans (mainly *Diaphanosoma*) and more teleosts (mainly *N. erebi, M. splendida inornata* and *Craterocephalus* spp.). In the Mid-wet season the microcrustacean component was smaller, as were the macrocrustacean and teleost components; the aquatic insects therefore dominated the diet in this season, with baetids, *Ischnura heterosticta* larvae, libellulid larvae and corixids being most commonly found in the stomachs.

By the Late-wet–Early-dry season a large unidentified organic material component — possibly partly digested fresh fish — was present in the diet. It persisted to the 1979 Late-dry season and then disappeared.

The diet at the end of the Wet season consisted mainly of aquatic insects (mainly baetids), teleosts (*M. splendida inornata, Ambassis* spp. and *P. tenellus*), macrocrustaceans

(*Macrobrachium*) and traces of microcrustaceans. In the Mid-dry season the diet became more varied, though baetids were still the main food items; however, there were more *Macrobrachium* and teleosts (*Ambassis* spp. and *M. splendida inornata*) and traces of microcrustaceans, algae, hydrophytes and terrestrial plants. In the 1979 Late-dry season *G. aprion* ate mainly macrocrustaceans, as in the 1978 Late-dry season; teleosts and aquatic insects (mainly chironomids) were also present in the stomachs, together with traces of microcrustaceans and terrestrial plant material. In the 1979–80 Early-wet season they ate mainly aquatic insects (mainly chaoborinids), unlike in 1978–79 when microcrustaceans became important in the diet, and also teleosts, *Macrobrachium* and terrestrial insects.

Fullness

A summary of mean fullness indices of *G. aprion* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 117. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 117 Mean fullness indices for *G. aprion* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

	Sampling period							
Habitat	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites)								
Upstream of RUPA:								
Escarpment main-channel waterbody	n/s	n/s	2.2 (14)	n/s	0 (1)	n/s	3.2 (5)	2.3 (20)
Lowland shallow backflow billabong	3.4 (11)	n/s	3.4 (8)	n/s	0.9 (7)	1.4 (10)	n/s	2.4 (36)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	4.0 (5)	n/s	0 (2)	0.3 (3)	n/s	n/s	2.0 (10)
Lowland channel backflow billabong	0 (1)	4.0 (3)	2.3 (12)	1.6 (24)	1.1 (27)	0.5 (14)	0.7 (3)	1.8 (84)
Lowland shallow backflow billabong	2.3 (6)	2.5 (6)	1.2 (6)	1.8 (37)	1.5 (47)	0.9 (12)	0 (1)	1.6 (115)
Corridor sandy billabong	3.0 (10)	2.5 (2)	0 (1)	n/s	1.0 (10)	0 (1)	n/s	1.9 (24)
Corridor anabranch billabong	1.7 (3)	n/s	n/s	0.7 (3)	2.3 (10)	2.0 (4)	n/s	1.9 (20)
Floodplain billabong	2.4 (36)	3.0 (25)	1.5 (2)	1.4 (34)	1.5 (24)	1.0 (14)	n/s	1.9 (135)
Nourlangie Creek catchment (regular sites)								
Lowland channel backflow billabong	2.8 (5)	0 (1)	1.8 (4)	0.8 (10)	2.0 (10)	1.7 (7)	n/s	1.7 (37)
Lowland shallow backflow billabong	2.0 (5)	0 (1)	0 (1)	n/s	2.2 (6)	n/s	n/s	1.8 (13)
Lowland sandy creekbed	n/s	1.7 (3)	n/s	2.3 (4)	1.9 (10)	n/s	n/s	2.0 (17)
Seasonal mean (all sites)	2.6	3.0	2.1	1.5	1.5	1.1	2.3	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment upstream of RUPA, the mean fullness indices were slightly higher than in downstream habitats. Escarpment mainchannel waterbody and shallow backflow billabong indices were very similar.

Downstream of RUPA, the mean fullness indices were much the same across most habitats examined, though slightly lower in the shallow backflow billabongs.

In the Nourlangie catchment, the mean fullness indices were close to those recorded in comparable habitats in the Magela Creek catchment.

Seasonal changes

The mean fullness index (all habitats combined) increased from the 1978 Late-dry season to peak in the 1978–79 Early-wet season. It then fell through the Mid-wet season to stabilise at a lower level during the Late-wet–Early-dry and 1979 Mid-dry seasons. In the 1979 Late-dry season it fell to a much lower level than in the 1978 Late-dry season, but then rose in the 1979–80 Early-wet.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland sandy creekbed; 1978–79 Early-wet season
- lowland channel backflow billabongs; 1978–79 Early-wet season
- lowland shallow backflow billabong (upstream of RUPA); 1978 Late-dry season
- lowland shallow backflow billabong (upstream of RUPA); 1978–79 Mid-wet season

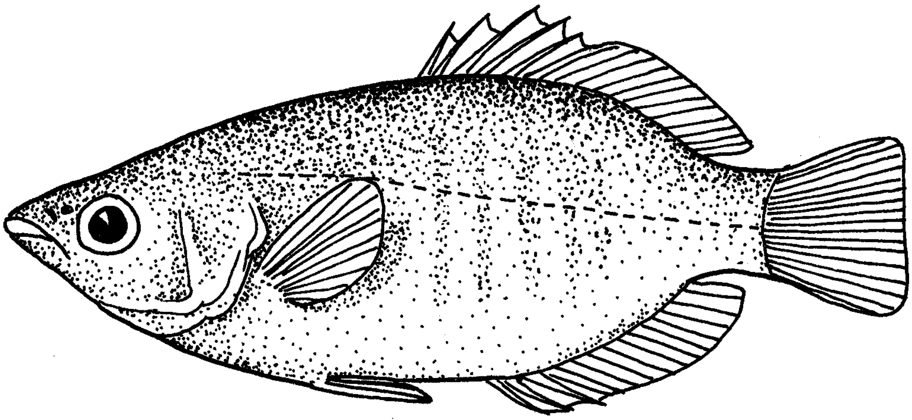
Nourlangie catchment

- lowland channel backflow billabongs; 1978 Late-dry season
- lowland sandy creekbeds; 1979 Late-wet–Early-dry season.

Family TOXOTIDAE

3.30 *Toxotes lorentzi* (Weber)

Toxotes lorentzi is commonly known as the primitive archer fish. It has been reported in the Northern Territory only in the Timor Sea drainage (map 3) at Yam Creek (Daly River system) by Whitley (1959), the Finniss River (below Rum Jungle) by Jeffree and Williams (1975), and at Sawcut, Deaf Adder and Baroalba Creeks (South Alligator River system) by Midgley (1973). W Rooney (pers comm) collected one specimen from Nourlangie Rock Billabong (NR) during the 1979–80 Wet season. *Toxotes lorentzi* is known from the Merauke River and the vicinity of Balimo in the central portion of southern New Guinea (Allen 1978b).[196]



Toxotes lorentzi

Information on catches at each site and in each season is given in volume 2. Only two specimens were captured: one from an escarpment mainchannel waterbody (Camp 1, Deaf Adder Creek) and another from a lowland channel backflow billabong (Baroalba Crossing) of the Nourlangie Creek systems; many specimens were observed in an escarpment perennial stream (Baroalba Springs) in this catchment.

Size composition

The length and weights of two specimens were determined. The smallest specimen (110 mm LCF) was captured in the Mid-wet season in a channel backflow billabong (Baroalba Crossing), and the largest (230 mm LCF) in the 1978 Late-dry season in an escarpment mainchannel waterbody (Deaf Adder). Smaller specimens (80–90 mm LCF) were observed in an escarpment perennial stream during the Mid-wet and Late-wet–Early-dry seasons.

Allen (1978b) examined specimens ranging from 69–150 mm TL in a recent taxonomic revision of the Toxotidae, and Lake (1971) recorded that *T. lorentzi* grew to only 140 mm. The largest specimen captured during the present study is thus the largest *T. lorentzi* recorded.

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[196] Allen (1991) noted that *T. lorentzi* is widespread in the Fly River delta area. In PNG it inhabits swamps and well-vegetated margins of streams.

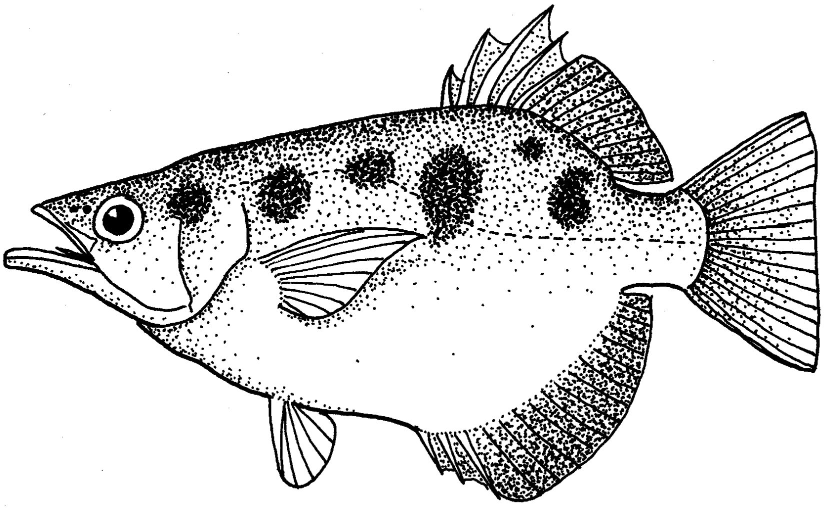
Feeding habits

No stomachs of *T. lorentzi* were examined in the present study. No literature on its feeding habits was found. However, *T. lorentzi* was observed to eject an aqueous bullet when preying upon small insects on overhanging terrestrial vegetation (W. Rooney, pers comm). This species is generally observed in surface waters, and probably has large terrestrial insect component in its diet, as does *T. chatareus*.

Family TOXOTIDAE

3.31 *Toxotes chatareus* (Hamilton-Buchanan)

Toxotes chatareus, commonly called archer fish or riflefish or seven spot[197] archerfish, has a relatively widespread distribution. The coastal populations in northern Australia extend approximately between Derby in WA and Townsville on the Pacific coast of Queensland. Freshwater populations are distributed in river systems flowing into the Timor and Arafura seas and the Gulf of Carpentaria (Allen 1978b). *Toxotes chatareus* is capable of penetrating far inland: Lake (1971) reported finding it 200 km up the Gregory River in northern Queensland; Pollard (1974) noted that it appeared to be common in all permanent freshwaters in the Region; Miller (in Taylor 1964) found many specimens in large billabongs in the Oenpelli area. It is also recorded from India, Sri Lanka, Malay Peninsula, Thailand, Vietnam, Singapore, Sumatra, Borneo and Papua New Guinea.[198]



Toxotes chatareus

Detailed information on catches at each site and in each season are given in volume 2. In summary, this species was found commonly in corridor and escarpment mainchannel waterbodies, and in most floodplain and backflow billabongs and sandy creekbed habitats. Specimens were found in escarpment perennial streams only in the Nourlangie Creek system; they were found in lower riverine floodplain billabongs and tidal and estuarine middle/lower reach habitats of the East Alligator River. In the 1978 Late-Dry season it was captured in only 6 sites (mainly escarpment mainchannel and corridor waterbodies); during the Mid-wet it had dispersed to 13 sites (with notable colonisation of backflow billabongs and floodplain billabongs); and by the Late-wet–Early-dry season it was found in 14 sites (sandy creekbed habitats, lowland backflow billabongs, and corridor and escarpment mainchannel waterbodies).

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[197] Archerfish have a series of six to seven alternating large and small black blotches along the sides of the body (Herbert & Peeters 1995).

[198] Allen (1991) indicated that in PNG *T. chatareus* has only been recorded from southern drainages at numerous localities between the Purari River area and Bintuni Bay, including Lake Jamur. It inhabits brackish mangrove estuaries and freshwater streams. It is frequently found well inland, for example as far as 800 km upstream in the Fly River.

Size composition

The lengths and weights of 290 specimens were determined. *Toxotes chatareus* was captured by seine nets (10 mm mesh), gillnets and dipnet; underwater observations indicated that for a given clear water sampling site, the specimens captured by the various netting methods reflected those observed in the waters. In the 1978–79 Early-wet season large numbers of juveniles were observed in surface waters; these were captured in dipnet trawls.

Length–weight relationship

The length–weight relationship for the sexes combined was described by the following expression:

$$W = 2.1 \times 10^{-2} L^{2.97} \qquad r = 0.99 \text{ (length in cm, weight in g)}$$

Haines (1979) gave the following length–weight expression (using the same units) for *T. chatareus* captured in the Purari River, Papua New Guinea.

$$W = 1.1 \times 10^{-2} L^{3.14}$$

Seasonal mean lengths, weights and condition factors are shown in table 118. The seasonal condition factor was very high during the 1978 Late-dry season and then fell to unity (probably due to spawning activity) by the 1978–79 Early-wet season. Condition remained stable through the Mid-wet and Late-wet–Early-dry seasons and then fell dramatically during the 1979 Mid-dry season, when mostly juveniles were captured. It improved into the 1979 Late-dry (probably because more adults were captured from escarpment mainchannel waterbodies) but did not reach the level recorded in the 1978 Late-dry season. Environmental conditions in the 1978 Dry season were more favourable to condition than in the 1979 season.

Table 118 Mean length, mean weight and condition factor for *T. chatareus*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	37	171.6	101.03	1.05
Early-wet (1978–79)	60	149.3	65.26	1.00
Mid-wet	61	82.5	10.89	1.00
Late-wet–Early-dry (1979)	38	79.2	10.02	1.00
Mid-dry	18	105.0	22.38	0.76
Late-dry	15	174.2	96.88	0.95
Overall	229	115.5	30.14	1.00

Length-frequency distribution

Specimens ranged in length from 4 mm LCF to 307 mm LCF (fig 138). The largest specimen known (400 mm TL) was captured by Roberts (1978) from the Fly River catchment, Papua New Guinea; the smallest specimen recorded by Roberts was 8 mm TL. Haines (1979) captured *T. chatareus* ranging in lengths from 80 to 330 mm TL in the Purari River, Papua New Guinea.

The mean length of all specimens captured was 115 mm LCF. The length at first sexual maturity was found to be 180–190 mm LCF, indicating that most of the fish captured were small juveniles. There are three major peaks in the length-frequency distribution, with modes at 20, 90 and 222 mm LCF. Few specimens between 110 and 200 mm LCF were captured.

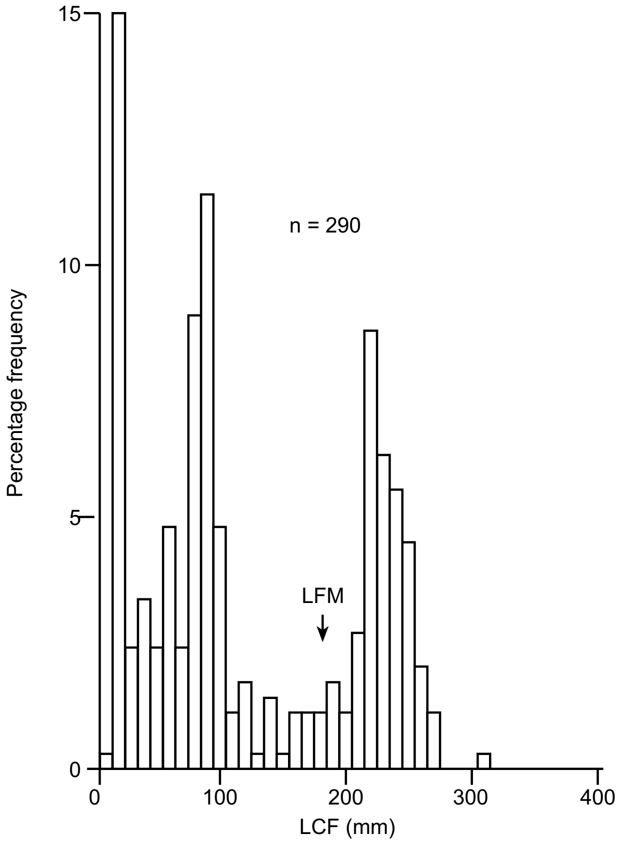

Figure 138 Length-frequency distribution of all *T. chatareus* captured

Seasonal changes in distribution

Seasonal length-frequency distributions of all *T. chatareus* captured are given in figure 139.

Most of the smallest juveniles were captured during the 1978–79 Early-wet season; a few were also caught during the Late-dry seasons (especially in 1978). The juveniles therefore appear to recruit to the populations mainly during the Early-wet season, though small numbers may be recruited in the Late-dry season (juveniles were observed even during the 1979 Mid-dry season).

The largest adult specimen was captured in the 1979 Late-dry season, but all other seasons except the Late-wet–Early-dry season had similar-sized specimens. During the Late-wet–Early-dry season no adults were sampled (so they were presumably in an unsampled habitat) and the largest specimen captured was 160 mm LCF.

The mean seasonal lengths of all specimens captured are shown in table 118. The mean lengths decreased slightly during the 1978–79 Early-wet season and reduced even further in the ensuing two seasons to reach a low by the Late-wet–Early-dry season when the juvenile recruits became more common in the populations. The mean lengths then increased through the following 1979 Mid-dry season, and by the 1979 Late-dry season they were similar to those recorded in the Late-dry 1978. The increase in mean lengths may have been caused by the growth of the juveniles and the increased catchability of adult specimens.

Growth rate

No published information on growth studies of *T. chatareus* could be found. Growth rates can be estimated for the juveniles spawned in the 1978–79 Early-wet season by following the progression of their size class (A on fig 139) throughout the remainder of the study. Growth appears to be fastest during the Wet season, with specimens attaining 70–90 mm LCF by the

Late-wet–Early-dry season (period of about 6 months). For the remainder of the Dry season, growth appears to be very slow, with only a further 10–20 mm being attained by the 1979 Late-dry season. The growth and survival of juveniles in the 1979 Dry season appears to be less than that recorded for juveniles spawned in the 1977–78 Early-wet season (B on fig 139).

Juveniles therefore do not appear to attain the LFM by the end of their first year; they probably spawn by the end of their second year.

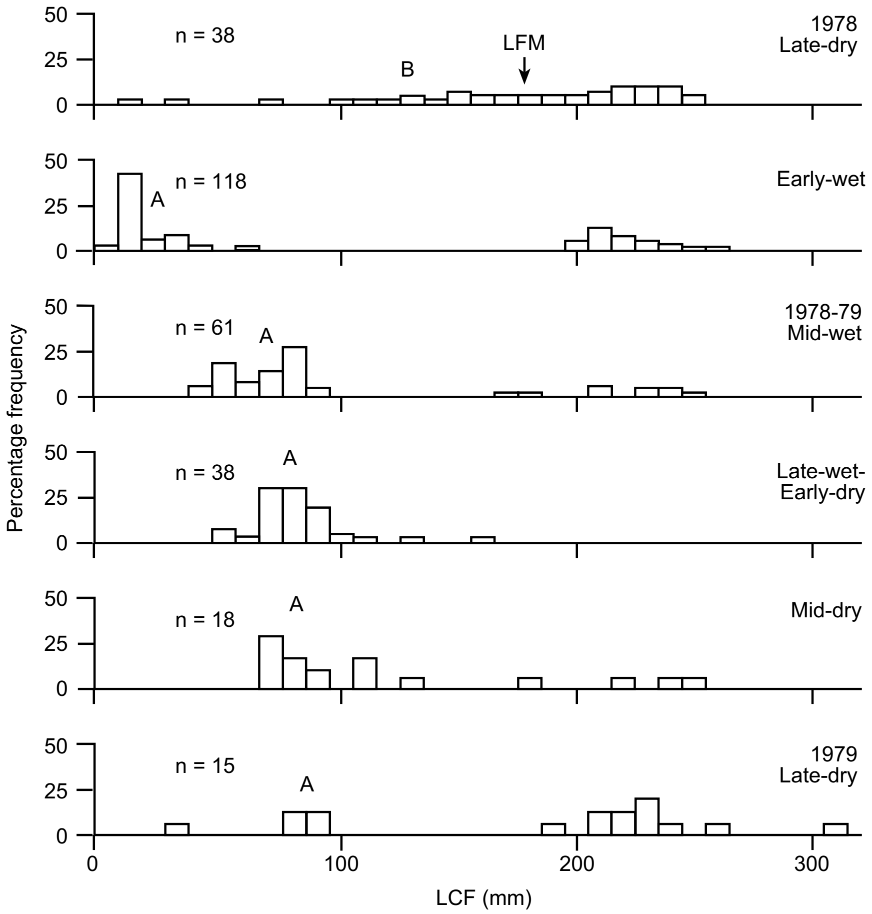

Figure 139 Seasonal length-frequency distribution of all *T. chatareus* captured

Habitat differences in distribution

The habitat preferences of all *T. chatareus* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are shown in figure 140.

Magela catchment

The smallest juveniles were found mainly in lowland shallow backflow billabongs, although a few were found in escarpment mainchannel waterbodies. The few large juveniles that were collected were found in lowland channel backflow billabongs and, to a lesser extent, in corridor anabranch billabongs. Medium-sized juveniles were found mainly in channel backflow and shallow backflow billabongs, and to a lesser extent in floodplain billabongs (these may have been swept downstream by the Wet season flow) and sandy creekbeds upstream and downstream of RUPA.

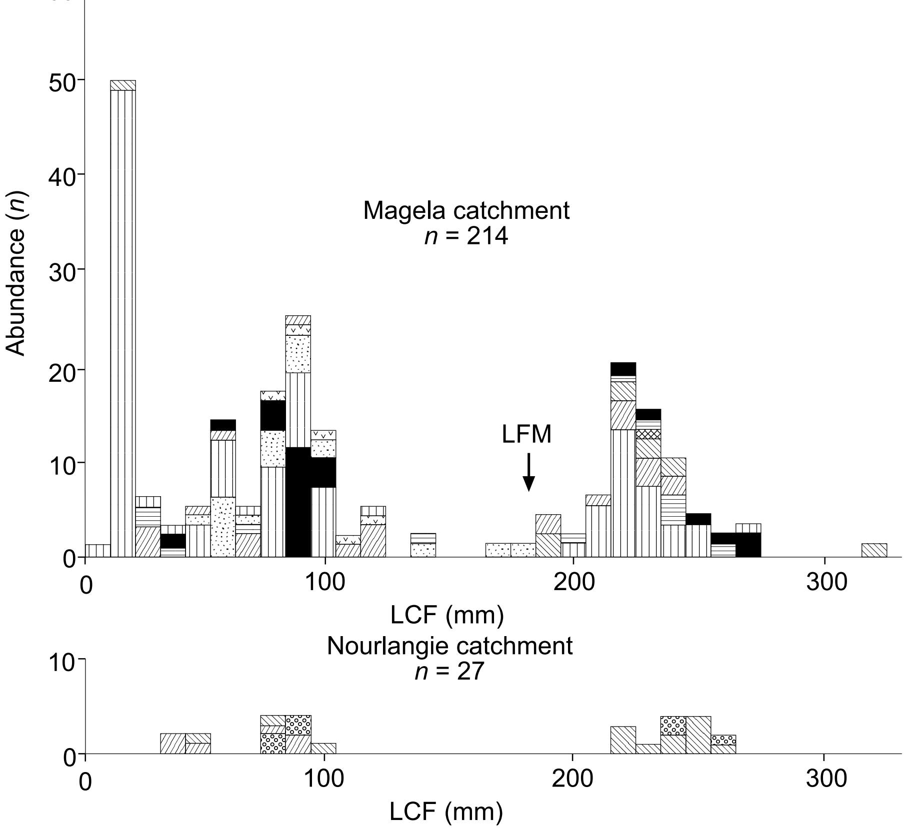

Figure 140 Length-frequency distribution and habitat preferences of all *T. chatareus* captured at regular sampling sites (see appendix 5 for key to the habitats)

The largest adult was found in an escarpment mainchannel waterbody. Most of the small adults were found in lowland shallow backflow billabongs, and a few in lowland sandy creekbeds and escarpment mainchannel waterbodies. Some small adults were also found in floodplain and corridor waterbodies.

Nourlangie catchment

Small- to medium-sized juveniles were found in sandy creekbeds, shallow backflow billabongs and in escarpment mainchannel waterbodies. Juveniles also appeared in escarpment perennial streams during the Wet season.

Adults were found mainly in escarpment mainchannel waterbodies and, to a lesser extent, in lowland shallow backflow billabongs. Some adults were observed in the lower reaches of an escarpment perennial stream during the 1979 Mid-dry season.

Environmental associations

Rank numbers for *T. chatareus* for the physico–chemical and habitat–structural parameters are shown in table 155.

Physico–chemical variables

Temperature

Toxotes chatareus was found in waters with surface temperatures ranging from 26 to 36°C (mean = 30.8°C), and with bottom temperatures ranging from 24[199] to 34°C (mean 29.5°C).

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[199] Merrick and Schmida (1984) indicate that *T. chatareus* can withstand temperatures down to 17°C.

These mean temperatures were close to the median values for all species studied, and both ranked at the base of the upper-middle quarter (see fig 170). Tolerance to this range of water temperature is indicative of the wide distribution of the species, from brackish-estuarine waters and river mouths to escarpment streams (Pollard 1974).

Dissolved oxygen

Dissolved oxygen concentrations in waters from which *T. chatareus* was captured ranged from 4.3 to 9.7 mg/L (mean = 6.3 mg/L) on the surface and from 0.2 to 7.4 mg/L (mean = 4.0 mg/L) on the bottom. These means ranked in the upper-middle and lower-middle quarters respectively (see fig 171).

Visibility

Secchi depths recorded in waters from which *T. chatareus* were captured ranged widely from 1 to 360 cm, with a mean of 83 cm (see fig 172). This mean was ranked at the base of the upper-middle quarter. This species was very pale in colouration when taken from highly turbid waters.

pH

Toxotes chatareus was found in waters with pH values ranging from 4.6 to 7.2 (mean = 6.1) on the surface, and from 4.8 to 7.3 (mean = 5.8) on the bottom (see fig 173). These means were both ranked at the base of the lower-middle quarter, indicating a slight tendency to be found in more acidic waters.

Conductivity

Conductivity values for waters in which *T. chatareus* were found ranged from 2 to 420 µS/cm in surface waters, and from 2 to 440 µS/cm in bottom waters. This species' tolerance of wide salinities has been reported by Pollard (1974) and Mees and Kailola (1977), who found it in waters ranging from brackish coastal to fresh inland. In the present study, specimens of *T. chatareus* were found in the East Alligator River in waters with salinity levels of up to 18 ppt.[200]

Habitat–structural variables

Substrate

In accordance with its wide distribution, *T. chatareus* was found in association with the entire range of substrate types defined in this study. Sand was the most dominant (upper-middle quarter), followed by mud (lower-middle quarter), then clay, leaves, gravel, rocks and boulders (see fig 174).

Hydrophytes

This species was found in waters with moderate vegetation content (vegetation-occurrence index 67.8%). Submergent vegetation was dominant, followed by emergent then floating hydrophytes. This species usually feeds by dislodging insects from overhanging vegetation (Lake 1971, Pollard 1974), so the presence of bank vegetation may influence the distribution of the species.

Reproduction

A total of 290 *T. chatareus* were captured; the reproductive condition of 284 was examined. A total of 162 were sexually indistinguishable (length range 4–112 mm LCF), 40 were female (82–260 mm LCF) and 82 were male (80–307 mm LCF).

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[200] Allen (1991) noted that in PNG breeding populations of *T. chatareus* are known from both fresh and brackish water.

Length at first maturity

The smallest maturing fish found were a 156 mm female and a 120 mm LCF male. As only a small number of medium-sized fish (100–190 mm LCF) were captured, the LFM could not be accurately estimated. High percentages of mature fish were consistently found above 180 mm for males and 190 mm for females, so the LFM was set at those lengths (fig 141).

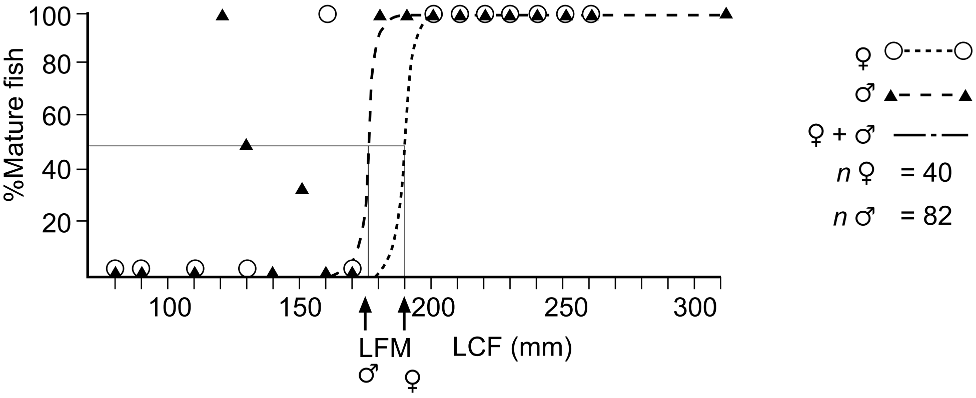


Figure 141 Estimated length at first maturity (LFM) of *T. chatareus*

Sex ratio

Over twice as many males as females were captured during the study. Chi-squared tests for each season on both all fish sampled and the adult fish only (table 119) indicated significantly more males in both samples during the 1978 Late-dry and 1978–79 Early-wet season. Over the entire length range, more males were identified during the 1978–79 Mid-wet season and 1979 Mid-dry season. In all other seasons the sex ratio was not significantly different from 1:1.

Haines (1979) found significantly more males than females in the total sample from the Purari River system; however, when divided into estuarine and riverine samples the deviation from 1:1 in the estuaries was not significant though there was a significant preponderance of males over females in the rivers. Haines suggested that either more males than females move up the rivers or that riverine populations are under some stress that reduces the proportion of females.

Sex ratios (male:female) for other major habitat types in the Magela Creek system, all seasons combined, are as follows:

Escarpment mainchannel waterbodies	2:5
Lowland sandy creekbeds	11:3
Backflow billabongs	28:12
Corridor waterbodies	7:6

A chi-squared test on these ratios found significant differences from a 1:1 ratio in the sandy creek habitats (0.01 <P <0.05) and the backflow billabongs (0.01 <P <0.05) with more males than females in both cases. The ratio was not significantly different from 1:1 in the escarpment area of Magela Creek, but the sample size was small. If the fish captured from the escarpment mainchannel waterbodies in the South Alligator system were added to the data, the ratio becomes 15 males to 13 females.

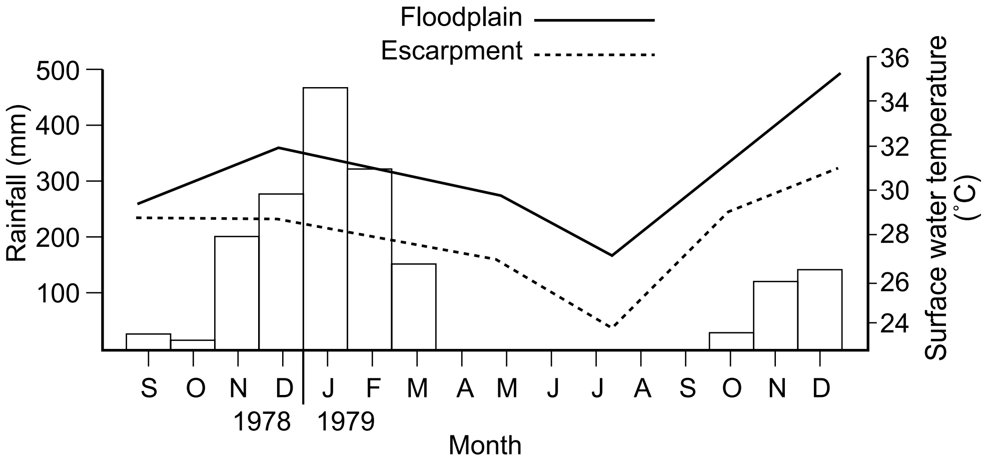
Table 119 Seasonal changes in sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) for *T. chatareus* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	8	11	3	3	6	8	1
+ adults	M	*n*	25	37	10	2	0	7	1
		χ^2	8.8	14.1	3.8	0.2	6.0	0.1	0.0
		P	**	***	*	n.s.	*	n.s.	n.s.
Adults only	F	*n*	6	11	3	0	3	5	1
	M	*n*	16	37	9	0	0	6	0
		χ^2	4.5	14.1	3.0	0	3.0	0.1	1.0
		P	**	***	n.s.	n.s.	n.s.	n.s.	n.s.
GSI	F	mean	1.02	5.3	0.5	–	0.4	1.5	4.9
Adults only		s.d.	0.4	2.4	0.1	–	0.1	0.5	–
	M	mean	1.9	1.9	0.5	–	–	1.0	–
		s.d.	3.3	1.4	0.7	–	–	0.3	–
	F+M	mean	1.5	3.6	0.5	–	–	1.2	–
		s.d.	2.6	2.7	0.6	–	–	0.4	–
GMSI									
Adults only	F	mean	3.7	5.0	2.0	–	2.3	4.3	4.0
		s.d.	0.7	0.6	0.	–	0.6	0.5	–
	M	mean	4.7	6.0	2.1	–	–	4.8	–
		s.d.	0.8	0.1	0.1	–	–	1.8	–
	F+M	mean	4.3	5.6	2.0	–	–	4.6	–
		s.d.	0.9	0.5	0.1	–	–	1.3	–

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.01$; *** = $P < 0.001$; s.d. = standard deviation

Breeding season

Toxotes chatareus appeared to have a well-defined breeding season around the 1978–79 Early-wet season. Gonads began to develop in the 1978 Late-dry season (fig 142). The female GSI had a higher peak during the breeding season than the male. Males showed very little change in GSI from the early development period of the 1978 Late-dry season to the actual spawning period in the Early-wet season. Males have been reported to ripen earlier in the season than females (Midgley 1980). The GSIs for both sexes had dropped to their lowest levels by the following 1978–79 Mid-wet season. Due to the small number of fish collected during the 1979–80 Early-wet season, it could not be determined whether *T. chatareus* was spawning before the onset of the Wet season proper (ie heavy and consistent rains and associated stream flow); however, some juveniles were observed in corridor waterbodies.



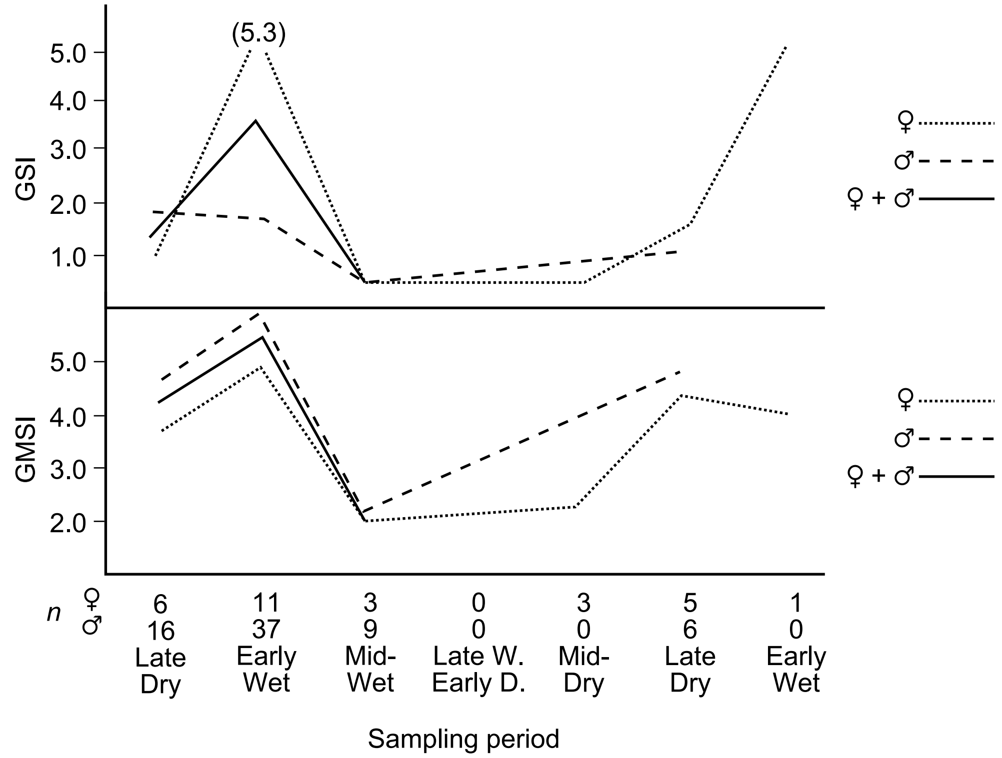


Figure 142 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *T. chatareus*

The occurrence of mature, ripe and spent fish (table 120) confirms an Early-wet season spawning period. Mature females were found during 1978 and 1979 Late-dry and 1978–79 Early-wet seasons, and mature males only during the 1978 Late-dry season. Ripe females were captured only during the 1978–79 Early-wet season and ripe males from 1978 and 1979 Late-dry and 1978–79 Early-wet seasons. Spent males and females were identified during the 1978–79 Mid-wet and one spent male was captured from the 1979 Late-dry; the latter suggests that some spawning may have occurred then. The range of gonad maturity stages is given in table 121.

Large numbers of postlarvae (4 to 7 mm LCF) were collected during the 1978–79 Early-wet season.

Table 120 Possible sites of spawning of *T. chatareus,* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juvenile
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	2	1	0	2	2	3	0
Lowlands							
Sandy creekbed	1	0	0	7	1	0	3
Backflow billabong	4	3	2	29	0	0	1
Corridor	1	2	0	5	0	1	1
Floodplain billabong							
Upper	1	0	0	0	0	0	0
Artificial	0	0	0	0	0	0	1

Table 121 Range of gonad maturity stages for each 1 cm length size class of *T. chatareus* for each season over all habitats

		Sampling season						
Sex	Length (cm)	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet-Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
F	8–1	–	–	–	i (1)	–	i, ii (2)	–
	9–1	–	–	–	i (1)	–	ii (1)	–
	11	–	–	–	–	i (1)	–	–
	13	–	–	–	i (1)	ii (1)	–	–
	16	iv (1)	–	–	–	–	–	–
	17	iii (1)	–	–	–	–	–	–
	18	–	–	–	–	ii (1)	–	–
	20	iii (1)	vi (1)	–	–	–	–	–
	21	iii (1)	iv, v (3)	vii (1)	–	–	iii, vi (2)	–
	22	iv (1)	v, vi (2)	–	–	ii (1)	iv (1)	iv (1)
	24	–	v (2)	vii (1)	–	iii (1)	–	–
	25	iv (1)	v (1)	–	–	ii (1)	–	–
	26	–	iv, v (2)	–	–	–	v (1)	–
M	8–1	–	–	–	–	–	–	ii (1)
	9–1	–	–	–	–	–	i (1)	–
	11	–	–	–	ii (1)	–	–	–
	12	v (1)	–	–	–	–	–	–
	13	iii, iv (2)	–	–	–	–	–	–
	14	iii (1)	–	–	–	–	–	–
	15	iii, iv (3)	–	–	–	–	–	–
	16	iii (1)	–	–	ii (1)	–	–	–
	17	iii (1)	–	ii (1)	–	–	–	–
	18	iv, v (2)	vi (1)	ii (1)	–	–	–	–
	19	v (1)	vi (1)	–	–	–	vi (1)	–
	20	v (1)	iv, vi (5)	–	–	–	–	–
	21	iii, iv (2)	vi (12)	ii, vii (3)	–	–	vi (1)	–
	22	iii, iv (3)	vi (9)	–	–	–	vi (2)	–
	23	iv, vi (2)	vi (6)	ii, vii (2)	–	–	iv (1)	–
	24	iv, vi (4)	vi, vii (2)	vii (1)	–	–	iv (1)	–
	25	vi (1)	vi (1)	ii (1)	–	–	–	–
	31	–	–	–	–	–	vii (1)	–

Numbers analysed are given in parentheses. F = female; M = male; – = no fish captured.

Midgley (1980) collected large numbers of juveniles (10–15 mm LCF) being carried downstream between mid- to late-January 1980; by early February the downstream drift of small fish had stopped, and fish 20–35 mm LCF were collected in quantity moving back upstream along the edges of the creek.

Gonad development was apparently well advanced by the 1978 Late-dry season, with running ripe males being collected before the ripe females were collected. Spawning generally occurred during the 1978–79 Early-wet season and most likely after the water flow began during late December to January in the 1979–80 Wet season. Stream flow, increase in water level, or changes in environmental conditions (such as food availability), are likely stimuli for final maturation of females and spawning. The males possibly respond to different stimuli than females, such as increased temperature, and therefore having a longer period of gonad maturation. This species has also been reported to exhibit aseasonal reproduction in Papua New Guinea (Roberts 1978).

Site of spawning

Ripe males were collected from a wide range of habitats, from escarpment mainchannel waterbodies through lowland sandy creekbed habitats and shallow backflow billabongs to corridor and floodplain billabongs (table 120). Ripe females, however, were only collected from two backflow billabongs, although spent females were collected from escarpment mainchannel waterbodies and lowland sandy creekbeds.

Large aggregations of adult *Toxotes* were observed at Camp 1 on Deaf Adder Creek, a large escarpment mainchannel waterbody, during the 1978 Late-dry season. No fish from the aggregation were captured and therefore the sex or reproductive condition of the individuals is unknown.

Newly hatched postlarvae (4–7 mm) were collected in large numbers from Gulungul Billabong, and 10–15 mm individuals were collected from shallow flooded grassy flats near the Mudginberri road crossing as they were carried downstream (Midgley 1980). The data suggest that *T. chatareus* was most likely spawning throughout its entire preferred range, particularly in lowland shallow backflow billabongs.

Fecundity

Three ovaries were examined for fecundity data. Egg diameters were relatively constant (0.35 ± 0.042 mm; 0.36 ± 0.052 mm; 0.43 ± 0.07 mm) with an average diameter of 0.4 mm. Egg numbers ranged from 20 000 to 150 000 (mean = 73 300). The eggs are reported to be pelagic (Midgley, pers. comm.). The development of the larvae at hatching is not known; however, larvae about 5 mm long have well-developed fins and mouth parts (Plate 5).

Summary

T. chatareus showed evidence of spawning over its entire distribution, which included most habitats of the Magela system, particularly lowland backflow billabongs, but only one of the four floodplain billabongs (Leichhardt Billabong). Males, possibly responding to a different stimulus (such as temperature) from females, were found running ripe before the females were ripe. Gonad maturation peaked during the 1978–79 Early-wet season, when spawning most likely occurred.

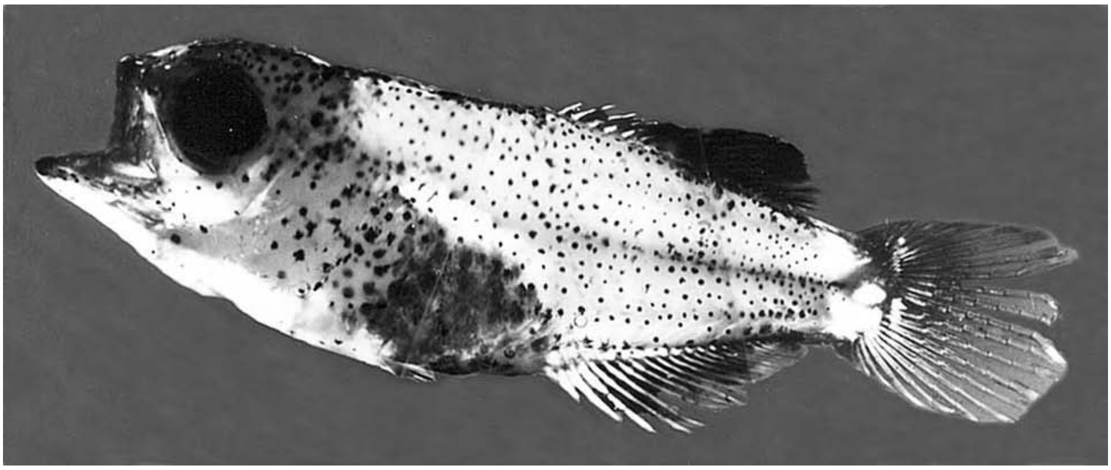


Plate 5 *T. chatareus* larva; TL 7.5 mm x 40

A large number (tens of thousands) of (0.4 mm diameter) eggs are spawned. The eggs are pelagic and tiny larvae less than 4 mm long are produced. The larvae are initially carried downstream with the floodwaters, but when they reach between 15 mm and 20 mm they are able to migrate back upstream.

Feeding habits

Overall diet

The stomachs of 236 specimens were examined; 225 contained food. The diet of *T. chatareus* is summarised in figure 143; the components are listed in table 122. The main components were terrestrial insects (53%) and aquatic insects (42%). The identifiable terrestrial insects were mainly zygopteran and orthopteran adults, ants (*Oecophylla*) and miscellaneous coleopterans. The identifiable aquatic insects were mainly gerrid bugs and miscellaneous coleopterans. Traces of gastropods, aquatic arachnids, micro- and macrocrustaceans, teleosts (*Ambassis* spp.), terrestrial plants and remains of reptiles and bird feathers were also found in the stomachs. *Toxotes chatareus* can therefore be classified as a meiophagic insectivore feeding opportunistically from overhanging terrestrial and aquatic emergent vegetation and the surface and midwaters of the waterbodies.

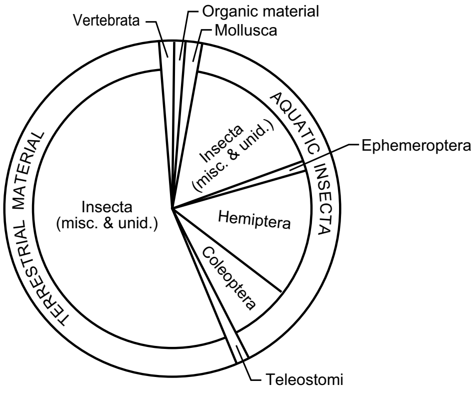


Figure 143 The components of the diet of *T. chatareus*

Table 122 Dietary composition of *T. chatareus*

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																	
Algae																	+
Miscellaneous	–	–	0.1	–	–	–	–	–	–	–	–	0.1	–	–	–	+	
Aquatic animals																	
Gastropoda																	0.5
Amerianna	–	–	1.3	–	–	–	–	–	–	1.6	–	–	0.6	–	–	0.5	
Arachnida																	0.3
Miscellaneous	–	–	0.6	–	–	–	–	–	–	–	0.9	–	–	–	–	0.2	
Hydracharina	–	–	0.1	–	–	–	–	–	–	–	0.2	–	–	–	–	0.1	
Microcrustacea																	0.4
Conchostraca																	
Miscellaneous	–	–	0.6	–	–	–	–	–	–	0.7	–	–	–	–	–	0.2	
Cyzicus	–	–	–	–	–	–	–	–	–	–	0.7	–	–	–	–	0.2	
Macrocrustacea																	0.3
Macrobrachium	–	–	0.2	–	–	–	–	–	–	–	0.3	–	–	–	–	0.1	
Hymensomatidae																	
P. transversa	–	–	–	–	–	3.9	–	–	–	0.8	–	–	–	–	–	0.2	
Insecta																	42.4
Fragmented	8.3	5.7	13.8	29.5	6.2	10.8	26.7	20.0	43.6	12.2	11.5	13.2	10.6	17.7	–	17.4	
Ephemeroptera																	
Baetidae	–	–	–	2.9	–	–	–	–	–	1.0	1.0	–	–	–	–	0.5	
Odonata																	
I. heterosticta	–	–	0.7	–	–	–	–	–	–	–	–	1.6	–	–	–	0.3	
Libellulidae	–	–	1.2	–	–	–	–	–	–	1.6	–	–	–	–	–	0.4	
Hemiptera																	
Naucoridae	–	–	2.2	–	–	–	–	18.0	–	2.8	0.2	2.4	–	–	–	1.2	
Gerridae	15.0	15.7	4.5	6.7	–	10.0	3.3	20.0	6.0	7.1	8.5	3.2	18.8	5.4	–	7.4	
Veliidae	–	–	–	6.2	–	–	6.7	–	7.7	0.7	–	–	–	–	–	1.4	
Hydrometridae	–	3.3	–	–	–	–	–	–	4.6	–	–	–	5.9	–	–	1.2	
Notonectidae	–	–	–	–	–	–	16.7	–	–	1.6	–	–	–	–	–	0.4	
Anisops	–	1.0	5.7	1.9	–	–	–	–	3.1	1.6	4.5	–	3.5	10.8	–	3.0	
Corixidae	–	0.3	1.3	2.9	0.6	–	–	–	0.6	1.1	1.6	0.3	–	7.7	–	1.3	

Table 122 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Coleoptera																	
Miscellaneous (adults)	–	8.7	9.5	2.4	1.3	2.3	–	2.0	10.3	6.9	5.6	2.4	18.0	0.8	–	6.7	
Diptera																	
Miscellaneous (larv.)	5.0	–	–	–	–	3.9	–	–	–	–	0.9	–	–	2.3	–	0.3	
Chironomidae (larv.)	–	–	–	–	–	–	–	–	–	–	0.5	–	–	–	–	0.1	
Chironomidae (pup.)	–	–	0.1	–	–	–	–	–	–	–	0.2	–	–	–	–	0.1	
Trichoptera																	
Leptoceridae	–	–	1.1	–	–	–	–	–	–	1.5	–	–	–	–	–	0.4	
Lepidoptera																	
Pyralidae	–	–	–	–	–	–	10.0	–	–	1.0	–	–	–	–	–	0.3	
Teleostomi																	1.3
Scales	–	–	2.3	–	–	–	–	–		–	–	–	–	15.4	–	0.9	
Ambassis spp.	–	–	0.6	–	–	–	–	–	–	–	1.6	–	–	–	–	0.4	
Terrestrial plants																	
Angiospermae																	0.2
Seed material	–	–	0.1	1.4	–	–	–	–	–	–	–	0.3	1.8	–	–	0.2	
Terrestrial animals																	
Insecta																	
Fragmented	–	29.0	9.7	7.6	4.4	33.9	5.0	–	8.6	20.3	14.1	20.5	18.2	–	–	10.9	53.0
Odonata																	
Zygopteran adults	3.3	4.0	16.2	4.8	80.0	13.1	13.3	20.0	5.9	3.1	29.8	34.7	–	–	10.0	15.4	
I. heterosticta	–	–	–	16.7	–	–	–	–	–	–	–	–	–	26.9	–	1.6	
Anisopteran (adults)	–	–	1.5	–	–	–	–	–	–	–	–	3.3	–	–	–	0.6	
Orthoptera	3.3	8.7	10.3	0.5	1.3	–	8.3	–	1.7	15.9	2.1	4.0	–	–	–	9.8	
Hemiptera	–	0.7	–	–	–	7.7	–	–	–	–	1.7	0.5	–	–	–	0.5	
Coleoptera																	
Miscellaneous	1.7	6.0	7.0	4.8	–	7.7	–	–	–	9.4	1.9	5.3	1.8	7.7	–	4.6	
Fragmented	–	–	0.7	–	–	–	–	–	–	–	–	–	–	–	30.0	0.3	
Diptera	28.3	–	0.4	–	–	–	–	–	2.9	–	0.5	–	–	5.4	–	0.9	
Trichoptera	–	–	0.1	–	–	–	–	–	–	–	0.1	–	–	–	–	+	

Table 122 continued

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Hymenoptera																	
Miscellaneous	–	–	1.4	–	–	–	–	–	–	–	–	3.2	–	–	–	0.5	
Formicidae	–	1.3	3.0	6.7	–	–	–	–	–	2.1	5.2	2.6	1.8	–	–	2.5	
Oecophylla	35.0	12.7	2.4	2.4	6.3	6.9	10.0	–	0.9	4.0	6.5	2.6	19.4	–	60.0	5.4	
Reptilia																	0.4
Egg material	–	1.0	–	–	–	–	–	–	–	0.5	–	–	–	–	–	0.1	
Scincidae	–	2.0	–	–	–	–	–	–	–	1.0	–	–	–	–	–	0.3	
Aves																	0.2
Feathers	–	–	–	–	–	–	–	–	1.1	–	–	–	–	–	–	0.2	
Parasites																	
Nematoda	–	–	–	–	–		–	–	+	–	–	–	–	–	+	+	+
Organic material	–	–	0.8	2.9	–	–	–	20.0	3.7	1.6	–	–	–	–	–	1.0	1.0
Number of empty fish	1	–	2	1	3	1	–	2	1	4	3	–	1	2	–	11	11
Number of fish with food	6	30	86	21	16	13	6	5	35	62	58	38	17	13	2	225	225

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Fb = Floodplain billabongs; Cb = corridor billabongs; Bb = Lowland backflow billabong; + = present (<0.1%)

The ability of this species, and other members of the Toxotidae, to utilise terrestrial food resources that are not in contact with the aquatic environment, has been the subject of papers by Zolotnisky (1902), Gill (1909), Smith (1936; 1945), and Allen (1973). Allen (1978b) noted that when the fish sights suitable prey, usually a small insect, it rises to the surface and ejects an aqueous 'bullet' from its mouth by forcefully compressing its gill covers. Specimens as small as 20 mm LCF have been observed feeding in this manner in Magela Creek. Their aim is uncannily accurate to a distance of 0.5 m for 30 mm LCF specimens and to 3 m for 250 mm LCF specimens (pers. obs.); in most cases the victim is knocked into the water, where it is usually tasted before being eaten (pers. obs.).[201]

Pollard (1974) noted that the diet of this species included insects and also reputedly shrimps, small fish, and occasionally berries falling into the water from terrestrial vegetation; however, the last three items were rare in the present study. Haines (1979) classified *T. chatareus* as a frugivore (fruit eater)/omnivore in the Purari River, Papua New Guinea, and noted that distributional differences occur in the diet (with crabs and fruit predominating in estuarine populations and insects and fruit in freshwater populations).[202]

Seasonal changes

In sampling periods 1 to 7 respectively, totals of 36 (3% empty), 66 (6% empty), 61 (5% empty), 38 (0% empty), 18 (6% empty), 15 (13% empty), and 2 (0% empty) stomachs of *T. chatareus* were examined (all habitats combined). The highest proportion of specimens with empty stomachs occurred during the 1979 Late-dry season and the lowest proportion in the Mid-wet season (the sample size for 1979–80 Early-wet season was small).

The diet in the 1978 Late-dry season was based primarily on aquatic insects (mainly coleopterans and surface-dwelling hemipterans). During the 1978–79 Early-wet season the terrestrial insect component (mainly orthopteran and coleopteran adults and ants) increased to become larger than the aquatic insect component (mainly on hemipterans and coleopterans). The diet in the 1978–79 Early-wet season became more varied and included gastropods, micro- and macro-crustaceans, small skinks and reptile eggs. The proportion of terrestrial insects (mainly zygopterans and ants) increased relative to the aquatic component during the 1978–79 Mid-wet season. Teleosts (*Ambassis* spp.) were eaten in small quantities during the Mid-wet season. By the Late-wet–Early-dry season the terrestrial component (again mainly zygopterans and ants) of the diet peaked and then fell dramatically into the 1979 Mid-dry season when gerrids and coleopterans were the main aquatic insect components. Traces of terrestrial plant material were found in the stomachs during the Mid-dry season.

The diet in the 1979 Late-dry season was based primarily on aquatic insects (mainly surface-dwelling hemipterans); however, the terrestrial insect component was slightly higher than in the 1978 Late-dry season. The few specimens examined in the 1979–80 Early-wet season were eating terrestrial insects only, with green tree ants (*Oecophylla*) and coleopterans being the main items.

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[201] Smith (1998) has observed *T. chatareus* from the Fly River in PNG using a less precise but equally effective feeding technique of squirting large quantities of water into clumps of grass and then consuming the numerous insects dislodged by the spray.

[202] Smith (1998) considered that *T. chatareus* from the Fly River in PNG was a surface feeder. Terrestrial insects scored most highly in dietary analyses, with aquatic insects and aquatic plants being scored around one third the level of terrestrial insects. Hymenoptera and Hemiptera were the main orders of terrestrial insects consumed. However, Smith noted that he had collected specimens from north Queensland that had fed almost exclusively on Atyidae shrimps, despite living in waters with abundant overhanging vegetation and an abundance of terrestrial insects.

Habitat differences

Magela catchment

A total of 166 stomachs of *T. chatareus* were analysed (all seasons combined): 7 (14% empty) from the Magela Creek catchment escarpment mainchannel waterbodies; 30 (0% empty) from lowland sandy creekbeds; 88 (2% empty) from shallow backflow billabongs; 22 (5% empty) from corridor waterbodies and 19 (16% empty) from floodplain billabongs. The highest proportions of empty stomachs were found in floodplain billabongs and escarpment water bodies and the lowest proportions at almost equal levels, in the other habitats mentioned above.

In the escarpment waterbodies, the small number of *T. chatareus* examined were feeding mainly on terrestrial insects (mainly green tree ants [*Oecophylla*] and miscellaneous dipteran adults) and, to a lesser extent, on aquatic insects (mainly gerrid bugs). In the lowland sandy creekbeds the aquatic insect component of the diet (gerrids and coleopterans) was slightly greater than in the escarpment water bodies, with the main terrestrial items being green tree ants, orthopteran and coleopteran adults. Small skinks and reptile eggs were also present in the diet in this habitat.

In the lowland shallow backflow billabongs, the aquatic component of the diet was more varied and larger possibly because bank vegetation on which terrestrial prey live is scarce in the Dry seasons or terrestrial prey are hard to see in muddied waters. The aquatic organisms eaten include insects (mainly coleopterans, *Anisops* and gerrids), gastropods, conchostracans, hydracarinids, teleosts (*Ambassis* spp.) and traces of algae, terrestrial plants and macrocrustaceans.

In corridor waterbodies *T. chatareus* fed extensively on aquatic insects (the main identifiable insects were the surface-dwelling gerrids and veliids) and to a lesser extent on terrestrial insects (mainly the zygopteran *Ischnura heterosticta* and ants); traces of terrestrial plant material were also found in the stomachs. The diet in the floodplains was almost exclusively based on terrestrial insects (mainly zygopteran adults and green tree ants).

Nourlangie catchment

A total of 27 specimens were analysed: 14 (7% empty) from the Nourlangie Creek system escarpment mainchannel waterbodies; 6 (0% empty) from lowland sandy creekbeds; and 7 (28% empty) from shallow backflow billabongs. The large difference in proportions of empty stomachs may be attributable to the small sample sizes.

The diet in the escarpment waterbodies was based mainly on terrestrial insects, as in the Magela system, with aquatic insects (mainly gerrids) of secondary importance. In the lowland sandy creekbeds, the terrestrial and aquatic insect components of the diet were fairly equal. The terrestrial insects were mainly zygopteran adults and green tree ants. As in the Magela Creek system, terrestrial insects were eaten less often in the lowland backflow billabongs, with gerrid and notonectid bugs being the main items in the stomachs.

Fullness

Mean fullness indices of *T. chatareus* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments are shown in table 123. These data are presented on the assumption that feeding times within the day do not vary with habitat or season.

Seasonal changes

The mean fullness index (all habitats combined) remained at a fairly high, stable level between the 1978 Late-dry and the Late-wet–Early-dry seasons. The index fell gradually through the following Dry season to reach zero in the few fish examined in the 1979–80 Early-wet season.

Table 123 Mean fullness indices of *T. chatareus* in different sampling periods and habitat types

	Sampling period							
Habitat	Late-dry	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	0 (1)	n/s	0 (1)	n/s	0 (1)	1.0 (3)	0 (1)	0.4 (7)
Lowland sandy creekbed	n/s	n/s	n/s	4.2 (6)	n/s	n/s	n/s	4.2 (6)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	3.6 (12)	3.8 (6)	1.5 (2)	2.8 (4)	n/s	n/s	3.3 (24)
Lowland channel backflow billabong	n/s	0 (1)	4.7 (7)	3.4 (7)	3.6 (5)	n/s	n/s	3.7 (20)
Lowland shallow backflow billabong	0 (1)	3.4 (33)	4.4 (10)	3.3 (17)	4.0 (2)	1.3 (4)	0 (1)	3.3 (68)
Corridor sandy billabong	4.2 (5)	n/s	n/s	n/s	n/s	n/s	n/s	4.2 (5)
Corridor anabranch billabong	n/s	4.7 (3)	0 (1)	0 (1)	2.5 (2)	1.8 (5)	n/s	2.3 (12)
Floodplain billabong	0 (1)	2.7 (3)	2.8 (18)	n/s	n/s	2.3 (3)	n/s	2.6 (25)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	0 (1)	4.3 (3)	1.9 (8)	n/s	1.0 (2)	n/s	n/s	2.3 (14)
Lowland shallow backflow billabong	n/s	0.7 (3)	n/s	4.0 (2)	2.0 (2)	n/s	n/s	2.0 (7)
Lowland sandy creekbed	n/s	4.3 (3)	n/s	4.0 (3)	n/s	n/s	n/s	4.2 (6)
Seasonal mean (all sites)	3.6	3.4	3.3	3.5	2.8	1.6	0	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment, upstream of RUPA, mean fullness indices were highest in the lowland sandy creekbeds and lowest in escarpment mainchannel waterbodies; however, sample sizes were small.

Downstream of RUPA the fullness indices were high throughout most habitats. The mean fullness indices were highest in sandy corridor waterbodies and channel backflow billabongs and lowest in corridor anabranch and floodplain billabongs.

In the Nourlangie catchment, mean fullness indices were highest in lowland sandy creekbed pools and lower in lowland shallow backflow billabongs and escarpment mainchannel waterbodies. The indices in the lowland sandy and escarpment habitats were much higher than those recorded in the equivalent Magela Creek habitats.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland channel backflow billabongs; 1978–79 Mid-wet season
- corridor anabranch billabong; 1978–79 Early-wet season
- lowland shallow backflow billabongs; 1978–79 Mid-wet season

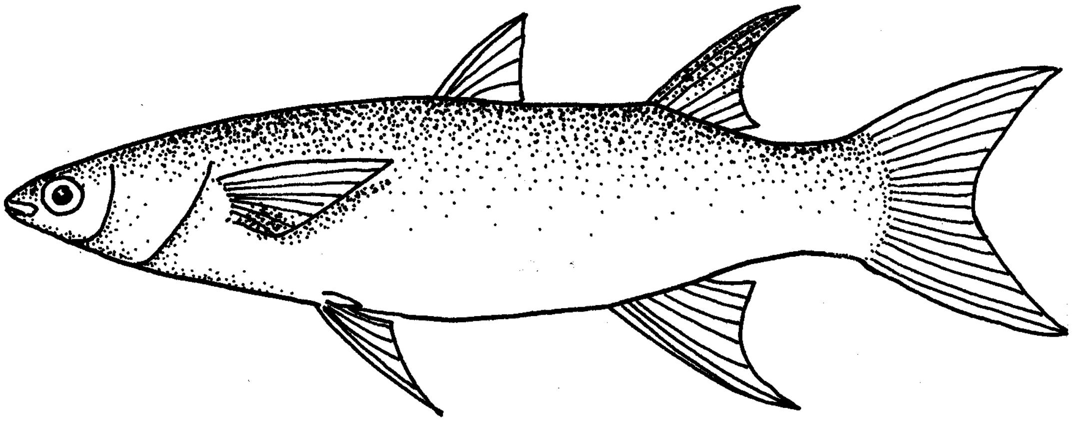
Nourlangie catchment

- escarpment mainchannel waterbody; 1978–79 Early-wet season
- lowland sandy creekbeds; 1978–79 Early-wet season

Family MUGILIDAE

3.32 *Liza alata* (Steindachner 1892)

This species is commonly known as the Ord River mullet. It is known from the Timor Sea drainage system of northern WA and the NT (see map 3).[203] Several other species of the family Mugilidae enter freshwater but most are essentially estuarine or marine. Pollard (1974) found this species to be abundant in tidal waterbodies of the East Alligator River. Miller (cited in Taylor 1964) found this species in billabongs in the Oenpelli area and in lower riverine floodplains of the East Alligator River. *Liza alata* is very similar morphologically to *Liza subviridis* (a species that Pollard and Miller also captured in the Region during their respective surveys), but the latter lacks both longitudinal dark lines and well-developed adipose eyelids.



Liza alata

Detailed information on catches on a site-by-site and season-by-season basis is given in volume 2. In summary, this species was found occasionally in all floodplain billabongs and in some corridor waterbodies; it was also found in lowland backflow billabongs in the Nourlangie Creek catchment. This species was found in 6 of 26 regularly sampled sites during the study.

The lengths and weights of 211 specimens were recorded. They placed this species at the base of the upper-middle quarter in the list of fish species ranked by the number of specimens examined (table 1).

Size composition

Length–weight relationship

The length–weight relationship was described by the following expression:

$W = 6.37 \times 10^{-2} L^{2.52}$ $r = 0.91$ (length in cm, weight in g)

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[203] Allen (1991) indicated that *L. alata* is widespread in the tropical Indo-West Pacific, from East Africa to Tonga. In PNG Allen noted that it had been reported from the Sepik River near Angoram. The habitat in the Sepik consisted mainly of coastal waters and estuaries, but it sometimes ascended rivers. Smith (1998) indicated that *L. alata* had also been recorded in the Fly River in PNG.

Seasonal mean lengths, weights and condition factors are shown in table 124. The seasonal condition factors were lowest in the 1978 Late-dry season and the 1979 Mid-dry season. The few specimens examined in the Mid-wet and Late-wet–Early-dry seasons had the highest condition factors.

Table 124 Mean length, mean weight and condition factor of *L. alata*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	5	261.2	210.02	0.89
Early-wet (1978–79)	33	355.5	500.18	0.97
Mid-wet	2	374.1	580.80	0.99
Late-wet–Early-dry (1979)	1	166.9	78.32	1.02
Mid-dry	5	190.1	91.64	0.86
Overall	46	316.6	384.68	1.00

Length composition

The smallest specimen captured in the study area was 128 mm LCF (fig 144). No smaller specimens were found in the catchments as this species does not breed in freshwaters (Roberts 1978). The largest specimen captured was 570 mm LCF. Lake (1971) indicated that this species grows to only 500 mm. Roberts (1978) found specimens up to only 410 mm in the Fly River, Papua New Guinea.

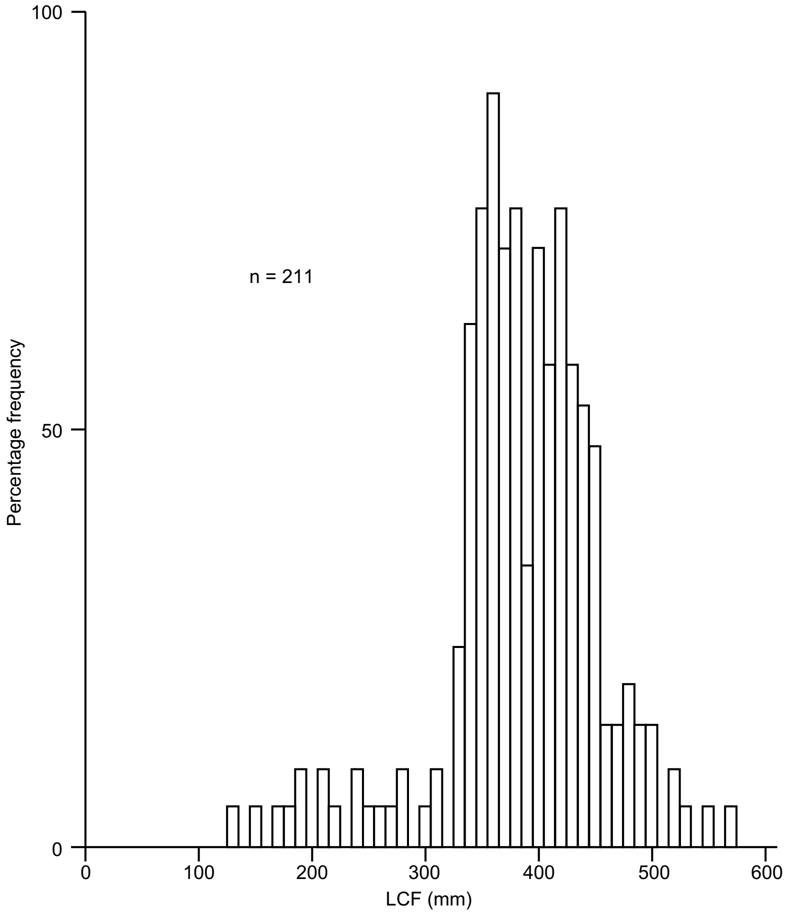


Figure 144 Length-frequency distribution of all *L. alata* captured

Length-frequency distribution

The mean length of all specimens captured was 370 mm and the modal length was 360 mm LCF. Only a few specimens were greater than 500 mm LCF; most ranged between 340 and 450 mm LCF.

The majority of specimens were collected during a fish kill in a floodplain billabong (Leichhardt Billabong) during the 1978–79 Early-wet season, but other specimens within the same length range were collected throughout the study. Small specimens were found in the 1978 Late-dry, 1978–79 Early-wet and Late-wet–Early-dry seasons; however, the smallest *L. alata* were captured in the 1979 Mid-dry season in the lower reach floodplain billabongs. The mean seasonal lengths (table 124) were lowest in the Late-wet–Early-dry and 1979 Mid-dry seasons. No small specimens were found in the Mid-wet season.

Habitat differences in distribution

Most specimens were captured in the Magela Creek catchment floodplain billabongs. The smaller specimens were mainly found in the lower reach floodplain billabongs; however, some small specimens, as well as a few large specimens, were found as far upstream as the corridor waterbodies. The largest specimen was also found in the floodplain billabongs.

Only a few small specimens were found in the Nourlangie Creek catchment. These were captured in shallow backflow billabongs in the 1978–79 Early-wet season. Larger specimens were frequently observed in the corridor waterbodies and there are unconfirmed reports that large schools may enter nearby escarpment mainchannel waterbodies.

Environmental associations

Rank numbers for *L. alata* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

L. alata was captured in waters with surface temperatures ranging from 27 to 35°C (mean = 30.7°C) and with bottom temperatures ranging from 26 to 34°C (mean = 29.7°C). These means were ranked into the lower-middle and upper-middle quarters, respectively (fig 170). Only small numbers of readings of environmental parameters were taken for this species; however, the close similarity of top and bottom water temperatures is notable.

Dissolved oxygen

Dissolved oxygen concentrations in waters in which *L. alata* was found were characteristically low, ranging from 0.1 to 8.0 mg/L (mean = 4.8 mg/L) on the surface and from 0.4 to 3.2 mg/L (mean = 2.4 mg/L) on the bottom. Both of these means were at the base of the lower quarters (see fig 171b). However, large numbers of this species were present in the Leichhardt Billabong fish kill (Bishop 1980), where surface DO concentrations fell to 0.1 mg/L.

Visibility

Secchi depth readings in waters from which *L. alata* was captured ranged from 1 to 150 cm, with a mean of 33 cm (see fig 172). This mean ranked in the lower quarter, indicating a preference for turbid waters. This species feeds in muddy benthic areas, so would be tolerant of highly turbid waters.

pH

pH values of waters from which *L. alata* were captured ranged from 5.1 to 7.4 (mean = 6.3) on the surface, and from 5.1 to 7.3 (mean = 5.9) on the bottom. These mean pH values ranked in the upper-middle and lower-middle quarters, respectively (see fig 173). These ranges of tolerance are relatively narrow.

Conductivity

Waters containing *L. alata* had surface conductivities ranging from 8 to 160 µS/cm, and bottom conductivities ranging from 8 to 230 µS/cm. Roberts (1978) found that *L. alata* was catadromous in the Fly River catchment, Papua New Guinea.

Habitat–structural variables

Substrate

The most dominant substrate type associated with *L. alata* was mud (upper quarter), followed by clay (lower-middle quarter), then sand, boulders and rocks (see fig 174). The marked dominance of mud substrate may be due to the feeding habits of the species, which browses for food in the benthic mud of lowland/floodplain waters.

Hydrophytes

Liza alata was found in waters with moderately high vegetation content (vegetation-occurrence index 94.7%). Emergent hydrophytes were dominant here (upper quarter) followed by submergent (lower-middle quarter) and floating hydrophytes. This species was often observed grazing on algae adhering to emergent vegetation.

Reproduction

A total of 27 *L. alata* were examined for reproductive condition: 12 females (length range 224–484 mm LCF), 5 males (167–405 mm LCF) and 10 sexually indistinguishable fish (128–327 mm LCF) (table 125).

Table 125 Number of sexually distinguishable *L. alata* captured showing gonad stage differences between habitats

	Gonad stage							
	Immature (I,II)		Developing (III)		Mature (V)		Spent (VII)	
Habitat	F	M	F	M	F	M	F	M
Corridor	0	0	0	1	0	0	2	0
Floodplain billabong								
Upper	4*	2	*6	0	0	1	0	0
Lower (riverine)	0	1	0	0	0	0	0	

* 2 immature and 6 developing females from fish kill (see Bishop 1980)

Length at first maturity

The LFM cannot be estimated due to the small number (3) of maturing fish captured. No maturing fish (ie greater than stage III) were found below 350 mm LCF.

Sex ratio

Of the 12 females and 5 males captured during the study (table 125) 9 females and 2 males were captured during the 1978–79 Early-wet season. When tested with a chi-squared test (Zar 1974) the sex ratio was found to be significantly ($0.01 < P < 0.05$) different from 1:1. The sample size was too small, however, to draw any general conclusions.

Breeding season

No information is available on the breeding season for this species. Plots of GSI and GMSI using all the male and female fish (as the LFM that distinguishes adults from juveniles was not determined) showed a minor peak during the 1978–79 Early-wet season (table 126). If a spawning migration to the estuaries takes place it must be during the Wet season, the only time that the Magela system is connected to the sea. *Liza argentia* has an extended period of reproductive development lasting from October to June in estuarine areas of southern NSW (SPCC 1981) and fish with ripe gonads were taken from December to June. Other mullet species, however, have winter breeding seasons. The SPCC (1981) recorded a spawning season of from March to July for *Mugil cephalus* in the estuary.

Table 126 Seasonal changes in gonadosomatic index (GSI) and gonad maturity stage index (GMSI) for *L. alata* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
GSI									
Juveniles +	F	mean	0.2	0.3	0.3	–	–	–	–
adults		s.d.	–	0.1	0.04	–	–	–	–
	M	mean	0.01	0.2	–	0.2	0.01	–	–
		s.d.	–	0.1	–	–	–	–	–
	F+M	mean	0.1	0.3	–	–	–	–	–
		s.d.	0.1	0.1	–	–	–	–	–
GMSI									
Juveniles +	F	mean	2.0	2.7	2.0	–	–	–	–
adults		s.d.	–	0.5	0.0	–	–	–	–
	M	mean	2.0	3.5	–	3.0	1.0	–	–
		s.d.	–	2.1	–	–	–	–	–
	F+M	mean	2.0	2.8	–	–	–	–	–
		s.d.	0.0	0.9	–	–	–	–	–

Key: F = female; M = male; s.d. = standard deviation

Site of spawning

Most species of mullet are essentially marine or estuarine although nearly all will enter freshwater occasionally (Lake 1971). Breder and Rosen (1966) suggested the family Mugilidae can breed in both shallow seas or freshwater. However, Moore, cited by Haines (1978), reported spectacular migrations of *L. alata* into the lower reaches of the Fly River (near the mouth) during the breeding season. *Liza alata* was observed in large numbers in the East Alligator River near Cahills Crossing during the 1978–79 Early-wet season, although no evidence of spawning was observed and no fish were collected to assess reproductive condition.

Fecundity

The family Mugilidae generally exhibit distinct pairing but evidently with some polyandry. The males are generally smaller than the females. A spawning migration occurs and pelagic, non-adhesive eggs are produced (Breder & Rosen 1966).

No ovaries of *L. alata* were examined. The females of *Mugil cephalus,* a related species that spawns off the coast of southern and eastern Australia, are reported to carry more than 2 x 10^6 eggs within the ovary, which can weigh up to 20% of the total fish weight (Lake 1971).

Summary

Due to the small sample size, no conclusions could be made about the reproductive strategy of this species. However, the data did support the observations of other researchers on mullet reproduction. Large spawning migrations of *L. alata* down to the estuarine areas and the mouth of the river in the Fly River system were reported by Moore (Haines 1978). Large numbers of tiny, planktonic, non-adhesive eggs are laid (Breder & Rosen 1966, Lake 1971) and juveniles recruit to estuarine areas and may then move up river.

Feeding habits

Overall diet

The stomach contents of 18 specimens were analysed; 17 stomachs contained food. The diet of *L. alata* is summarised in figure 145; the components are listed in table 127. The main components were algae (48%) and detrital material (45%). The identifiable algae consisted mainly of conjugatophytes (*Mougeotia* and *Spirogyra*), dinoflagellates, desmids and diatoms. Traces of hydrophytes, aquatic arachnids and insects, and terrestrial plant material were also present in the diet. *Liza alata* may therefore be classified as a benthic herbivore (primarily algae)/detritivore. These data are generally in agreement with Lake (1971), who noted that the freshwater Mugilidae of Australia feed on algae from bottom mud, which they take into their gizzard-like stomachs. Haines (1979) noted that mullet of the genus *Liza* are detritophages in the Purari River, Papua New Guinea.

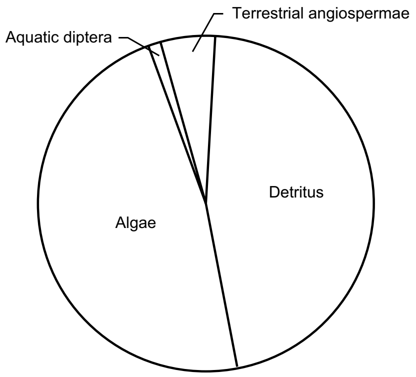


Figure 145 Dietary components of *L. alata*

Seasonal changes

Totals of 5, 5, 2, 1 and 5 stomachs of *L. alata* were analysed (all habitats combined) in sampling periods 1, 2, 3, 4 and 5, respectively. Only one fish during the whole study (in the 1978 Late-dry season) had no food in its stomach; the other specimens analysed in that season contained only detritus material. Specimens captured in the Early-wet season had eaten mainly detritus and algae, though large amounts of terrestrial plant material and traces of hydrophytes (*Hydrilla*), aquatic arachnids and chironomids were present in the stomachs.

During the Mid-wet season only algae (mainly *Spirogyra*) were found in the few stomachs examined. A specimen captured in Magela Creek channel (Magela Crossing) just downstream of a corridor waterbody (Mudginberri corridor) during the Mid-wet season contained the following algal genera (H Ling & D Thomas, pers comm): large numbers of dinoflagellates (*Peridium*); in smaller numbers, diatoms (*Eunotia, Gomphonema* and *Pinnularia*), conjugatophytes (*Oedogonium, Spirogyra* and *Mougeotia*), and desmids (*Pleurotaenium, Costerium, Desmidium* and *Cosmarium*).

The single specimen analysed in the Late-wet–Early-dry season had eaten only detritus. In the 1979 Mid-dry season the few specimens analysed were feeding only on algae (*Mougeotia* and desmids).

Table 127 Dietary composition of *L. alata*

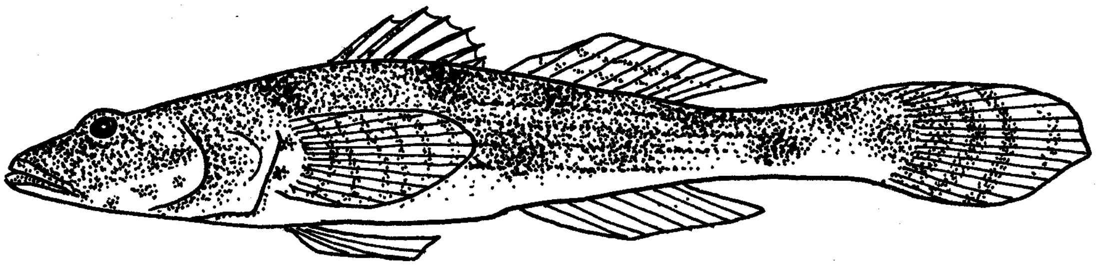
	Season					Overall	
	1978	1978–79	1978–79	1979	1979		
Stomach contents	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Sub-mean	Main-mean
Plant material							
Algae							48.0
Miscellaneous	–	37.0	5	–	–	11.1	
Desmidaceae	–	–	–	–	40.0	10.3	
Conjugatophyta							
Mougeotia	–	–	–	–	56.0	15.5	
Spirogyra	–	–	95	–	–	11.1	
Hydrophytes							0.3
Hydrilla	–	1.0	–	–	–	0.3	
Aquatic animals							
Arachnida							0.3
Hydracarina	–	1.0	–	–	–	0.3	
Insecta							0.6
Diptera							
Chironomidae	–	2.0	–	–	–	0.6	
Terrestrial plants							
Angiospermae							5.3
Fragmented	–	19.0	–	–	–	5.3	
Detrital material	100	40.0	–	100	4.0	45.3	45.3
Number of empty fish	1	–	–	–	–	1	1
Number of fish with food	4	5	2	1	5	17	17

Figures represent the mean percentage volume determined by the estimated volumetric method.

Family GOBIIDAE

3.33 *Glossogobius giuris* (Hamilton-Buchanan)

Glossogobius giuris is commonly known as the flathead goby or tank goby. It is probably one of the most widely distributed *Glossogobius* species, and is found from marine coastal waters to inland freshwaters (eg in mountain torrents in the Papua New Guinea highlands). It is found in the drainage systems of the north-east coast, Gulf of Carpentaria, Timor Sea, and Indian Ocean (see map 3) and also in Papua New Guinea and throughout the Indo-Pacific from East Africa to the Pacific islands. Pollard (1974) reported that this species was one of the less common fishes in the Magela Creek area, with only a few specimens collected from vegetation around the banks of waterholes. Although *G. giuris* attains a reasonably large size, no information is available on its eating qualities.



Glossogobius giuris

Detailed information on catches at each site and in each season is given in volume 2. This species appeared to be more common during the present study than during Pollard's 1974 study. In summary, it was found commonly in all escarpment mainchannel waterbodies (as well as terminal waterbodies in the Jim Jim Creek system) and corridor waterbodies (especially sandy types) and occasionally in lowland sandy creekbed habitats, lowland backflow and floodplain billabongs. In the 1978 Late-dry season it was found in six sites (mainly escarpment mainchannel waterbodies and corridor waterbodies); in the Mid-wet season in only two sites (one each of the above); and in the Late-wet–Early-dry season in two sites (corridor waterbodies).

Size composition

The lengths and weights of 278 specimens were recorded. This species was placed in the upper-middle quarter in the list of fish species ranked by the number of specimens examined (see table 1).

Method artefacts

All specimens were collected by seine net. The net was sometimes clogged by algae, which resulted in the capture of large numbers of very small juveniles (especially in the Mid-dry season).

Length–weight relationship

The length–weight relationship was described by the following expression:

$$W = 1.03 \times 10^{-2} L^{2.78} \qquad r = 0.98 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 128. The seasonal condition factor was stable between the 1978 Late-dry and 1978–79 Early-wet seasons and then fell to a low during the Mid-wet and Late-wet–Early-dry seasons; however, this drop may have been an artefact of the small number of specimens examined. By the 1979 Mid-dry season the condition factor rose to reach a level in the 1979 Late-dry season similar to that attained in the same season in 1978. The condition factor increased further in the 1979–80 Early-wet season to a record level.[204]

Table 128 Mean length, mean weight and condition factor of *G. giuris*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	52	43.5	0.63	1.03
Early-wet (1978–79)	43	41.6	0.55	1.02
Mid-wet	5	46.1	0.63	0.88
Late-wet–Early-dry (1979)	6	51.9	0.88	0.88
Mid-dry	53	42.4	0.55	0.97
Late-dry	8	42.8	0.60	1.04
Early-wet (1979–80)	8	41.1	0.56	1.08
Overall	175	42.9	0.59	1.00

The changes in body condition of *G. giuris* indicate that the environmental conditions experienced in the Late-dry–Early-wet seasons were favourable to this species, and that the extreme 1979 Dry season was possibly more favourable than the 1978 season.

Length composition

Pollard (1974) stated that this species reputedly grows to 350 mm in Asia. In Papua New Guinea, *G. giuris* ranged in length from 50 to 200 mm in the Purari River (Haines 1979), and 13 to 171 mm in the Fly River (Roberts 1978).

Length-frequency distribution

The mean and modal lengths of all specimens captured were 40.6 and 33–34 mm TL, respectively. The LFM for females (fig 146) was approximately 35 mm TL, indicating that slightly more adults were captured than juveniles. The overall distribution displayed a negative skew, indicating lower survival for larger-sized fish. Most specimens were between 19–20 and 55–56 mm TL.

Seasonal mean lengths are shown in table 128. The mean seasonal length decreased slightly in the 1978–79 Early-wet season and then increased through the Mid-wet season to peak in the Late-wet–Early-dry season; this increase may have been an artefact, as few specimens were collected. The mean seasonal length then dropped in the 1979 Mid-dry season when large numbers of juvenile recruits entered the populations, and remained low for the remainder of the study.

Growth rate

Estimation of the growth rate of *G. giuris* from seasonal length-frequency distributions is difficult due to the frequency with which juveniles appeared to recruit.

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[204] Jadhav and Patil (1984) examined the condition of *G. giuris* from the Godavari River in India and recorded condition factors (K) ranging from 0.75 to 0.92. The condition factor was found to vary between size groups and through time as related to cycles in gonadal maturity, spawning season, feeding habit, growth and environment.

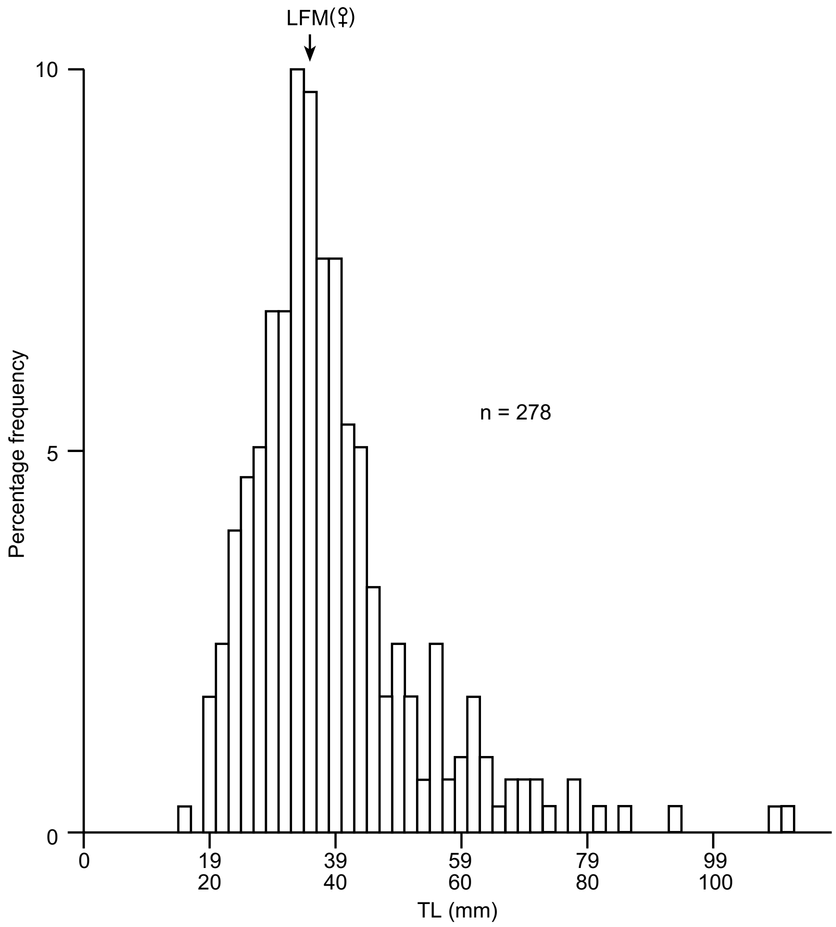

Figure 146 Length-frequency distribution of *G. giuris* (all sites)

The growth of juveniles (modal length 29–32 mm TL) present in the 1979 Late-dry season can possibly be followed (A on fig 147) until the 1979 Mid-dry season about ten months later, when a mean length of 64–65 mm was attained. This rate of growth suggests *G. giuris* may attain the LFM within its first year of life.

Habitat differences in distribution

The habitat preferences of all *G. giuris* captured in regular sampling sites in the Magela catchment are shown in figure 148.

Most of the juveniles, including the smallest, were found in sandy corridor waterbodies. A few were found in lowland sandy creekbeds, escarpment mainchannel waterbodies and corridor anabranch billabongs. Juveniles were also found in escarpment mainchannel billabongs of the Nourlangie system.

The smallest juveniles were captured during the 1979 Mid-dry season in a sandy corridor waterbody (Mudginberri Corridor). Juveniles were also collected frequently in the 1978 Late-dry and 1978–79 Early-wet seasons (fig 149). Comparatively few specimens were captured in the Mid-wet and Late-wet–Early-dry seasons (mainly due to sampling difficulties caused by the high flow) and the 1979 Late-dry and 1979–80 Early-wet seasons, resulting in a small range of specimens captured.

The largest adults were captured in the 1978 Late-dry season and the 1979 Mid-dry season.

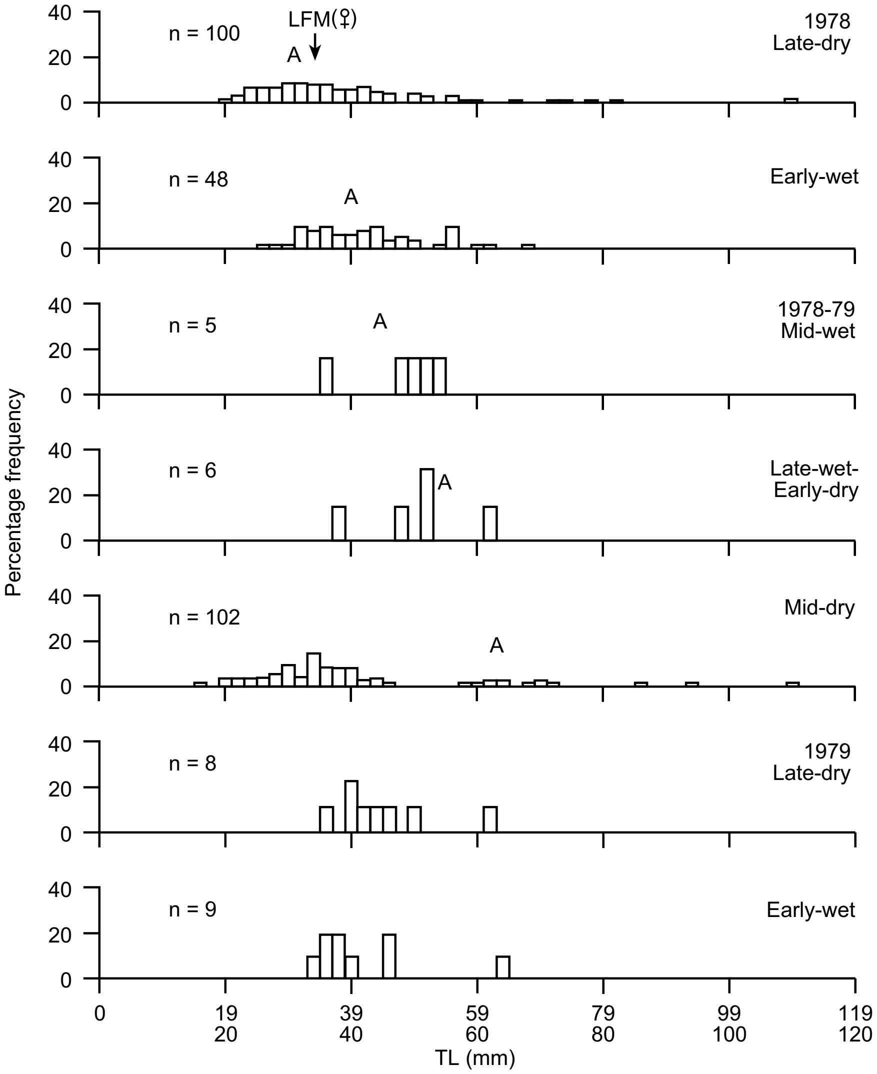

Figure 147 Seasonal length-frequency distribution of all *G. giuris* captured

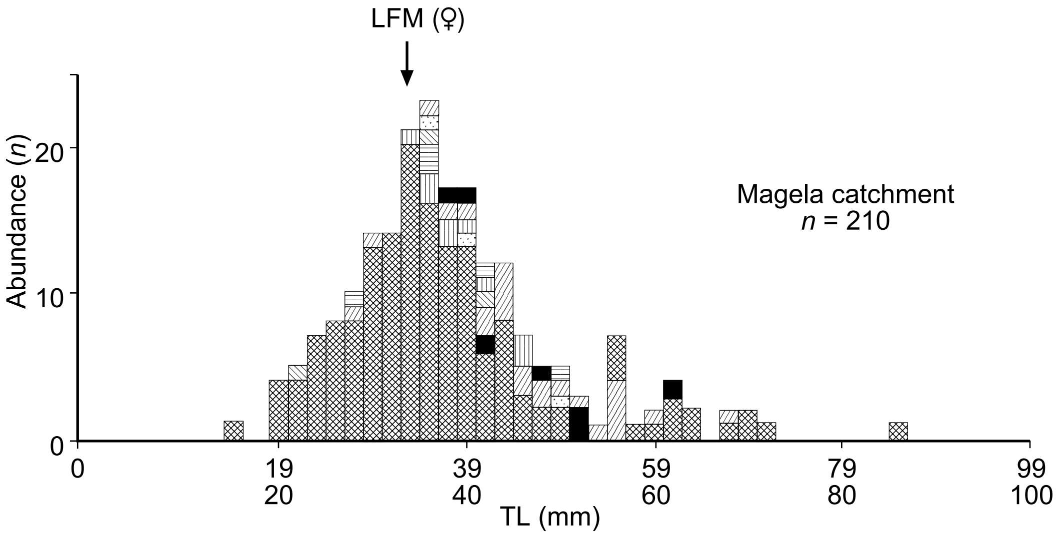

Figure 148 Length-frequency distribution and habitat preferences of *G. giuris* captured at regular sampling sites (see appendix 5 for key to the habitats)

The largest adults were found in sandy corridor waterbodies, as were most of the smaller adults; however, juveniles apparently dispersed to a wider variety of habitats upon attaining the LFM, as larger proportions of these small adults were found in lowland sandy creekbeds, lowland backflow billabongs, floodplain billabongs and escarpment mainchannel waterbodies. Few adults were found in lowland habitats upstream of the RUPA.

Of the few adults captured in the Nourlangie Creek system, the smallest and largest were found in lowland sandy creekbeds and the intermediate sizes were found in escarpment mainchannel waterbodies. No adults were ever observed in perennial or seasonal escarpment streams. Large numbers of adults and juveniles were observed in the littoral zone of occasionally sampled sandy corridor waterbodies in the Nourlangie system.

Environmental associations

Rank numbers for *G. giuris* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

At sites where *G. giuris* were captured, temperatures ranged from 23 to 38°C (mean = 30.7°C) on the surface, and from 23 to 35°C (mean = 29.7°C) on the bottom. Both means were ranked in the upper-middle quarter (see fig 170).[205]

Dissolved oxygen

Concentrations in waters in which *G. giuris* was found ranged from 5.4 to 7.4 mg/L (mean = 6.4 mg/L) at the surface, and from 5.2 to 6.8 mg/L (mean = 6.3 mg/L) on the bottom. Both means were ranked in the upper quarter (see fig 171). *Glossogobius giuris* appears to prefer a narrow range of moderately high DO concentrations, but the number of readings of DO concentrations was too small to be certain.

Visibility

Glossogobius giuris was captured in waters ranging from very clear to very turbid, as evidenced by the range of Secchi depths at sites where it was found (1–360 cm, mean depth = 76 cm). The mean depth was ranked in the upper quarter (see fig 172).

pH

The pH values of waters inhabited by *G. giuris* ranged from 5.6 to 8.3 (mean = 6.5) on the surface, and from 5.1 to 6.7 (mean = 6.2) on the bottom. These means were ranked in their respective upper quarters (see fig 173). This range of pH values is less acidic than the waters in which most other species in this study were found.

Conductivity

Readings in waters at sites where this species was captured ranged from 4 to 56 µS/cm on the surface, and from 6 to 36 µS/cm on the bottom. *Glossogobius giuris* is euryhaline, being found in coastal marine to inland freshwater habitats (Pollard 1974, Roberts 1978).[206]

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[205] Geevarghese and John (1984) showed that the relationship of oxygen consumption to body weight in *G. giuris* was negative. Oxygen consumption also showed a positive exponential relationship with temperature and the partial pressure of the medium, while it was negatively exponentially related to salinity. Consumption of oxygen was higher in females than males.

[206] Geevarghese and John (1984) showed that there was a negative exponential relationship between salinity and the oxygen consumption of *G. giuris*. The fish examined had been acclimated to 13.4 ppt salinity for 14 days before the experimentation.

Habitat–structural variables

Substrate

Glossogobius giuris was captured over a wide variety of substrates. Sandy substrates were clearly the most common (upper quarter), followed by leaf litter (upper quarter) then, in order, mud, rocks and clay (see fig 174). As with the physico–chemical parameters (above), the species' distribution is reflected in the variety of substrates over which it was found.

Hydrophytes

Glossogobius giuris was commonly found in moderately vegetated waters (vegetation-occurrence index 66%). Submergent and emergent hydrophytes were equally abundant in all sites sampled, and their percentage dominance values were both ranked into the upper quarter. Pollard (1974) found all of his specimens of *G. giuris* living amongst vegetation at the banks of waterholes.

Reproduction

A total of 118 *G. giuris* were examined for reproductive condition: 22 females (length range 35–110 mm TL), 25 males (32–108 mm TL) and 71 sexually indistinguishable fish (19–77 mm TL) (fig 149).

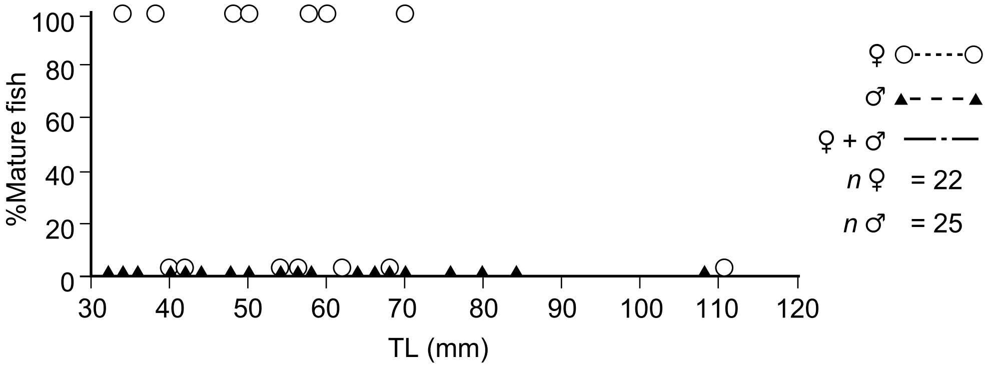

Figure 149 Estimated length at first maturity (LFM) of *G. giuris*

Length at first maturity

As no males with gonad stages greater than III (developing) were collected, neither a minimum length of maturation nor LFM could be estimated.

Maturing females were identified at even the smallest size of sexually distinguishable fish. The LFM was most likely around 35 mm TL, as gonads from fish captured below this length were indistinguishable (table 129).

Sex ratio

Glossogobius giuris was captured infrequently throughout the study, with no males or females being identified in the 1979 Late-wet–Early-dry or 1979–80 Early-wet seasons, and only one male in the 1978–79 Mid-wet season. Sex ratios were not significantly different from 1:1 in the remaining seasons (table 130).

Breeding season

The breeding season of this species cannot be determined from the data available (tables 129 & 130; fig 150). The GSI and GMSI fell between the 1978 Late-dry and 1978–79 Early-wet seasons, but rose again during the 1979 Mid-dry and 1979 Late-dry seasons, especially the females'. Too few fish were captured between the 1978–79 Early-wet and the 1979 Mid-dry seasons to determine the stages of reproductive development during that time.

Table 129 The range in gonad stages of each 10-mm-length size class of *G. giuris*

		Range of gonad stages						
Sex	Length (mm)	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
F	30–39	iii,iv	–	–	–	–	ii,v	–
	40–49	iv,v	–	–	–	–	ii,iii	–
	50–59	iii,v	–	–	–	ii	–	–
	60–69	–	i	–	–	i,v	v	–
	70–79	iv	–	–	–	–	–	–
	110	–	–	–	–	iii	–	–
M	30–39	ii	ii	–	–	–	–	–
	40–49	ii	–	–	–	–	i	–
	50–59	ii	i,ii	i	–	–	–	–
	60–69	iii	i	–	–	ii	–	–
	70–79	ii	–	–	–	iii	–	–
	80–89	iii	–	–	–	iii	–	–
	108	ii	–	–	–	–	–	–

Table 130 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *G. giuris* over all habitats.

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	8	1	–	–	7	6	–
Adults	M	*n*	13	6	1	–	4	1	–
		χ^2	1.2	3.6	1.0	–	0.8	3.6	–
		P	n.s.	n.s.	n.s.	–	n.s.	n.s.	–
GSI									
Adults only	F	mean	3.4	0.1	–	–	1.4	2.6	–
		s.d.	1.8	–	–	–	2.1	2.2	–
	M	mean	0.7	0.2	0.1	–	0.2	0.1	–
		s.d.	0.5	0.1	–	–	0.1	–	–
	F+M	mean	1.5	0.1	–	–	0.8	2.5	–
		s.d.	1.4	0.1	–	–	0.9	2.4	–
GMSI									
Adults only	F	mean	4.1	1.0	–	–	2.7	3.3	–
		s.d.	0.6	–	–	–	1.3	1.4	–
	M	mean	2.2	1.7	1.0	–	2.5	1.0	–
		s.d.	0.4	0.5	–	–	0.6	–	–
	F+M	mean	2.8	1.5	–	–	2.7	3.1	–
		s.d	1.1	0.5	–	–	0.4	1.6	–

n = number identified; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); $\bar{x}$ = mean; s.d. = standard deviation.

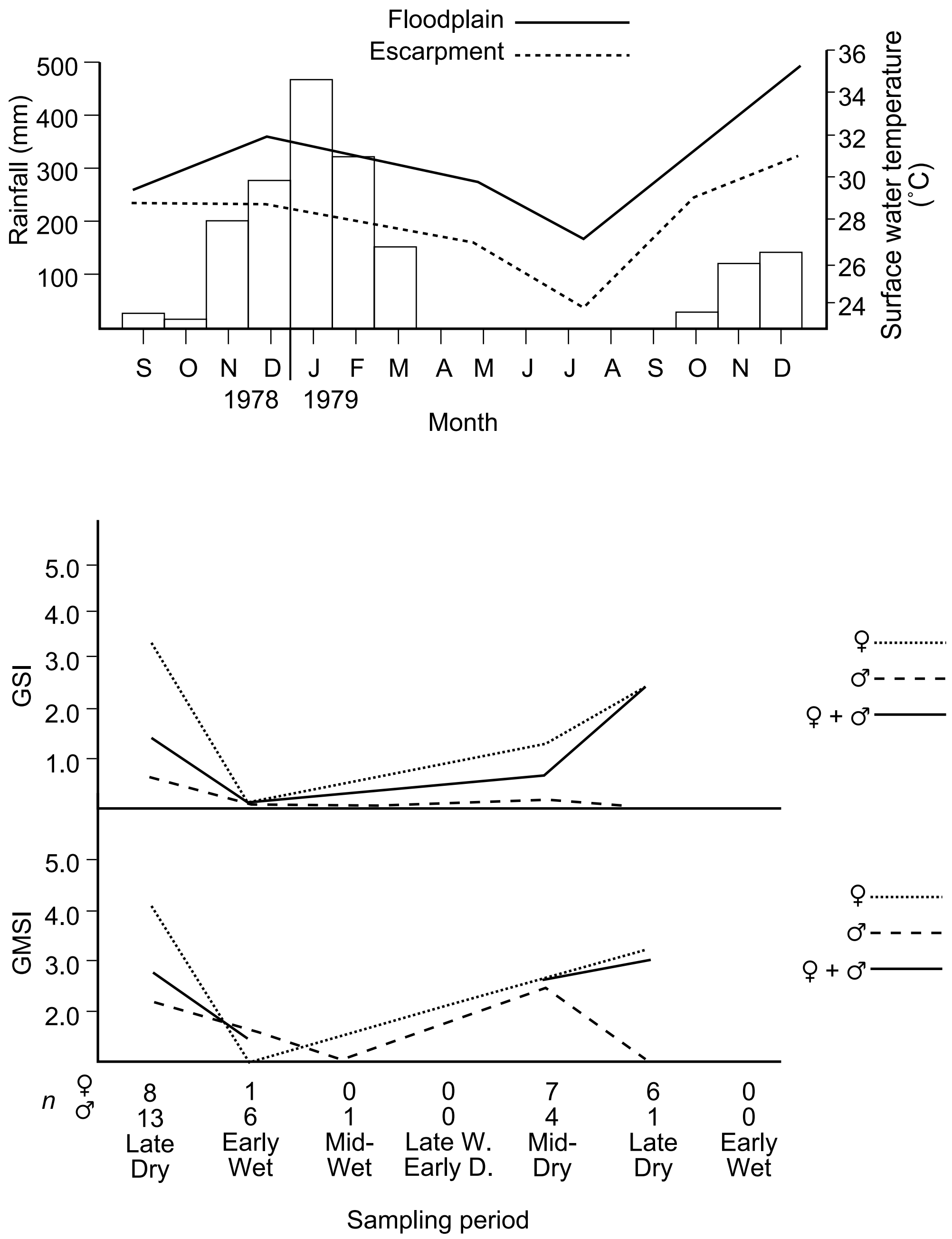

Figure 150 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad stage maturity index (GSMI) of *G. giuris*

Maturing females were identified in the 1978 Late-dry season and mature females in the 1978 Late-dry, 1979 Mid-dry and 1979 Late-dry seasons. Juvenile fish were collected mainly in the 1978 Late-dry and 1979 Mid-dry seasons (three juveniles were also collected in the 1978–79 Early-wet season).

The evidence suggests this species may breed during the Dry season, but no definite conclusions can be drawn. *Arenigobius bifrenatus*, a goby found in freshwater in southern Australia, spawns in spring and early summer (Hoese & Larson 1980) and *G. giuris brunneus* (=*olivaceus*) spawns in mid-summer in southern Japan (Ishikawa & Nakamura; in Breder & Rosen 1966). *Glossogobius* sp. bred aseasonally in Papua New Guinea (Roberts 1978).

Site of spawning

Mature fish were collected from a backflow billabong (Deaf Adder) in the South Alligator system, and two corridor waterbodies (Mudginberri Corridor and Buffalo Billabong) in the Magela Creek system. Juvenile fish were caught in a range of habitats from escarpment mainchannel waterbodies (Bowerbird Billabong) through lowland sandy creekbeds (Magela bed) to corridor waterbodies (Mudginberri Corridor). No ripe or spent fish or fish smaller than 15 mm were captured.

Hora (in Breder & Rosen 1966) suggested that *G. giuris* migrates to the sea to reproduce. As very few fish were captured during the Wet season in the present study, it is possible that there was a migration out to sea, but the drop in GSI at the start of the Wet season suggests that reproductive development was not increasing, as would be expected before a spawning migration. Juvenile fish (20–24 mm TL) were found in the escarpment area of Magela Creek in the 1978 Late-dry, and 15–19 mm TL fish were found in lowland sandy creekbeds near Gulungul Billabong in the same season. As there had been no flow, and the pools had been isolated from each other (and the sea) for at least four months, breeding was likely occurring at these and the other sites where small juveniles were found (table 131).

Table 131 Possible sites of spawning of *G. giuris,* as indicated by the abundance (*n*) of maturing, mature, ripe and juvenile fish

	Gonad stage						
	Maturing (IV)		Mature (V)		Ripe (VI)		Juvenile
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	0	0	0	0	0	0	3
Lowlands							
Sandy creekbed	0	0	0	0	0	0	16
Backflow billabong	4	0	5	0	0	0	0
Corridor	1	0	3	0	0	0	49

Fecundity

Three ovaries were examined. Egg numbers were approximately 1000 (length of fish 35 mm TL; GSI 6.25), 5000 (61 mm TL, GSI 4.53) and 16 000 (60 mm TL, GSI 6.20).[207] The eggs were pyriform in shape (approximately 0.3 mm long and 0.1 mm wide) and uniformly packed together. Each egg contained thousands of spherical granules.

Many records of breeding in the family Gobiidae (eg Breder & Rosen 1966) cite relatively small fecundities (eg 150–250 eggs per *Chlamydogobius eremius* female, Lake Eyre drainage, Central Australia) and egg sizes around 3 mm long by 1 mm diameter (eg 3.5 mm long for *G. giuris brunneus* from southern Japan). However, larger fecundities, of the order found in this study, have been reported: *Bathygobius soporator* from Florida, United States of America, spawns 15 000 to 18 000 eggs (Tavolga, in Breder & Rosen 1966) and *Favonigobius reichei* from India, which spawns before the monsoon season (October/ November), has eggs only 0.4 mm long. Aiyar (in Breder & Rosen 1966) attributed their

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[207] Gosh and Konar (1992) examined various aspects of the biology of *G. giuris* in the organically polluted Mathabhanga-Churni River in India. Oxygen depletion was the primary impact mechanism. In the most polluted zone the fecundity ranged from 200–300 eggs per female. Eighty kilometres further downstream the fecundity ranged from 400–500 eggs per female.

hatching more rapidly (in three days) than the European forms to the extremely small eggs and the higher temperatures of the habitats.

As both small eggs and relatively high temperatures occur in the Alligator Rivers area, a similar incubation period is suggested.

Summary

No definite breeding season or site of spawning could be determined, due to the small sample size captured. Reproductive development appeared to fall after the end of the 1978 Dry season and rose again at the 1979 Mid-dry season; however, very few maturing fish were captured during the study. Juvenile fish were found over a range of sites at the end of the 1978 Dry season, when the pools had been isolated for many months. This suggests *G. giuris* bred at those sites during the Dry season. A large number of very small eggs are spawned. The incubation period is probably short, due to the size of the eggs and the high water temperatures.

The family Gobiidae generally exhibit secondary sexual dimorphism. The males are often larger and with longer fins and brighter colours. Their urinogenital papilla is often longer and pointed, while females have a flatter, more rounded papilla. Males may pair with successive females. Demersal eggs with either threads or an adhesive pedestal are attached to the bottom or to objects on the bottom. The male builds a nest or selects a nesting site and guards, and usually aerates, the eggs (Breder & Rosen 1966), which hatch in a few days into planktonic larvae (Hoese & Larson 1980).

Feeding habits

Overall diet

The stomachs of 117 specimens were examined; 93 contained food. The diet of *G. giuris* is summarised in figure151: the components are listed in table 132. The main components were aquatic insects (68%) and microcrustaceans (13%). The aquatic insects were mainly chironomid larvae and then corixid bugs. Cladocerans (*Diaphanosoma*) were the main microcrustaceans. Oligochaetes and teleosts, as well as traces of nematomorphs and aquatic arachnids, were also eaten. *Glossogobius giuris* can therefore be classified as a meiophagic carnivore feeding opportunistically in the benthic and midwater zones of the waterbodies.[208]

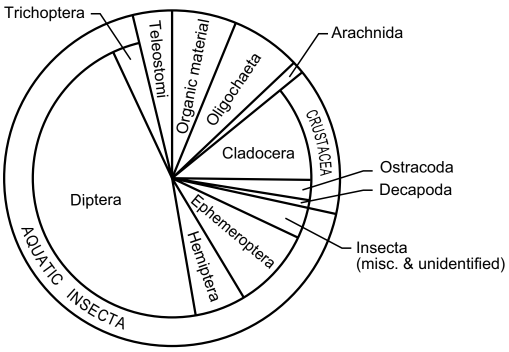

Figure 151 Dietary components of *G. giuris*

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[208] Mehta et al. (1990) indicated that *G. giuris* has a supraterminal mouth capable of straining food particles and preventing the prey from escaping. It was also noted that the cavity of the mouth cannot be enlarged much.

Table 132 Dietary composition of *G. giuris*

	Habitat					Season								
	Magela system				Nourlangie system	1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Em	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic animals														
Nematomorpha	–	–	–	–	–	–	3.9	–	–	–	–	–	1.1	1.1
Oligochaeta	–	–	–	5.4	–	13.9	–	–	–	–	–	–	5.4	5.4
Arachnida														1.1
Hydracarina	–	–	–	2.7	–	2.8	–	–	–	–	–	–	1.1	
Microcrustacea														12.7
Conchostracea														
Cyzicus	–	–	–	0.5	–	–	0.8	–	–	–	–	–	0.2	
Cladocera														
Miscellaneous	–	–	–	5.4	–	3.9	3.9	–	–	–	–	–	2.6	
Diaphanosoma	–	2.0	61.8	–	–	–	1.2	–	–	–	–	97.1	7.6	
Ostracoda	–	6.7	6.4	–	–	2.2	3.9	–	–	–	1.9	2.9	2.3	
Macrocrustacea														1.1
Macrobrachium	–	6.7	–	–	–	2.8	–	–	–	–	–	–	1.1	
Insecta														68.0
Fragmented	33.3	–	–	3.0	–	5.6	0.4	20.0	–	11.1	–	–	4.4	
Ephemeroptera														
Baetidae	–	21.3	–	2.8	–	–	16.4	–	–	–	–	–	4.6	
Atalophlebia	–	22.7	–	–	–	–	13.1	–	–	–	–	–	3.7	

Table 132 continued

	Habitat					Season								
	Magela system				Nourlangie system	1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Em	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Hemiptera														
Corixidae	–	–	–	13.0	20.0	–	–	20.0	–	–	60.0	–	6.2	
Diptera														
Chironomidae (larvae)	33.3	22.7	13.2	52.4	74.0	36.7	46.2	60.0	50.0	60.6	25.0	–	39.4	
Chironomidae (pupae)	–	–	–	5.4	–	9.4	–	–	–	–	–	–	3.7	
Ceratopogonidae	–	6.7	–	1.9	6.0	0.8	7.7	–	–	–	10.0	–	3.3	
Trichoptera														
Hydroptilidae	–	–	–	2.7	–	–	–	–	–	11.1	–	–	1.1	
Leptoceridae	–	–	9.1	1.4	–	–	–	–	–	16.7	–	–	1.6	
Teleostomi														4.4
Fragmented	–	–	–	–	–	2.8	–	–	–	–	–	–	1.1	
Craterocephalus spp.	–	–	–	–	–	2.8	–	–	–	–	–	–	1.1	
Ambassis spp.	33.3	–	–	–	–	2.8	–	–	–	–	–	–	1.1	
G. giurus	–	–	–	–	–	2.8	–	–	–	–	–	–	1.1	
Parasites														
Nematoda	–	–	–	0.5	–	1.7	–	–	–	–	3.1	–	0.9	0.9
Inorganic material	–	–	0.5	0.1	–	–	0.2	–	–	0.6	–	–	0.1	0.1
Organic material	–	11.3	9.1	2.7	–	9.2	2.7	–	50.0	–	–	–	5.4	5.4
Number of empty fish	–	5	2	6	–	15	2	–	4	2	–	1	24	24
Number of fish with food	3	15	11	37	5	36	26	5	2	9	8	7	93	93

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs

Pollard (1974) postulated that this species was probably an opportunistic carnivore. Haines (1979) noted that it was a 'prawn eater' in the Purari River, Papua New Guinea, while Roberts (1978) noted that it feeds on insects and prawns in the Fly River, Papua New Guinea.[209]

Habitat differences

A total of 79 stomachs of *G. giuris* were analysed (all seasons combined) from the Magela Creek catchment: 3 (0% empty) from escarpment mainchannel water-bodies, 20 (75% empty) from lowland sandy creekbeds, 13 (15% empty) from shallow backflow billabongs, and 43 (14% empty) from corridor waterbodies. The highest proportion of empty stomachs was thus found in fish from sandy creekbeds and the lowest proportion in the few fish from escarpment mainchannel waterbodies (table 132).

The small number of *G. giuris* examined from the escarpment zone were feeding only on aquatic insects (chironomids and unidentified fragments) and fish (*Ambassis* spp.). In the sandy creekbed lowland pools the diet consisted mainly of aquatic insects (baetids and chironomid larvae) and some macrocrustaceans (*Macrobrachium*) and microcrustaceans (mainly ostracods).

In the lowland shallow backflow billabongs, *G. giuris* had eaten mainly cladocerans (*Diaphanosoma*) with some aquatic insects (chironomid larvae and leptocerid larvae). In the corridor waterbodies, the diet was more varied (possibly due to the small sample size): mainly aquatic insects (mainly chironomid larvae and corixid bugs) with some oligochaetes, hydracarinids, cladocerans and traces of conchostracans.

Catchment differences

Five stomachs of *G. giuris* from an escarpment mainchannel waterbody in the Nourlangie Creek system were analysed; all contained food. The fish had eaten only aquatic insects (chironomid larvae, corixid bugs and ceratopognid larvae) and no teleosts, unlike the fish in the equivalent Magela Creek system habitat.

Seasonal changes

In sampling periods 1–7, respectively, 51 (29% empty), 28 (7% empty), 5 (0% empty), 8 (67% empty), 11 (18% empty), 8 (0% empty) and 8 (13% empty) stomachs of *G. giuris* were analysed (all habitats combined). The highest proportions of empty stomachs were thus found in the Late-wet–Early-dry season and the lowest proportions in the 1978–79 Mid-wet and 1979 Late-dry seasons.

The diet in the 1978 Late-dry season was based primarily on aquatic insects (as in all other seasons except the 1979–80 Early-wet season), with chironomid larvae as the main component. Oligochaetes, micro- and macrocrustaceans and teleosts (this was the only season when teleosts, namely *Craterocephalus* spp., *Ambassis* spp. and *Glossogobius* spp., appeared in the diet) were also found in the stomachs. The aquatic insects remained important in the diet during the 1978–79 Early-wet season, with an increase in baetid and chironomid larvae. Microcrustaceans became a more important component in the 1978–79 Early-wet season;

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[209] Singh and Datta Munshi (1985) concluded that *G. giuris* from the River Ganga in India was a voracious carnivore. The gut contents comprised fishes, crustaceans, insect larvae and molluscs. It was also observed that the fish was a bottom dweller but a mid-water feeder. A cannibalistic food habit was also apparent, confirming findings by Bhiuyan and Haque (1984) who examined *G. giuris* from the River Padma. The latter authors noted that adults were highly cannibalistic, particularly the males. Note that in the present study in the Alligator Rivers Region *G. giuris* occurred in the stomach contents of the same species during the 1978 Late-dry season.

similarly, cladocerans (*Diaphanosoma*) and ostracods were the sole food in the stomachs in the 1979–80 Early-wet season.

During the Mid-wet season the few specimens examined had eaten only aquatic insects, with a larger component of chironomid larvae than at any other season. During the Late-wet–Early-dry season they appeared to eat mainly chironomid larvae, but large volumes of unidentified organic material were also present. In the 1979 Mid-dry season they again ate only aquatic insects (mainly chironomid, hydroptilid and leptocerid larvae). By the 1979 Late-dry season the aquatic insects were still most important, but there were more corixid bugs in the stomachs; microcrustaceans (ostracods) appeared for the first time since the previous Early-wet season.

Fullness

A summary of mean fullness indices of *G. giuris* for different periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 133. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 133 Mean fullness indices of *G. giuris* in different sampling periods and habitats

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	3.5 (2)	n/s	0 (1)	n/s	n/s	n/s	0 (1)	1.8 (4)
Downstream of RUPA:								
Lowland sandy creekbed	1.2 (5)	2.4 (15)	n/s	n/s	n/s	n/s	n/s	2.1 (20)
Lowland channel backflow billabong	0.7 (3)	n/s	n/s	n/s	0 (1)	n/s	n/s	0.5 (4)
Lowland shallow backflow billabong	n/s	0 (1)	n/s	n/s	n/s	n/s	1.4 (8)	1.2 (9)
Corridor sandy billabong	3.2 (5)	3.8 (1)	1.0 (2)	n/s	2.5 (10)	3.8 (5)	n.s.	3.1 (23)
Corridor anabranch billabong	2.0 (4)	n/s	n/s	n/s	n/s	1.5 (2)	n/s	1.8 (6)
Floodplain billabong	n/s	n/s	n/s	0.4 (5)	n/s	0 (1)	n/s	0.3 (6)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	3.5 (2)	0 (1)	1.5 (2)	n/s	n/s	n/s	n/s	2.0 (5)
Lowland sandy creekbed	n/s	0 (1)	n/s	0 (1)	n/s	n/s	n/s	0 (2)
Seasonal mean (all sites)	1.8	3.0	1.4	0	1.6	3.0	1.7	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment upstream of RUPA, the mean fullness indices in escarpment waterbodies were similar to some other downstream habitats.

Downstream from RUPA, the mean fullness indices were highest in corridor sandy billabongs and lowest in floodplain and channel backflow billabongs.

Few specimens were captured in the Nourlangie catchment; however, in the escarpment waterbodies their mean fullness indices were slightly higher than in the equivalent Magela catchment. The few specimens captured in the lowland sandy creeks had not been feeding.

Seasonal changes

The mean fullness index (all habitats combined) peaked in the 1978–79 Early-wet season then gradually fell to a low in the Late-wet–Early-dry season. It rose again to peak in the 1979 Late-dry season, and then fell in the following Early-wet season.

Summary[210]

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- corridor sandy billabong; 1978–79 Early-wet season, 1978 and 1979 Late-dry seasons
- escarpment mainchannel waterbody; 1978 Late-dry season

Nourlangie catchment

- escarpment mainchannel waterbody; 1978 Late-dry season.

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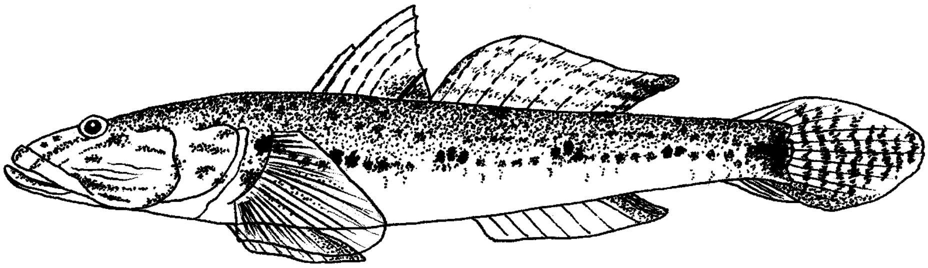
[210] Singh and Datta Munshi (1985) showed that *G. giuris* from the River Ganga in India fed throughout the year. Feeding activity peaked on three occasions: January, March to May, and October/November. It was apparent that less food was consumed during the monsoon (June to August) and winter (December) periods.

Family GOBIIDAE

3.34 *Glossogobius aureus* (Akihito and Meguro)

Glossogobius aureus (identified by Dr D Hoese of the Australian Museum) is commonly known as the golden goby. It is found in tropical freshwaters within the western Pacific and Eastern Indian ocean regions; the northern limit is Japan (Lat. 24°20'), the western limit is West Penang (Malaysia) and the southern limit is the Laura and Normandy Rivers (Lat. 15°50') of north Queensland, Australia.[211] In Australia it has been collected in the north-east coastal and Gulf of Carpentaria drainages (map 3); there is one previous record (unspecified site) for the Northern Territory.[212] A number of species of *Glossogobius* are found in the Indo-Pacific region, some in marine waters, some in brackish estuaries, and some in freshwaters. There appear to be no previous reports on the biology of this or other species of *Glossogobius*.[213] *Glossogobius aureus* differs marginally from *G. giuris* in having a slightly more rounded head, having an elongate black spot near the base of the sixth dorsal spine of the first dorsal fin, and having single (uniserial) rather than double or triple papillae in the five papillae rows across its cheek.



Glossogobius aureus

Information on catches for each site and each season is given in volume 2. It was only found in occasionally sampled lower riverine floodplain billabongs.

Size composition

The lengths and weights of 53 specimens were recorded.

Length composition

The specimens ranged in length from 20 mm to 125 mm TL.[214] The mean length was 53.3 mm TL and the modal lengths were 50–51 mm and 36–37mm. The smallest specimen was captured in the 1978 Late-dry season and the largest in the Mid-wet season. All specimens were either found in a riverine floodplain billabong (Cannon Hill Billabong) or tidal billabong (Rock Hole).

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[211] Note footnotes in the *G. giuris* section that arise from recent publications on that species.

[212] Larson and Martin (1989) indicated that in the Northern Territory this species is widely distributed and found in the Timor and Gulf drainages, from Victoria River across eastern Arnhem Land to the Nicholson River.

[213] Allen (1991) indicated that *G. aureus* has only been collected from a single creek system near Wewak in northern Papua New Guinea. It inhabits clear to turbid water over sand or gravel.

[214] Herbert and Peeters (1995) indicated that *G. aureus* grows to 200 mm TL.

Length–weight relationship

The length–weight relationship is described by the following expression:

$W = 5.47 \times 10^{-3} L^{3.19}$ r = 1.00 (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors are shown in table 134. The condition factor was highest in the 1978 Late-dry season and lowest in the Mid-wet season, as was the case for *G. giuris*.

Table 134 Mean length, mean weight and condition factor of *G. aureus*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry	47	52.3	1.09	1.01
Mid-wet 1978–79	6	61.8	1.68	0.91
All seasons combined	53	53.3	1.14	1.00

Reproduction

Of 50 *G. aureus* examined, 30 were sexually indistinguishable (length range 20–74 mm TL), 8 were females (41–125 mm TL) and 12 were males (48–100 mm TL).

Except for one male captured in a tidal billabong (Rock Hole) during the 1978–79 Mid-wet season, all specimens were collected in the 1978 Late-dry and 1978–79 Mid-wet seasons from a riverine floodplain billabong (Cannon Hill Billabong).

Length at first maturity

No LFM was determined for this species, as few fish were collected. The smallest maturing fish were an 82 mm TL male and a 48 mm TL female.

Sex ratio

Most of the fish were collected from Cannon Hill Billabong in the 1978 Late-dry season. Ten were males and five were females, which is not significantly different (χ^2 test) from a 1:1 ratio.

Breeding season

Three of the five females in the 1978 Late-dry were mature, and two of the ten males were either maturing or mature. No ripe or spent fish were captured. One maturing female was caught in the 1978–79 Mid-wet season; the remainder were immature. Breeding may have taken place soon after the 1978 Late-dry season.

Site of spawning

Since fish were captured from only two sites in the study area, the range of possible spawning habitats could not be determined; however, as maturing fish and small juveniles (20 mm TL) were found in a riverine floodplain billabong (Cannon Hill Billabong), spawning most likely occurs at this site.[215]

Summary

The small range in sites and seasons of capture for this species resulted in limited information being available for analysis. Fish were maturing during the 1978 Late-dry season and probably spawning in the 1978–79 Early-wet season in the riverine floodplain billabong.

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[215] Herbert and Peeters (1995) indicated that *G. aureus* probably has a marine larval stage.

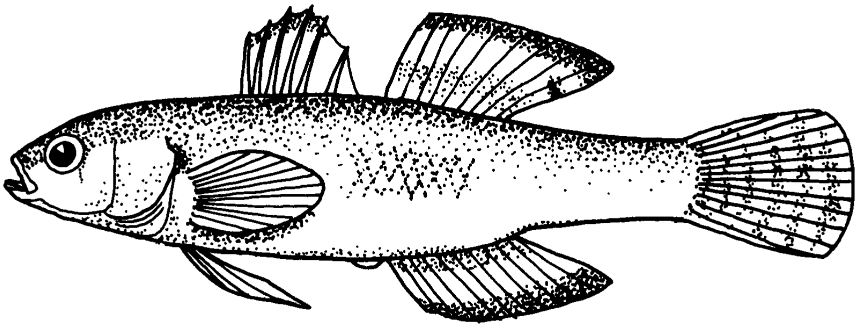
Feeding habits

The stomachs of 26 specimens were examined; 24 contained food. The main components of the diet were aquatic insects (49%), teleosts (17%) and macrocrustaceans (*Macrobrachium*). The aquatic insects were mainly chironomid larvae and pupae, chaorborinids and *Anisops*. The teleosts were *M. splendida inornata, Ambassis* spp. and *Glossogobius* spp. Oligochaetes, microcrustaceans (cladocerans), terrestrial zygopterans and traces of filamentous green algae also appeared in the diet. *Glossogobius aureus* could be classified as a meiophagic carnivore, opportunistically capturing organisms from the benthic, mid-water, and sometimes surface waters. This species appears to have similar feeding habits to *G. giuris,* but with the difference that it eats larger-sized and surface-dwelling organisms.

Family ELEOTRIDIDAE

3.35 *Hypseleotris compressa* (Krefft)

Hypseleotris compressa is commonly known as the empire fish or northern carp gudgeon. It is relatively common at low altitudes in coastal streams of Victoria, New South Wales, Queensland, the Northern Territory, and northern Western Australia, and also occurs in the coastal streams of Papua New Guinea.[216] All other species in this genus appear to be restricted to freshwaters; however, *H. compressa* can tolerate brackish water (Larson & Martin 1989), and has been collected from seawater creeks (Northern Territory Museum records) from brackish waters in the Hunter River catchment, New South Wales.[217] Midgley (1973) reported that *H. simplex* (which is now considered synonymous with *H. compressa*) was commonly captured in floodplain billabongs of the Alligator Rivers Region. This and the other related species in the genus make excellent aquarium fishes.



Hypseleotris compressa

Detailed information on catches at each site and each season is given in volume 2. In summary, this species was found occasionally in all floodplain billabongs and corridor anabranch billabongs. In the Nourlangie Creek catchment it was captured only in lowland shallow backflow billabongs. This species was also captured in lower riverine floodplain billabongs of the East Alligator Rivers. In the 1978 Late-dry it was captured in six sites; in the Mid-wet season it was found only in one floodplain billabong; in the Late-wet–Early-dry season no specimens were captured in the study area.

Size composition

The lengths and weights of 70 specimens were recorded.

Method artefacts

All specimens were collected by seine net. Clogging of the meshes by algae and hydrophytes sometimes resulted in the capture of considerable numbers of small juveniles.

Length–weight relationship

The length–weight relationship was described by the following expression:

$$W = 5.53 \times 10^{-3} L^{3.41} \qquad r = 0.94 \text{ (length in cm, weight in g)}$$

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[216] Allen (1991) noted that unlike in Australia where *H. compressa* is common, there are few reports of this species in PNG. Most reports are from the Fly River delta region including the Bensbach River.

[217] Herbert and Peeters (1995) indicated that *H. compressa* is common to abundant in all coastal streams of Cape York Peninsula to within about 30 km of tidal influence.

Seasonal condition factors, mean lengths and mean weights are shown in table 135.

Table 135 Mean length, mean weight and condition factor of *H. compressa*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	41	47.6	1.04	0.92
Early-wet (1978–79)	4	39.8	0.70	1.14
Mid-wet	18	51.2	1.71	1.18
Late-wet–Early-dry (1979)	1	62.0	2.00	0.80
Mid-dry	5	37.9	0.55	0.93
Late-dry	1	27.0	0.30	0.99
Overall	70	48.5	1.21	1.00

The seasonal condition factor was highest in the 1978–79 Early-wet and Mid-wet seasons and lowest in the Late-wet–Early-dry season. The condition in the Late-dry seasons was slightly better in the 1979 season; however, few specimens were examined in this period. The high level recorded in the Mid-wet season was most likely a result of the large proportion of sexually ripe fish found during the season; the drop in condition thereafter would have been a result of spawning activity, as juvenile fish were recorded by the 1979 Mid-dry season.

Length composition

The range in length was 22 mm to 69 mm TL (fig 152) Auty (1978) reported that this species grows to 100 mm. Bishop (1979) found *H. compressa* from 26 to 44 mm TL in a temperate coastal Australian drainage — the Shoalhaven River, New South Wales.

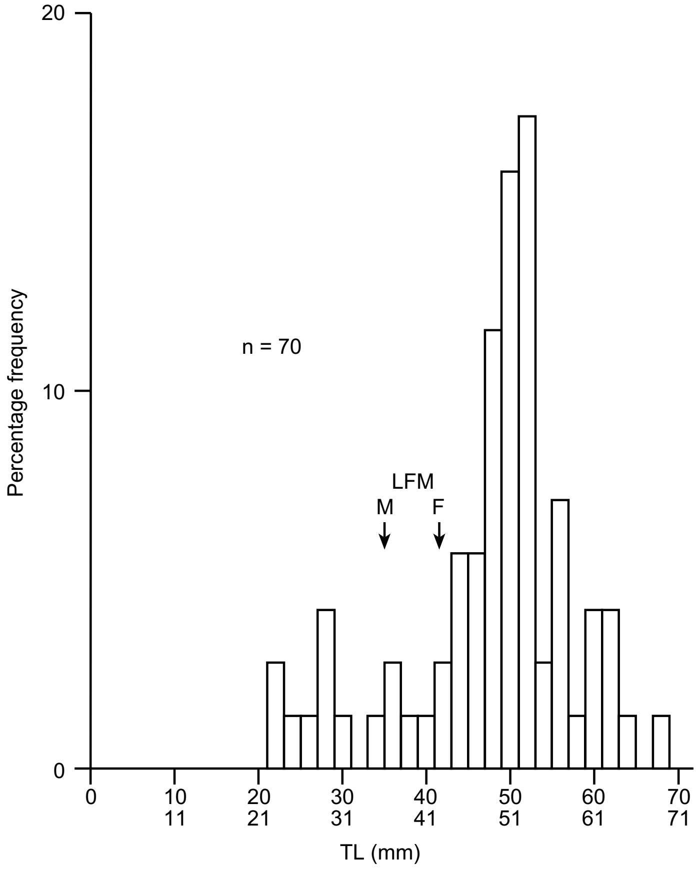

Figure 152 Length-frequency distribution of all *H. compressa* captured (all sites)

The smallest specimens were found in the Mid-dry season, followed closely by the 1978 and 1979 Late-dry seasons (fig 153) so juveniles probably recruit in those seasons. The largest specimen was captured in the Mid-dry season.

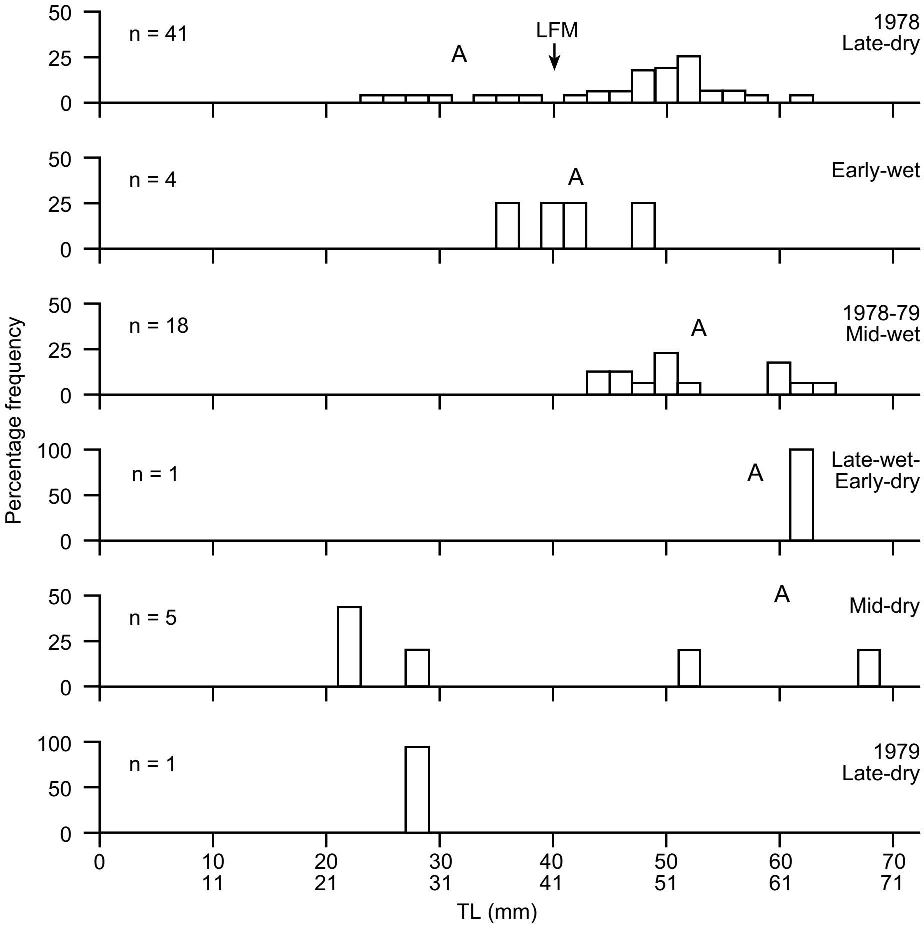

Figure 153 Seasonal length-frequency distribution of all *H. compressa* captured

Length-frequency distribution

The mean and modal lengths of all specimens captured were 48.5 and 52–53 mm TL, respectively. The length at first sexual maturity for males was 37 mm TL, and for females 43 mm TL, indicating that most specimens were adults. A mean LFM of 40 mm TL will be used in the following sections. Most specimens were between 44 and 56 mm. The overall distribution displayed a positive skew. (Very small specimens were frequently captured with aquatic plants that had clogged the 10 mm mesh.)

Seasonal mean lengths are shown in table 135. These were greatest in the Mid-wet and Late-wet–Early-dry seasons and lowest in the 1979 Late-dry season, followed by the Mid-dry and 1978–79 Early-wet seasons.

During the 1978 Late-dry season, there were strong adult and weak juvenile components in the samples (fig 153). By the 1978–79 Early-wet season only large juveniles and small adults were caught; these groups were dominated by adults in the Mid-wet and Late-wet–Early-dry seasons that followed. The small sample sizes make it difficult to interpret the length-frequency distributions for the remainder of the study. Juvenile peaks did, however, reappear during the 1979 Mid-dry season (with a diminishing adult component) and a juvenile was also found in the 1978 Late-dry season.

Growth rate

Estimation of growth rates from seasonal length-frequency distributions is complicated by the apparent frequency with which juveniles were recruited.

The growth of juveniles (median length 31–32 mm TL) in the 1978 Late-dry season may possibly be followed (A on fig 153) until the 1979 Mid-dry season 10 months later, when a median length of 60–61 mm was attained. This implies they grew about 30 mm, so this species may attain its LFM by the end of the first year of life.

Habitat differences in distribution

Most of the juveniles were found in floodplain billabongs and only large juveniles and small adults were found in corridor anabranch billabongs. No juveniles were found upstream from the corridor zone of the Magela Creek catchment. One large juvenile was found in a lowland shallow backflow billabong adjacent to a corridor waterbody in the Nourlangie Creek system.

Most adults were found in floodplain billabongs, with a few small adults being found in corridor anabranch billabongs. No adults were found upstream of the corridor waterbodies in the Magela Creek catchment.

Environmental associations

Rank numbers for *H. compressa* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Hypseleotris compressa was caught in waters with temperatures ranging from 28 to 36°C (mean = 30.8°C) on the surface, and from 27 to 33°C (mean = 29.9°C) on the bottom. These means were both placed in the upper quarter (see fig 170). Most specimens were found in the warmer floodplain billabongs. Bishop (1979) recorded specimens in the Shoalhaven River, New South Wales, at water temperatures down to 12°C, indicating this species can tolerate a wider range of temperatures than those recorded in the present study.

Dissolved oxygen

Concentrations in waters in which *H. compressa* was captured ranged from 3.7 to 7.8 mg/L (mean = 6.1 mg/L) at the surface. However, the narrow range may be because only six recordings were taken. The mean ranked in the lower-middle quarter (see fig 171). No bottom-water DO readings were obtained.[218]

Visibility

Secchi depths recorded in waters in which *H. compressa* was found ranged from 3 to 110 cm (mean = 25 cm) (see fig 172). This mean ranked at the base of the lower quarter, indicating a tendency for this species to be found in more turbid waters.

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[218] Gee and Gee (1991) found that 10, 50 and 90% of an experimental population of *H. compressa* commenced aquatic surface respiration (ASR) when dissolved oxygen levels fell below 1.0, 0.6 and 0.3 mg/L respectively. To perform ASR fish move to the surface and ventilate their gills with surface water (a few mm deep) which has a high oxygen content. Buoyancy control is critical for midwater fish like *H. compressa* during ASR because they must be at or near neutral levels and must position the body at an appropriate angle so that their mouth is within the upper few mm of the water column. *Hypseleotris compressa* maintained their buoyancy by swimming slowly at the surface, and not ingesting a buccal bubble as in other gobioid fish.

pH

Hypseleotris compressa were found at sites with surface water pH values ranging from 5.0 to 9.1 (mean = 6.9). This mean was ranked in the upper quarter (see fig 173). No bottom-water pH readings were taken.

Conductivity

Surface-water conductivities for waters associated with this species ranged from 4 to 160 µS/cm. Only ten readings of surface-water and one (18 µS/cm) of bottom-water conductivity were taken. Pollard (1974) stated that this species is generally found in fresh water. However, Bishop (pers. obs.) observed this species using a fish ladder at Seaham Weir, Hunter River, New South Wales, in waters of 10 ppt salinity.[219]

Habitat–structural variables

Substrate

Hypseleotris compressa was usually found in waters with muddy substrates (upper quarter), followed by clay (lower-middle quarter), then sand, rocks, gravel and leaves. This is in accord with this species' apparent preference for turbid waters (see fig 174). Lake (1971) and Pollard (1974) observed that this species attaches its eggs to firm submerged objects, such as rocks and plants; Hoese et al (1980) state that all species of Eleotridae attach their eggs to bottom substrates or to vegetation (see also Auty 1978). Thus, the type of substrate may be important to this species in its breeding seasons.

Hydrophytes

Hypseleotris compressa was found in the most heavily vegetated waters encountered in this study (vegetation-occurrence index 100%).[220] Submergent hydrophytes (upper quarter) were the most common, followed by emergent (upper-middle quarter) then floating-attached hydrophytes.

Reproduction

A total of 57 *H. compressa* were examined for reproductive condition; 13 were found to be female (length range 43–67 mm TL), 20 were male (35–62 mm TL), and 24 were sexually indistinguishable (20–54 mm TL).

Length at first maturity

The smallest maturing male and female were 38 and 43 mm TL, respectively. No females smaller than 43 mm were identified and all but one fish above this length were mature, so the LFM for females is taken to be 43 mm TL. The LFM for male fish is taken to be 37 mm TL (fig 154), as the males at 41 mm that were not maturing were sampled outside the breeding season, when they would not be expected to be mature, whereas the 38 mm male was sampled during the breeding season.

Sex ratio

All the adult fish (except one juvenile male) could be sexed. Significantly more males were identified ($0.01 < P < 0.05$) during the 1978 Late-dry season (table 136). Only one female

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[219] Data arising from Pollard and Hannan's (1994) study on fish communities in the lower Clarence River estuary in NSW indicated that 50% of the *H. compressa* captured came from waters with salinity > 7 ppt. The reducing proportions in relation to increasing salinity was as follows: 40% @ 11 ppt, 30% @ 12 ppt, 20% @ 13 ppt, and 10% @ 16 ppt (based on graphical data presented by Bishop [1999]). Williams and Williams (1991) investigated the salinity tolerance of the closely related *H. klunzingeri* from the Murray-Darling River system. They found that median lethal salinity (LD50) was 38.0 ± 1.1 ppt. The corresponding conductivities are far higher than any recorded in the Alligator Rivers Region.

[220] Allen (1991) indicated that in PNG *H. compressa* is usually found in flowing streams amongst vegetation or submerged tree branches. Herbert and Peeters (1995) indicated that *H. compressa* in Cape York Peninsula prefer slow-moving or still water with abundant cover from aquatic plants, twigs or branches.

was identified in that season, which may be due to undeveloped females being classified as sexually indistinguishable (the GSI was very low).

The sex ratio was not significantly different from 1:1 at any other season.

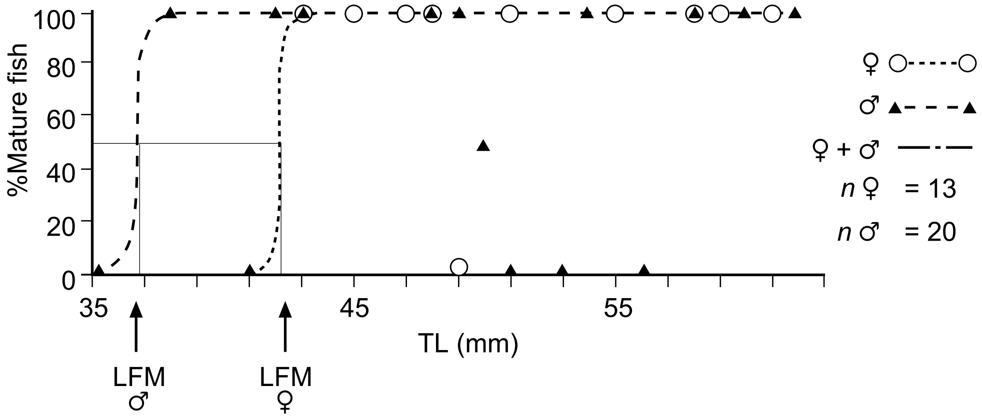

Figure 154 Estimated length at first maturity of male and female *H. compressa*

Table 136 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *H. compressa* over all habitats

Parameter	Sex	Statistic	Sampling period						
			Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	1	0	11	0	1	0	0
+ adults	M	*n*	8	3	7	1	1	0	0
		χ^2	5.4	3.0	0.9	1.0	0.0	–	–
		P	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	1	0	11	0	1	0	0
	M	*n*	8	2	7	1	1	0	0
		χ^2	5.4	2.0	0.9	1.0	0.0	–	–
		P	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s
GSI									
Adults only	F	mean	0.4	–	14.4	–	0.8	–	–
		s.d.	–	–	10.1	–	–	–	–
	M	mean	0.2	0.6	8.7	1.4	0.3	–	–
		s.d.	0.2	0.2	3.0	–	–	–	–
	F+M	mean	0.3	–	12.1	–	0.6	–	–
		s.d.	0.2	–	8.4	–	0.4	–	–
GMSI									
Adults only	F	mean	3.0	–	4.6	–	4.0	–	–
		s.d.	–	–	0.7	–	–	–	–
	M	mean	3.0	3.5	5.0	4.0	2.0	–	–
		s.d.	0.5	0.7	0.0	–	–	–	–
	F+M	mean	2.9	–	4.8	–	3.0	–	–
		s.d	0.5	–	0.3	–	1.4	–	–

n = number identified; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; s.d. = standard deviation.

Breeding season

The catches of *H. compressa* were small and were not evenly distributed over the seven sampling periods. It was therefore difficult to determine the breeding season for this species. The GSI (fig 155 and table 136) indicate a very large peak in reproductive development over the 1978–79 Mid-wet season.

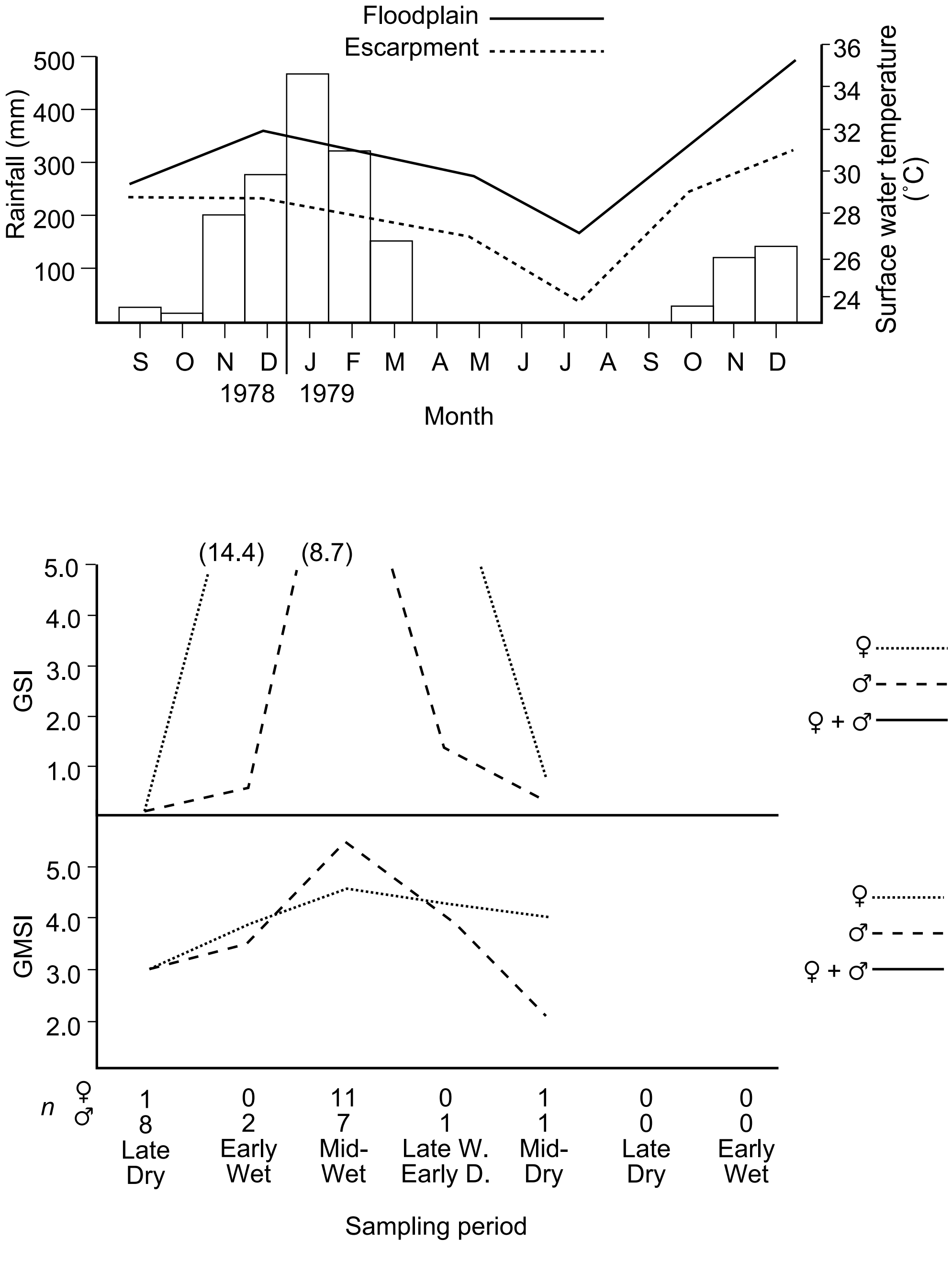

Figure 155 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad stage maturity index (GMSI) of male and female *H. compressa*

The GMSI also indicated a peak in development in that season, but this parameter remained high for longer: from the 1978 Late-dry season until the 1979 Late-wet–Early-dry season for males, or until the 1979 Mid-dry for females only.

Without samples from all seasons, it cannot be concluded that *H. compressa* breeds only in the Mid-wet season, although the evidence to date suggests this.

Mature fish were identified only in the 1978–79 Mid-wet, and juveniles (20–29 mm TL) were collected from the 1978 and 1979 Late-dry and the 1979 Mid-dry seasons. This information also supports a Mid-wet breeding season.

Site of spawning

Mature fish were captured from the upper Magela floodplain and on the East Alligator floodplain. None were ripe. Juveniles (20–29 mm TL) were captured in upper floodplain billabongs (table 137).

Table 137 Possible sites of spawning of *H. compressa* as indicated by the abundance (*n*) of mature and juvenile fish

	Gonad stage		
	Mature (V)		Juvenile
Habitat	F	M	
Floodplain billabongs			
Upper	1	0	0
Lower (riverine)	7	7	8

Fecundity

Egg numbers, from examination of seven ovaries, ranged from 4000 (45 mm TL; GSI 12.27) to 35 000 (48 mm TL; GSI 19.2) with a mean fecundity of 18 000 (standard deviation = 12 000). The eggs were, on average, 0.16 mm in diameter, ranging up to 0.32 mm in diameter.

In an aquarium, *H. compressa* spawned up to 20 times a season, with an average estimated egg count per laying of 2500 (ie up to 40 000 eggs per season; Auty 1978). Auty describes the eggs as demersal, very small and pear-shaped (0.26–0.28 x 0.30–0.32 mm), with an adhesive disc. They hatched in 10 to 10.5 hours at 30°C and in 12–12.5 hours at 26–28°C. The prolarvae were about 1 mm long and poorly developed, with no mouth or fins. Within 84 hours the eyes became pigmented, the jaw became functional and fins were developing.

The male guards the eggs, which are attached to firm objects, including plants (Lake 1978, Auty 1978, Hoese et al 1980).

Summary

Few *H. compressa* were captured during the study. Males were apparently smaller than females (this may be due to the small sample size). Males had an estimated LFM of 37 and females of 43 mm TL, and the sex ratio was 1:1 at all times except during the 1978 Late-dry season, when significantly more males were identified.

The peak in reproductive activity appeared to be during the 1978–79 Mid-wet, when many active specimens were collected from the lower riverine floodplain habitats. Juveniles are frequently found in estuaries (Hoese et al 1980). The male selects a territory and each female may mate with more than one male at a spawning session. A large number of tiny eggs are laid and attached to firm objects. The prolarvae are most likely washed down into the estuaries with the floods during the breeding season.

During breeding, the vertical fins of the male become more brightly coloured, and a bright orange colour develops under the head, belly and on the lower sides of the body (Hoese et al

1980, Auty 1978). The female develops a distinctive black spot at the base of the pectoral fins during spawning; the spot is normally present in mature males (Auty 1978).[221]

Feeding habits

Overall diet

The stomachs of 57 specimens were examined; 48 contained food. The diet of *H. compressa* is summarised in figure 156; the components are listed in table 138. The main components were microcrustaceans (mainly the cladoceran *Diaphanosoma* and copepods) and aquatic insects (mainly chironomid larvae). The large volume of unidentified organic material found in the stomachs was probably partly digested microcrustaceans. There were also algae (mainly phytoplankton) and traces of oligochaetes, detritus and inorganic material. *Hypseleotris compressa* can therefore be classified as a microphagic opportunistic carnivore (sometimes omnivorous) feeding on the benthos and from the mid-water zones of the waterbodies. These data agree with those of Lake (1978), who noted that this species ate small invertebrates, including mosquito larvae and cladocerans.

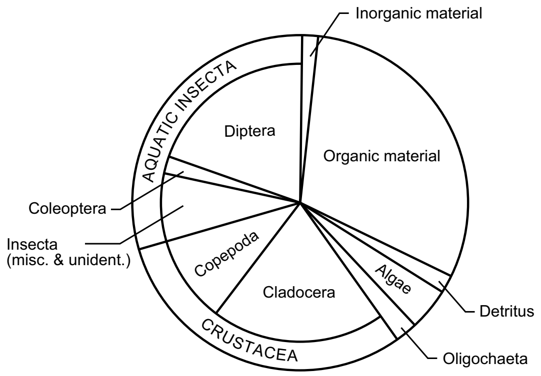

Figure 156 Dietary components of *H. compressa*

Habitat differences

Totals of 5 (20% empty) and 22 (18% empty) stomachs of *H. compressa* were analysed (all seasons combined) from the Magela Creek catchment corridor and floodplain billabongs, respectively. The largest volumes of organic, inorganic and detritus material, and some copepods and chironomid larvae were found in specimens from floodplain billabongs. Oligochaetes, cladocerans (*Diaphanosoma*) and chironomid larvae were mainly eaten by specimens in the corridor waterbodies.

Seasonal changes

In sampling periods 1, 2, 3 and 5, respectively, 28 (25% empty), 4 (0% empty), 18 (11% empty) and 5 (0% empty) stomachs of *H. compressa* were analysed (all habitats combined). The highest proportion of empty fish was in the 1978 Late-dry season.

Aquatic insects (mainly chironomid larvae) were most important in the diet in the 1978 Late-dry season; however, substantial quantities of unidentified organic material and small proportions of copepods and algae (mainly phytoplankton) were also eaten. During the Early-wet season aquatic insects were still important in the diet, but copepods and oligochaetes

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[221] Konagai and Rimmer (1985) described the larval ontogeny of the closely related fire-tailed gudgeon, *H. galii*.

became increasingly common. By the Mid-wet season *H. compressa* ate fewer aquatic insects and copepods, which were replaced by cladocerans (*Diaphanosoma*). Copepods (the large organic material component may have included digested copepods) were eaten most frequently during the Mid-dry season, when detritus and algae were also present in the stomachs.

Table 138 Dietary composition of *H. compressa*

	Habitat		Season					
	Magela system		1978	1978–79	1978–79	1979	Overall	
Stomach contents	Cb	Fb	Late-dry	Early-wet	Mid-wet	Mid-dry	Sub-mean	Main-mean
Aquatic plants								
Algae								4.3
Miscellaneous	–	1.1	8.6	–	–	4.0	4.2	
Conjugatophyta								
Mougeotia	–	–	–	–	0.3	–	0.1	
Aquatic animals								
Oligochaeta	25.0	–	–	25.0	–	–	2.1	2.1
Microcrustacea								30.3
Cladocera								
Miscellaneous	–	–	–	–	6.3	–	2.1	
Diaphanosoma	22.5	–	–	–	47.8	–	17.8	
Copepoda	–	22.2	9.5	22.5	6.3	40.0	10.4	
Insecta								30.4
Fragmented	–	11.1	6.2	25.0	4.4	–	6.3	
Coleoptera								
Miscellaneous (larvae)	–	5.6	4.8	–	–	–	2.1	
Diptera								
Chironomidae	12.5	11.1	31.9	12.5	10.0	–	20.4	
Ceratopogonidae	–	–	1.0	–	–	–	0.4	
Egg material	15.0	–	–	15.0	–	–	1.2	
Detrital material	–	4.4	–	–	–	16.0	1.7	1.7
Inorganic material	–	3.3	2.9	–	–	–	1.3	1.3
Organic material	25.0	41.1	35.2	–	25.0	40.0	30.0	30.0
Number of empty fish	1	4	7	–	2	–	9	9
Number of fish with food	4	18	21	4	16	5	48	48

Figures represent the mean percentage volume determined by the estimated volumetric method.

Cb = corridor billabong, Fb = floodplain billabong

Fullness

A summary of mean fullness indices of *H. compressa* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 139. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 139 Mean fullness indices of *H. compressa* in different sampling periods and habitats

Habitat	Sampling period						Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	
Magela Creek catchment (regular sites only)							
Downstream of RUPA:							
Corridor anabranch billabong	0 (1)	4.3 (3)	2.1 (15)	n/s	n/s	n/s	2.3 (19)
Floodplain billabong	1.4 (14)	0 (1)	0 (1)	0 (1)	1.6 (5)	0 (1)	1.2 (23)
Nourlangie Creek catchment (regular sites only)							
Lowland shallow backflow billabong	0 (1)	n/s	n/s	n/s	n/s	n/s	0 (1)
Seasonal mean (all sites)	1.8	3.8	1.9	0	1.7	0	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment *H. compressa* was found only downstream of the RUPA in corridor anabranch and floodplain billabongs. It fed most actively in the former habitat in the 1978–79 Early-wet and Mid-wet seasons. The only fish analysed in the Nourlangie Creek catchment had no food in its stomach.

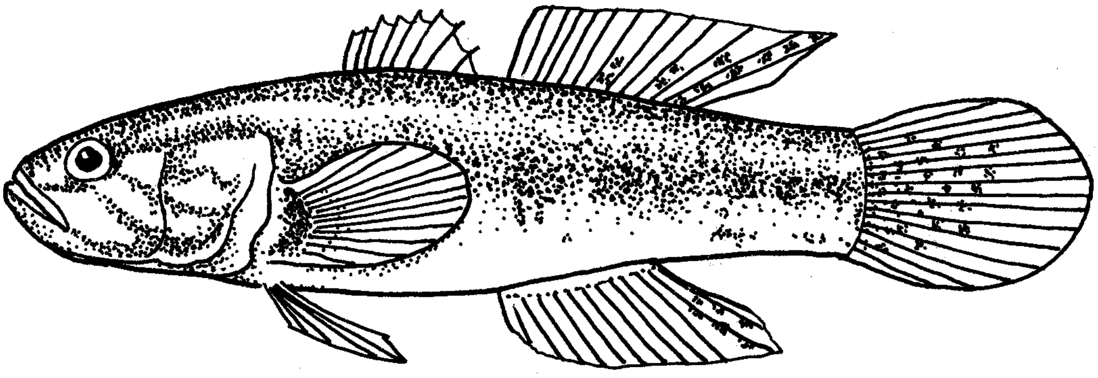
Seasonal changes

The stomachs of this species were most often full in the Early-wet season and least often in the Late-wet–Early-dry and 1979 Late-dry seasons; however, the sample sizes were very small.

Family ELEOTRIDIDAE

3.36 *Mogurnda mogurnda* (Richardson)

Mogurnda mogurnda is commonly known as the purple-spotted gudgeon, chequered gudgeon or trout gudgeon. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3), and Papua New Guinea. Related species are relatively common in some localities in the central Australian Lake Eyre drainage system as far south as northern South Australia and north-western New South Wales. Pollard (1974) concluded that this species is a permanent inhabitant of freshwaters and probably occurs in most waterbodies in the Region. All species of this genus are restricted to freshwater; however, other members of the family are found in brackish estuarine waters and some in purely marine waters. It is an attractive species with considerable potential as an aquarium fish.



Mogurnda mogurnda

Detailed information on the catches at each site and in each season is given in volume 2. In summary, *M. mogurnda* was common in all floodplain, corridor and lowland backflow billabongs. It was found in most lowland sandy creekbed habitats up- and downstream of RUPA and in escarpment streams.[222] It was most abundant in the upper reaches of streams where other fish species could not penetrate.[223] In the 1978 Late-dry season it was found in only ten sites (mainly lowland backflow billabongs); by the Mid-wet season its distribution apparently decreased, as it was found in only four sites (mainly floodplain billabongs); but by the Late-wet–Early-dry season it was found in seven sites (mainly lowland backflow billabongs).[224]

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[222] Robertson and Baidam (1983) found *M. mogurnda* to be very common in feeder streams of the Ok Tedi River in Papua New Guinea. They were particularly abundant in the lower reaches of these streams, but were also captured in the main river.

[223] In 1984 *M. mogurnda* was observed (Bishop, pers obs) climbing vertical wet surfaces around waterfalls. This climbing ability explains its presence in escarpment stream reaches isolated from the lowlands by apparently insurmountable waterfalls or cascades. Herbert and Peeters (1995) indicated that in Cape York Peninsula *M. mogurnda* prefer the headwaters of streams where they are particularly abundant, but are usually found throughout river systems. They also indicated that *M. mogurnda* have remarkable powers of migration, being one of the few fish frequently found above large obstacles such as waterfalls.

[224] Whitehead (1985) studied the closely related *M. adspersa* in a tropical upland stream in north-eastern Queensland and found patterns of habitat use and movement to be related to seasonal fluctuations in water levels. Fish moved to deep pools and aggregated around refuge sites during the dry season.

Size composition

The lengths and weights of 263 specimens were determined. Most of the specimens were caught by seine net, and therefore mesh selectivity influenced only the minimum size of specimens captured. Some of the smallest specimens were obtained by rotenone poisoning followed by collection with dipnets.

Length–weight relationship

The length–weight relationship was described by the following expression:

$W = 8.84 \times 10^{-3} L^{3.19}$ $r = 0.99$ (length in cm, weight in g)

Mean lengths, weights and seasonal condition factors are shown in table 140. The seasonal condition factor was lowest in the 1978–79 Early-wet season and highest in the Late-wet–Early-dry season. The condition factors in the two Late-dry seasons were similar. The drop in condition after the 1978 Late-dry season may have been caused by spawning activity.

Table 140 Mean length, mean weight and condition factor for *M. mogurnda*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	72	56.1	2.17	1.00
Early-wet (1978–79)	6	50.9	1.37	0.86
Mid-wet	49	39.8	0.72	0.99
Late-wet–Early-dry (1979)	8	37.1	0.73	1.25
Mid-dry	16	62.1	2.86	0.95
Late-dry	41	67.4	3.94	1.01
Early-wet (1979–80)	0	–	–	–
Overall	192	52.8	1.79	1.00

Length composition

The smallest specimen captured was 6 mm TL; the largest was 103 mm TL (fig 157). Specimens up to 180 mm in length were observed in escarpment habitats where no other fish species were seen. Pollard (1974) reported this species reputedly grows to 200 mm. Haines (1979) found specimens ranging in length from 10 to 110 mm in the Purari River, Papua New Guinea.[225]

The smallest specimen was found in the Mid-wet season. The largest specimens were found in the 1979 Mid-dry season followed closely by the 1978 Late-dry season (fig 158).

Length-frequency distribution

The mean length of specimens was 52.8 mm TL. The distribution peaked between 22 and 29 mm, and 49 and 63 mm (fig 157). The length at first sexual maturity (LFM on fig 157) was 51 mm for females and 55 mm for males, indicating that slightly more juveniles than adults were captured.

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[225] Using hook and line, Robertson and Baidam (1983) collected *M. mogurnda* ranging in size from 60–162 mm (3–59 g weight range) in feeder streams of the Ok Tedi River in Papua New Guinea. Kyle et al (1986) determined the concentrations of zinc, copper, lead and cadmium in whole specimens of *M. mogurnda* from the upper Ok Tedi River system in 1981. The specimens ranged in length from 75 to 162 mm and were collected before any mining activity.

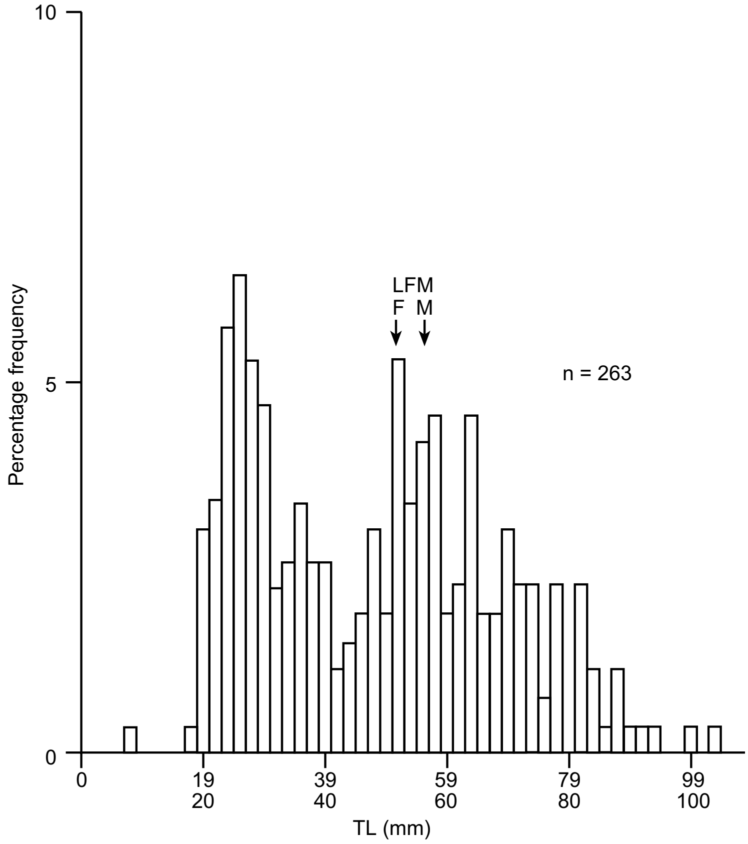

Figure 157 Length-frequency distribution of all *M. mogurnda* captured (all sites)

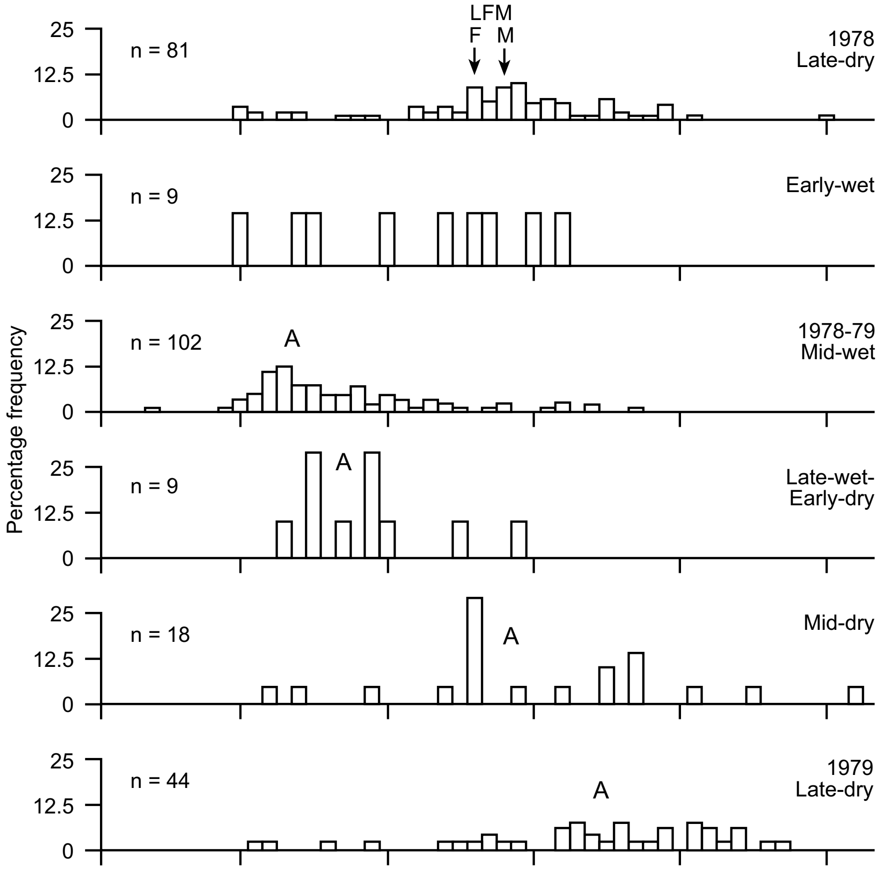

Figure 158 Seasonal length-frequency distribution of all *M. mogurnda* captured

Seasonal mean lengths are shown in table 140. The mean lengths were smallest during the Mid-wet and Late-wet–Early-dry seasons when most juvenile recruits appeared to enter the population (small numbers of juveniles were found throughout the study) and when the fewest adults were captured. The large adult and small juvenile components were strongest during the 1978 and 1979 Late-dry seasons. There was a strong adult component in the 1979 Late-dry season, but not in the same season in 1978.

Growth rate

Estimation of growth rates from the seasonal length-frequency distributions is difficult due to the frequency with which juveniles are recruited. The growth of juveniles present in the Mid-wet season (modal length 25–26 mm TL) may possibly be followed (A on fig 158) until the 1979 Late-dry season about 10 months later, when they appeared to attain lengths between 63 and 77 mm TL. The indications are therefore that this species may attain the LFM within its first year of life.

Habitat differences in distribution

The habitat preferences of *M. mogurnda* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are shown in figure 159.

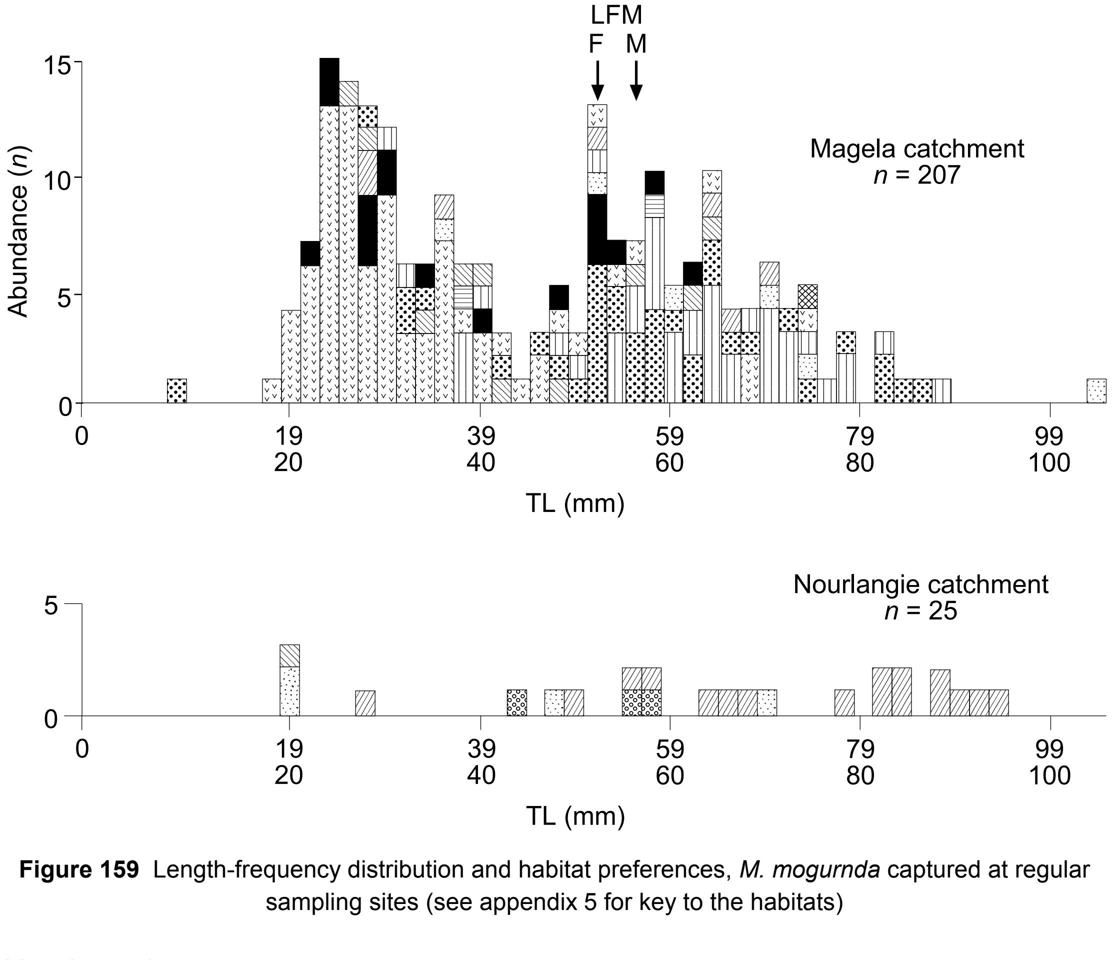

Figure 159 Length-frequency distribution and habitat preferences, *M. mogurnda* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment

Juvenile *M. mogurnda* are defined as those fish less than the mean length (for males and females) at first sexual maturity (LFM 55–56 mm TL). The smallest juvenile was captured in a lowland shallow backflow billabong upstream of RUPA. Most of the smaller juveniles were captured in lowland sandy creekbeds upstream of RUPA, and secondarily in lowland shallow backflow billabongs (upstream and downstream of RUPA), floodplain billabongs and escarpment mainchannel waterbodies.

Smaller adults were captured in a range of habitats, though most frequently in lowland backflow billabongs up- and downstream of RUPA; sandy creekbed habitats did not appear important to these adults. Larger adults were found mainly in lowland shallow backflow billabongs up- and downstream of RUPA, with the largest specimen being captured from a channel backflow billabong.

Adults were frequently observed in an escarpment perennial stream, Radon Springs; very large adults were found in rock pools isolated from other fish species by insurmountable escarpment cascades.

Nourlangie catchment

The smallest juveniles were found in channel backflow billabongs and escarpment mainchannel waterbodies. The largest juveniles were found in backflow billabongs and in sandy creekbed lowland pools.

Adults were found mainly in lowland sandy creekbeds, with a few of the smaller specimens being found in backflow billabongs. Some small adults were found in plateau habitats.

Environmental associations [226]

Rank numbers for *M. mogurnda* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Water temperatures at sites where *M. mogurnda* was captured ranged from 25° to 36°C for surface waters (mean = 30.1°C), and from 24° to 35°C (mean = 28.9°C) for bottom waters. Both means were placed in the lower-middle quarters (see fig 170).

Dissolved oxygen

Mogurnda mogurnda was found in waters with dissolved oxygen concentrations ranging from 3.0 to 7.8 mg/L (mean = 5.6 mg/L) on the surface, and from 2.9 to 5.5 mg/L (mean = 4.8 mg/L) on the bottom. These mean DO concentrations ranked in the lower, and upper-middle quarters, respectively (see fig 171).

Visibility

This species was found in relatively turbid waters, with Secchi depths ranging from 1 to 190 cm (mean = 25 cm). This mean depth ranked at the base of the lower quarter (see fig 172). Pollard (1974) found large numbers of specimens of *M. mogurnda* in a turbid costean in RUPA.[227]

pH

The pH values of waters in which *M. mogurnda* was found ranged widely from 3.9 to 8.3 (mean = 5.9) on the surface, and from 3.9 to 6.7 (mean = 5.1) on the bottom (see fig 173).

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[226] *M. mogurnda* has subsequently been used in toxicity testing for predicting the potential for mining impacts in the Alligator Rivers Region (Holdway 1991). Sensitive tests have been developed for egg hatchability, embryo heart rate changes, larval survival, reproduction and growth. This species appears to be quite sensitive to metal toxicity in its early life history stages. Investigating the influence of one potential mining-related substance, Rippon et al (1992) exposed 4-day old larval *M. mogurnda* to a range of concentrations of sodium cyanide dissolved in Alligator Rivers Region water. Concentrations up to 200 ug/L were tested yet no affect was detected.

[227] Herbert and Peeters (1995) indicated that *M. mogurnda* appear to prefer clear flowing water environments.

These means both ranked at the base of the lower quarter, indicating this species is generally found in more acidic waters (as in the escarpment zone), although some specimens were found in quite basic waters.

Conductivity

Conductivity values of waters in which this species was captured ranged from 6 to 202 µS/cm on the surface, and from 4 to 60 µS/cm on the bottom. This range reflects the wide distribution of *M. mogurnda* from escarpment to floodplain habitats.

Habitat–structural variables

Substrate

As might be expected from its wide distribution in the Alligator Rivers Region, *M. mogurnda* was captured over a range of substrates, chiefly mud, closely followed by sand and clay, then leaf litter, boulders, rocks and finally gravel. The percentage dominance values for mud and sand ranked in the upper-middle and lower-middle quarters, respectively. The predominance of muddy substrates accords with the low Secchi depths recorded for this species. The presence of boulders,[228] leaves and rocks is characteristic of the escarpment waters in which *M. mogurnda* was abundantly found.

Hydrophytes

This species was often found in waters with moderately thick vegetation (vegetation-occurrence index 75.4%), mainly submergent hydrophytes, followed by emergent hydrophytes then floating-attached hydrophytes.

Reproduction

A total of 178 *M. mogurnda* were examined for reproductive condition: 55 females (length range 27–88 mm TL), 53 males (34–103 mm TL) and 70 sexually indistinguishable fish (6–65 mm TL).

Length at first maturity

The smallest maturing male and female were 58 and 51 mm TL, respectively. The length at first maturity was calculated from 5-mm-length groups. The LFM was 55 mm TL for males, and 51 mm TL for females (fig 160).

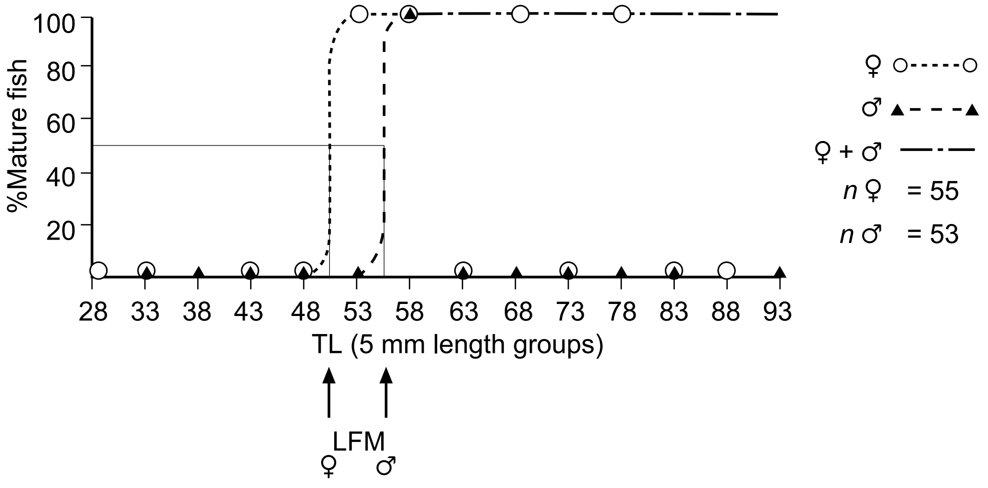

Figure 160 Estimated length at first maturity (LFM) of male and female *M. mogurnda*

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[228] Robertson and Baidam (1983) noted that *M. mogurnda* characteristically takes refuge amongst boulders in feeder streams of the Ok Tedi River in Papua New Guinea.

Sex ratio

Chi-squared tests were carried out on all male and female fish and on adult males and females only; these tests indicated a significantly greater proportion of males in both groups during the 1978 and 1979 Late-dry seasons ($P < 0.005$) (table 141). These are also the only two seasons during which more than 11 fish were captured. The unequal sex ratio may be due to misidentification of immature gonads, or a behavioural characteristic that may have resulted in the fishing methods selectively catching only one sex.

Breeding season

Very little change was observed in the reproductive state of *M. mogurnda* over the study period.[229] GSI and GMSI levels were slightly higher during the 1978–79 Early-wet season than in the 1979 Mid-dry and Late-dry seasons (table 141; fig 161). No mature or ripe fish were captured over the entire study period. Maturing fish were captured only in the 1978 Late-dry (10 fish), 1978–79 Early-wet (1 fish) and 1978–79 Mid-wet (1 fish) seasons. Juvenile fish were collected in all seasons, although the smallest (about 20 mm TL) were caught only in the 1978 Late-dry and 1978–79 Early-wet and 1978–79 Mid-wet seasons.

Table 141 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *M. mogurnda* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles + adults	F	*n*	12	2	3	1	6	31	0
	M	*n*	34	3	3	0	5	8	0
		χ^2	10.5	0.2	0	1.0	0.1	13.6	–
		P	**	n.s.	n.s.	n.s.	n.s.	***	n.s.
Adults only	F	*n*	9	2	3	1	2	27	0
	M	*n*	27	1	3	0	5	8	0
		χ^2	9.0	0.3	0	1.0	1.3	10.3	
		P	**	n.s.	n.s.	n.s.	n.s.	**	n.s
GSI									
(Adults only)	F	mean	1.4	2.6	1.7	0.3	0.7	0.7	–
		s.d.	1.9	1.0	2.1	–	0.4	0.2	–
	M	mean	0.2	0.5	0.3	–	0.2	0.2	–
		s.d.	0.1	–	0.2	–	0.2	0.1	–
	F+M	mean	0.7	1.9	1.1	–	0.4	0.6	–
		s.d.	1.3	1.4	1.7	–	0.4	0.3	–
GMSI									
(Adults only)	F	mean	3.4	3.5	3.0	2.0	2.5	–	–
		s.d.	0.9	0.7	1.0	–	0.7	0.3	–
	M	mean	2.8	3.0	2.0	–	2.0	2.1	–
		s.d.	0.6	–	1.4	–	0.8	0.4	–
	F+M	mean	3.1	3.3	2.6	–	2.2	2.4	–
		s.d	0.8	0.6	1.1	–	0.8	0.3	–

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); ** = $0.001 < P < 0.01$; *** = $P < 0.001$; s.d. = standard deviation.

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[229] Herbert and Peeters (1995) indicated that *M. mogurnda* appear to breed at the onset of the wet seasons and may breed continuously while temperatures are high.

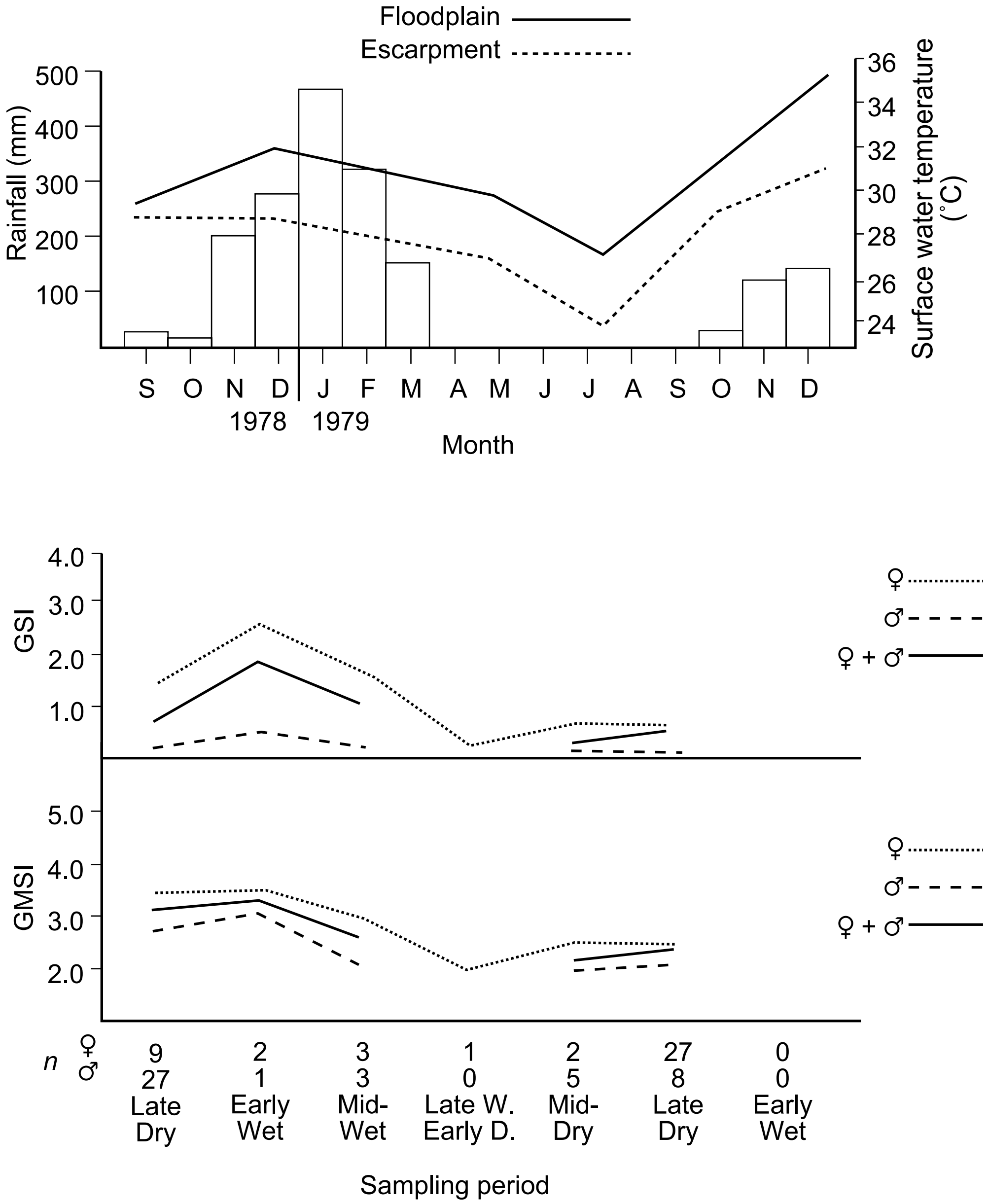

Figure 161 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad stage maturity index (GMSI) of male and female *M. mogurnda*

Mogurnda mogurnda is believed to have a similar spawning pattern to *M. adspersa* in eastern Australia: it breeds between December and February when temperatures vary from 26° to 34°C and food is abundant. Flooding was not essential for stimulating spawning in *M. adspersa* (Hoese et al 1980). *Mogurnda mogurnda* is believed to breed at the end of the year or any time of the year when conditions are suitable (Midgley, pers comm).

Site of spawning

Because no mature ripe fish were captured, the possible site of spawning could not be determined. Possibly this species moves into spawning areas that our methods or regular sampling sites did not cover. Both adults and small juveniles have been observed near waterfalls in escarpment perennial streams in habitats not regularly sampled in this study; breeding may occur at these sites. Juveniles were collected over a wide range of habitats, including escarpment area streams, sandy creekbed streams and shallow backflow billabongs (table 142).

Table 142 Possible sites of spawning of *M. mogurnda* as indicated by the abundance (*n*) of maturing and juvenile fish. No mature or ripe fish were captured.

	Gonad stage		
	Maturing (IV)		Juvenile
Habitat	F	M	
Escarpment			
Mainchannel waterbodies	1	0	3
Seasonal feeder streams	0	1	0
Perennial streams	0	0	2
Lowlands			
Sandy creekbed habitats	1	0	56
Backflow billabong	7	2	4
Corridor	0	0	4
Floodplain billabong			
Upper	0	0	5

Eggs are most likely laid in slow-flowing waters among aquatic weeds or attached to solid objects, often very close to the surface or on the underside of floating vegetation (see Llewellyn 1971 for *M. adspersa*).

Fecundity

The ovaries from the female with the highest GSI were examined to give some idea of relative fecundity and egg size. The fish was 73 mm TL long with a GSI of 4.73; the ovary contained 430 eggs of approximately 1 mm diameter. Female *M. adspersa,* which may spawn repeatedly, produce between 280 and 1300 ova at each spawning (Hoese et al 1980) or 500 to 800 ova (Llewellyn 1971).

The eggs of *M. adspersa* are adhesive, elongated and pointed at both ends, 2.6–3.8 mm long, and 1.1 to 1.3 mm wide. There are numerous small oil globules within the yolk. A sticky basal mass at one of the pointed ends allows attachment of a cluster of eggs to a solid object. The eggs are fanned and cared for by the male. Hatching takes from 3 to 8 days at temperatures around 29–30°C, and the prolarvae are about 3.5–4 mm long. The yolk is fully absorbed in about six days, when feeding on zooplankton begins (Llewellyn 1971, Hoese et al 1980). The sexes of *M. adspersa* are very similar, although the urino-genital papilla is pointed in males and broad with a fringed margin in females (Hoese et al 1980).

Summary

A breeding season and spawning site could not be determined because of the small number of maturing fish, and lack of mature and ripe fish.

A slight increase in reproductive development was observed during the 1978–79 Early-wet season. The breeding season may depend on food being abundant (L Llewellyn, pers comm).

The total absence of mature and ripe fish may be due to the fish breeding in a habitat we did not sample (such as heavily vegetated or rocky escarpment areas). *Mogurnda mogurnda* lays relatively few (around 500) of largish (1 mm diameter) eggs.

Feeding habits

Overall diet

The stomachs of 163 specimens were examined; 135 contained food. The diet is summarised in figure 162; the components are listed in table 143.

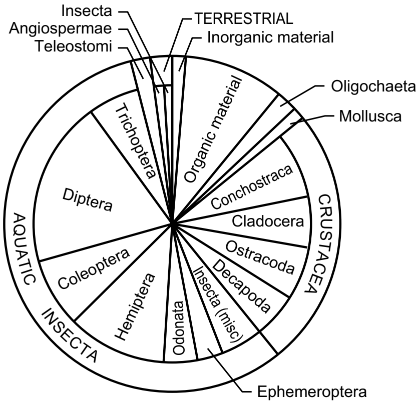

Figure 162 Dietary components of *M. mogurnda*

The main dietary items were aquatic insects (57%) and microcrustaceans (19%). A variety of aquatic insects were eaten, the most important being chironomid larvae and corixid bugs. The microcrustaceans were conchostracans, cladocerans and ostracods. *Macrobrachium* comprised less than 5% of the overall diet. Traces of oligochaetes, gastropods, teleosts, terrestrial plant material and terrestrial animals were also found in the stomachs. *Mogurnda mogurnda* can therefore be classified as a meiophagous carnivore feeding opportunistically in benthic and sometimes in the midwater zones of the waterbodies. Pollard (1974) suggested *M. mogurnda* was an opportunistic carnivore, eating insects, crustaceans and probably also small fish. Sanderson (1979) considered that *M. mogurnda* was an opportunistic carnivore, eating a variety of aquatic and terrestrial insects, helped by its cryptic occupation of pools and riffles in an intermittent stream running into the floodplain billabongs of the lower Magela Creek. Jeffree and Williams (1977) found that the diet of *M. mogurnda* in the Finniss River, Northern Territory, varied in unpolluted and polluted zones downstream from the mined area of Rum Jungle. However, Haines (1979), who studied this species in the Purari River, Papua New Guinea, classified it as an insectivore/detritophage. Fish do not appear to be important in its diet; however, large specimens could readily eat fish.[230]

Habitat differences

A total of 128 stomachs of *M. mogurnda* were examined (all seasons combined) in the Magela Creek catchment: 10 (10% empty) from escarpment mainchannel waterbodies, 28 (25% empty) from lowland sandy creekbeds, 72 (25% empty) from lowland backflow billabongs, 7 (43% empty) from corridor waterbodies and 11 (18% empty) from floodplain billabongs. The highest proportion of empty stomachs was thus found in corridor waterbodies and the lowest in escarpment mainchannel waterbodies.

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[230] Whitehead (1985) studied the diet of the closely related *M. adspersa* in a tropical upland stream in northeastern Queensland. Chironomids were of particular importance in the diet of small fish, while in large fish, ephemeropteran nymphs were of greatest importance. Both diel and seasonal variation in the composition of the diet were observed for small fish but not for large fish. Microcrustaceans were important in the diet of small fish during the day, but at night, chironomids were more important. Seasonally, microcrustaceans were more important for small fish towards the end of the Wet season, however, during the Dry season chironomids assumed dominance.

Table 143 Dietary composition of *M. mogurnda*

	Habitat								Season							
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Aquatic animals																
Oligochaeta	–	14.3	–	–	–	–	–	–	–	–	8.6	–	–	–	2.1	2.1
Gastropoda																1.2
Taxa1	–	–	1.3	–	–	–	–	20.0	3.3	–	–	–	–	–	1.2	
Microcrustacea																18.7
Conchostraca																
Miscellaneous	–	–	1.1	–	–	–	–	20.0	1.2	–	–	–	–	–	0.4	
Cyzicus	–	–	–	–	–	–	64.1	–	–	–	–	–	–	36.6	7.2	
Cladocera																
Miscellaneous	–	–	3.7	–	–	–	–	–	5.9	–	2.9	–	–	–	2.8	
Diaphanosoma	–	–	1.7	25.0	22.2	–	–	–	–	–	2.6	–	14.3	3.6	2.7	
Ostracoda	–	–	2.0	25.0	11.1	–	–	–	9.4	–	3.1	14.3	7.1	–	5.6	
Macrocrustacea																4.9
Macrobrachium	–	6.7	8.5	–	11.1	–	–	–	10.6	–	4.6	–	–	–	4.9	
Insecta																57.3
Fragmented	–	12.4	7.8	–	–	–	–	–	7.5	–	4.6	–	–	7.1	5.2	
Ephemeroptera																
Baetidae	–	1.0	2.8	–	–	20.0	–	–	1.2	28.6	0.6	7.1	–	3.6	3.0	
Odonata																
Lestidae	–	–	–	–	11.1	–	–	–	–	–	–	–	7.1	–	0.7	
I. heterosticta	–	–	3.0	–	–	–	–	–	–	–	4.6	–	–	–	1.1	
Gomphidae	–	4.8	1.8	–	–	–	–	–	3.9	–	–	–	–	–	1.4	
Libellulidae	–	–	3.5	–	–	–	–	–	3.7	–	–	–	–	–	1.3	
Hemiptera																
Corixidae	32.8	4.8	13.9	–	–	–	–	–	19.1	14.3	8.4	–	19.2	2.1	12.0	
Coleoptera																
Miscellaneous (adults)	18.9	4.8	2.9	–	–	20.0	–	40.0	5.1	14.3	4.9	–	14.3	–	5.1	
Miscellaneous (larvae)	11.1	–	1.7	–	–	–	–	–	1.8	–	2.9	–	–	–	1.3	

Table 143 continued

	Habitat								Season							
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Rhantus	–	3.3	–	–	–	–	–	–	–	–	2.0	–	–	–	0.5	
Macrogyrus	–	–	1.8	–	–	–	6.3	–	–	–	–	–	7.1	3.6	1.4	
Hydrophilidae	–	–	0.7	–	–	–	–	–	–	–	1.1	–	–	–	0.3	
Diptera																
Miscellaneous (larvae)	–	–	–	–	–	–	4.4	–	–	–	–	–	5.0	–	0.5	
Chironomidae (larvae)	11.1	7.2	15.4	–	8.9	48.0	18.1	–	13.6	5.7	14.6	35.7	5.0	18.2	14.6	
Chironomidae (pupae)	–	2.9	–	–	–	–	2.5	–	0.8	–	1.7	–	–	1.4	1.0	
Ceratopogonidae	14.4	2.4	0.4	–	11.1	–	0.6	–	–	2.9	5.1	–	0.7	3.6	2.2	
Tabanidae	–	–	–	–	2.2	–	–	–	–	–	0.6	–	–	–	0.1	
Trichoptera																
Leptoceridae	–	7.1	10.4	–	–	12.0	4.1	–	2.7	20.0	5.4	–	14.3	5.9	5.9	
Teleostomi	–	–	4.8	–	–	–	–	–	1.6	–	–	14.3	5.7	–	1.8	1.8
Terrestrial plants																0.7
Angiospermae	–	–	1.9	–	–	–	–	–	–	–	–	–	–	3.6	0.7	
Terrestrial animals																
Insecta																1.4
Hymenoptera																
Formicidae	–	–	–	25.0	–	–	–	–	–	–	–	–	–	3.6	0.7	
Oecophylla	–	4.8	–	–	–	–	–	–	–	–	2.9	–	–	–	0.7	
Parasites																
Nematoda	–	4.8	–	–	–	–	–	–	0.1	–	2.9	–	–	–	0.7	0.7
Inorganic material	11.7	4.8	–	–	–	–	–	–	–	–	5.7	–	–	–	1.4	1.4
Organic material	–	14.3	8.9	25.0	22.2	–	–	20.0	8.6	14.3	10.3	28.6	–	7.14	9.2	9.2
Number of empty fish	1	7	18	3	2	2	1	–	7	2	6	–	4	16	35	35
Number of fish with food	9	21	54	4	9	5	16	5	51	7	35	7	14	28	128	128

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs Cb = corridor billabongs; Fb = floodplain billabongs

Mogurnda mogurnda in the escarpment waterbodies were feeding entirely on insects (mainly corixids, miscellaneous beetles and ceratopogonids); the presence of sand in their stomachs indicates that it was benthic-dwelling when preying upon these insects. Aquatic insects were also important in the diet in sandy creekbeds; however, oligochaetes, *Macrobrachium* and terrestrial (green tree) ants were also eaten.

The diet in the lowland shallow backflow billabong was largely based on aquatic insects (corixids, chironomid larvae and leptocerid larvae); however *Macrobrachium,* microcrustaceans (conchostracans, cladocerans and ostracods), gastropods and traces of terrestrial plant material were also eaten. The few specimens examined from corridor waterbodies had eaten microcrustaceans and terrestrial ants that had fallen into the water. There were large quantities of unidentified organic material in the stomachs of specimens from corridor and floodplain billabongs. In floodplain billabongs *M. mogurnda* ate mostly microcrustaceans (cladocerans and ostracods) and *Macrobrachium,* and fewer aquatic insects.

Catchment differences

A total of 29 stomachs of *M. mogurnda* were analysed from Nourlangie Creek: 7 (28.6% empty) from escarpment mainchannel waterbodies, 17 (6% empty) from lowland sandy creekbeds and 5 (0% empty) from shallow backflow billabongs. The highest proportion of empty fish was found in the escarpment waterbodies and the lowest in the shallow backflow billabongs (in contrast to Magela Creek).

Mogurnda mogurnda ate only aquatic insects in the escarpment mainchannel waterbodies (with strong emphasis on chironomid larvae), as it did in the Magela catchment. In the lowland sandy creekbeds it ate mainly conchostracans (*Cyzicus*) and, to a lesser extent, aquatic insects (unlike the Magela catchment specimens). Coleopteran adults were eaten mainly in the shallow backflow billabongs, but *M. mogurnda* also ate gastropods and a quantity of conchostracan components.

Seasonal changes

In sampling periods 1 to 6, respectively, 58 (12% empty), 9 (22% empty), 41 (15% empty), 7 (0% empty), 18 (22% empty) and 44 (36% empty) stomachs of *M. mogurnda* were examined (all habitats combined). The highest proportion of empty fish was found in the 1979 Late-dry season and the lowest in the Late-wet–Early-dry season.

A variety of aquatic animals was found in the stomachs in the 1978 Late-dry season, the most important being aquatic insects (corixids and chironomid larvae), microcrustaceans (ostracods and cladocerans) and *Macrobrachium*, and traces of gastropods and teleosts. The diet was similar in the 1979 Late-dry season. In the 1978–79 Early-wet season the few specimens examined were eating exclusively aquatic insects (baetids and leptocerids).

The diet in the Mid-wet season appeared to became more varied than in the 1978–79 Early-wet, partly because more specimens were analysed. It included crustaceans, oligochaetes and terrestrial ants. In the Late-wet–Early-dry season, there was much unidentified organic material in the stomachs, as well as aquatic insects (mainly chironomid larvae), ostracods and teleosts. The diet in the 1979 Mid-dry season was similar to that in the Late-dry seasons, with microcrustaceans, aquatic insects (corixids, beetles and leptocerid larvae) and some teleosts being eaten.

Fullness

A summary of mean fullness indices of *M. mogurnda* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 144. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 144 Mean fullness indices of *M. mogurnda* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period						
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Habitat mean
Magela Creek catchment (regular sites only)							
Upstream of RUPA:							
Escarpment main-channel waterbody	n/s	n/s	2.5 (10)	n/s	n/s	n/s	2.5 (10)
Lowland shallow backflow billabong	2.4 (10)	n/s	3.1 (8)	n/s	0 (1)	0.9 (7)	2.1 (26)
Lowland sandy creekbed	n/s	0 (1)	2.5 (20)	n/s	n/s	n/s	2.4 (21)
Downstream of RUPA:							
Lowland sandy creekbed	1.1 (7)	n/s	n/s	n/s	n/s	n/s	1.1 (7)
Lowland channel backflow billabong	n/s	0 (1)	0 (1)	n/s	1.2 (4)	n/s	0.8 (6)
Lowland shallow backflow billabong	2.9 (15)	1.5 (2)	n/s	2.0 (5)	3.0 (2)	0.4 (16)	1.7 (40)
Corridor sandy billabong	n/s	n/s	0 (1)	n/s	0 (1)	n/s	0 (2)
Corridor anabranch billabong	n/s	n/s	n/s	0 (1)	0 (1)	n/s	0 (2)
Floodplain billabong	0 (1)	0 (1)	3.5 (2)	0 (2)	2.0 (5)	1.2 (5)	1.3 16)
Nourlangie Creek catchment (regular sites only)							
Escarpment main-channel waterbody	n/s	0 (1)	n/s	n/s	n/s	n/s	0 (1)
Lowland channel backflow billabong	n/s	n/s	n/s	n/s	1.0 (2)	n/s	1.0 (2)
Lowland shallow backflow billabong	1.7 (3)	n/s	n/s	n/s	n/s	n/s	1.7 (3)
Lowland sandy creekbed	n/s	0 (1)	n/s	n/s	3.0 (2)	3.6 (14)	3.4 (17)
Seasonal mean (all sites)	2.3	2.1	2.5	1.4	1.7	1.7	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela Catchment upstream from RUPA, mean fullness indices were higher than in similar downstream habitats, but were fairly equal between habitats.

Downstream from RUPA the mean fullness index was highest in shallow backflow billabongs and lowest in corridor waterbodies. Channel backflow billabongs also had a low mean fullness index.

In the Nourlangie Catchment, mean fullness indices were highest in the lowland sandy creekbed, and higher than in any habitat in the Magela catchment. The single specimen analysed in the escarpment mainchannel waterbody had an empty stomach.

Seasonal changes

The mean fullness index (all habitats combined) was fairly stable between the 1978 Late-dry and the 1978–79 Mid-wet seasons. The index then fell to a low after the Wet season (probably due to low dissolved oxygen levels in bottom-waters) and then increased slightly to reach a stable level between the Mid-dry and Late-dry season.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- floodplain billabongs; 1978–79 Mid-wet season
- lowland shallow backflow billabongs (upstream of RUPA); 1978–79 Mid-wet season
- lowland shallow backflow billabongs (downstream of RUPA); 1979 Mid-dry season

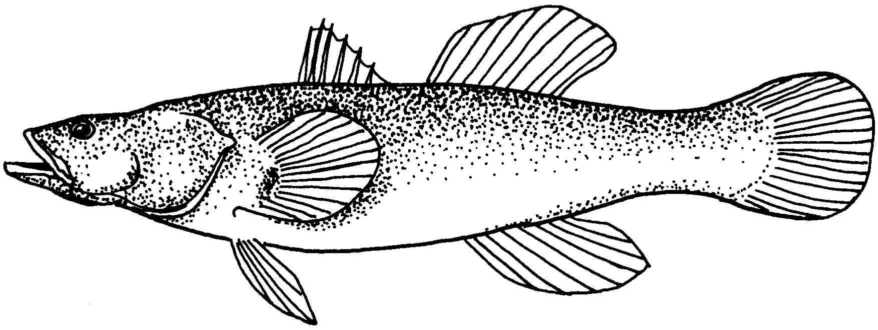
Nourlangie catchment

- lowland sandy creekbeds; 1979 Late-dry season, 1979 Mid-dry season.

Family ELEOTRIDIDAE

3.37 *Oxyeleotris lineolata* (Steindachner) vel assin[231]

Oxyeleotris lineolata is commonly known as the sleepy cod or sleeper. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3), and also in Papua New Guinea. Pollard (1974) found large specimens in the lowland backflow billabongs (Georgetown Billabong and Indium Billabong) in the Magela Creek catchment and smaller specimens in fringing vegetation along the creek (Magela bed).



Oxyeleotris lineolata

Most members of the family Eleotrididae live in freshwater, but many are found in brackish and estuarine waters, and some in purely marine waters. *Oxyeleotris* appears to be a permanent inhabitant of freshwaters. It can be caught on hook and line and is excellent eating, though it is not a sport fish as it is extremely sluggish in relation to its size.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found commonly in all floodplain, corridor and lowland backflow billabongs and in lowland sandy creekbed habitats downstream of RUPA. It was observed only once in an escarpment mainchannel waterbody. In the 1978 Late-dry season it was found in only 5 sites (mainly lowland backflow billabongs); in the Mid-wet season, after some apparent recolonisation, it was found in 7 sites (backflow billabongs and floodplain billabongs); and in the Late-wet–Early-dry season it was found in 12 sites (lowland backflow billabongs, sandy creekbeds and floodplain billabongs).[232]

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[231] The vel assin. specification (meaning ‘or close relative’) provides notice that *O. lineolata* samples analysed may have been contaminated by two closely related species, the dwarf (or poreless) gudgeon, *O. nullipora*, and/or the black-banded (or giant) gudgeon, *O. selheimi*. The dwarf gudgeon was recorded in the Alligator Rivers Region during 1984 (Bishop, pers obs). According to Larson and Martin (1989) this species has a discontinuous distribution across northern Australia, being found in the Northern Territory from the Reynolds to the Blyth Rivers. The black-banded gudgeon is widespread in the Timor Sea and Gulf drainages and Herbert et al (1995) recently recorded it in some north-east coast drainages (the Stewart and Annan Rivers of Cape York). In 1999 Helen Larson of the NT Museum advised that collections she has made from the Alligator Rivers Region contained more black-banded gudgeons than sleepy cod, *O. lineolata*. However, collections by Herbert et al (1995) from Cape York Peninsula indicated that *O. lineolata* was far more common than *O. selheimi*. Pollard (1974) considered small specimens with a colour pattern resembling *O. selheimi* (then known as *Bunaka herwerdenii*) to be but a juvenile colour phase of *O. lineolata*.

[232] Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to display greater catch rates on the floodplain compared with lakes during most of the flood season, confirming that this species prefers the floodplain habitats when it is flooded. Catches were probably greatly influenced by movements of the main stock onto and off the floodplain as river levels fluctuated.

Size composition

The lengths and weights of 134 specimens were determined. Most of the specimens were captured by seine net and therefore mesh selectivity influenced only the minimum size of specimens captured. Hydrophytes sometimes clogged the meshes, which resulted in the capture of some of the smallest juveniles. The few adult specimens that were captured by gill nets caused the minor peaks in the adult size range in figure 163.

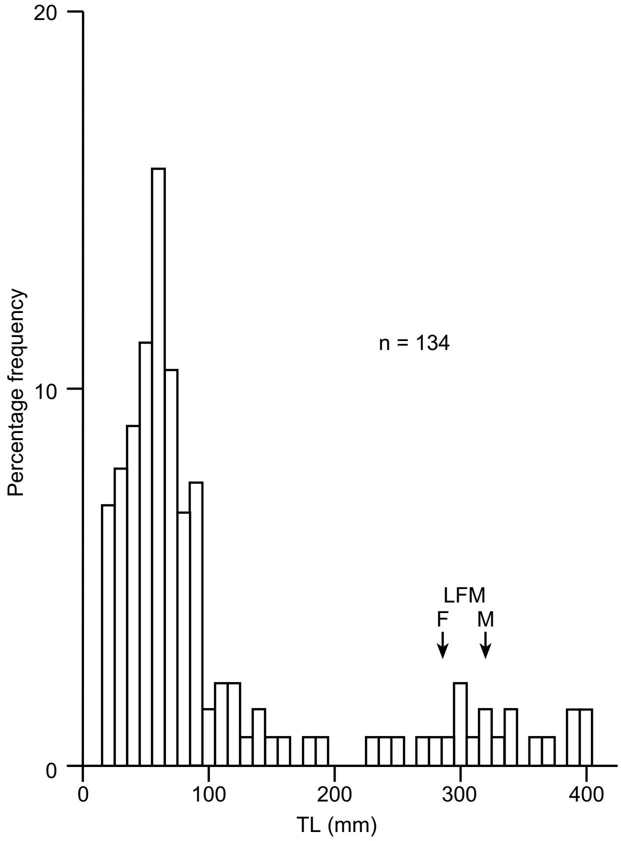

Figure 163 Length-frequency distribution of all *O. lineolata* captured (all sites)

Length–weight relationship

The length–weight relationship was described by the following expression:

$W = 7.68 \times 10^{-3} L^{3.14}$ $r = 1.00$ (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors are shown in table 145. The seasonal condition factor was highest in the Late-dry seasons (especially in the 1978 season) and lowest from the 1978–79 Mid-wet to the 1979 Mid-dry season. The environmental conditions in the Late-dry seasons therefore appeared to be more favourable for good body condition in *O. lineolata*.[233]

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[233] Coates (1992) found that the closely related *O. heterodon* in the Sepik River of PNG to have a condition factor which exhibited little seasonality.

Table 145 Mean length, mean weight and condition factor of *O. lineolata*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	25	82.5	6.32	1.09
Early-wet (1978–79)	7	57.5	1.855	0.99
Mid-wet	9	84.3	5.97	0.96
Late-wet–Early-dry (1979)	20	75.6	4.22	0.96
Mid-dry	27	100.0	10.32	0.97
Late-dry (1979)	28	92.0	8.24	1.01
Early-wet (1979–80)	4	145.4	34.5	1.00
Overall	120	87.0	6.87	1.00

Length composition

Specimens ranged in size from 16 mm to 395 mm TL (fig 163). This species reputedly grows to 500 mm TL (Pollard 1974).[234]

Small juveniles were captured throughout all seasons of the study; however the smallest were captured in the 1978–79 Early-wet, 1979 Mid-dry and 1979 Late-dry seasons. The largest specimens were captured in the Mid-wet, 1979 Mid-dry and Late-dry seasons (fig 164).

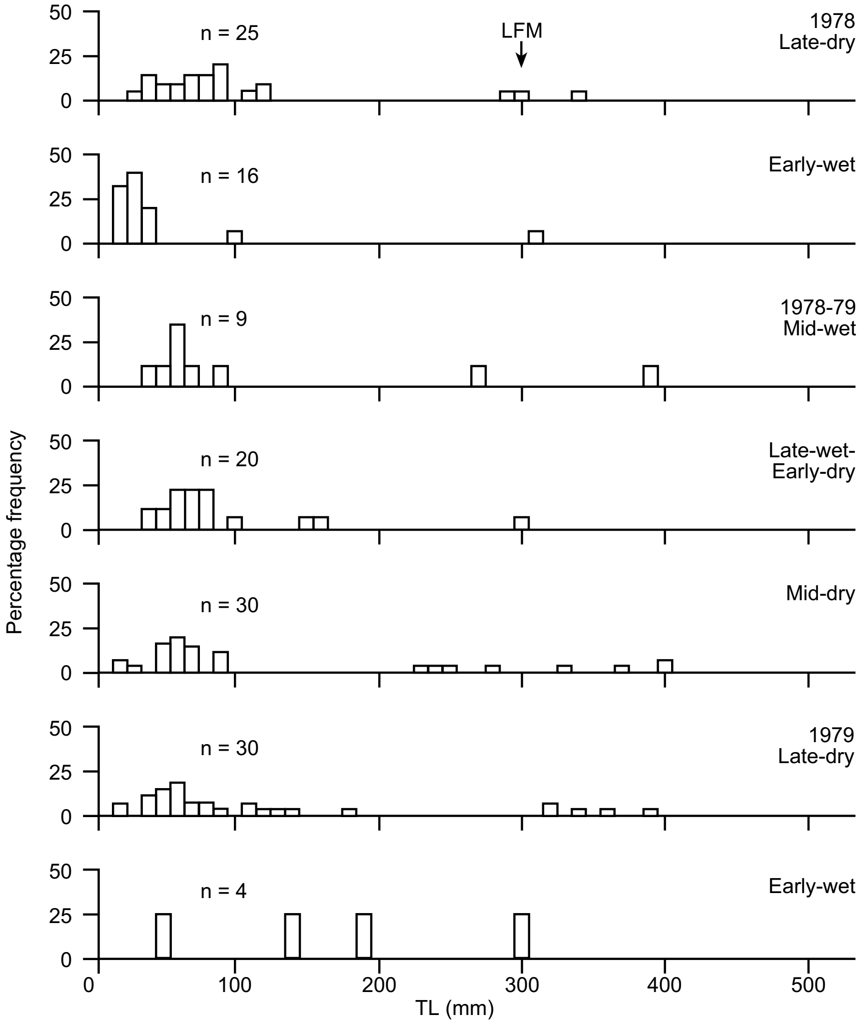

Figure 164 Seasonal length-frequency distribution of all *O. lineolata* captured

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[234] Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to attain 483 mm standard length (1.83 kg weight).

Length-frequency distribution

The mean and modal lengths of all specimens captured were 87 and 60 mm TL, respectively. The length at first sexual maturity (LFM on fig 163) ranged from 290 (females) to 320 mm TL (males), indicating that mostly juveniles were captured. Most specimens ranged in length from 20 to 90 mm TL. No specimens between 200 and 230 mm TL were captured. The overall distribution showed a strong negative skew, which illustrates the lower chances of juvenile specimens surviving to adulthood.

Seasonal mean lengths are shown in table 145. The shortest mean length was recorded in the 1978–79 Early-wet season, and the longest in the 1979–80 Early-wet. Evidently there is considerable yearly variation in juvenile recruitment in the study area, presumably due to differences in environmental conditions. Large juveniles and small adults appeared to be most common in the 1979 Mid-dry and Late-dry seasons (fig 164).

Growth rate

Estimation of the growth rate of *O. lineolata* from the seasonal length-frequency distributions is difficult due to the near-constant recruitment of juveniles.

Habitat differences in distribution

The habitats in which *O. lineolata* were captured in regular sampling sites in the Magela and Nourlangie catchments are shown in figure 165.

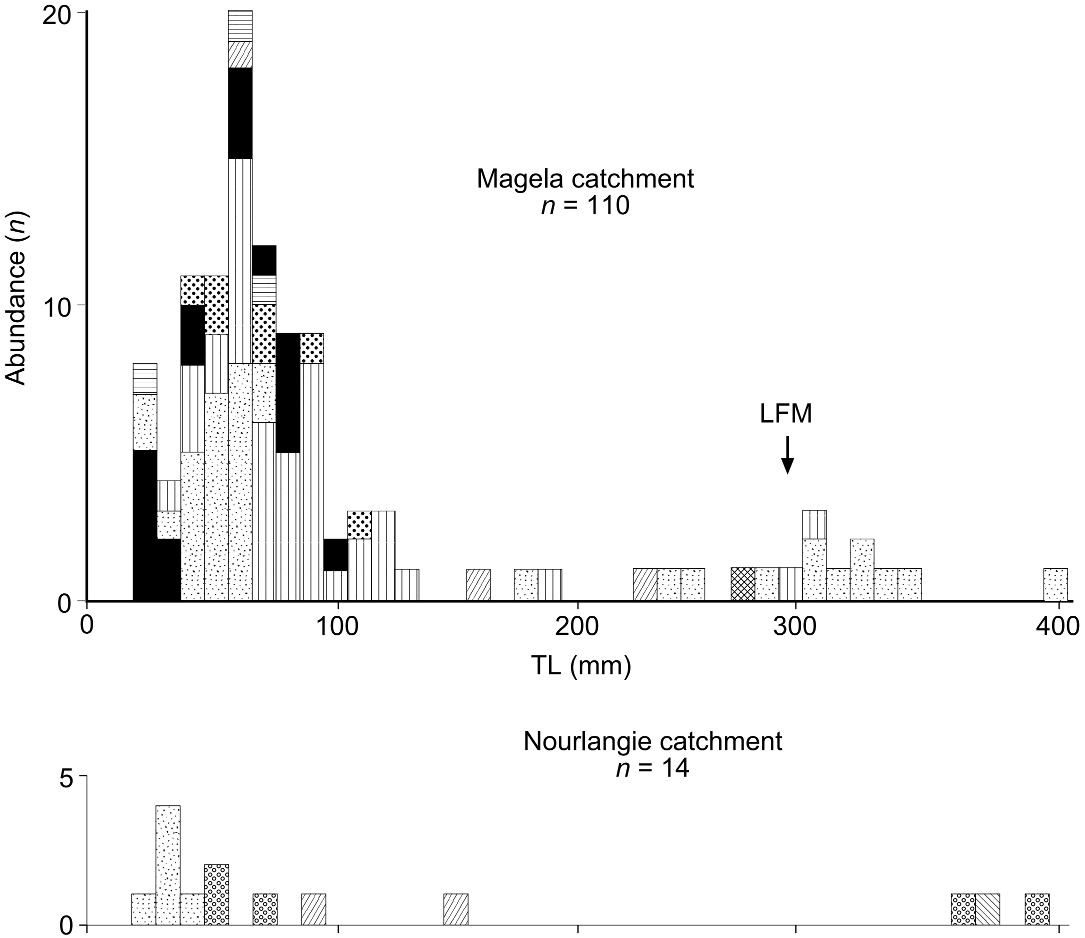

Figure 165 Length-frequency distribution and habitat preferences of *O. lineolata* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment

The few large juveniles that were captured were found in lowland backflow billabongs, sandy corridor waterbodies and lowland sandy creekbeds (their presence in the last two may indicate dispersal before attaining the LFM). The smallest juveniles were mainly captured in backflow billabongs downstream and, to a lesser extent, upstream of RUPA in floodplain billabongs and corridor anabranch billabongs. No juveniles were found in escarpment habitats.

Most adults were found in backflow channel lowland billabongs downstream of RUPA. No adults were found in escarpment habitats.

Nourlangie catchment

No large juveniles were found in the Nourlangie system. The small juveniles were found mainly in lowland backflow billabongs, and the intermediate-sized specimens were found in sandy creekbeds. The few adults were captured in a lowland shallow backflow billabong and one specimen was found in an escarpment mainchannel waterbody. No juveniles were captured in the escarpment mainchannel waterbody. No juveniles or adults were found in escarpment perennial or seasonal streams.

Environmental associations

Rank numbers for *O. lineolata* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Water temperatures recorded at sites where *O. lineolata* was captured ranged from 26° to 38°C (mean = 31.1°C) on the surface, and from 23° to 35°C (mean = 29.3°C) on the bottom. Both means ranked in the upper-middle quarter (see fig 170). Specimens were often found lying in shallow waters at the edges of waterbodies, as reflected in its apparent preference for relatively high surface water temperatures.[235]

Dissolved oxygen

Dissolved oxygen concentrations in waters inhabited by *O. lineolata* ranged from 1.0 to 9.1 mg/L (mean = 5.8 mg/L) on the surface, and from 1.7 to 9.5 mg/L (mean = 4.6 mg/L) on the bottom. These means were ranked into their respective lower-middle and upper-middle quarters (see fig 171). The unexpectedly high extremes of both surface- and bottom-water ranges (*O. lineolata* is typically found in sluggish lowland waters) may be caused by photosynthetic production of oxygen by hydrophytes in the littoral waters (see below).

Visibility

Oxyeleotris lineolata was typically captured in very turbid waters, with Secchi depths ranging from 1 to 100 cm (mean = 26 cm) (see fig 172). This mean depth was ranked at the base of the lower quarter, indicating that this species was commonly found in some of the most turbid waters of the study area.

pH

The pH values of waters in which *O. lineolata* was captured ranged from 4.8 to 9.1 (mean = 6.4) on the surface, and from 4.5 to 7.1 (mean = 6.1) on the bottom. Both means were ranked in the upper-middle quarter (see fig 173). The range of pH values was broad.

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[235] Merrick and Schmida (1984) indicated that *O. lineolata* spawned when water temperatures exceeded 24°C, which is virtually all year round in the Alligator Rivers Region.

Conductivity

Conductivity readings for waters in which this species was captured had a wide range, from 4 to 498 µS/cm on the surface, and from 2 to 478 µS/cm on the bottom.

Habitat–structural variables

Substrate

Oxyeleotris lineolata was most commonly found in waters with mud substrates (upper quarter), followed by clay (upper-middle quarter) then sand, gravel, leaf litter and rock substrates; this accords with the low visibility recorded.

Hydrophytes

Oxyeleotris lineolata was typically captured in heavily vegetated waterbodies (vegetation-occurrence index 80%): mainly submergent, followed by emergent then floating-attached hydrophytes. Pollard (1974) noted this species is found in heavily vegetated pools, often basking amongst vegetation at the shallow edges of waterholes.

Reproduction

A total of 133 *O. lineolata* were examined for reproductive condition; 94 were sexually indistinguishable (length range 16–164 mm TL), 17 were female (80–395 mm TL) and 22 were male (65–395 mm TL).

Length at first maturity

The smallest maturing male and female were 330 and 285 mm TL, respectively. The LFM, calculated with 10-mm-length groups, was 320 mm TL for males and 290 mm TL for females (fig 166).[236] No sexually indistinguishable fish were found above the LFM.

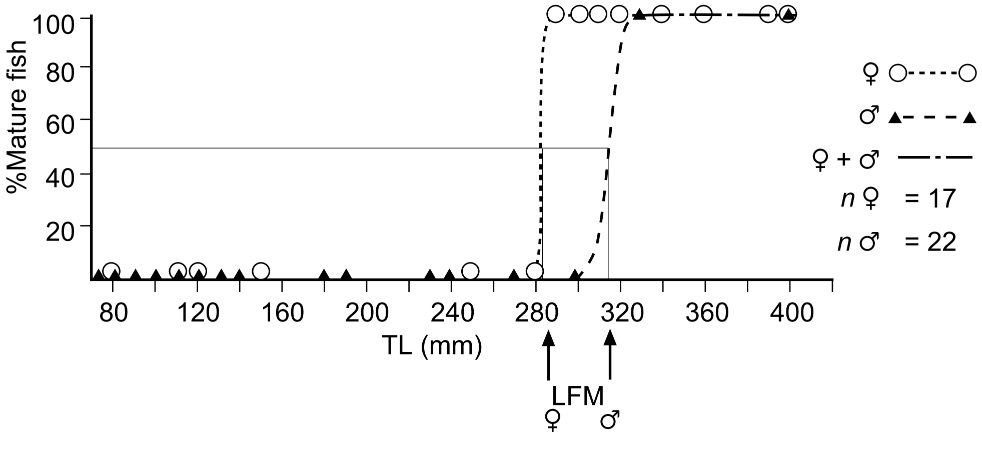

Figure 166 Estimated length at first maturity (LFM) of *O. lineolata*

Sex ratio

The ratio of males to females was not significantly different from 1:1 over the study period, both for the adult and juvenile fish combined and for the adult fish only (table 146).[237]

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[236] Coates (1992) found the size at 50% maturity for the closely related *O. heterodon* in the Sepik River of PNG to be 210–230 mm for males, and 176–200 mm for females.

[237] Merrick and Midgley (1982) indicated that adult *O. lineolata* were easily sexed by external examination using the dimorphic urogenital papillae, that of the female being longer and fatter than the males. Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to have equal numbers of each sex all year round.

Breeding season

The samples of adult males and females were very small (one to five fish) in every season (table 146). No ripe fish, and only eight mature fish, were collected. Figure 167 indicates a high GSI and GMSI throughout the year, with a drop in reproductive development during the 1978–79 Mid-wet season. Juveniles were collected throughout the year, although the highest number were collected during the 1978–79 Early-wet season. Eggs were collected by Midgley (pers comm) from mid-November 1979 until the end of January 1980. Mature fish were captured only in the 1978 and 1979 Late-dry and 1979 Mid-dry seasons.

Table 146 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *O. lineolata* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles + adults	F	*n*	3	1	1	2	3	7	0
	M	*n*	4	1	1	1	6	6	3
		χ^2	0.1	0	0	0.3	1.0	0.1	3.0
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	3	1	1	1	1	4	0
	M	*n*	0	0	0	0	2	1	0
		χ^2	3.0	1.0	1.0	1.0	0.3	1.8	–
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	1.9	1.9	0.0	1.2	1.4	1.7	–
		s.d.	0.8	–	–	–	–	0.6	–
	M	mean	–	–	–	–	0.2	0.3	–
		s.d.	–	–	–	–	0.3	–	–
	F+M	mean	–	–	–	–	0.3	1.4	–
		s.d.	–	–	–	–	0.2	0.8	–
GMSI									
Adults only	F	mean	4.7	4.0	2.0	4.0	5.0	4.7	–
		s.d.	0.6	–	–	–	–	0.6	–
	M	mean	–	–	–	–	4.5	5.0	–
		s.d.	–	–	–	–	0.7	–	–
	F+M	mean	–	–	–	–	4.7	4.8	–
		s.d	–	–	–	–	0.6	0.5	–

n = number identified; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); s.d. = standard deviation.

The data, although sparse, suggest *O. lineolata* was spawning throughout the year, though possibly more were spawning around the Mid- to Late-dry seasons.[238] Other studies (Lake 1978; Midgley, pers comm) suggest that the breeding season extends from mid-October through to February, when temperatures reach 24°C. The virtually continuous breeding suggested by our data may be an artefact of the small samples of adult fish.

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[238] Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to breed all year round. An examination of seasonal patterns in the gonadosomatic index indicated that breeding activity increased at the end of the flood season into the beginning of the dry season.

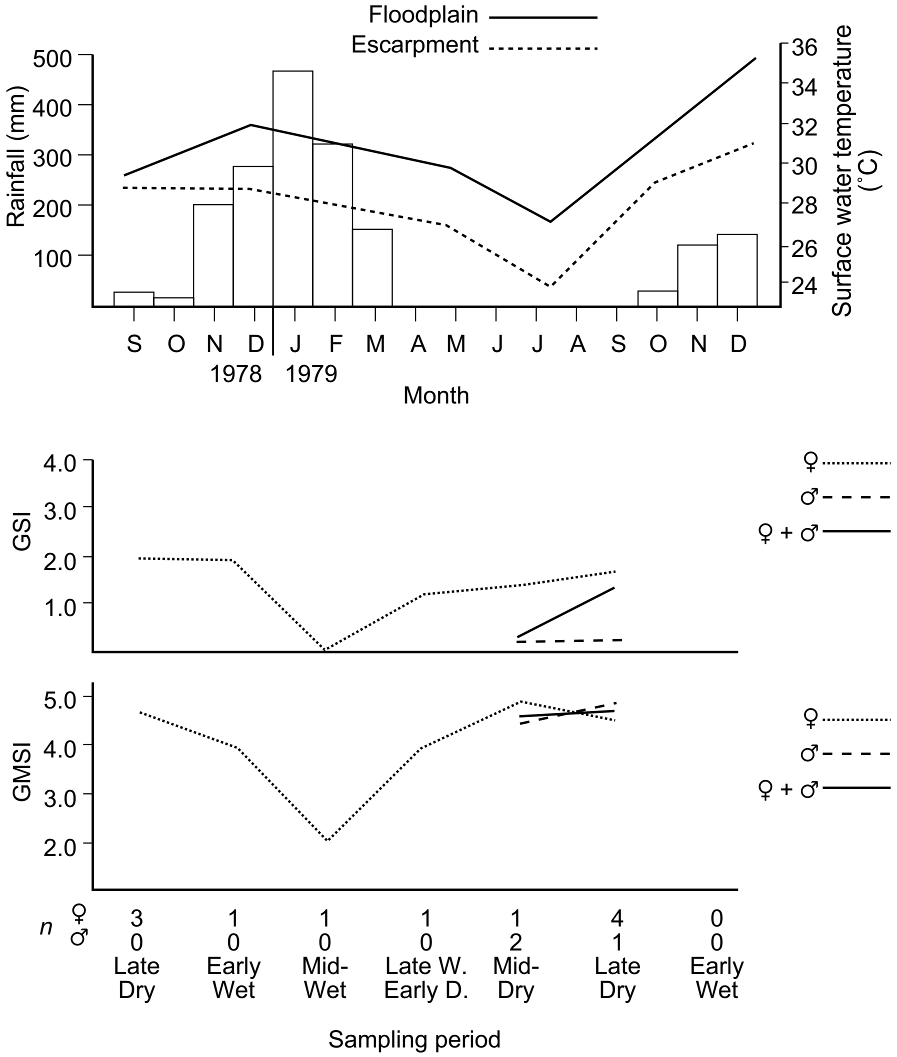

Figure 167 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *O. lineolata*

Site of spawning

No spawning was observed during our study, but Midgley collected about 700 000 eggs from four traps (five-gallon steel drums placed in billabongs) set in Georgetown Billabong and Indium Billabong, from mid-November 1979 to the end of January 1980 (Midgley 1980). The mature fish were collected from lowland backflow billabongs and from the East Alligator floodplain billabongs (table 147). Juveniles were generally collected from backflow billabongs and floodplain billabongs.

Table 147 Possible sites of spawning of *O. lineolata* as indicated by the abundance (*n*) of mature, ripe and juvenile fish

	Gonad stage				
	Mature (V)		Ripe (VI)		Juvenile
Habitat	F	M	F	M	
Lowlands					
Backflow billabong	5	2	0	0	23
Floodplain billabong					
Upper	0	0	0	0	10
Lower (riverine)	1	0	0	0	1

Fecundity

Six ovaries were examined. The number of eggs ranged from 35 000 (fish length 310 mm TL; GSI 1.88) to 170 000 (390 mm, 1.13), with an average of about 100 000. The diameters ranged between 0.3 and 0.5 mm (mean about 0.4 mm).[239] About 50 000 eggs are believed to be laid on patches generally ranging in area from 0.3 to 0.4 m^2 (Midgley, pers comm). The eggs are long and pear-shaped, with an adhesive disc that attaches the egg to objects in the water (plate 6).[240] The male guards the egg patch.

Summary

The data suggest that *O. lineolata* may breed throughout the year whenever conditions are suitable; however, very few adult fish were collected. Other reports indicate they breed from October until February, when water temperatures are above 24°C (Lake 1978; Midgley, pers comm).

Males are generally larger than females and have smaller urinogenital papilla (Midgley, pers. comm; Lake 1978). In the present study the males were smaller than the females.

Oxyeleotris lineolata most likely bred in the backflow billabongs and possibly in the floodplain billabongs. A large number (around 100 000) of tiny adhesive eggs (0.4 mm diameter) are laid in a patch, which is attached to an object in the water. The male guards this egg patch. The eggs incubate for about five to six days. The larvae are about 3 mm long with large pigmented eyes and a well-developed mouth.

Feeding habits

Overall diet

The stomachs of 133 specimens were examined; 106 contained food. The diet of *O. lineolata* is summarised in figure 168; the components are listed in table 148.

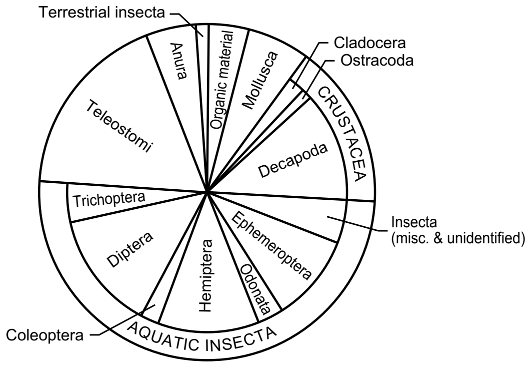

Figure 168 Dietary components of *O. lineolata*

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[239] Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to have a mean mature egg diameter of 0.46 (± 0.05) mm. The fecundity (F) versus standard length (SL) relationship for females with ripe gonads was:

$F = 0.206 x SL2.25$ ($r = 0,55$, $p < 0.001$).

The mean fecundity was approximately 160 eggs per gram of total body weight.

[240] Merrick and Midgley (1982) described the eggs and early development of two species of *Oxyeleotris*, including *O. lineolata*. The development of drum traps used as a spawning substrate was detailed and the culture of harvested eggs to the feeding stage was described.

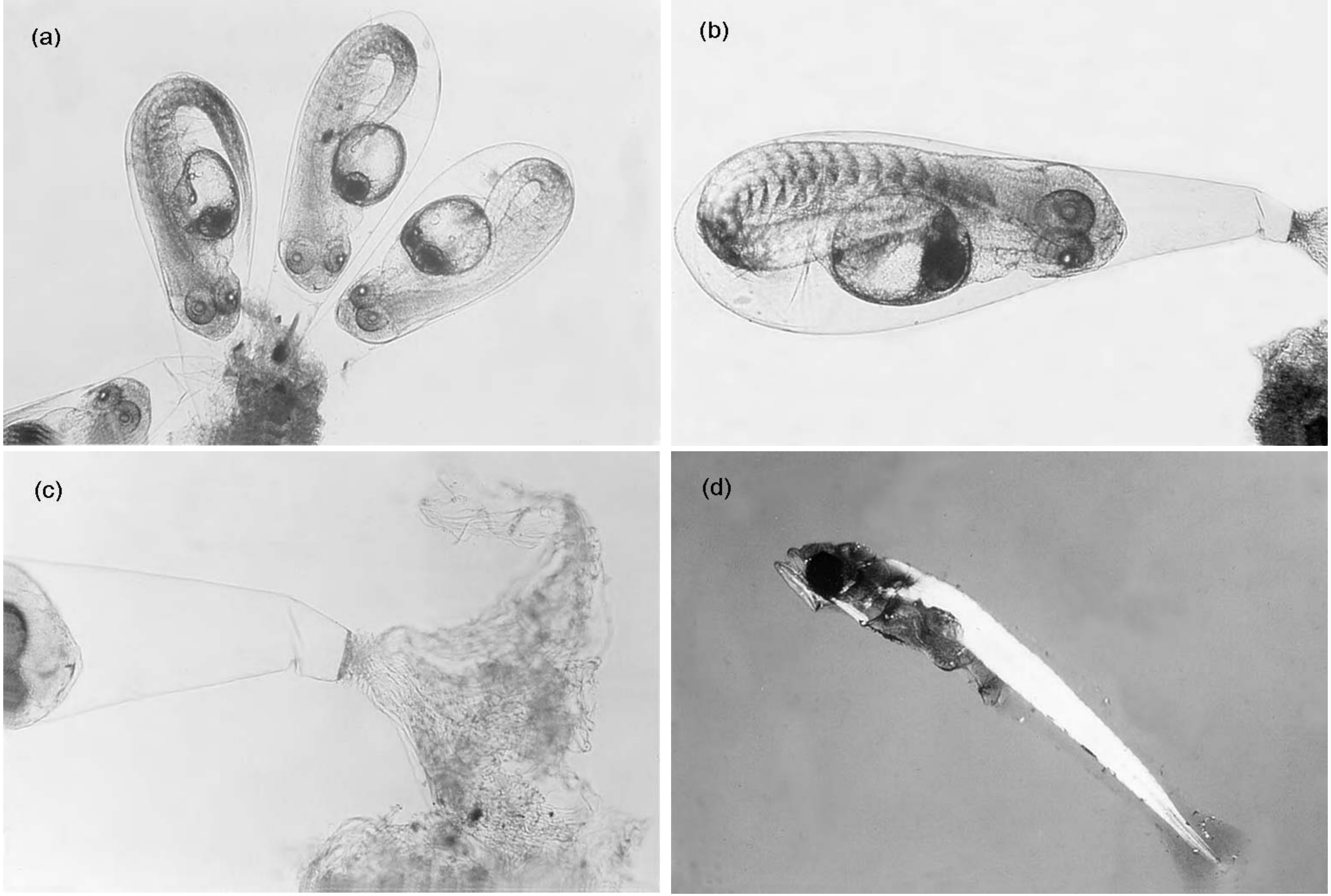

Plate 6 Stages in embryonic and larval development of *O. lineolata*: (a) eggs approximately 3 days after fertilisation x25; (b) x40; (c) adhesive basal disk of egg x100; (d) newly hatched larva, TL 3.1 mm, approx. 8 days after fertilisation.

Table 148 Dietary composition of *O. lineolata*

	Habitat						Season							Overall	
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic animals															
Gastropoda															6.4
Taxa 1	–	1.1	–	7.7	–	30.0	–	–	4.4	6.3	12.2	–	–	4.0	
Taxa 2	–	2.6	–	–	–	7.5	–	–	6.7	–	8.3	–	–	2.4	
Microcrustacea															2.9
Cladocera															
Diaphanosoma	–	–	25.0	7.7	–	–	–	–	–	–	–	4.6	–	1.9	
Ostracoda	–	–	–	0.4	–	–	5.3	7.1	0.6	–	–	–	–	1.0	
Macrocrustacea															12.5
Macrobrachium (juv)	–	5.1	–	–	–	–	19.5	–	–	–	–	–	–	3.5	
Macrobrachium (adults)	–	9.1	25.0	–	–	15.0	29.2	1.4	–	6.3	4.3	8.2	–	9.0	
Insecta															49.3
Fragmented	–	5.4	–	7.7	–	–	–	7.1	–	11.9	4.3	4.6	–	4.6	
Ephemeroptera															
Baetidae	–	11.5	–	7.7	50.0	–	–	7.1	11.1	16.3	24.8	–	–	9.7	
Odonata															
Libellulidae	–	2.4	–	7.7	–	–	8.9	–	11.1	6.3	–	–	–	3.5	
Hemiptera															
Gerridae	–	1.4	–	–	–	–	–	–	–	–	4.3	–	–	0.9	
Anisops	–	1.1	–	–	–	–	4.2	–	–	–	–	–	–	0.7	
Corixidae	–	13.6	–	7.7	–	–	7.4	7.1	–	6.3	14.8	18.2	–	10.2	
Coleoptera															
Miscellaneous	–	0.1	–	–	–	–	–	–	–	0.6	–	–	–	0.1	
Dytiscidae (larvae)	–	–	–	7.7	–	–	–	7.1	–	–	–	–	–	0.9	
Berosus	–	1.0	–	–	–	–	–	–	–	–	3.0	–	–	0.7	
Diptera															
Chaoborinae	–	6.9	–	–	–	–	–	–	–	–	–	22.7	–	4.7	
Chironomidae (larvae)	–	7.7	–	24.2	–	–	5.5	14.3	1.7	2.5	4.8	14.6	33.5	8.4	
Chironomidae (pupae)	–	0.1	–	–	–	–	–	–	–	–	0.4	–	–	0.1	
Ceratopogonidae	–	1.5	–	–	–	–	–	–	11.1	–	0.4	–	–	1.0	

Table 148 continued

	Habitat						Season							Overall	
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Trichoptera															
Leptoceridae	50.0	4.2	–	–	–	–	–	–	11.1	6.2	4.3	4.6	–	3.8	
Teleostomi															16.2
Fragmented	–	4.2	–	–	50.0	–	–	–	–	18.8	–	–	33.5	3.8	
Miscellaneous (larvae)	–	1.4	–	–	–	–	–	–	–	6.2	–	–	–	0.9	
M. splendida inornata	–	3.9	–	–	–	–	14.7	–	–	–	–	–	–	2.6	
P. tenellus	–	–	25.0	13.1	–	–	–	–	18.9	–	4.3	–	–	2.5	
Ambassis spp.	–	1.4	–	–	–	–	–	–	–	6.2	–	–	–	0.9	
A. agrammus	–	–	25.0	–	–	–	5.3	–	11.1	–	–	–	–	1.9	
L. unicolor	50.0	–	–	–	–	–	–	–	–	6.2	–	–	–	0.9	
G. aprion	–	1.4	–	–	–	–	–	–	–	–	4.3	–	–	0.9	
Glossogobius spp.	–	1.4	–	–	–	–	–	–	–	–	–	–	33.5	0.9	
M. mogurnda	–	1.4	–	–	–	–	–	7.1	–	–	–	–	–	0.9	
Anura															5.4
Miscellaneous (larvae)	–	1.4	–	–	–	47.5	–	34.3	11.1	–	–	–	–	5.4	
Terrestrial plants															
Angiospermae															0.2
Fragmented	–	0.3	–	–	–	–	–	–	–	–	0.9	–	–	0.2	
Terrestrial animals															
Insecta															0.9
Coleoptera	–	1.4	–	–	–	–	–	–	–	–	–	4.5	–	0.9	
Parasites															
Nematoda	–	–	–	0.8	–	–	–	–	1.1	–	–	–	–	0.1	0.1
Organic material	–	6.9	–	7.7	–	–	–	7.1	–	–	4.3	18.2	–	5.7	5.7
Number of empty fish	1	17	3	2	–	3	6	2	–	4	6	8	–	27	27
Number of fish with food	2	72	4	13	2	8	19	14	9	16	23	22	3		

Figures represent the mean percentage volume determined by the estimated volumetric method.

Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs; Fb = floodplain billabongs

The main components were aquatic insects (49.3%), teleosts (16.2%) and macrocrustaceans (12.5%, *Macrobrachium* and probably some *Caridina*). The aquatic insects were mainly corixid bugs, baetid mayflies (mainly *Cloen*) and chironomid larvae. Nine species of teleosts were identified (mainly from the larger specimens); the most abundant were *M. splendida inornata, P. tenellus* and *Ambassis* spp. Gastropods, microcrustaceans (cladocerans and ostracods) and anuran larvae were also eaten, and there were traces of terrestrial plants and animals in the stomachs. *Oxyeleotris lineolata* can therefore be classified as a macrophagic carnivore opportunistically feeding in the benthic, midwater and littoral zones of waterbodies. These findings agree with Pollard's (1974) and Lake's (1978) that this species is an opportunistic carnivore, eating crustaceans, insects and small fishes. However, Haines (1979) reported that the closely related *O. fimbriatus* in the Purari River, Papua New Guinea, is a detritophage/insectivore.[241]

Habitat differences

A total of 114 stomachs of *O. lineolata* were examined (all seasons combined) from the Magela Creek catchment: 3 (33% with empty stomachs) from lowland sandy creekbeds, 89 (19% empty) from backflow billabongs, 7 (42.8% empty) from corridor waterbodies, and 15 (13% empty) from floodplain billabongs. The highest proportions of fish with empty stomachs were found in corridor waterbodies and the lowest proportions in floodplain and lowland shallow backflow billabongs.

The few stomachs of *O. lineolata* examined from the lowland sandy creekbeds contained only *L. unicolor* and leptocerid caddis fly larvae. The more numerous stomachs of *O. lineolata* from lowland backflow billabongs contained a greater variety, mainly corixid bugs, baetid mayfly larvae, chironomid and chaoborin larvae, *Macrobrachium* and *Caridina*; the identifiable fish were *M. splendida inornata, Ambassis* spp., *G. aprion, Glossogobius* spp. and *M. mogurnda*.

The few stomachs examined from corridor waterbodies contained only crustaceans and fish (*P. tenellus* and *Ambassis* spp.). The stomachs of *O. lineolata* from the floodplain billabongs mainly contained a wide range of aquatic insects, and to a lesser extent fish, crustaceans and gastropods. The most important food items in the floodplain billabongs were chironomid larvae and *P. tenellus*.

Catchment differences

A total of 13 stomachs of *O. lineolata* were examined (all seasons combined) from the Nourlangie Creek catchment: 2 (0% empty) from lowland sandy creekbeds and 11 (27% empty) from shallow backflow billabongs.

As in the Magela catchment, *O. lineolata* in the sandy creekbed pools, had eaten aquatic insects and fish. In the Nourlangie catchment the diet in the backflow billabongs was different from that in the Magela catchment: anuran larvae and gastropods were the main food items.

Seasonal changes

In sampling periods 1–7, respectively, 25 (24% empty), 16 (13% empty), 9 (0% empty), 20 (20% empty), 29 (21% empty), 30 (27% empty) and 4 (25% empty) stomachs of *O. lineolata* were examined (all habitats combined). The highest proportion of fish with empty stomachs was in the Late-dry seasons and the lowest proportion in the Mid-wet season.

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[241] Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to be primarily a piscivore, targeting almost exclusively *Ophieleotris aporos*. Large crustaceans (*Macrobrachium* and *Cardinia*) were also consumed.

The main food items in the diet of *O. lineolata* were different in the two Late-dry seasons: in 1978 they were the macrocrustaceans *Macrobrachium* and *Caridina*, the teleost *M. splendida inornata* and corixid bugs; in 1979 they were chaoborin and chironomid larvae and corixid bugs. In the 1978–79 Early-wet season anuran larvae became important in the diet and chironomid larvae were also eaten more often; *Macrobrachium* virtually disappeared and were replaced by aquatic insects such as baetid mayfly larvae and dytiscid beetle larvae; fish became less important and only *M. mogurnda* was found in the stomachs. The few fish examined in the 1979–80 Early-wet season had eaten mainly fish (*Glossogobius* spp.) and chironomid larvae.

During the Mid-wet season, the fish component (mainly *P. tenellus* and *Ambassis* spp.) of the diet increased, gastropods appeared and anuran larvae became less important. Ostracods, which were eaten in the previous seasons, had almost vanished, as had chironomid larvae. In the Late-wet–Early-dry season, the fish component of the diet became larger, corixid bugs reappeared, and baetid mayfly larvae were eaten more often. During the Mid-dry season, the fish component became smaller and more gastropods and aquatic insects (baetids and corixids) were eaten.

Fullness

A summary of mean fullness indices of *O. lineolata* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 149. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 149 Mean fullness indices of *O. lineolata* in different sampling periods and habitats in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet	Mid-wet 1978–79	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Lowland shallow backflow billabong	0 (1)	n/s	2.0 (2)	n/s	0 (1)	0.5 (2)	n/s	0.8 (6)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	n/s	n/s	3.0 (2)	1.0 (7)	1.4 (5)	n/s	1.4 (14)
Lowland channel backflow billabong	n/s	0 (1)	0 (1)	0.7 (7)	2.5 (14)	1.5 (17)	3.0 (2)	1.7 (42)
Lowland shallow backflow billabong	2.7 (20)	0 (1)	0 (1)	2.0 (6)	1.0 (10)	0.6 (5)	2.5 (2)	1.9 (45)
Corridor sandy billabong	n/s	n/s	0 (1)	n/s	n/s	n/s	n/s	0 (1)
Corridor anabranch billabong	n/s	0 (1)	n/s	n/s	2.0 (2)	n/s	n/s	1.3 (3)
Floodplain billabong	n/s	1.6 (7)	5.0 (2)	0.4 (7)	n/s	2.5 (2)	n/s	1.6 (18)
Nourlangie Creek catchment (regular sites only)								
Lowland channel backflow billabong	n/s	2.5 (6)	n/s	n/s	n/s	0.5 (2)	n/s	2.0 (8)
Lowland shallow backflow billabong	n/s	n/s	0 (1)	n/s	4 (5)	n/s	n/s	3.3 (6)
Lowland sandy creekbed	n/s	n/s	n/s	0 (1)	0 (1)	n/s	n/s	0 (2)
Seasonal mean (all sites)	1.2	2.2	3.1	1.3	2.5	0.8	2.8	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Seasonal differences

The mean fullness index (all habitats combined) increased during the 1978–79 Early-wet season and then peaked in the 1978–79 Mid-wet season.[242] After the Wet season the index fell close to the level recorded in the previous Late-dry season. The low dissolved oxygen levels recorded in the bottom-water of most backflow billabongs during the Late-wet–Early-dry season may have reduced the feeding activity of this benthic-dwelling species. The fullness index increased in the Mid-dry season and then fell to a low in the 1979 Late-dry season. It increased in the 1979–80 Early-wet season, as it had the previous year.

Habitat differences

In the Magela catchment upstream from RUPA, the few specimens analysed were from a lowland shallow backflow billabong. They had very low mean fullness indices compared with specimens from similar downstream habitats.

Downstream from RUPA, the mean index was highest in shallow backflow and channel backflow billabongs and floodplain billabongs. The indices were lowest in corridor waterbodies.

In the Nourlangie catchment, the mean fullness indices were highest in shallow backflow and lowland channel backflow billabongs, and comparatively higher than in these habitats in the Magela catchment. The few specimens examined from the lowland sandy creekbeds had empty stomachs.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- floodplain billabongs; 1978–79 Mid-wet season
- lowland channel backflow billabongs; 1979–80 Early-wet season
- lowland sandy creekbeds; 1979 Late-wet–Early-dry season
- lowland shallow backflow billabongs (downstream of RUPA); 1978 Late-dry season

Nourlangie catchment

- lowland shallow backflow billabongs; 1979 Mid-dry season
- lowland channel backflow billabongs; 1978–79 Early-wet season.

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[242] Coates (1992) found that the closely related *O. heterodon* in the Sepik River of PNG had a stomach fullness index which exhibited little seasonality. Variation in the index reflected the changing abundance of the fish species (*Ophieleotris aporos*) it almost exclusively consumed.

4 Discussion

4.1 Size composition

Because freshwater fish characteristically display a considerable range of growth rates, depending on conditions such as food, space, numbers, competition and water temperature, a particular species does not necessarily achieve a specific maximum size (Weatherley & Roger 1978). In tropical waters, which have prevailing high temperatures, fish generally grow faster, mature younger, and have a shorter life span than fish in temperate waters (Lowe-McConnell 1975). Tropical fish species do, however, display a wide range of sizes, growth rates and life spans.[243] Certain adaptive characteristics (eg high efficiency as a predator, ability to avoid predators and to swim long distances) enable some species to grow rapidly and attain a large size. Other species remain small, their chances of survival improved by their ability to exploit foods not used by larger species,[244] to avoid predators within dense cover,[245] and to enter well-differentiated communities.

In communities of floodplain fishes in the seasonal tropics, a species may have an advantage if it can reproduce at a small size and early age (Lowe-McConnell 1975). Many smaller species living in such environments mature within a year — or larger ones within two years — enabling the fish to spawn in the next or next but one flood season. There is thus a high turnover in populations, and the results of 'good' or 'bad' spawning years (influenced by, for example, the extent of flooding, physical and chemical conditions, and also biotic factors) are rapidly reflected in catches. These seasonal fish populations in floodplain areas thus have high proportions of young-of-the-year, and the dynamic system of interacting variables results in large fluctuations in fish numbers both seasonally and annually.

Relative sizes of fish species

The mean lengths and weights of all species measured during the present study are shown in ranked order in figures 169a and b, respectively. From these data (particularly the mean weights) the fish species were grouped by size into small, medium, large and very large species.

The small species (mean lengths generally less than 50 mm LCF or TL and weights generally less than 2 g) were mainly members of the families Atherinidae, Ambassidae, Gobiidae, Eleotrididae (except for *O. lineolata*) and Melanotaeniidae. Most members of these families were carnivorous (except the melanotaeniids and *P. tenellus,* which were omnivorous). The atherinids and ambassids frequently exploited microcrustaceans from the middle of the water column, while the more predatory eleotrids and gobiids were bottom-water dwellers.

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[243] Peters (1983) has subsequently discussed the profound ecological consequences of body size, and Welcomme (1995) has highlighted the greater vulnerability of riverine fish taxa with large body size.

[244] Pusey et al (1995) examined the feeding ecology of freshwater fishes in two rivers of the Australian wet tropics. Five trophic guilds were recognised, and substantial discrimination between guilds on the basis of body size was observed. Small fishes (< 5 gm body weight) consumed a variety of insect larvae and small terrestrial insects. The diet of the large fish was characterised by the presence of large aquatic invertebrates and fish. A third group of intermediate sized fish (10–20 gm), which included the 0+ age class of three species of larger fish, also consumed aquatic invertebrates, but only a small proportion of terrestrial invertebrates.

[245] Bishop (1987) examined the dynamics of freshwater fish communities in the Alligator Rivers Region. Clear evidence was revealed that small species were better adapted than large species to shallower and more heavily vegetated areas.

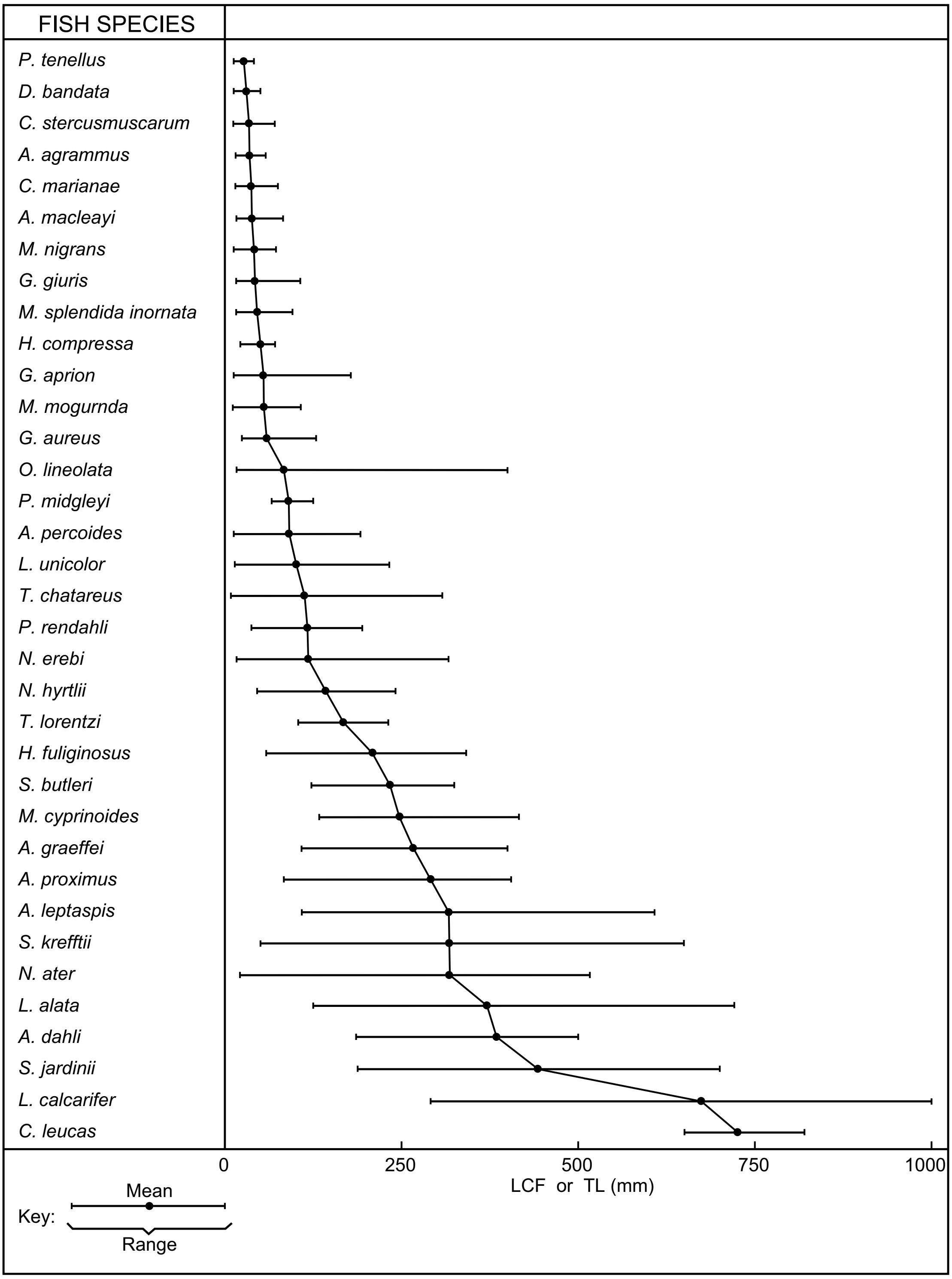

Figure 169a Ranked order of mean lengths of all species measured in the present study

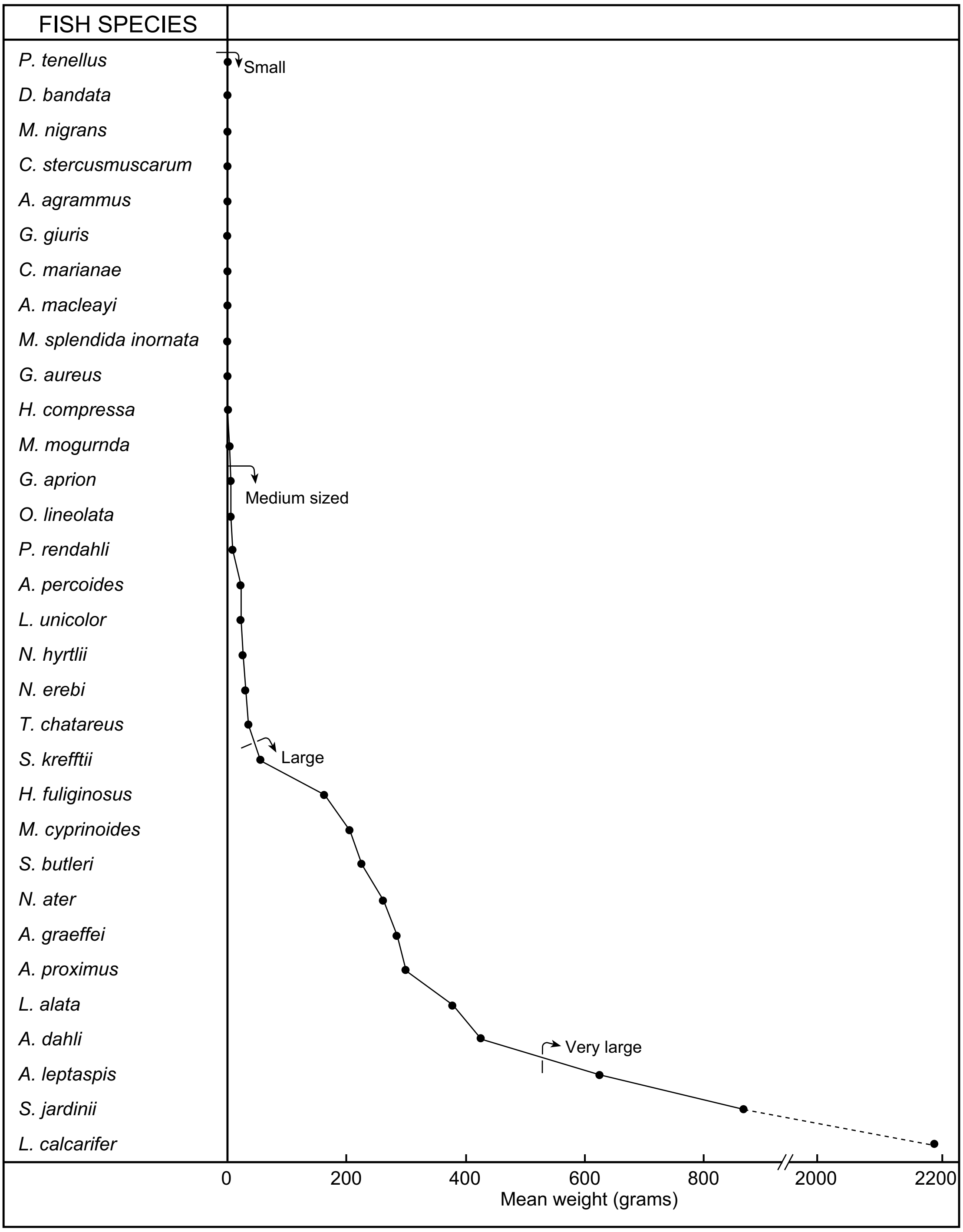

Figure 169b Ranked order of mean weights of all species measured in the present study

Medium-sized species (mean lengths and weights greater than the small species but less than 200 mm LCF or TL and 30 g) were *G. aprion*, the two small plotosid species (*P. rendahli* and *N. hyrtlii*), the smaller terapontids (*P. midgleyi*, *L. unicolor* and *A. percoides*), *O. lineolata, N. erebi* and *T. chatareus*. Although the last three species frequently grow to over 300 mm, their populations are usually dominated by young-of-the-year, which in turn correlates with their high fecundity. The feeding habits of all of these medium-sized fish species vary and in some cases are quite specialised (eg *P. midgleyi* and *T. chatareus*). *G. aprion, L. unicolor* and *O. lineolata* were piscivorous.

Large species were those with mean lengths greater than the medium-sized species and mean weights of less than 500 g. (Mean weight was the preferred variable, as it gives a better multi-dimensional perspective of size.) These included *S. krefftii*, the larger terapontids (*H. fuliginosus* and *S. butleri*), the larger plotosids (*N. ater* and *A. dahli*), *M. cyprinoides*, *L. alata* and two ariid catfishes (*A. graeffei* and *A. proximus*).

The two ariid catfishes might have been considered as very large species if more specimens had been collected in other seasons. The large species were mostly captured in deeper and more permanent waterbodies. Their feeding habits were varied; however, two were piscivores (*S. krefftii* and *M. cyprinoides*).

Very large species (mean weights greater than 500 g) were *A. leptaspis*, *S. jardinii*, *L. calcarifer*, and from estuarine upper reach habitats, *C. leucas*. These species were usually found in deeper and more permanent waterbodies. Their feeding habits varied, but at least three of the species were piscivorous.

Although the largest sizes of most species recorded were less than those reported in the published literature, individuals of five species (*S. butleri*, *T. lorentzi*, *A. dahli*, *N. ater* and *P. rendahli*) exceeded the published record lengths.

Methods

The small-sized and some medium-sized species were usually captured by seine net (SA, SZ, etc); some medium-sized and the large and very large species were usually captured by gillnet (GN and BN).

The two standard methods (SA and GN) caught the same species when large adult specimens of small and medium-sized species were captured by small-mesh gillnets, and small juvenile specimens of large and very large species were captured by seine nets. Fish of a considerable range of sizes were observed under water in clear escarpment streams.

The very small juveniles of primarily small fish species were caught only in seine nets that had become clogged with hydrophytes and filamentous algae, which reduced the effective mesh size. Very large species frequently escaped from monofilament gillnets (GN) during sets, as they were strong enough to break free from the entangling meshes. Some species (eg *H. fuliginosus* and *S. jardinii*) appeared to avoid gillnets set in clear waters, for few of them were caught, even though they were observed to be relatively abundant at such sites. The mesh selectivity of seine nets and gillnets frequently resulted in length-frequency peaks that were due to selectivity rather than real size trends (eg for *S. krefftii*).

After completing fish fauna surveys in the Finniss River (Northern Territory, Rum Jungle ex-uranium mining catchment), Jeffree and Williams (1975) concluded that spotlighting and poisoning tended to sample the same species, whereas gillnetting tended not to. The database of the present study should be examined to determine the size and species selectivity of each method, particularly gillnetting, so that comparison can be made with the study of Jeffree and Williams.

Size structure of samples

It was difficult to classify some species (eg *S. krefftii*) into adult and juvenile size groups because of apparent sexual differences in the lengths at first sexual maturity. Length-frequency analyses by separate sexes are thus required before such species can be assigned to the correct size grouping. Of the species for which there was enough biological information, fairly equal proportions were classified into the following three juvenile–adult dominance groups: skewed towards juveniles; approximately equal numbers of juveniles and adults; and skewed towards adults.

Nine species had length-frequency distributions skewed towards juvenile sizes. No small species were found in this group, as the mesh of the seine nets was generally too large to catch many of their juveniles. Three of the four very large species are in this group, as well as two catadromous species (*L. calcarifer* and *M. cyprinoides*) and several species with high fecundities (*N. erebi*, *T. chatareus* and *O. lineolata*). *Scleropages jardinii* and *N. ater,* which are also in this group, are particularly long at first maturation. The mortality of adult *G. aprion* is apparently high after it attains its LFM.

Eight fish species had fairly equal numbers of juveniles and adults. This group comprised only small species. Evidently, the LFM of most of these species coincided approximately with the mesh selectivity of the 10 mm mesh seine net (SA). This may reflect mesh-selectivity bias in the calculation of LFM or a high turnover of populations in the study area or both.

Nine species had length-frequency distributions skewed towards adult sizes, which could be because the juveniles grow quickly, the adults live longer, or both. In this group were small species (*M. splendida inornata*, *A. macleayi* and *H. compressa*) that have smaller LFM than the other species captured by seine net. Four species (*A. leptaspis*, *A. dahli*, *S. butleri* and possibly *P. midgleyi*) were also included in this group as their juveniles were seldom found abundantly (in some cases not at all), and therefore a greater number of adults than juveniles were captured in the samples. Male *A. leptaspis* buccally incubate their young until they attain 50 to 80 mm LCF; this fact, and the apparently fast growth of large juveniles, may explain the rarity of smaller juveniles of this species in the samples. The juveniles of *P. rendahli*, *L. unicolor* and *A. percoides* also grow rapidly, which may account for juveniles being present for only short periods during the year.

Habitats occupied by adult and juvenile size-groups

Lowe-McConnell (1975) suggested that young stages of many fish species often live in different biotopes from those of the parent fish. Many species move up rivers to spawn, and the newly hatched young often remain either upstream (where they may be more likely to escape predation by larger fishes) or in floodplain pools (although many of them may perish when the pools dry up, or fall prey to birds or the predatory fishes that frequent these pools).

For each species, habitats were defined as primary (the habitat where the species was most abundant) and secondary (where it was next most abundant). Primary and secondary habitats in which smaller juveniles, larger juveniles/smaller adults, and larger adults of some fish species were captured in the study area are shown in table 150. (The three size-groups above were considered as larger juveniles — smaller adults of some species occupied different habitats from smaller juveniles and larger adults.)

Table 150 Primary and secondary habitats in which smaller juveniles, larger juveniles/small adults and larger adults of various fish species were captured

	Smaller juveniles		Larger juveniles/smaller adults		Larger adults	
Habitat	Primary	Secondary	Primary	Secondary	Primary	Secondary
Escarpment mainchannel waterbody	*H. fuliginosus*	*C. marianae* *A. percoides* *G. giuris*	*H. fuliginosus* *P. midgleyi*	*C. marianae*	*H. fuliginosus* *S. butleri* *P. midgleyi* *T. chatareus*	*S. jardinii* *C. marianae* *A. percoides* *L. unicolor* *G. giuris*
Escarpment perennial stream	*M. nigrans* *P. midgleyi*	*H. fuliginosus* *S. butleri* *M. mogurnda*	*S. jardinii* *N. hyrtlii* *M. nigrans*	*H. fuliginosus* *L. unicolor* *P. midgleyi*	*M. nigrans*	*H. fuliginosus* *P. midgleyi* *M. mogurnda*
Lowland sandy creekbed	*M. splendida inornata* *C. marianae* *L. unicolor* *S. butleri* *M. mogurnda*	*N. hyrtlii* *S. krefftii* *M. nigrans*	*C. marianae* *P. tenellus* *A. percoides* *M. mogurnda*	*N. erebi* *N. ater* *S. krefftii* *C. stercusmuscarum* *D. bandata* *G. aprion* *T. chatareus* *G. giuris* *O. lineolata*	*C. marianae*	*M. nigrans*
Lowland backflow billabong	*S. jardinii* *A. leptaspis* *N. ater* *N. hyrtlii* *P. rendahli* *T. chatareus* *O. lineolata*	*M. cyprinoides* *N. erebi* *M. splendida inornata* *P. tenellus* *A. macleayi* *D. bandata* *L. unicolor* *G. aprion*	*N. erebi* *P. rendahli* *S. krefftii* *L. unicolor*	*N. hyrtlii* *A. agrammus*	*N. hyrtlii* *P. rendahli* *S. krefftii* *A. macleayi* *L. unicolor* *M. mogurnda* *O. lineolata*	*A. leptaspis* *M. splendida inornata* *C. stercusmuscarum* *P. tenellus* *A. agrammus* *D. bandata* *G. aprion*

Table 150 continued

	Smaller juveniles		Larger juveniles/smaller adults		Larger adults	
Habitat	Primary	Secondary	Primary	Secondary	Primary	Secondary
Corridor billabong	*N. erebi*	*A. agrammus*	*A. leptaspis*	*M. cyprinoides*	*N. erebi*	*M. cyprinoides*
	C. stercusmuscarum	*L. calcarifer*	*N. ater*	*S. jardinii*	*C. stercusmuscarum*	*N. ater*
	A. macleayi	*T. chatareus*	*M. splendida inornata*	*H. compressa*	*D. bandata*	*S. butleri*
	A. percoides	*L. alata*	*C. stercusmuscarum*		*L. calcarifer*	*T. chatareus*
	G. giuris	*H. compressa*	*A. macleayi*		*A. percoides*	*L. alata*
		O. lineolata	*D. bandata*		*G. giuris*	*H. compressa*
			L. calcarifer			
			G. aprion			
			T. chatareus			
			G. giuris			
			O. lineolata			
Floodplain billabong	*M. cyprinoides*	*A. leptaspis*	*M. cyprinoides*	*A. leptaspis*	*M. cyprinoides*	*N. erebi*
	S. krefftii	*N. ater*	*A. agrammus*	*P. rendahli*	*S. jardinii*	*P. rendahli*
	P. tenellus	*P. rendahli*	*H. compressa*		*A. leptaspis*	*S. krefftii*
	A. agrammus	*C. stercusmuscarum*			*N. ater*	*A. macleayi*
	D. bandata				*M. splendida inornata*	*L. calcarifer*
	L. calcarifer				*P. tenellus*	
	G. aprion				*A. agrammus*	
	L. alata				*G. aprion*	
	H. compressa				*L. alata*	
					H. compressa	

Smaller juveniles

The smaller juveniles of the largest numbers of species were found in lowland backflow billabongs and floodplain billabongs; for nine species these were primary habitats and for four, secondary habitats. The lowland backflow billabongs alone were a primary habitat for seven species and a secondary for eight. These two habitats therefore appear to be important nursery areas. The smaller juveniles of fewer species were found in corridor billabongs and sandy lowland creekbed pools; they were both primary habitats for five species, but the corridor billabongs were secondary habitats for six species and the sandy lowland creekbed pools for three. There were fewest species with smaller juveniles in escarpment perennial streams and escarpment mainchannel waterbodies, which indicates that the more diverse escarpment communities recruit larger juveniles/smaller adults from downstream habitats in the Wet season. Although escarpment habitats appear to be of little importance as nurseries for downstream species, they may be nurseries for some of the species of the more upstream communities.

Larger juveniles/smaller adults

The greatest number of species with larger juveniles/smaller adults were found in corridor billabongs, and slightly fewer species in sandy lowland creekbeds. Corridor billabongs were primary habitats for eleven species and secondary habitats for three; sandy lowland creekbeds were primary habitats for only three species, but secondary habitats for nine. These two habitats therefore appear to be important for some species when the juveniles are just becoming sexually mature. As the more permanent waterbodies (the floodplain and escarpment mainchannel waterbodies) connect with each other and the lowland backflow billabongs in the Wet season, corridor billabongs and sandy lowland creekbeds appear to be migration or dispersion routes for sexually maturing fish of various species.[246] Larger juveniles/smaller adults of fewer species were found in lowland billabongs and floodplain billabongs; both habitats were secondary for two species, but the floodplain billabongs were primary for four species, and the lowland backflow billabongs were primary for three. This suggests that sexually maturing fish move from floodplain and lowland backflow billabongs to corridor and sandy creekbed habitats. Larger juveniles/smaller adults of the fewest species were found in escarpment mainchannel and perennial stream habitats: the former was primary habitat to three species, secondary to three; the latter was primary to two and secondary to one.

Larger adults

The floodplain billabongs had the highest diversity of species present as larger adults: for ten they were the primary habitat, and for five the secondary. The lowland backflow billabongs were primary habitats for seven species, and secondary for seven. These habitats thus provided shelter for large adults, as did corridor billabongs and, to a lesser extent, escarpment mainchannel waterbodies. The corridor billabongs were primary habitats for six species and secondary for six; the escarpment mainchannel was primary habitat for four and secondary for five. This would be expected in these deeper and more permanent waterbodies. The lowest diversity of species present as large adults was in lowland sandy creekbeds (primary for one species and secondary for one) and escarpment perennial streams (primary for one species and secondary for three). The small size of these habitats and the seasonal nature of the lowland sandy creekbeds would account for these low numbers.

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[246] Bishop et al (1995) reported studies on fish movement dynamics within Magela Creek. Corridor billabongs were shown to be used as major movement routes between the floodplains and the lowlands towards the end of the Wet season.

‘Reservoirs’ of large adults of many species are thus found in floodplain, lowland backflow and corridor billabongs and, to a lesser extent, in escarpment mainchannel waterbodies. Smaller juveniles are recruited from these habitats. As they become sexually mature, many appear to disperse via the corridor billabongs and lowland sandy creekbeds that link between the reservoirs. Recolonisation of lowland billabongs, which shrink during the Dry season, is described in section 4.6 and volume 2. It appears that these habitats become important feeding areas for many species during the Wet season (‘Feeding habits’ section of the Discussion). The exact species- and size-composition and timing of fish migrations to and from the reservoirs is unknown and should be investigated in detail in future studies.[247]

Distribution of species relative to Ranger Uranium Project Area (RUPA)

The distribution of fish species downstream and upstream of RUPA is shown in table 151. It is important to know which species are abundant within the Magela Creek catchment downstream of RUPA, as they could be exposed to contaminants intentionally or accidentally released from the project area. It is also important to know whether the species found downstream have upstream populations, so that any effects of contaminants on downstream populations can be assessed. However, upstream populations may be based on migrations from downstream communities and so they could possibly be indirectly affected by impacts arising from contaminants. Of the 24 species found abundantly in many sites downstream of RUPA, 5 were found rarely in some upstream sites, 12 were found commonly in a few upstream sites, and 7 were found abundantly in many upstream sites. Upstream of RUPA, 13 species, including the last 7 species, were abundant in many sites, and 3 were found commonly, and 3 rarely, in a few sites.

Table 151 Distribution of fish species relative to the Ranger Uranium Project Area (RUPA) within the Magela Creek catchment

Downstream of RUPA/Upstream of RUPA				
++/–	++/+	++/++	+/++	–/++
M. cyprinoides	*N. erebi*	*M. splendida inornata*	*S. jardinii*	*H. fuliginosus*
O. gutturale	*A. leptaspis*	*C. marianae*	*S. butleri*	*P. midgleyi*
L. calcarifer	*N. ater*	*C. stercusmuscarum*	*M. mogurnda*	*M. nigrans*
L. alata	*N. hyrtlii*	*A. macleayi*		
H. compressa	*P. rendahli*	*A. percoides*		
	S. krefftii	*L. unicolor*		
	P. tenellus	*T. chatareus*		
	A. agrammus			
	D. bandata			
	G. aprion			
	G. giuris			
	O. lineolata			

++ Found abundantly in many sites; + Found commonly in a few sites; – Found rarely in some sites

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[247] This work was initiated in the studies of Bishop et al (1995).

Seasonal recruitment of juveniles

The seasonal pattern of juvenile recruitment of fish species for which adequate biological information was obtained is shown in table 152. Recruitment is defined as occurring when juveniles become abundant in the samples; larvae are generally smaller than the minimum effective mesh size of the nets used for capture and may or may not be present in unsampled habitats.

Table 152 Seasonal juvenile recruitment of various fish species for which adequate biological information was collected

	Seasons				
	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry
Recruitment peak usually in only one season					
Primary		*N. erebi*	*M. cyprinoides*	*H. compressa*	
		N. ater	*L. calcarifer*		
		A. percoides	*L. alata*		
		L. unicolor	*S. jardinii*		
		T. chatareus	*A. leptaspis*		
			S. krefftii		
			H. fuliginosus		
			S. butleri		
			P. midgleyi		
Secondary	*A. percoides*				*A. percoides*
	T. chatareus				
Continuous recruitment with a few peaks					
Primary		*M. splendida inomata*	*M. nigrans*	*P. tenellus*	*C. marianae*
		A. agrammus	*C. stercusmuscarum*	*G. aprion*	*G. giuris*
		M. macleayi	*D. bandata*		
			M. mogurnda		
Secondary	*C. marianae*			*D. bandata*	*M. splendida inomata*
	G. giuris			*M. mogurnda*	*M. nigrans*
					C. stercusmuscarum
					A. agrammus
					G. aprion
					H. compressa
Continuous recruitment with no apparent peaks					
		O. lineolata (no season)			

Three types of juvenile recruitment were apparent:

- *Type A* recruitment usually limited to one season
- *Type B* continuous recruitment, with a few peaks during the year
- *Type C* continuous recruitment, with no apparent peaks during the year.

Where recruitment peaked in more than one season, the largest peak was defined as primary and the next largest as secondary.

Type A recruitment was mainly apparent in medium-, large- and very large-sized species. The juveniles of most of these species were recruited to their populations during the Early-wet and Mid-wet seasons, when the whole aquatic environment was expanding or had expanded due to rising water levels. Juvenile recruits of two or three catadromous species (*M. cyprinoides*, *L. calcarifer* and possibly *L. alata*) enter the freshwaters of the study area mainly during the Mid-wet season when these waters connect with estuarine middle/lower reaches of the main rivers. *Amniataba percoides* and *T. chatareus* also had secondary peaks in the Late-dry seasons. Large numbers of juvenile recruits of the former species were also found in the Mid-dry seasons in sandy corridor billabongs.

Type B juvenile recruits were mainly of small species, which would not require as much space (particularly depth in the Dry season) in waterbodies as the larger species. However, environmental conditions in the Wet season are generally optimal for juvenile survival. Large numbers of species therefore recruited primarily in the Mid-wet season, while fewer species recruited in the Late-wet–Early-dry and Mid-dry seasons, and none in the Late-dry season. The secondary recruitment for some of these species extended over the Late-wet–Early-dry season and the Late-dry season, the largest numbers of species being recruited in the Mid-dry season. This secondary peak may arise because many of the small fish species reach their LFM in less than one year (table 153) and therefore fish present as juveniles in the Wet season may have sexually matured towards the Mid-dry season and be themselves then producing juveniles. Marchant (1982) noted a secondary resurgence of macroinvertebrate communities in corridor billabongs during the 1979 Mid-dry and Late-dry seasons. This increase in available food would coincide with the presence of juvenile fish in some corridor billabongs.

Only one species (*O. lineolata*) displayed type C recruitment.

Juvenile recruitment was generally higher for most species towards the end of 1978 than the end of 1979. This annual variation in juvenile recruitment was apparently caused by the more severe 1979 Dry season, with rainfall lower than average in the 1978–79 Wet season (so billabongs in the Dry season shrank further than in previous years), and rains in the 1979–80 Early-wet season later than average (so the creeks did not flow strongly at the same time as the previous year).

Table 153 Estimated time periods in which various fish species attain their length at first maturity

Time taken to attain LFM						
Within one Wet season	Less than one year	One year	One to two years	Two years	Three years	Four years
M. nigrans	*P. rendahli*	*M. cyprinoides*[1]	*A. leptaspis*	*S. krefftii (F)*	*S. jardinii*[2]	*L. calcarifer*[3]
M. splendida inornata	*C. marianae*	*N. erebi*	*S. krefftii (M)*	*T. chatareus*		
C. stercusmuscarum	*P. tenellus*	*N. ater*				
A. agrammus	*A. macleayi*	*A. percoides*				
D. bandata	*L. unicolor*	*H. compressa*				
	G. giuris					
	M. mogurnda					

M = male; F = female; 1 Based on Wade et al (1966); 2 Based on Lake & Midgley (1970a) for *S. leichardti;* 3 Based on Reynolds (1978)

Time taken to attain the LFM

Lowe-McConnell (1975) found that the growth rates of tropical fishes in natural waters are very difficult to determine, as the breeding seasons are generally not well defined, which makes it difficult to follow length-frequency mode progressions. This was a problem in the present study, and it was compounded by the effects of fishing-gear selectivity and the wide variety of habitats sampled (seasonal length-frequency analyses for this report were carried out on data from combined habitats). Further studies are required before our tentative growth estimates can be confirmed.

Tentative estimates of early growth rates were possible for 19 species. Generally, growth was fastest between the Early-wet and Late-wet–Early-dry seasons, and had stopped for most species towards the Late-dry season. Lowe-McConnell (1975) found that the ‘highwater’ time in tropical freshwaters is the main feeding, growing and fattening season for nearly all species.

Estimates of growth rate were undertaken primarily to obtain an indication of the time species took to attain their LFM. Catches of species that attain their LFM very young rapidly reflect environmental conditions that adversely affect spawning success. Tentative time periods in which various fish species attained their LFM in the study area are shown in table 153.

Most (17) of the fish species studied attain the LFM in one year or less. The 12 species that attain the LFM in less than one year were nearly all small-sized species (except *L. unicolor* and *P. rendahli*, which are widely distributed medium-sized species). The 5 species that attained the LFM within one Wet season were (except for *M. nigrans*) the most abundant and widely distributed species in the study area. These may be considered to be the most ‘successful’ of the small fish species.

The species that may attain the LFM after their first year are mainly medium, large and very large: the very large species *S. jardinii* attains it in four years; *L. calcarifer* in three years; *A. leptaspis* (which apparently grows very rapidly) in one to two years.

Seasonal changes in body condition

A concomitant of somatic growth in fish is change in body condition during life. Such changes can be great or small, smoothly progressive, intermittent, or cyclically related to breeding. The many studies detailing changes in condition of fish populations frequently provide insight into the lives of fishes in relation to food supply and the timing and duration of breeding activity.

Nikolski (1963) suggested that, in several species of fishes, temperature acts as a ‘signal factor’, in that a reduction of the temperature below a certain level leads to a cessation of protein growth and the start of fat accumulation. Pollard (1972) thought that external factors probably influence the timing and control of the mobilisation of nutrient reserves.

Sampling seasons during which the highest and lowest body conditions were recorded for various fish species are shown in table 154. Most species attain their best body condition from the Mid-wet to the Mid-dry seasons, with a peak in the Late-wet–Early-dry season. This trend reflects that observed for the relative numbers of fish species per season showing the greatest feeding activity (see section 4.4). However, peak body condition appears to follow slightly after peaks in feeding activity. More species attained their best body condition in the 1978 Late-dry season than in the same season in 1979; environmental conditions appear to have been much less favourable in the 1979 Dry season. Some species (eg *T. chatareus*) attained greater gonadal maturation in the 1978 than in the 1979 Late-dry seasons.

Seasonal trends in the numbers of species of fish with poorest condition were more complex. The greatest number of species in their poorest condition during the study occurred in the 1978–79 Early-wet season, caused mainly by the presence of recently spent specimens of several species (eg *N. erebi* and *A. leptaspis*). Such a peak in the number of species with low condition did not recur in the 1979–80 Early-wet, as few species appeared to have bred successfully in this season, presumably because the creeks and channels had not begun to flow by the time sampling ended, unlike the 1978–79 Early-wet season.

Table 154 Sampling seasons in which the highest and lowest body condition (K) was recorded for various fish species in the study area

	Sampling season						
Condition	1978 Late-dry	1978–79 Early-wet	Mid-wet	Late-Wet–Early-dry	Mid-dry	1979 Late-dry	1979–80 Early-wet
Highest	*S. jardinii* *D. bandata* *H. fuliginosus* *T. chatareus*	*A. macleayi*	*S. krefftii* *M. splendida inomata* *P. midgleyi* *H. compressa*	*N. erebi* *M. nigrans* *C. marianae* *P. tenellus* *L. calcarifer* *A. percoides* *L. unicolor* *G. aprion* *L. alata* *M. mogurnda*	*M. cyprinoides* *A. leptaspis* *P. rendahli* *N. hyrtlii* *C. stercusmuscarum* *A. agrammus*	*O. lineolata*	*G. giuris*
	Total number of species						
	4	**1**	**4**	**10**	**6**	**1**	**1**
Lowest	*M. cyprinoides* *M. nigrans* *L. alata* *O. lineolata*	*N. erebi* *A. leptaspis* *N. ater* *C. marianae* *D. bandata* *L. calcarifer* *M. mogurnda*	*S. butleri*	*P. rendahli* *A. agrammus* *G. giuris* *H. compressa*	*S. krefftii* *P. midgleyi* *T. chatareus*	*C. stercusmuscarum* *A. percoides* *H. fuliginosus* *L. unicolor*	*S. jardinii* *N. hyrtlii* *M. splendida inomata* *A. macleayi* *G. aprion*
	Total number of species						
	4	**7**	**1**	**4**	**3**	**4**	**5**

Four species were in their poorest body condition in the Late-dry seasons of both 1978 and 1979. However, most species lost more condition in the 1979 Dry season than in the 1978. A secondary peak in the numbers of fish species in their lowest condition occurred during the Late-wet–Early-dry season, which was unexpected, as most other species attained their best condition in this season. The phenomenon may have been a result of the anoxic conditions recorded in the bottom waters of most lowland backflow and floodplain billabongs during this season, as most of the species (eg *P. rendahli*, *N. ater*, *G. giuris* and *N. erebi*) with low body condition at this time were benthic feeders. However *N. erebi* adapted by changing its feeding habits during this period: from being predominantly a benthic feeder, it became a midwater feeder.

Seasonal changes in the body condition of various fish species in the present study appeared to show the effects of breeding activity, supply of food and other environmental variables. Before such factors can be used to predict environmentally induced stresses on fish species in the Alligator Rivers Region, the effects on seasonal body condition of such phenomena as the sex and size of fish, the habitat in which they are captured, and the occurrence of parasites, must be elucidated.

4.2 Environmental associations

Although this study was carried out over only 16 months, much useful information indicative of the environmental associations of 32 fish species was obtained. Many of the abiotic factors, such as dissolved oxygen, water temperature, pH and substrate, interact with one another, but will generally be considered separately here. The rankings of fish species by various physico–chemical and habitat–structural variables are shown in table 155. Refer to table data in appendix 6 and 7. Further work of this type is necessary, as well as supplementary laboratory and experimental work, particularly on the effects of disturbances on particular characteristics in the environment of a species. The trends observed for each physico–chemical and habitat–structural variable are briefly discussed below in the same order as in the accounts of the individual species in chapter 3.

The physico–chemical characteristics studied at each sampling site were water temperature, dissolved oxygen concentration, water visibility, pH, conductivity, type of substrate and vegetation. Bank vegetation and water flow were also recorded.

Water temperature

The surface and bottom water temperatures (means, standard errors and ranges) for the fish species captured in the study are shown in figures 170a and b, respectively.

Water temperatures in the study area varied widely, since they are affected by a number of factors.

- the topographic difference between the escarpment and lower reaches of the catchment: waterbodies in the escarpment areas have steep valley sides and overhanging terrestrial vegetation, so they are generally cooler than the waterbodies of the lower reaches.
- the water depths and surface areas of the channels: the shallower, wider channels are more influenced by changes in air temperature than are the narrower, deeper channels more commonly found in escarpment areas.
- the velocity and turbidity of the water: slow-moving, turbid waters will absorb more heat than fast-moving, clear waters. As the escarpment waterbodies are usually narrower, faster-flowing and clearer than the waterbodies of the lower reach habitats, they are usually cooler.

Table 155 Rank numbers for *in situ* physico–chemical and habitat structural parameters for the majority of the species studied. The greater the rank number, the higher the mean value, or dominance, of a parameter.

	Physico–chemical							Substrate				Hydrophytes			
Species	Temp		DO		pH		Visibility	Bedrock	Mud	Sand	Clay	Floating-attached	Emergent	Submergent	Vegetation-occurrence index
	S	B	S	B	S	B									
'No catch'	23	13	6	9	20	12	19	1	23	14	29	33	12	9	17
M. cyprinoides	8	9	21	2	31	22	24	28	20	9	33	25	7	33	24
N. erebi	25	15	26	13	21	11	20	11	22	10	32	28	9	29	20
S. jardinii	4	3	12	11	4	6	29	34	7	27	11	35	4	27	10
A. leptaspis	15	11	9	3	12	7	22	14	29	5	36	27	8	26	26
A. proximus	10	1	31	9	19	6	29	2	33	1	37	20	1	35	35
A. graeffei	7	13	2	4	2	31	28	3	9	39	13	8	13	18	2
A. dahli	12	12	16	19	4	27	31	4	14	32	6	34	3	36	3
Neosilurus sp. A	29	27	10	8	7	4	25	13	18	21	7	32	27	15	18
Neosilurus sp. B	9	9	11	26	5	8	30	32	5	29	8	32	2	2	6
Neosilurus sp. C	24	13	18	5	29	18	11	29	31	3	26	34	12	7	12
N. ater	4	1	3	6	5	14	26	1	12	13	33	33	10	5	14
N. hyrtlii	7	1	20	10	23	21	9	19	26	8	28	36	6	16	13
P. rendahli	10	7	5	12	17	19	4	6	35	2	30	29	12	14	31
S. krefftii	16	14	28	14	30	20	21	21	21	17	32	30	15	19	21
M. splendida inornata	20	24	13	25	15	16	12	26	15	23	17	14	20	22	19
M. nigrans	2	5	13	29	1	2	30	36	4	25	1	16	21	4	4
C. marianae	17	25	23	32	25	29	13	14	6	33	4	7	25	34	8
C. stercusmuscarum	28	28	7	27	16	28	15	17	11	24	20	12	23	25	25
P. tenellus	29	32	31	28	9	–	16	18	19	7	34	10	30	8	32

Table 155 continued

	Physico–chemical							Substrate				Hydrophytes			
	Temp		DO		pH										
Species	S	B	S	B	S	B	Visibility	Bedrock	Mud	Sand	Clay	Floating attached	Emergent	Submergent	Vegetation-occurrence index
A. agrammus	33	27	16	17	28	18	5	16	27	22	9	26	29	5	28
A. macleayi	18	20	23	20	18	24	14	15	17	18	19	15	24	13	23
D. bandata	27	29	15	16	26	26	7	7	28	12	13	18	18	20	33
L. calcarifer	14	10	1	6	1	13	17	24	30	13	27	6	32	10	30
A. percoides	12	18	22	32	22	23	27	23	10	11	12	23	11	31	9
H. fuliginosus	3	6	17	33	3	3	33	37	1	26	2	2	33	3	1
L. unicolor	13	16	25	18	13	9	18	31	13	19	16	24	17	23	11
S. butleri	6	12	20	30	8	15	32	33	3	30	10	1	35	1	7
P. midgleyi	1	4	14	31	2	5	34	35	2	28	3	3	5	6	5
G. aprion	19	19	24	23	24	14	10	25	23	14	24	6	16	21	29
T. chatareus	21	23	17	15	14	10	23	22	16	20	21	22	28	11	16
L. alata	12	27	1	1	24	17	6	27	36	6	14	4	34	12	34
G. giuris	21	26	29	33	32	30	33	20	8	31	5	5	31	28	15
H. compressa	30	31	19	–	33	–	2	9	34	4	15	9	22	32	36
M. mogurnda	11	17	4	24	6	1	1	30	20	15	18	11	20	17	22
O. lineolata	26	21	14	21	27	25	3	10	32	8	23	19	14	24	27

S = Surface

B = Bottom

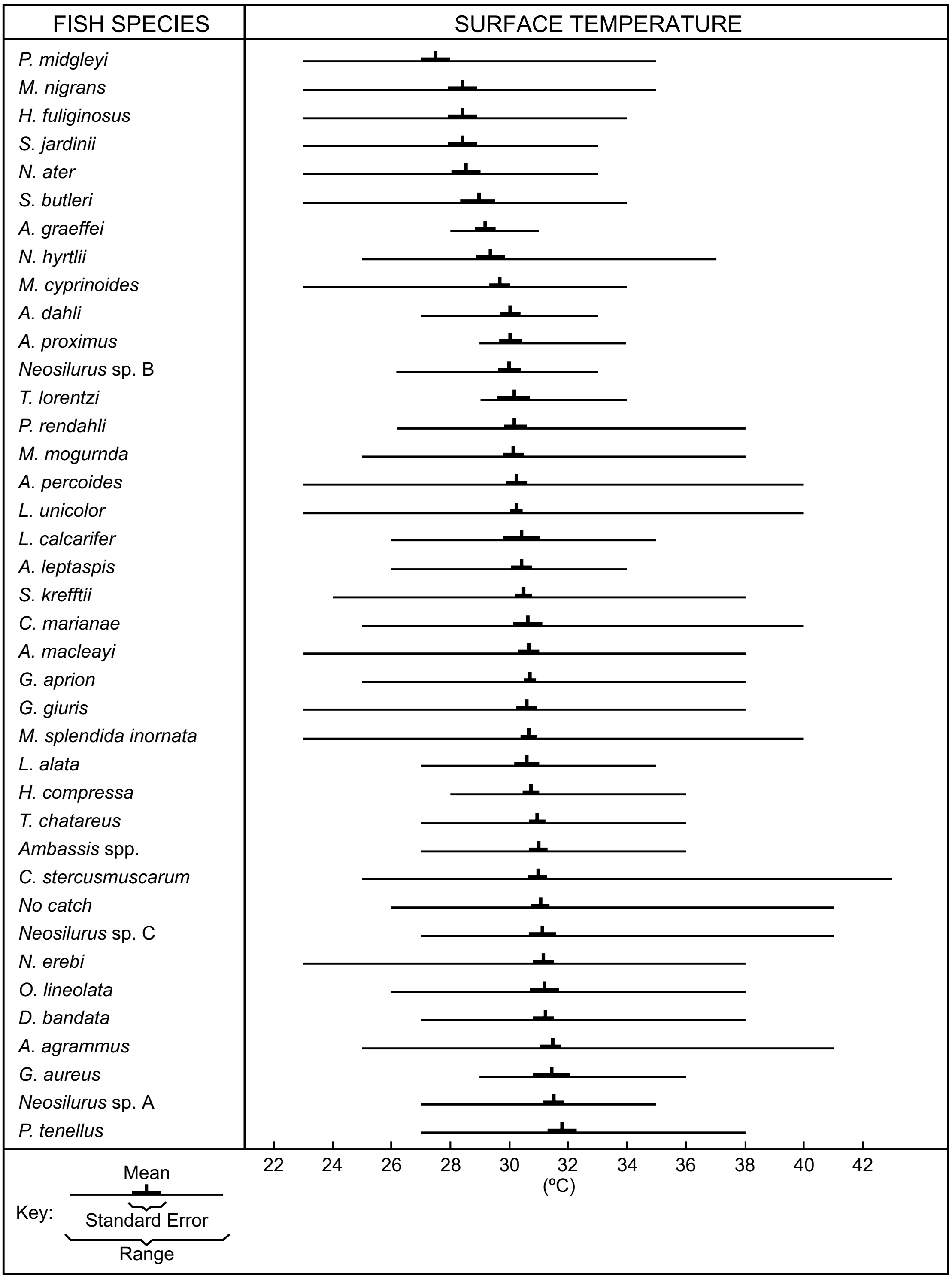

Figure 170a *In situ* surface water temperatures (means, standard error and ranges) for various fish species captured during the study period (see appendix 6)

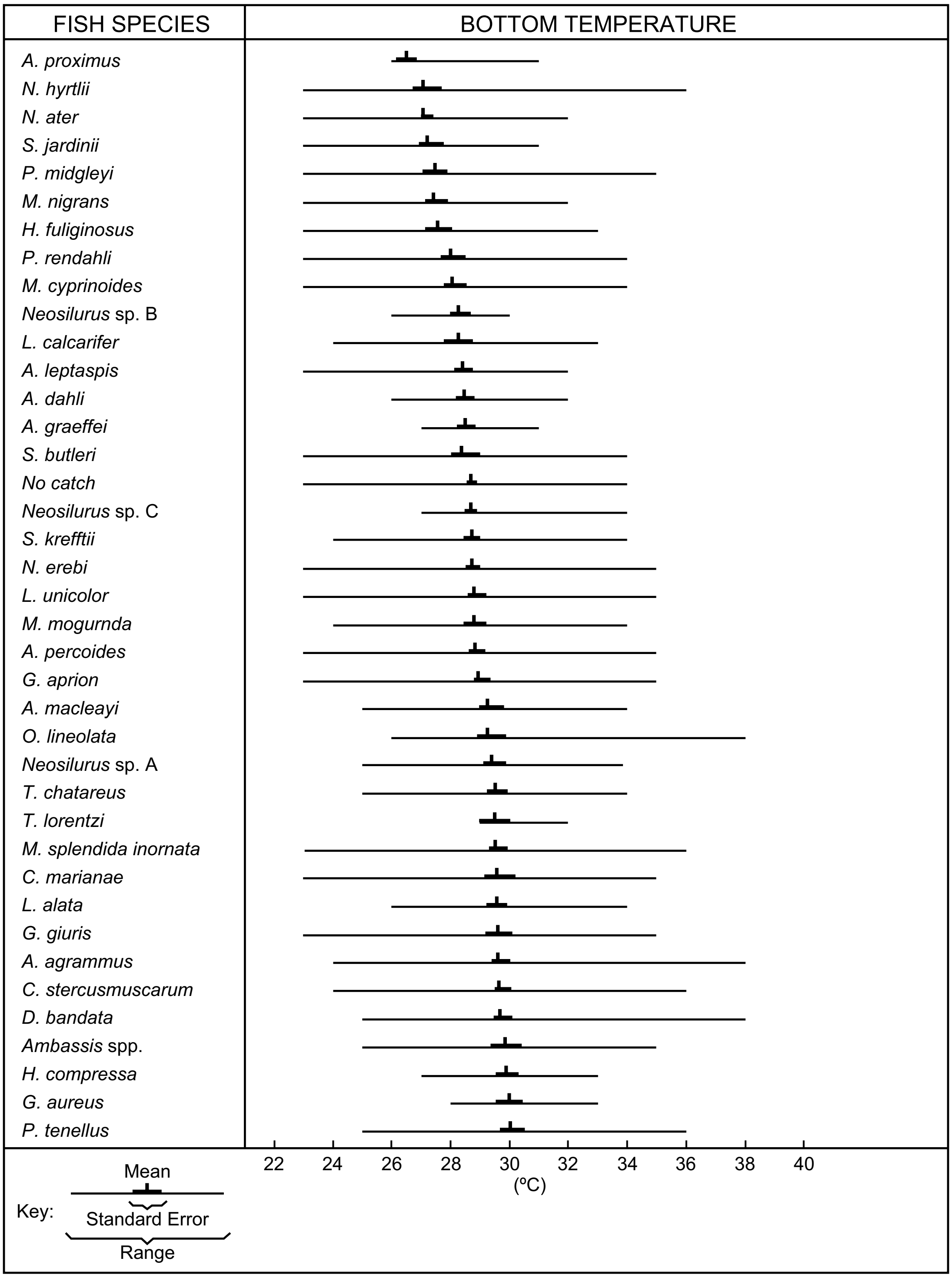

Figure 170b *In situ* bottom water temperatures (means, standard error and ranges) for various fish species captured during the study period (see appendix 6)

Water temperature limits both the broad geographical distributions of stream fishes and their local occurrences within a single watercourse. Their tolerance to different water temperatures clearly affects the overall distribution of fish species (Hynes 1970).

During the present study, water temperatures ranged from 23° to 43°C. As water temperature varies vertically (ie from top to bottom of the water column), both the surface and bottom water temperatures were recorded at each sampling site to give a more representative estimate of temperatures at that site and to quantify the difference between the two environments potentially available to fish. Many species were found typically in either surface or bottom waters; some plotosid catfishes, for example, spend most of their time feeding in benthic areas and are thus classified as 'bottom dwellers'. For these, and other 'vertically specialised' species, surface (or conversely bottom) water temperature readings may not be very relevant. With these vertical habitat differences in mind, the range of water temperatures associated with a species was usually found to be a good indicator of that species' distribution and often confirmed or added to the findings of other workers on the temperature tolerances of that species or its family or genus.

Generally, fish found primarily in the escarpment zone lived in cooler waters with lower means and narrower ranges than those found primarily in lower reaches. The species found in waters with the widest ranges of temperatures (*A. percoides*, *L. unicolor*, *C. stercusmuscarum*, *M. splendida inornata*, *C. marianae*, *N. hyrtlii*, *N. erebi* and *A. agrammus*) were the most common and/or widely distributed species. More temperature readings were taken in waters in which the more abundant species were found than in those inhabited by less abundant species. This 'sample size' effect must be kept in mind when considering the relationship between a species and its apparent 'preferred' water temperatures. Thus species like *A. dahli* and *H. compressa* were associated with narrow ranges of water temperatures, but this narrowness may be a function of the small number of temperature readings taken in conjunction with these species. Other workers have found that *H. compressa* tolerates a wider range of temperatures than is indicated in this study. The other narrow-range species were *L. calcarifer*, *A. leptaspis* and *A. graeffei*, plotosid catfishes and other bottom-dwelling species.

The plotosids and escarpment-area dwellers, such as *S. jardinii*, *P. midgleyi*, *H. fuliginosus*, *M. nigrans* and *S. butleri*, were captured in waters with low minimum and mean temperatures. These species are typically found in cooler bottom or escarpment waters. At the other extreme, *A. agrammus*, *C. stercusmuscarum*, *A. percoides*, *L. unicolor*, *M. splendida inornata* and *N. hyrtlii* were found in waters with temperatures up to and above 40°C. Previous workers have found some of these species to be tolerant of hot waters (eg *Craterocephalus* spp.) or desiccation (eg *L. unicolor*). Generally, fish found typically in the lower reaches of the catchment, and widely distributed hardy species, could withstand the greatest ranges of, and extremely high, temperatures. Since these species were usually common, 'sample size' error was reduced.

Water temperatures recorded for a particular species are a function of the distribution of the species and may reflect its tendency to be found in bottom, middle or surface levels of its 'preferred' habitats. Some good indications of the natural temperature tolerances of individual species have been obtained, but further work is necessary. The upper and lower water temperatures that are lethal to a species should be tested in the laboratory for all stages of the life cycles of the species studied. Further field studies should also be done on the effects of water temperature on the biology of a species, perhaps including experimental manipulations to find out whether, for example, populations of a particular species found in escarpment habitats have the same upper lethal temperature as populations of the same species from the lower reaches of the catchments.

Dissolved oxygen

The surface and bottom dissolved oxygen levels (means, standard errors and ranges) for the fish species captured in the study are shown in figures 171a and b, respectively.

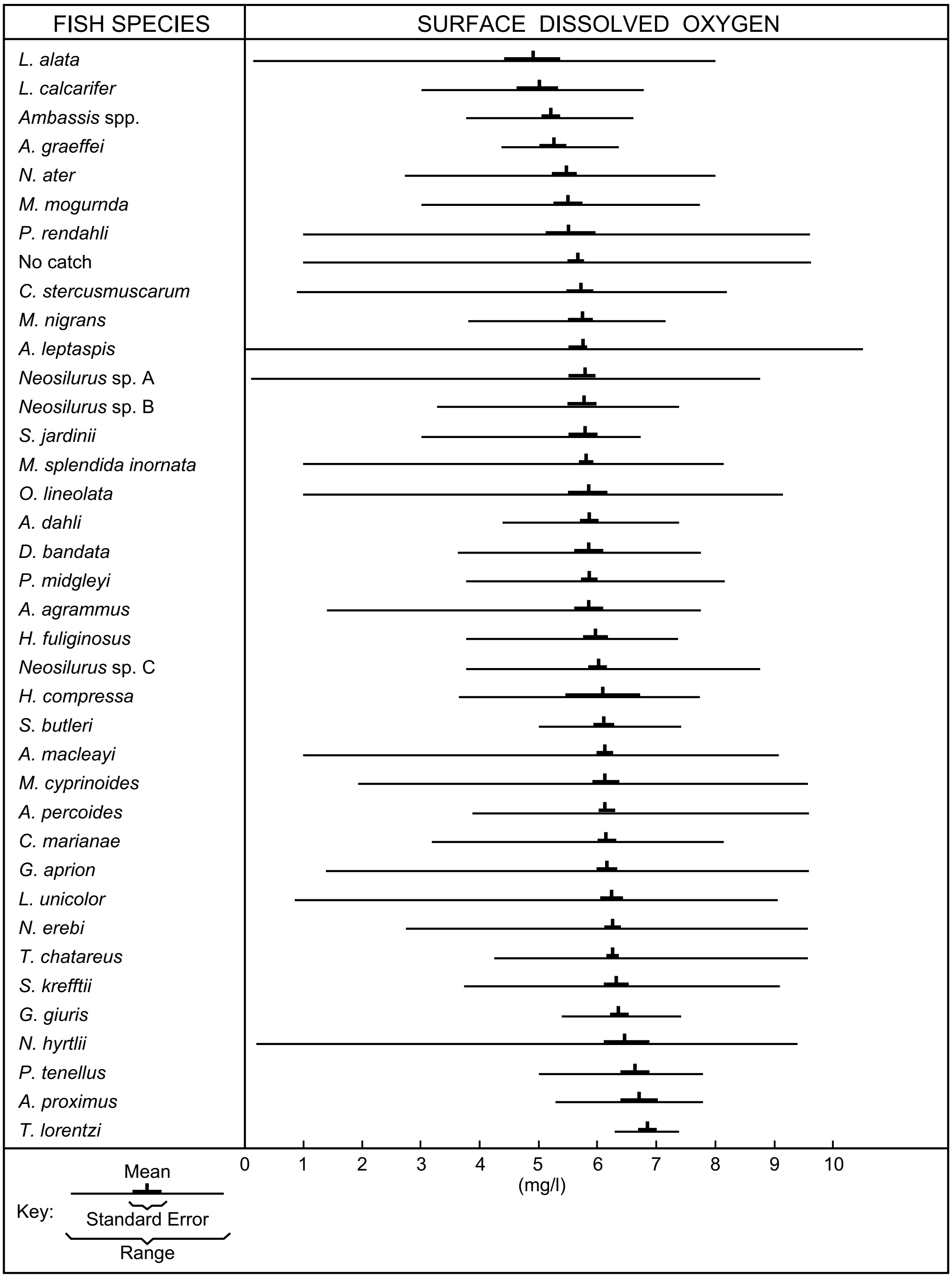

Figure 171a *In situ* surface dissolved oxygen levels (means, standard errors and ranges) for various fish species captured during the study period (see appendix 6)

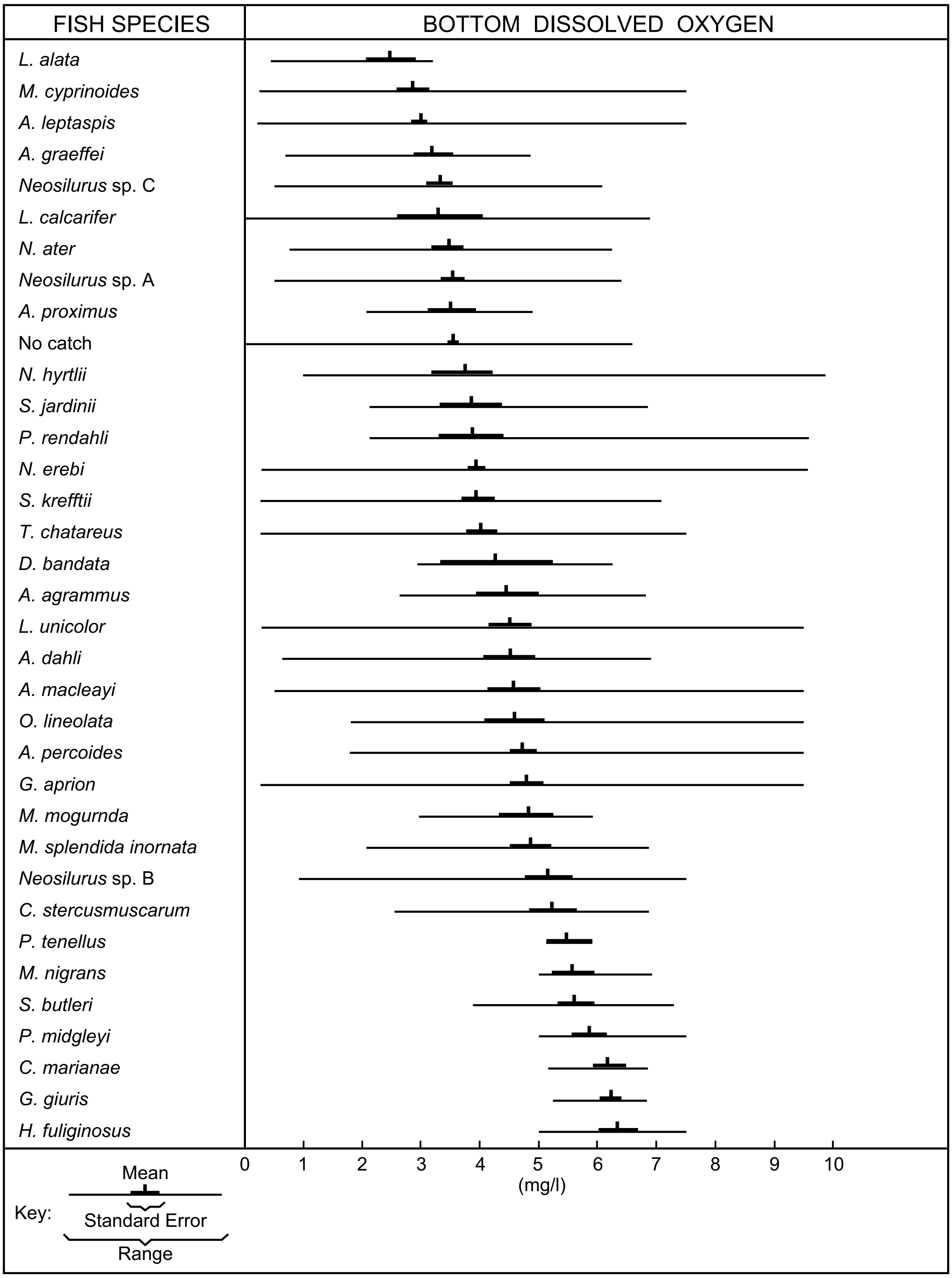

Figure 171b *In situ* bottom dissolved oxygen levels (means, standard errors and ranges) for various fish species captured during the study period (see appendix 6)

The dissolved oxygen (DO) concentration in water limits the distribution and abundance of fish species (Hynes 1970), many species being adapted to tolerate the range of DO concentration characteristic of their preferred environment. DO concentration in water varies with water temperature, depth and surface area of the channel or waterbody, pH, velocity of water flow and the vegetation content of the waters. For example, DO concentrations are likely to be higher in cool, fast-flowing, shallow streams than in warm, deep, lentic billabongs. Owing to diffusion characteristics, DO levels of surface waters are generally higher than of bottom waters, especially in still, unmixed waterbodies. Fish acclimated to running waters use more oxygen than do fish from still waters, where DO may be in short supply (Winberg 1956). DO readings were taken at both the water surface and the bottom at most sample sites.

Escarpment and lowland waters are distinguished by a difference in DO concentrations, which is a result of the differences in flow, water temperature, depth and pH. DO concentrations ranged from 0.0 to 10.0 mg/L in the waters sampled. In turbulent waters, surface and bottom DO levels are similar; in unmixed waters they are different, which would not affect species that are generally bottom-dwelling or surface-swimming fish. DO variables are best interpreted in the light of the species' vertical distribution in the waterbodies it inhabits and other aspects of its ecology.

Species of fish found in escarpment or shallow waters were associated with higher mean DO concentrations than species found in other habitats. Since surface waters are more influenced by temperature, diffusion and wind, their DO levels are generally more variable than bottom-water DO levels, which are therefore more likely to be reliable indicators of 'average' local DO characteristics at the sampling sites. High levels of DO at the bottom indicate waters that are cool, well mixed or heavily vegetated; the highest mean bottom-water DO levels were found in cool, turbulent escarpment streams. The species typically inhabiting these streams were *M. nigrans*, *H. fuliginosus*, *C. marianae*, *S. butleri* and *P. midgleyi.* Other species associated with waters with high mean bottom-water DO values were *O. lineolata*, *A. percoides*, *G. aprion*, some of which are lowland dwellers found in heavily vegetated or shallow waters. Surface DO values (means and extremes) do not show any clearcut relationships with the distribution of species.

The lowest mean DO concentrations in bottom-water were associated with *L. alata*, *M. cyprinoides*, *A. leptaspis*, *A. graeffei*, *L. calcarifer* and *N. ater*; the lowest bottom-water DO recorded were found in waters associated with *L. calcarifer*, *A. percoides*, *G. aprion*, *N. erebi*, *S. krefftii*, *L. unicolor* and *T. chatareus*. The species found in waters with the lowest mean surface-water DO were *L. calcarifer*, *A. graeffei* and *N. ater*; those waters with the lowest surface-water DO were *P. rendahli*, *A. leptaspis* and *N. hyrtlii*. Plotosid and ariid catfishes occurred in waters that were almost anoxic, and some of the more widely ranging species (*L. unicolor*, *A. percoides*, *M. cyprinoides* and *G. aprion*) tolerated low DO levels. However, many of these species were present in a fish kill in Leichhardt Billabong that was thought to be caused by low DO levels (Bishop 1980).

The most widely distributed species were associated with wide ranges of DO levels, as they were with other variables. These species were *L. unicolor*, *A. percoides*, *G. aprion*, *M. cyprinoides*, *P. rendahli* and *N. hyrtlii*. Two others — *O. lineolata* and *A. leptaspis* — associated with wide ranges of DO are less widely distributed. However, they are often associated with thick aquatic vegetation and show a tolerance of anoxic bottom-water. The species associated with the narrowest ranges of both surface and bottom DO concentrations included the more typically 'escarpment' associated species *P. midgleyi*, *H. fuliginosus*, *S. butleri*, *M. nigrans* and *G. giuris*, and the shallow-water dwellers *C. marianae* and *C. stercusmuscarum,* all of which were associated with higher levels of DO. *Lates calcarifer* and *L. alata*, which are typically found in turbid floodplain waters, were associated with a narrow range of DO, but at the lower concentrations.

DO concentration may be a useful indicator of a species' distribution, when interpreted along with other variables such as flow, water temperature (including thermocline position), groundwater inflows, time of day (lowest DO occur at dawn after aquatic plants respire through the night) and hydrophyte occurrence. The groups of species that could be most readily distinguished by DO characteristics were the escarpment dwellers (high DO), the catfishes (low or widely ranging DO) and floodplain dwellers such as *L. calcarifer* and *L. alata* (low DO). Whether all these species differ in their respiratory requirements is unknown. There is no reason to expect fishes from different environments to show differences in their basal rates of oxygen consumption, but Winberg (1956) suggested that the amount of oxygen a fish uses would vary according to the environment it was inhabiting. Further work should be done on the respiratory tolerances of the species studied.[248]

Visibility

Measurements of visibility in the water column (visibilities less than the greatest depth of the waterbody, given as means, standard errors and ranges) for various fish species captured during the study period are shown in figure 172.

Water visibility was estimated by Secchi disc measurements classified as maximum (M, Secchi depth greater than depth of waterbody) and non-maximum (non-M). In the environmental associations discussions in chapter 3, only non-M visibilities are discussed, with reference to M visibilities where relevant. The Secchi disc technique proved to be quick and convenient for the purposes of this study, giving reliable and easily standardised estimates of water turbidity at the sampling sites.

The variables that most affect water turbidity are the type of substrate and the turbulence of the water. The conductivity of the water and the temperature determine the maximum colloid load that can be suspended. There was also a seasonal effect on water turbidity in this study. The first flush of the Wet season brings down large quantities of dissolved solids and suspended silt as it flows over the dusty soil and through the muddy, dried-up watercourses. After this flush, visibility increases at all sites during the Wet season. The frequency and intensity of flooding also affects visibility, as does the position of a site within the catchment. Escarpment streams (and to a lesser extent corridor billabongs) tend to be clear, whilst the downstream reaches of a river tend to be more turbid, mainly owing to the accumulation of fine sediments. Algal blooms also influence Secchi depth measurements.

Species typically found in specialised habitats are associated with the visibilities characteristic of those habitats, eg the *Craterocephalus* spp. are often found in clear, sandy watercourses (although, because of the shallowness of these waters, Secchi depths may give misleading visibility estimates) and *L. calcarifer*, which is typically found in the deep, turbid, lower reaches of the catchment.

Many fish species are limited in their distributions by their inability to tolerate high turbidity or silt concentrations in the water (Hynes 1970). Increases in turbidity due to industrial or agricultural siltation affect a variety of species (Lachner 1956).

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[248] Investigations into the effects of changing dissolved oxygen concentrations have subsequently been undertaken by Wells et al (1997) on *M. cyprinoides*, *S. jardinii* and *L. calcarifer*, Gehrke and Fielder (1988) on *L. unicolor*, Gee and Gee (1991) on *H. compressa*, and Geevarghese and John (1984) on *G. giuris*.

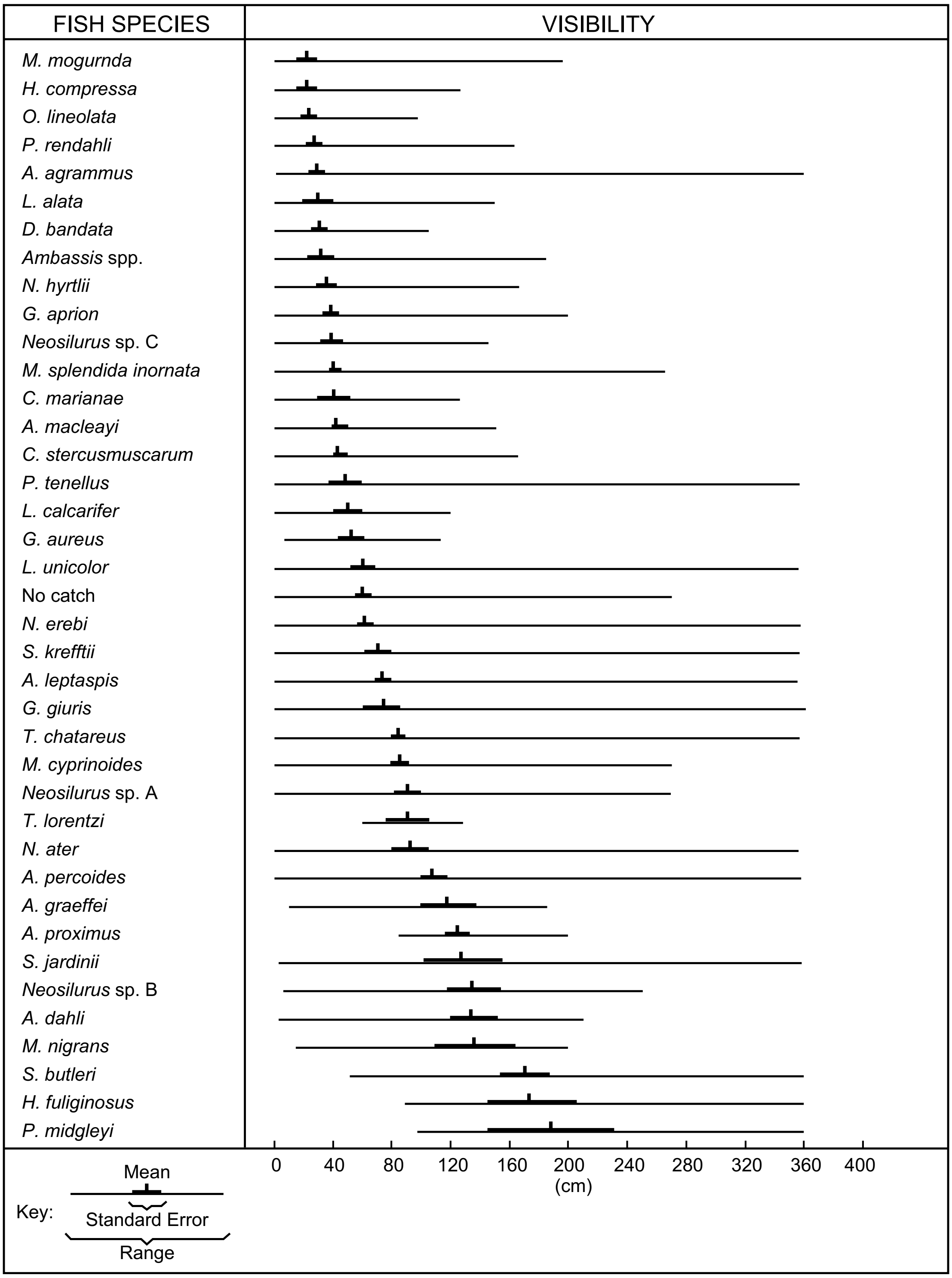

Figure 172 *In situ* visibility measurements (visibility < maximum depth of waterbody) (means, standard errors and ranges) for various fish species captured during the study period (see appendix 6)

Overall, Secchi depths ranged from 1 to 360 cm, the latter value being the greatest fishing depth of an escarpment mainchannel waterbody. Readings may vary widely for widely distributed fish; in these cases mean depths are only useful when considered together with their standard error. Visibility estimates are best interpreted in association with other variables and a knowledge of the ecology of the species.

As with other physico–chemical variables, the most common, widely distributed species had wide ranges of associated water visibilities; for example, the species associated with the greatest ranges of visibility (1 to 360 cm) included the widespread species *L. unicolor*, *A. percoides*, *A. agrammus*, *N. ater*, *S. jardinii*, *S. krefftii*, *P. tenellus*, *A. leptaspis*, *N. erebi* and *T. chatareus*.

Species living over rocky or sandy substrates are usually associated with clear waters. This is particularly true for primarily escarpment-dwelling species such as *M. nigrans*, *P. midgleyi*, *H. fuliginosus* and *S. butleri*, all of which inhabit waters with high mean Secchi depth values and wide ranges. Species that were commonly found in very turbid waters included *M. mogurnda*, *H. compressa*, *O. lineolata*, *P. rendahli*, *L. alata* and *D. bandata*. These fish were captured mainly in lower reaches of the catchment (although *M. mogurnda* was also found abundantly in escarpment waters).

Species such as *P. rendahli* and *N. hyrtlii*, both of which are bottom-dwelling plotosid catfishes, may actually contribute to the turbidity of the water by stirring up the mud over which they feed. *M. mogurnda* has the widest range here (corresponding to its wide distribution), followed closely by *G. aprion*, *M. splendida inornata*, *M. nigrans*, *S. butleri* and *L. unicolor*. The habitats of *D. bandata*, *G. giuris*, *H. compressa*, *O. lineolata* and *P. rendahli* have low, narrow ranges; those of *A. leptaspis* and *N. ater* have high, narrow ranges. Escarpment-dwelling species again have the highest means (eg *S. butleri*, *S. jardinii*, *H. fuliginosus*, *N. ater*). Low mean visibility was associated with *H. compressa*, *G. giuris*, *C. marianae*, *A. agrammus*, *D. bandata*, *O. lineolata* and *P. rendahli*. However, these low mean visibility values may also indicate shallow, clear waters (eg *O. lineolata*, *D. bandata*, *H. compressa*). Maximum visibility readings are therefore more useful in evaluating such cases than are non-Maximum readings.

Generally, water visibility proved to be a good indicator of a species' longitudinal distribution: escarpment-dwelling species were found in distinctly clearer waters than were species typical of the lower reaches. To a lesser extent, visibility is also an indicator of a species' vertical distribution within waterbodies (eg the plotosids were often found in muddied bottom waters).

Secchi-depth estimates of turbidity, although convenient in the field, may be misleading in the final analysis, especially with respect to shallow waters. Other methods of estimating turbidity may provide additional useful information. However, the trends indicated by Secchi-depth estimates of visibility were similar to those of other variables.

pH

Surface and bottom pH levels (means, standard errors and ranges) for various fish species are shown in figures 173a and b respectively.

Most species of fish have a wide tolerance to pH (and hence presumably also to water hardness and specific conductivity). However, some species prefer waters with specific pH characteristics, and pH may indirectly affect the growth rates of some fish and their invertebrate prey (Hynes 1970).

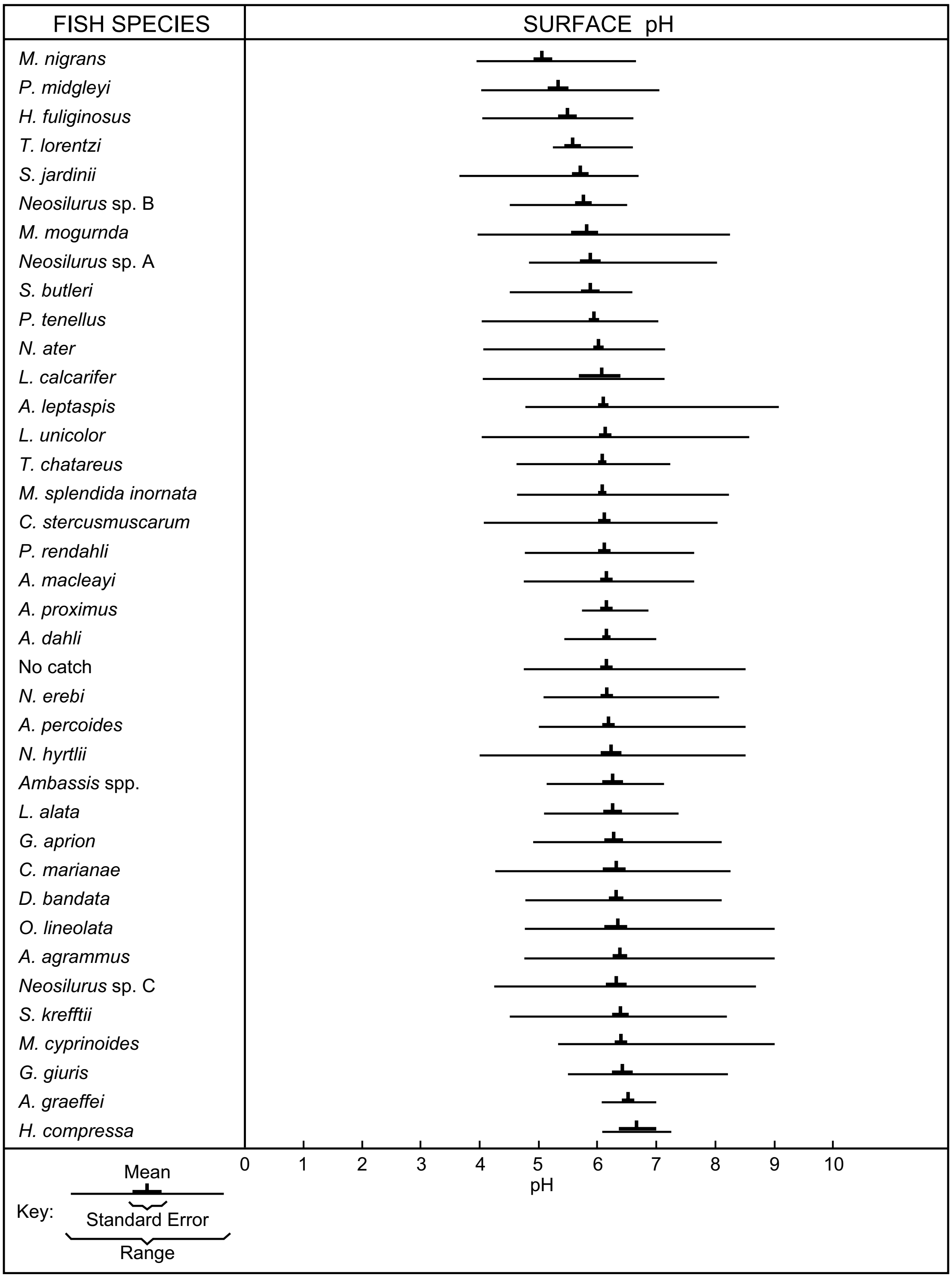

Figure 173a *In situ* surface pH levels (means, standard errors and ranges) for various fish species captured during the study period (see appendix 6)

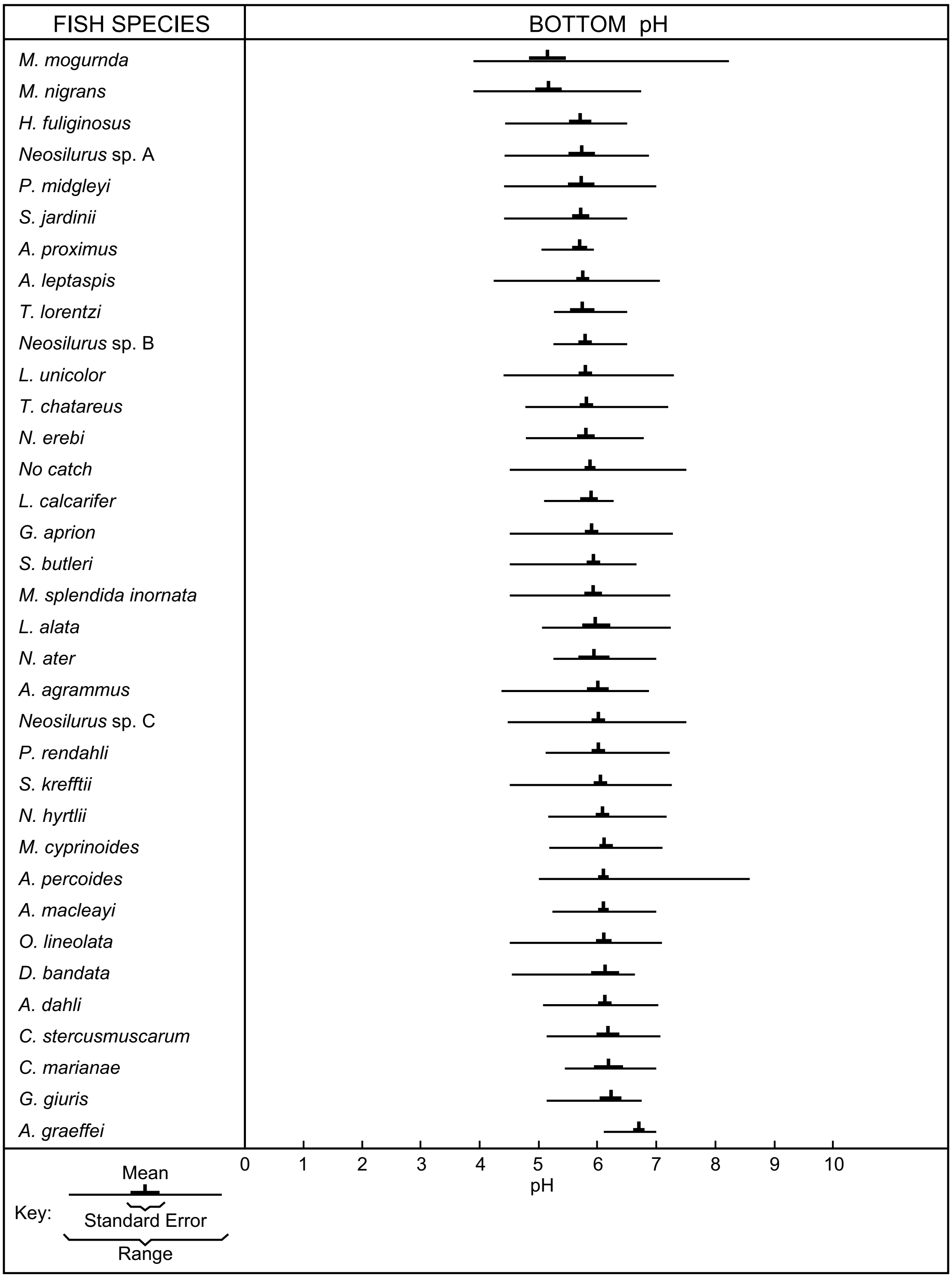

Figure 173b *In situ* bottom pH levels (means, standard errors and ranges) for various fish species captured during the study period (see appendix 6)

The waters sampled during this study were generally acidic, although the pH range was between 3.8 and 9.2. pH is affected by water temperature, type of substrate, conductivity, and the content of dissolved oxygen and carbon dioxide (the last two being a function of hydrophyte content, rate of detrital decay and water temperature). pH is a highly variable characteristic, and wide diurnal variations were measured at many sites. Despite this, the mean pH values for both surface and bottom waters were clustered around a median value, although the ranges varied widely. As with other variables, there was a difference between the values for escarpment and lowland waters, for surface and bottom waters, and for species with wide and narrow distributions. These distinctions were less obvious than for other variables.

Generally, the most acidic waters were found in the seasonal and perennial streams of the escarpment. Species such as *M. mogurnda*, *H. fuliginosus*, *P. midgleyi*, *M. nigrans* and *S. jardinii* were found in waters with mean pHs lower than those associated with other species, in both surface and bottom waters. All these species are found typically in escarpment waters. The perennial streams of the escarpment area are fed by seepage through rocks. In transit, the seepage becomes highly ionised, which appears to lead to acidic conditions. *Arius graeffei*, *G. giuris* and *H. compressa* inhabited waters with the highest mean pH values; those inhabited by *G. giuris* had a high range and mean at both the surface and bottom.

The species inhabiting waters with the widest surface pH range were *M. mogurnda*, *A. percoides*, *A. leptaspis*, *L. unicolor* and *N. hyrtlii,* followed by the two *Craterocephalus* spp., *O. lineolata* and *A. agrammus*. All except *O. lineolata* were found in habitats from the escarpment to the floodplain zones. The narrowest ranges of surface- and bottom-water pH were associated with *L. calcarifer*, *A. graeffei*, *H. compressa*, *P. tenellus*, *S. butleri* and *A. proximus*, although the samples were all small, which may have biased the range. Some catfishes (*A. leptaspis*, *A. graeffei*, *N. hyrtlii*, *N. ater*) were characteristically found in acidic waters, probably because they are usually at the bottom, where decaying matter and anoxic conditions promote a build-up of carbon dioxide.

pH is a useful environmental variable when used in association with others; on its own, the differences between ranges and mean pHs associated with individual species are not sufficiently clear to be good indicators of these species' distributions. This may be because, as previously noted, most fish species tolerate fairly wide fluctuations in pH. Bottom pH is less variable than surface pH, and is thus a more reliable estimate of local pH conditions, although it may be relevant only to bottom-dwelling species.

Conductivity

Conductivity is a measure of the water's electrolytic salt content, which gives an indication of its dissolved solids load and some measure of its salinity. Fresh, flowing waters subject to low evaporation generally have lower electrolyte concentrations than lentic, turbid waters subject to high evaporation. Cooler waters may hold less dissolved solids than warmer waters. The distinction here between escarpment habitats and the lower reaches of the catchment is apparent: escarpment streams, being cooler, faster-flowing and fresher, have lower conductivity readings than the warmer, slower-moving waters of the lowlands and floodplains.

Conductivity readings proved to be so highly variable that any mean conductivity values were relatively worthless, so the range of conductivity associated with each species is therefore discussed instead. As conductivity often varied vertically, both surface and bottom conductivities were read at each site. The values ranged from 2 to 1600 µS/cm, however, fish were recorded only within the range 2 to 620 µS/cm . The lower conductivity values indicate fresher waters, and the higher values more turbid, stagnant lentic waters. Fish are generally found to be tolerant of wide ranges of conductivities and salinities (Hynes 1970) and (except in specialised cases) conductivity is unlikely to be a limiting factor in the freshwater distribution of the species studied.

The species associated with the widest range of water conductivities were *G. aprion*, *L. unicolor*, *A. macleayi*, *P. rendahli*, *N. hyrtlii* and *A. leptaspis*, all of which were widely distributed, common, or both. The species with the narrowest ranges were *S. jardinii*, *S. butleri*, *P. midgleyi*, *S. krefftii* and *A. proximus*, the first three of which were typically found in escarpment streams or corridor billabongs. The narrow range for *A. proximus* is probably biased by the small sample size. Most species were found in waters with conductivities of less than 10 µS/cm, which indicates they can tolerate waters with fairly low concentrations of dissolved solids. The species associated with the widest ranges of conductivity were all found in waters with conductivities as low as 2 µS/cm (as in escarpment streams) and as high as 620 µS/cm, the latter reading indicating a tolerance to higher levels of dissolved solids, such as might be found in the more turbid or lower reaches of the system.

Substrate

In situ percentage dominance of boulder (including bedrock), rock, sand, clay and mud substrates in the sites in which various fish species were captured during the study period is shown in figures 174a, b, c and d respectively.

The percentage dominance system used for the seven subclasses of substrate type defined in this survey proved to be a fairly accurate index of both the distribution and the microhabitat preferences of the species studied. For example, a high percentage dominance figure for mud and clay substrates was commonly associated with species typically found in turbid billabongs and other downstream waterbodies, whilst boulder, rock, gravel and/or leaf litter substrates typically dominated the habitats of escarpment-dwelling species. *Craterocephalus marianae* (and to a lesser extent *C. stercusmuscarum*) showed a marked preference for shallow, sandy watercourses.

The type of substrate over which water flows plays a large part in determining the visibility and conductivity of the water, and the type and amount of vegetation growing in it. It may, therefore, be important to various aspects of the ecology of different fish species, from water quality influences to the provision of shelter and feeding areas.

It is apparent that the type of substrate is one of the most important variables in the environmental requirements of the fish species examined, and may reveal the most about the ecology of a species. In contrast, Cleary and Greenbank (1954) concluded that ‘although many species [of North American fish] are definitely associated with substrates, for the great majority of species, the type of substrate is of little consequence, except at times of breeding, and current velocity and depth of the water seem more important’. In this study, both dominant and subdominant types of substrate were noted at each sample site (these readings were summed up for each species, using the weighted ‘percentage dominance’ method) in order to more accurately represent the overall occurrence of each substrate type. The fact that a fish was caught over a particular substrate at a sampling site does not automatically mean that fish prefers or inhabits only waters with that substrate type. A knowledge of the biology of the species is a necessary adjunct to final interpretation.

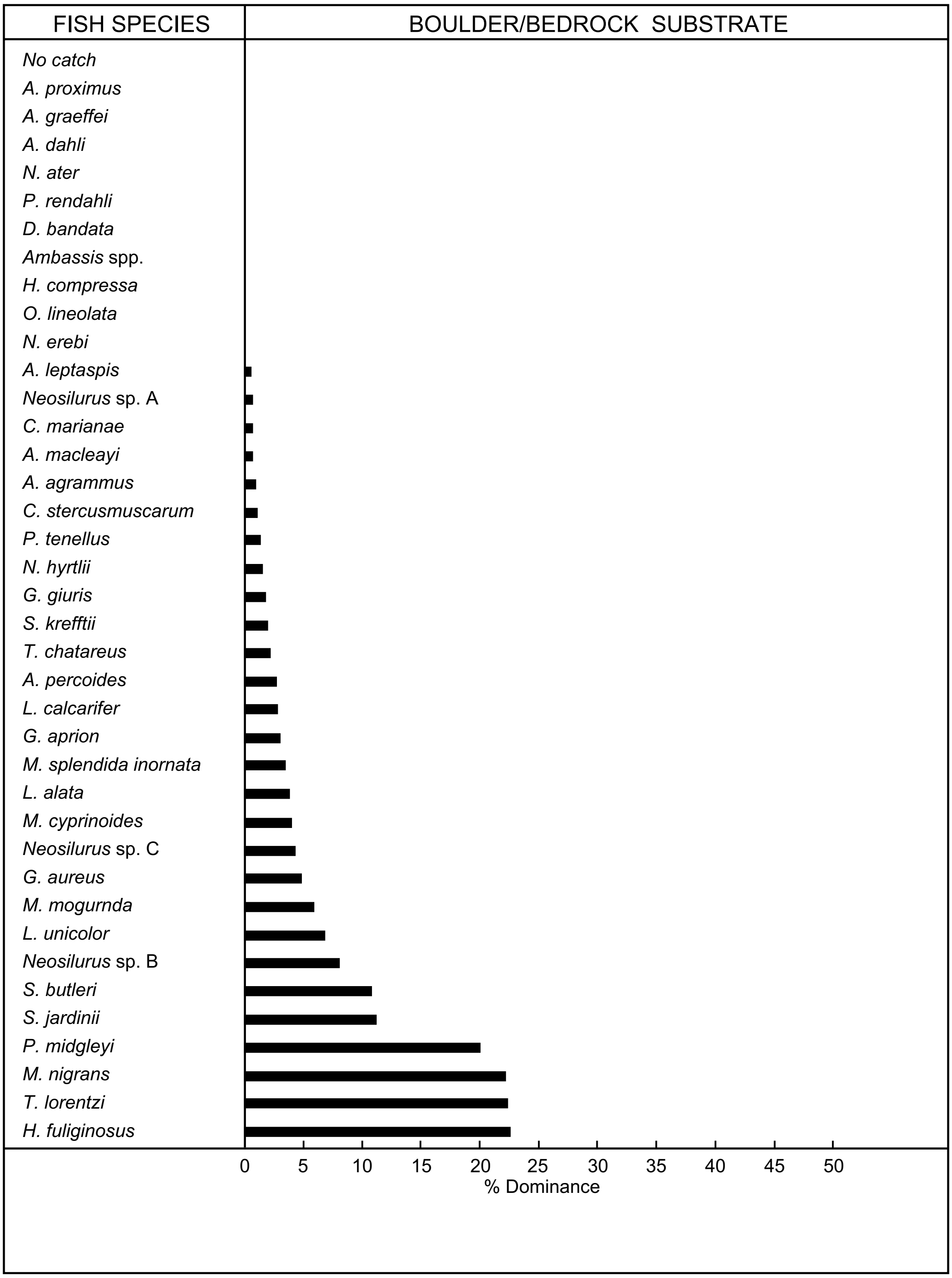

Figure 174a *In situ* percentage dominance of bedrock substratum in sites in which various fish species were captured during the study period (see appendix 7)

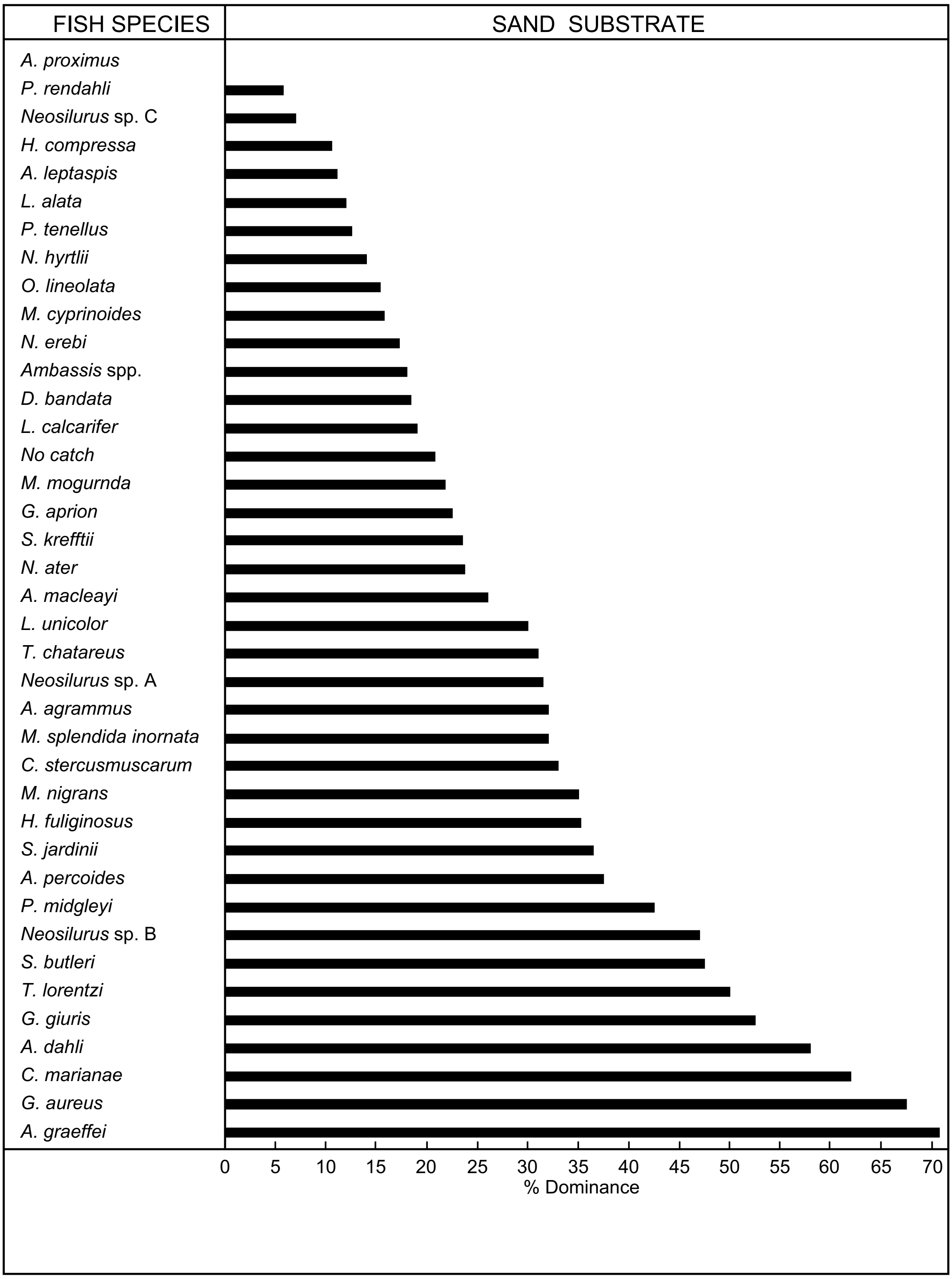

Figure 174b *In situ* percentage dominance of sand substratum in sites in which various fish species were captured during the study period (see appendix 7)

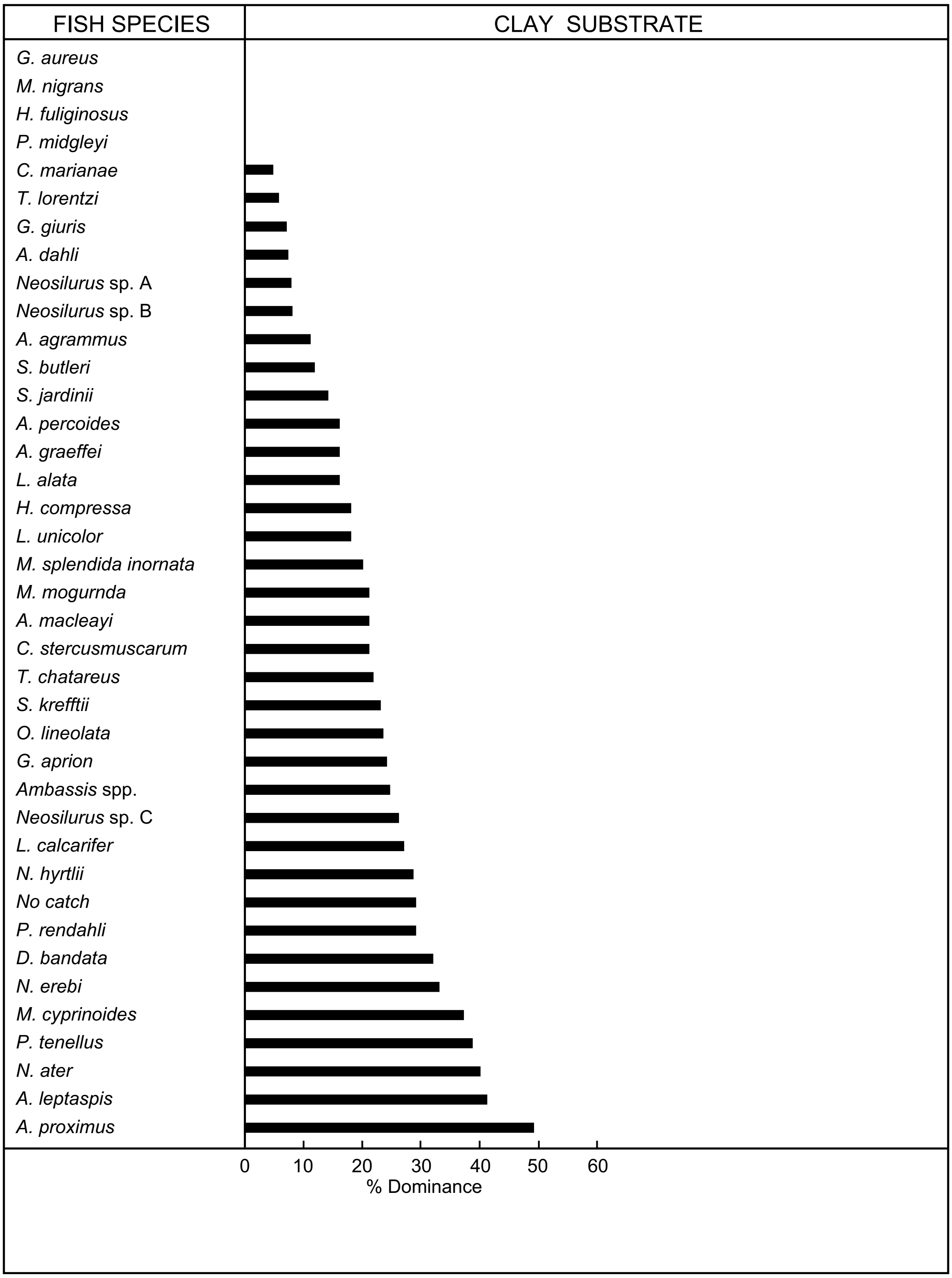

Figure 174c *In situ* percentage dominance of clay substratum in sites in which various fish species were captured during the study period (see appendix 7)

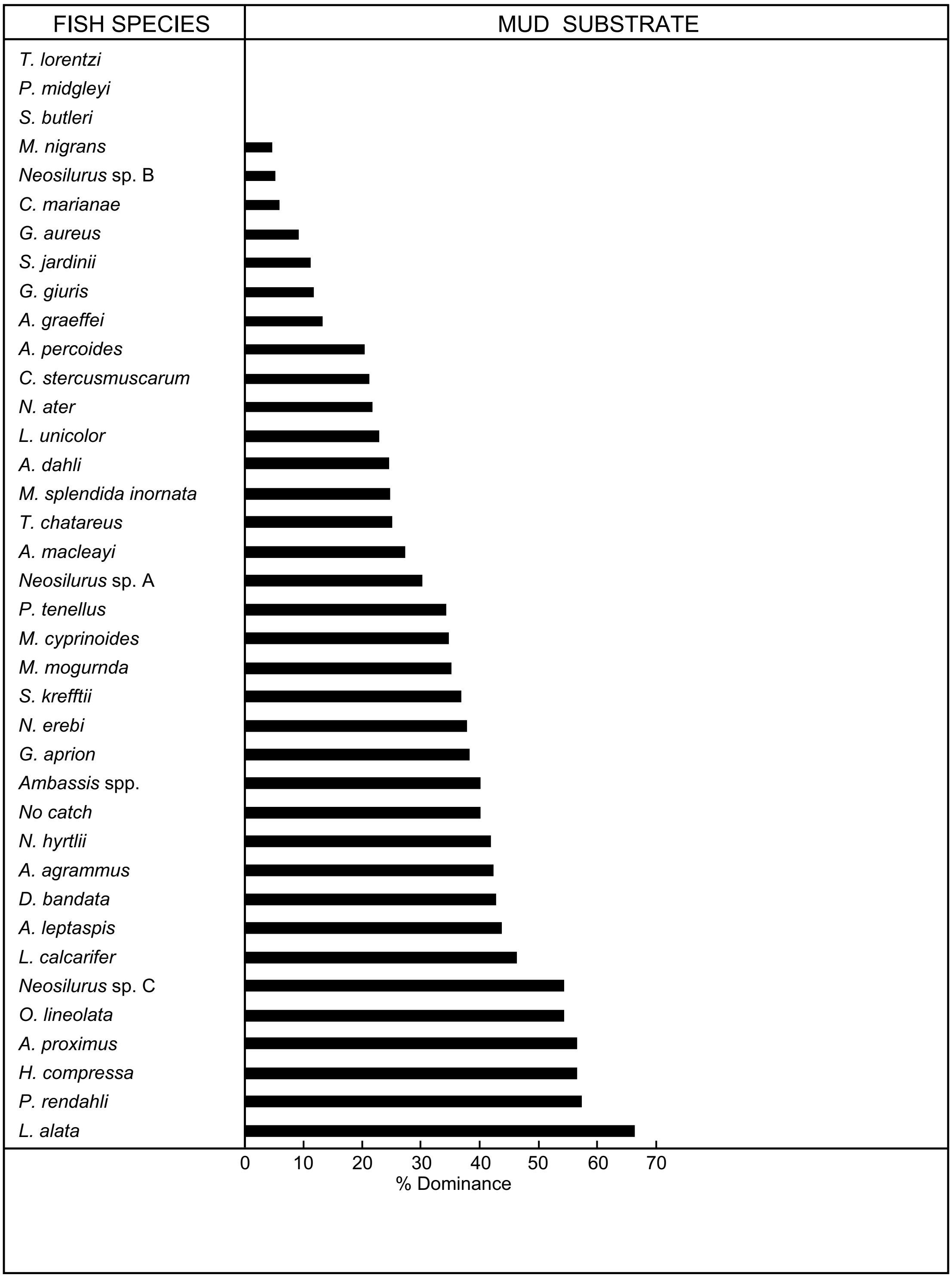

Figure 174d *In situ* percentage dominance of mud substratum in sites in which various fish species were captured during the study period (see appendix 7)

As a reference point, the overall frequency of occurrence of substrate types for all species (including 'no catch') is given in table 156. This is, in effect, the number of times a substrate type was found at all sampling sites. This frequency is a useful reference when comparing the apparent preferences species show for different substrates. The substrate type most commonly found was mud, followed by clay and sand, and less frequently, leaf litter, rocks, gravel and boulders. If a species is most commonly associated with mud, a significant proportion of the association may be due to random factors (eg the species was captured over mud while in transit to its preferred substrate); but if a species is most commonly associated with boulders, it is more obvious that an active preference may be involved. However, by analysing other variables and taking into account the biology of the species, the actual preferences for substrate type may be fairly satisfactorily defined.

Table 156 Proportional and absolute frequency of occurrence of substrate parameters over all sites sampled in study

	Substrate type						
Occurrence type	Boulders (including bedrock)	Rock	Gravel	Sand	Mud	Clay	Leaf litter
% occurrence	4.1	6.3	4.0	39.1	29.8	20.8	6.6
Standard error	1.03	1.06	0.73	2.82	2.98	2.02	0.72
Absolute occurrence	143	347	371	1581	2095	1609	550

Proportional occurrence = % occurrence of substrate type for each species / total number of species (*n* = 36)

Absolute occurrence = total number of times substrate type occurred at sampling sites; includes 'no catch'

As with the preceding environmental variables, the most widely distributed and common species were found over the entire range of substrate types defined in this study. These species were *M. splendida inornata*, *L. unicolor*, *M. mogurnda*, *C. marianae*, *C. stercusmuscarum*, *G. aprion*, *A. leptaspis*, *N. hyrtlii*, *L. unicolor*, *A. macleayi*, *N. erebi* and *S. jardinii*. More specialised or rarer species tended to be found over only a few types of substrate, eg the plotosid catfishes *P. rendahli* and *A. dahli* and the fork-tailed catfishes *A. proximus* and *A. graeffei*, were all found almost exclusively over sand, mud or clay substrates, and were rarely or never found over rock, boulder, gravel or leaf substrates. The two species of *Craterocephalus* were most commonly found over sand, but *C. stercusmuscarum*, which has a wider distribution than *C. marianae*, was found more often over other substrate types. Generally, the greater the variety of substrates a fish was associated with, the greater the variety of preferred micro-habitats or the wider its distribution.

An alternative method of interpreting substrate data is to examine each substrate type and the species of fish most commonly associated with it. However, high percentage dominance figures for the relatively rare species could be deceptive, as sample sizes were small. For the more common species, determining a species' degree of association with different types of substrate can help build a clearer picture of its environmental requirements.

The species most clearly associated with boulder/rock substrates (fig 174a) were *H. fuliginosus*, *M. nigrans*, *P. midgleyi*, *S. jardinii* and *S. butleri*, all of which are typically found in escarpment streams. These streams, which are mostly fed by water seeping through the bedrock, cut through steep, rocky valleys overhung by thick bank vegetation. Not surprisingly, the species most commonly associated with leaf litter (*M. nigrans*, *H. fuliginosus*, *G. giuris*, *C. marianae*, *C. stercusmuscarum*, *P. midgleyi* and *N. hyrtlii*) are also almost all escarpment-dwellers. The common species most often associated with gravel substrates were *A. macleayi*, *L. unicolor* and *S. krefftii*.

Species that were most commonly associated with sandy substrates (fig 174b) were *A. graeffei*, *C. marianae* and *A. dahli*, but the samples of *A. graeffei* and *A. dahli* were small. Most of the other species listed are primarily escarpment-dwellers, sandy shallows and pools being common in the lower escarpment area.

As might be expected, plotosid catfishes, other bottom-dwellers, and other species typically found in turbid waters, were all strongly associated with muddy substrate (fig 174d). These included *L. alata*, *P. rendahli*, *H. compressa*, *A. proximus*, *O. lineolata*, *L. calcarifer* and *A. leptaspis*. Some of these species were found mainly in the lower reaches (eg *O. lineolata*, *L. alata*, *L. calcarifer*, *H. compressa*), the rest being bottom-dwelling catfishes that often feed in the mud. The species most often associated with clay substrates were *A. proximus*, *A. leptaspis*, *N. ater*, *P. tenellus*, *M. cyprinoides*, *N. erebi*, *D. bandata* and *P. rendahli* (fig 174c).

As before, a clear-cut distinction is apparent, on the basis of substrate preferences, between escarpment and 'lower reach' species. Other distinctive groups, such as the bottom-dwelling catfishes or the hardyheads, can also be distinguished. To be able to predict the occurrence of fish species from substrate data, further field work on the importance of particular substrates to a species, and laboratory experiments on habitat preferences should be undertaken.

Hydrophytes

The percentage dominance of emergent, submergent and floating-attached hydrophytes in sites in which various fish species were captured during the study period is shown in figures 175a, b and c, respectively.

As with substrates, the types of hydrophytes associated with a species are often a good indication of the type of habitat preferred by that species. Since the amount of vegetation found in waters associated with a species is also important, the vegetation-occurrence index will also be discussed.

The amount of vegetation at a given place varied a great deal between Wet and Dry seasons, owing to changes in nutrient levels and evaporation rates, growth of algal blooms and the effects of flooding. The amount and type of vegetation is affected by the type of substrate, which also affects plant growth rates and settlement of seeds (Hynes 1970). As with substrate type, fish species that were collected rarely could be ranked misleadingly. The relations of fish species to vegetation are often unclear, or unknown, and further work is required, particularly on the breeding of fish.

The species found in waters with the heaviest vegetation content (according to the vegetation-occurrence index) were *H. compressa*, *D. bandata*, *A. proximus*, *P. rendahli*, *G. aprion*, *A. agrammus* and *O. lineolata*, of which *H. compressa*, *G. aprion* and *O. lineolata* have some important aspect of their biology associated with hydrophytes. Many of the fish species studied include vegetation in their diet. Thus, the type and quantity of hydrophytes associated with some species are good indicators of the type of environment or microhabitat preferred by these species, rather than of their spatial distribution as are substrate and the physico–chemical variables.

The species most commonly associated with emergent hydrophytes (fig 175a) were *S. butleri*, *L. alata*, *H. fuliginosus*, *L. calcarifer*, *G. giuris*, *P. tenellus* and *A. agrammus*, a list that includes both lowland and escarpment-dwelling fish. Unlike all other variables, emergent hydrophyte variables could not distinguish between the two zones. *S. butleri*'s strong association may be attributable to the small sample size.

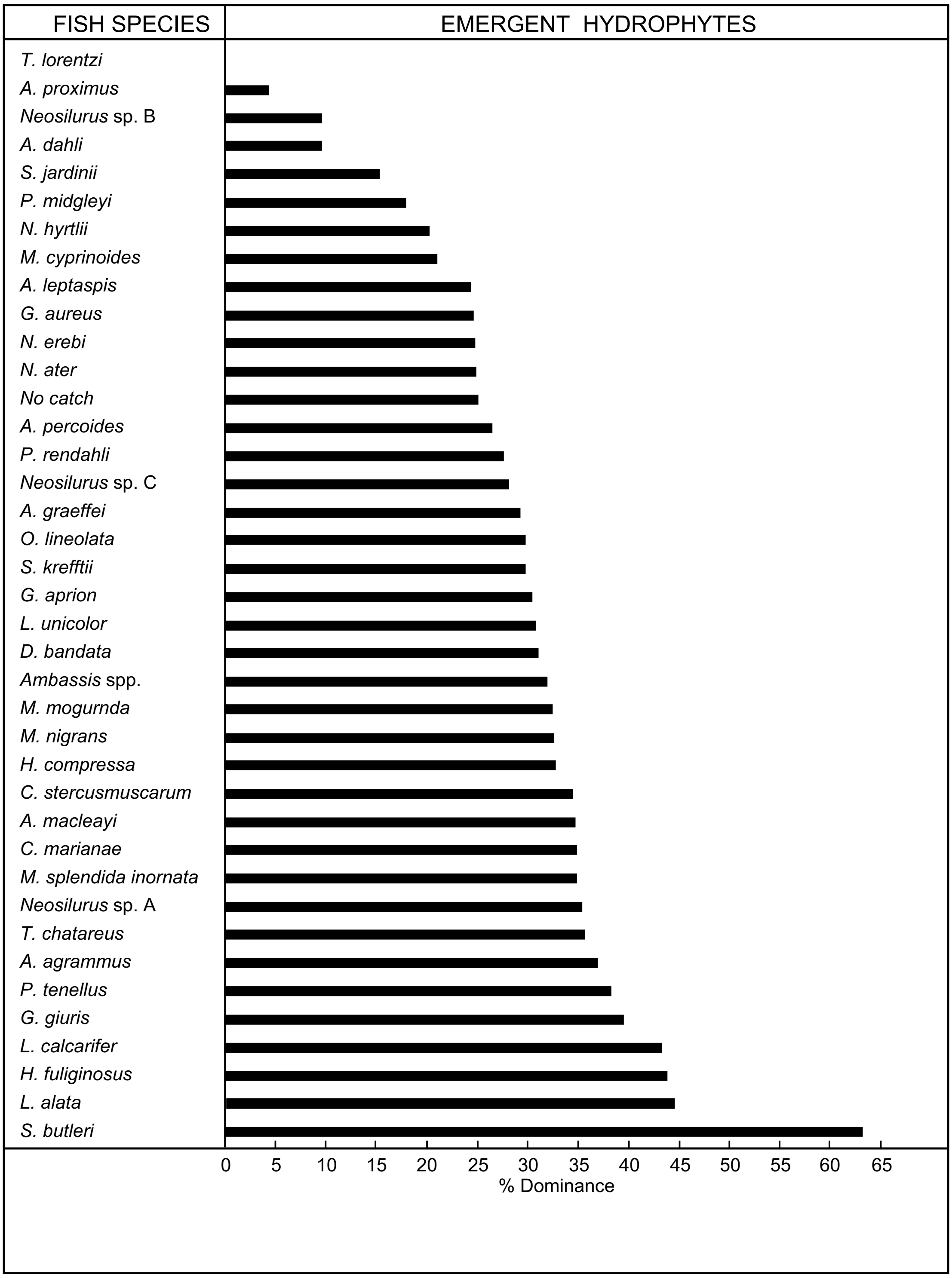

Figure 175a *In situ* percentage dominance of emergent hydrophytes in sites in which various fish species were captured during the study period (see appendix 7)

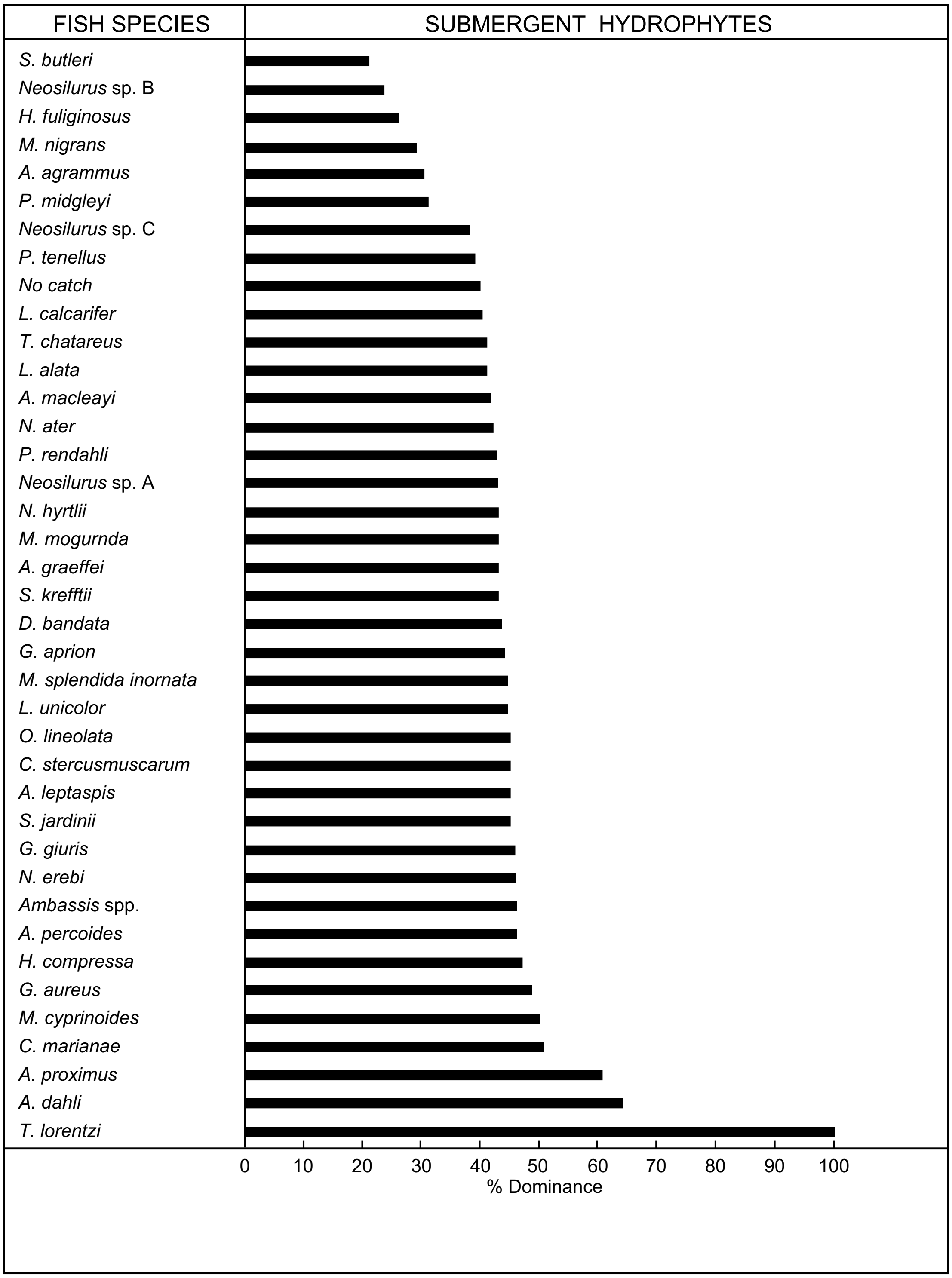

Figure 175b *In situ* percentage dominance of submergent hydrophytes in sites in which various fish species were captured during the study period (see appendix 7)

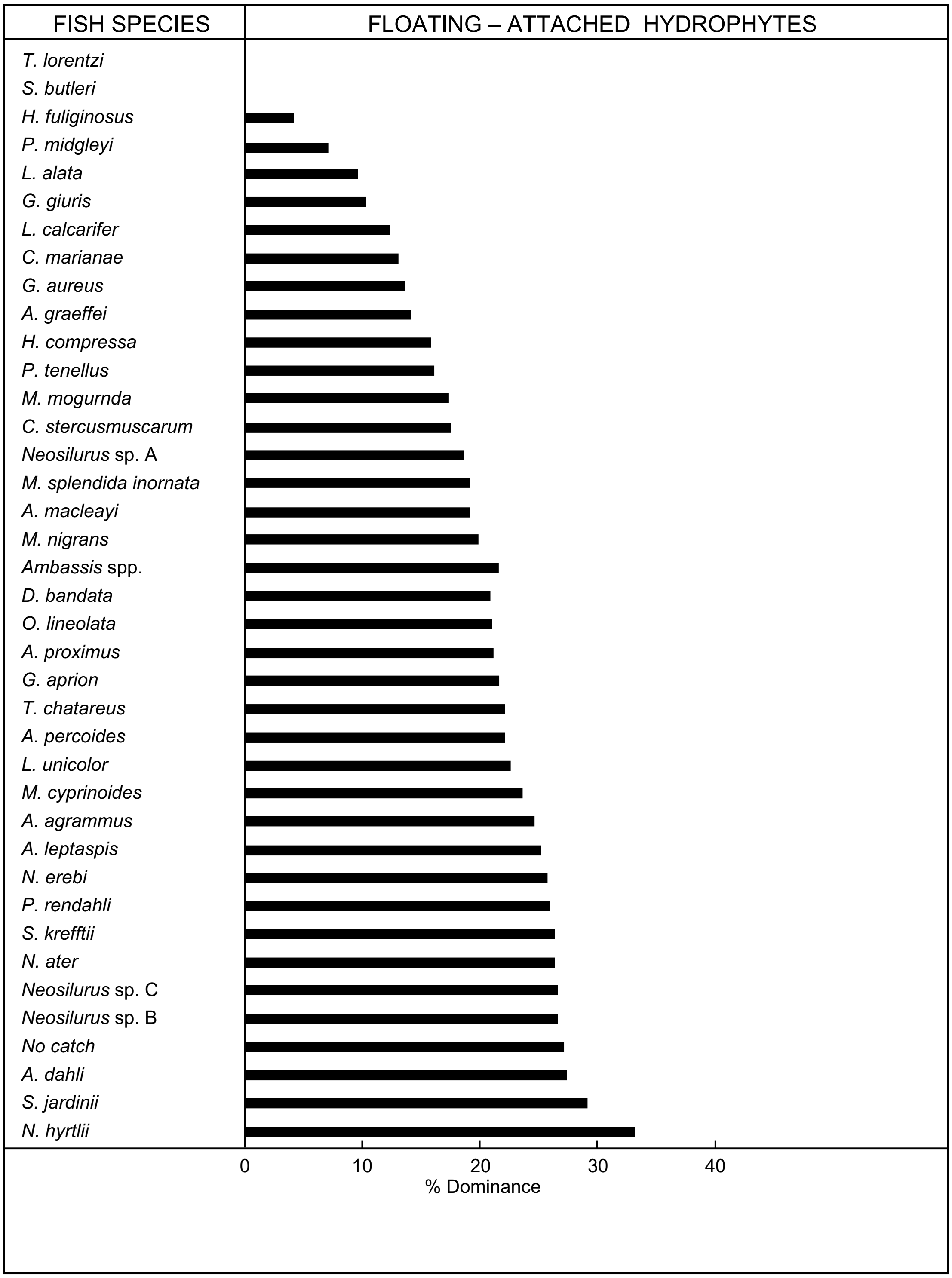

Figure 175c *In situ* percentage dominance of floating-attached hydrophytes in sites in which various fish species were captured during the study period (see appendix 7)

Submergent hydrophytes (fig 175b) were associated predominantly with *A. dahli*, *A. proximus*, *C. marianae*, *M. cyprinoides*, *H. compressa*, *A. percoides* and *N. erebi*. The association for *A. dahli* was exaggerated by its small sample size, but species such as *H. compressa* lay their eggs on submergent vegetation. Again, the preference for type of hydrophyte is apparently independent of the zone in which the species was typically found.

A most interesting phenomenon is apparent with respect to floating-attached vegetation and the plotosids. Floating-attached vegetation (fig 175c) were most dominant in waters containing *N. hyrtlii*, *S. jardinii*, *A. dahli*, *N. ater*, *S. krefftii* and *P. rendahli* (with other plotosid catfishes close behind). The connection between the presence of floating vegetation and plotosid occurrence may thus warrant investigation.

Synthesis

It is apparent that few of the environmental variables examined actually limit the distribution of a fish species at a local level. Potentially, the most limiting factors were temperature, dissolved oxygen concentration and visibility. However, a species of fish that inhabits a particular type of environment may be associated with a particular set of environmental variables. A species' distribution, therefore, may also be correlated with the range of environmental variables for waters in which it is found. Thus, sets of seasonally changing environmental variables may be used as indices describing aspects of the environment in which a fish was found.

The three main groups of species distinguished by characteristic combinations of associated factors were species that lived on the escarpment, species that lived in the lower reaches, and widely distributed species found in both of these zones. Escarpment-dwelling species were usually associated with waters with low temperatures, high DO concentrations (especially in bottom waters), acidic pH values, low conductivity, low turbidity, and substrates of rock, boulder, gravel, leaf or sand. Species in the lower reaches were typically associated with high temperatures, low DO concentrations, more neutral pH values, high conductivities, high turbidity, greater vegetation content, and predominance of mud, clay and sand substrates. Widely ranging species inhabited waters with correspondingly wide ranges of environmental variables.

These three groups are broadly defined, although often distinctive, but there were some exceptions and some uncertainties where sample sizes were small. Overall, some useful data were obtained for many species and gaps in knowledge were highlighted.

The most important aspect of the environmental associations section is that there now exists a fairly solid database, descriptive (some more than others) of the types of environments in which the different fish species are typically found. These data can be used as a basis for further work that could lead to describing the Alligator Rivers catchment, and distinguishing its habitat types, in terms of the physico–chemical and habitat–structural characteristics, and to predicting with some confidence the species composition of fish communities in these habitats.[249]

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[249] Arthington and Pusey (1994) presented information, arising from studies in a range of Queensland rivers, which indicated that the influence of habitat factors on fish communities is likely to be low in river systems with highly-variable flow regimes. Magela Creek has such a regime, but it has a highly predictable seasonal component to the variability, ie the Wet/Dry cycle. In response to Arthington and Pusey's findings, Grant and Bishop (1998) noted that such rivers have extended periods when flows are remarkably stable (eg recessions after floods, during the Dry season, etc). Grant and Bishop argued that habitat factors are likely to have a major influence during these times.

4.3 Reproduction

Among the few accounts of the reproductive biology of fishes from Australia's tropical freshwaters are those of Dunstan (1959) on *Lates calcarifer*, Beumer (1976, 1979b) on *Therapon* (= *Leiopotherapon*) *unicolor* and *Nematocentris* (= *Melanotaenia*) *splendida*, and Lake and Midgley (1970a and b) on freshwater ariids and *Scleropages leichardti*.[250] The reproduction of tropical freshwater fishes has also been studied in British Guiana (Lowe-McConnell 1963), Panama (Kramer 1978), Africa (Welcomme 1969) and New Guinea (Haines 1979; Roberts 1978).

A number of the Alligator Rivers Region species, or their close relatives, are also found in the Murray–Darling River system. Some of the studies on their reproductive biology are Merrick (1974) on *L. unicolor*; Davis (1977b) on *T. tandanus*; Llewellyn (1971) on *C. fluviatilis* (a subspecies of *C. stercusmuscarum,* Ivantsoff, pers comm), *L. unicolor* and *M. mogurnda*; Llewellyn (1973) on *L. unicolor*; Llewellyn (1979) on *C. fluviatilis*; and Auty (1978) on *H compressa*.

The objectives of our study of the Alligator Rivers Region freshwater fishes included determining, for each species, the length of the fish at first sexual maturity, whether the sex ratio was significantly different from 1:1, the seasonality of reproduction and the duration and peak of spawning activity, the site of spawning or larval development or both, the mean fecundity and egg size, and any other general aspects of their reproductive biology.

Estimating gonad maturity stages was quicker than calculating gonosomatic indices (GSIs). Maturity stages were subjectively attributed (see section 2.5) and an advance to the next stage does not necessarily correspond to an arithmetic progression in the weight of the gonads. The feasibility of accurately determining a fish's reproductive period by calculating an index of mean gonad maturity stage (GMSI) for each season was investigated and the GMSI compared with the calculated GSI values. Histological sections of gonads were examined to confirm visual staging techniques, but a comparative seasonal histological analysis was not undertaken.

The combination and interaction of the fish's physiology and behaviour and its approach to reproduction is here termed the 'reproductive strategy' (Bond 1979). Such strategies must ensure survival of at least a portion of the eggs by various means — force of numbers or concealment or parental care — and the strategies include the placement of the earliest feeding stage of the young near to ample and suitable food.

Lowe-McConnell (1975) classified fishes into 'big bang' spawners, which spawn once in a lifetime and then die; 'total' spawners, which are mostly highly fecund and often make seasonal migrations; 'partial' spawners, which either produce many broods throughout a season or have a seasonal spawning; and 'small brood' spawners, which generally spawn seasonally and often guard their eggs and young.

Roberts (1978) used the following categories to describe spawning fish:

1 Those that reproduce locally in middle and upper reaches of the river are of three types:

  - spawners of numerous small eggs (newly hatched young less than 10 mm long)

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[250] Investigations into various aspects of the reproductive biology of fish species found in the Alligator Rivers Region have subsequently been undertaken by Puckeridge and Walker (1990) on *N. erebi*, Rimmer (1985b&c) on *A. graeffei*, Orr and Milward (1984) on *N. ater* and *N. hyrtlii*, Ivantsoff et al (1988) on *M. nigrans*, *M. splendida inornata*, *C. stercusmuscarum* and *A. macleayi*, Howe (1987) on *P. tenellus*, Semple (1986) on *C. marianae*, Davis (1982 & 1985b) on *L. calcarifer*, Moore (1982) on *L. calcarifer*, Semple (1985) on *A. agrammus*, and Hogan (1994) on *H. fuliginosus*.

    - oral brooders with relatively few, large eggs (newly hatched young more than 10 mm long in some species)
    - ovoviviparous (young probably longer than 50 mm)
2. Those that migrate to tidal or estuarine areas to spawn (catadromous)
    - generally large species with very many small eggs.

A refined classification based on Lowe-McConnell's and Roberts's categories, and using the information collected on the fishes of the Alligator Rivers Region, is outlined in this report.

Enough data were collected on at least 32 species to outline some general characteristics of their reproductive biology. The reproductive data from the present study, together with information from research on the same or closely related species in other parts of Australia, are summarised in table 157. The data on species that were collected either infrequently or in small numbers are likely to be modified with further research.

Length at first maturity

Because of the relatively small samples of some species collected, the method used for estimating the LFM, which was adopted from that described in State Pollution Control Commission (1981), often meant the line of best fit had to be chosen from a number of very close alternatives.

A summary of lengths and sizes of smallest maturing fish and other reproductive information for the common fish species is presented in table 158.

No species had a length at first maturity that was less than 25% of the largest size at which it was captured during the study. The LFM was generally between 25% and 75% of that length (table 159) . Species with the LFM greater than 75% of the largest specimen of the species captured were *Megalops cyprinoides*, male *Denariusa bandata*, female *Syncomistes butleri* and male *Oxyeleotris lineolata*. *Megalops cyprinoides* is reported to grow up to 1000 and possibly 1500 mm (Pollard 1980). The LFM in our study appeared to be high because the largest fish captured was only 410 mm. For the other species listed, the proportionately high LFM was probably due to the small numbers of mature fish captured; additional data might change the estimate.

The difference between the LFM for each sex in five species was greater than 10% of the longest specimen. In *M. nigrans* and *D. bandata* the females had a smaller LFM, while in *H. fuliginosus*, *S. butleri* and *S. krefftii* the males had a smaller LFM. Wide differences in LFM can be due to sex reversal; only *S. krefftii* was tested for this, but no evidence of it was found. For the remaining species the large differences in estimated LFM were probably due to the low numbers of maturing fish collected.

A difference in the size of the sexes is sometimes related to parental behaviour: the sex that guards the nest or exercises other parental care is usually the larger. A difference in size is also found in species that produce many eggs: the female is generally the larger (Breder & Rosen 1966). Of those species with significantly different male and female LFM, only in *M. nigrans* were the greatest lengths recorded for males and females significantly different (60 mm and 50 mm LCF respectively). This species is not known to exhibit any form of parental care.

Two species in which the longest females were substantially longer than the longest males were *A. leptaspis* and *A. agrammus*. Supporting the generalities above, *A. agrammus* is fecund. In contradiction, male *A. leptaspis* guard (mouth brood) the eggs, yet this sex is the smaller.

Table 157 Breeding sites and seasons, with other reproductive parameters, for 33 fish species in the Alligator Rivers Region

Family and species	Marine or Fresh	Breeding seasons	Breeding sites **	Fecundity	Egg diam. (mm) (embryos)	Egg type	Incubation period	Development or size of larvae at hatching	Reproductive strategy	Additional information sources *
Carcharhinidae										
C. leucas	Marine	–	F	5–13*	600–700*	ovoviviparous*	10–11 mths*	juvenile*	live bearer	1
Megalopidae										
M. cyprinoides	Marine	Early-wet	F	High	Small	pelagic*	?	leptocephalus	pelagic	2
Clupeidae										
N. erebi	Fresh	Aseasonal	C	80 000–230 000	0.4	pelagic	?	poor	pelagic	3
Osteoglossidae										
S. jardinii	Fresh	Late-dry Early-wet	AE	90	8–10	yolky	10–14 days*	advanced*	buccal incubat.*	4
Ariidae										
A. leptaspis	Fresh	Late-dry Early-wet	ABCDE	26–70	12–16	yolky	4 weeks*	advanced	buccal incubat.	4
A. proximus	?	?	?	?	?	?	?	?	?	3
A. graeffei	(?) Fresh	Wet	D	?	2–5	?	?	?	? nests*	5
Plotosidae										
A. dahli	Fresh	Wet	?	?	?	?	?	?	nests/territ.*	6
N. ater	Fresh	Early-wet	ABCDE	8000	1.4	demersal* non-adhesive	<1 week*	poor*	nests/territ.*	6
N. hyrtlii	Fresh	Early-wet	C	4000	1.3	demersal* non-adhesive	<1 week*	poor*	nests/territ.*	6
P. rendahli	Fresh	Early-wet	C	900	1.3	demersal* non-adhesive	<1 week*	poor*	nests/territ.*	7
Belonidae										
S. krefftii	Fresh	Early-wet	ABCD	?	4	adhesive threads	1–5 weeks*	?	aquat. veg.*	
Melanotaeniidae										
M. nigrans	Fresh	Extended	A	350	?	tendrils	~1 week	advanced	aquat. veg.	
M. splendida inornata	Fresh	Extended	ABCDE	170	0.6	tendrils	~1 week	advanced	aquat. veg.	
Atherinidae										
C. marianae	Fresh	Aseasonal	AB	400	0.74	adhesive threads	–	–	demersal	
C. stercusmuscarum	Fresh	Extended	ABCE	70	1.0	adhesive	–	advanced	demersal	

Table 157 continued

Family and species	Marine or Fresh	Breeding seasons	Breeding sites **	Fecundity	Egg diam. (mm) (embryos)	Egg type	Incubation period	Development or size of larvae at hatching	Reproductive strategy	Additional information sources *
Pseudomugilidae										
P. tenellus	(?) Fresh	Aseasonal	CE	40	1.0	(?) adhesive or threads	2 weeks* 21–26°C		?	8
Ambassidae										
A. agrammus	Fresh	Late-dry Early-wet	BCE	1614	0.3	(?) adhesive demersal	36 h* 28°C	(?) undeveloped	demersal	7
A. macleayi	Fresh	Extended	BC	1340	0.3	(?) adhesive demersal	36 h*	(?) undeveloped	demersal	7
D. bandata	Fresh	Aseasonal	CE	?	?	?	?	?	?	
Centropomidae										
*L. calcarifer**	Marine	Wet	F	2.2–16.8 x 10^6	6.7 x 6.8	demersal pelagic ?	short	undeveloped	pelagic	9
Terapontidae										
A. percoides	Fresh	Late-dry Early-wet	ABCDE	125 000	0.4	demersal* non-adhesive	?	?	nests/territ.*	3
H. fuliginosus	Fresh	Early-wet	AB	710 000*	3.0*	demersal* non-adhesive	short*	?	?	10
L. unicolor	Fresh	Early-wet	C	48 000	0.27	demersal* non-adhesive	50 h 23–26°C	undeveloped	?	
S. butleri	Fresh	Late-dry Early-wet	ABD	30 000	0.86	?	?	?	?	
P. midgleyi	Fresh	Early-wet	AB	?	?	?	?	?	?	
Apogonidae										
G. aprion	Fresh	Aseasonal	CE	250	1.5	demersal* non-adhesive	2 weeks*	advanced	buccal incubat.	10
Toxotidae										
T. chatareus	Fresh	Late-dry Early-wet	ABC	70 000	0.4	pelagic	?	undeveloped	pelagic	11
Mugilidae										
L. alata	Marine	Late-dry Early-wet	F*	2 x 10^{6}*	tiny*	pelagic	?	?	?	5, 12, 3
Gobiidae										
G. giuris	Fresh	Late-dry	CD	7000	0.3 x 0.1	non-adhesive demersal	short*	pelagic*	nests/territ.*	3, 13, 5
Eleotridae										
H. compressa	Fresh	Mid-wet	E	18 000	0.16	adhesive demersal	10 h* 30°C	pelagic	nests/territ.*	14
M. mogurnda	Fresh	Early-wet Mid-wet	ABC	430	1.0	adhesive	3–8 days	4 mm	nests/territ.*	15
O. lineolata	Fresh	Aseasonal	CE	100 000		adhesive	5–6 days*		nests/territ.*	11

* Information from additional sources: (1) Bass et al (1973) (2) Wade (1962) (3) Breder & Rosen (1966) (4) Lake & Midgley (1970b) (5) Haines (1979) (6) Davis (1977b) (7) Lake (1971) (8) Ivantsoff (1980 for *P. signifer*) (9) Reynolds (1978) (10) Lake (1978) (11) Midgley (pers comm) (12) Scott (1973) (13) Hoese & Larson (1980) (14) Auty (1978) (15) Llewellyn (1971) for *M. adspersa*

** (A) Escarpment area (B) Lowland sandy creekbed (C) Lowland backflow billabong (D) Corridor billabong (E) Floodplain billabong (F) Estuarine or coastal

Table 158 Reproductive information on males and females of species captured: longest and shortest specimens, sizes of smallest maturing fish, length at first maturity (LFM), number of specimens at LFM, highest Gonadosomatic Index (GSI), and highest gonad stage

Fish species	Sex	*n*	Shortest (mm)	Longest (mm)	Min. length at gonad stage >3	LFM (mm)	Number at LFM	Max. GSI	Highest gonad stage
Carcharhinus leucas	M	6	850	1020	–	–	–	0.5	2
	F	3	825	910	–	–	–	0.53	2
Megalops cyprinoides	M	7	186	360	353	300	2	0.66	5
	F	2	390	410	390	300	2	1.83	7
Nematalosa erebi	M	157	110	340	130	130	154	8.96	7
	F	168	106	325	140	140	150	15.32	7
Scleropages jardinii	M	3	440	660	440	?	?	1.26	4
	F	7	420	560	435	?	?	3.70	5
Arius leptaspis	M	271	165	460	187	270	235	0.74	7
	F	360	190	600	270	300	336	12.07	7
Arius proximus	M	2	245	395	–	–	0	0.05	2
	F	4	360	400	400	?	?	0.79	7
Arius graeffei	M	10	191	352	285	?	?	0.25	7
	F	17	186	395	270	?	?	2.99	7
Anodontiglanis dahli	M	15	226	400	356	370	10	0.74	7
	F	14	380	490	404	400	11	4.71	7
Neosilurus ater	M	119	110	420	260	255	107	2.21	7
	F	214	120	508	220	275	192	10.79	7
Neosilurus hyrtlii	M	36	110	240	130	135	18	1.12	4
	F	54	110	240	140	135	35	10.13	5
Porochilus rendahli	M	112	70	385	100	100	100	1.12	7
	F	209	60	288	100	110	183	11.25	7
Strongylura krefftii	M	102	195	615	267	290	67	3.19	7
	F	68	133	640	317	410	20	3.40	7
Melanotaenia nigrans	M	72	24	66	24	39	29	10.00	6
	F	81	23	50	27	27	77	7.64	7
Melanotaenia splendida inornata	M	445	20	97	28	33	395	6.00	7
	F	470	17	90	29	25	446	10.00	7
Pseudomugil tenellus	M	35	17	30	23	23	35	4.00	4
	F	69	16	31	18	23	46	11.33	5
Craterocephalus marianae	M	137	22	67	22	29	121	6.70	6
	F	186	20	70	28	32	149	6.63	6
Craterocephalus stercusmuscarum	M	274	18	60	22	27	224	7.00	6
	F	429	18	67	22	29	328	10.50	7

Table 158 continued

Fish species	Sex	*n*	Shortest (mm)	Longest (mm)	Min. length at gonad stage >3	LFM (mm)	Number at LFM	Max. GSI	Highest gonad stage
Lates calcarifer	M	3	375	1000	–	–	–	0.18	2
	F	–	–	–	–	–	–	–	–
Ambassis agrammus	M	349	20	48	27	27	324	8.72	7
	F	235	18	62	21	26	220	14.42	6
Ambassis macleayi	M	285	16	74	31	33	260	6.00	6
	F	195	20	81	27	29	188	7.27	7
Denariusa bandata	M	255	12	41	29	31	78	5.00	7
	F	205	18	38	22	25	189	9.50	6
Amniataba percoides	M	219	50	180	70	65	216	2.96	7
	F	188	40	180	50	45	186	8.33	7
Hephaestus fuliginosus	M	34	80	320	150	200	21	1.13	7
	F	16	170	340	260	250	9	1.11	7
Leiopotherapon unicolor	M	132	61	205	81	74	130	7.70	7
	F	138	64	231	94	94	126	5.35	7
Syncomistes butleri	M	19	125	320	125	125	19	5.55	7
	F	21	122	304	227	234	18	10.75	7
Pingalla midgleyi	M	34	70	120	75	75	31	5.92	7
	F	26	71	116	79			0.66	7
Glossamia aprion	M	158	33	140	61	63	109	1.23	7
	F	146	33	157	70	65	104	18.00	7
Toxotes chatareus	M	82	80	307	120	176	68	5.07	7
	F	40	82	260	156	190	29	9.26	7
Liza alata	M	5	167	405	398	?	?	0.24	5
	F	12	224	484	350	?	?	0.52	7
Glossogobius giuris	M	25	32	108	–	–	–	1.50	3
	F	22	35	110	35	?	?	6.25	5
Glossogobius aureus	M	12	48	100	82	?	?	0.38	5
	F	8	41	125	48	?	?	8.38	5
Hypseleotris compressa	M	20	35	62	38	37	17	14.35	5
	F	13	43	67	43	42	13	40.50	5
Mogurnda mogurnda	M	53	34	103	58	55	43	1.00	4
	F	55	27	88	51	50	44	4.73	7
Oxyeleotris lineolata	M	22	65	395	330	315	3	0.36	5
	F	17	80	395	285	284	11	2.58	5

? unknown; – no maturing fish captured

Table 159 The length at first maturity (LFM) in relation to the longest specimen of each species whose LFM was determined

LFM as percentage of longest specimen		
25–49%	50–74%	75–100%
N. erebi	*A. leptaspis*	*M. cyprinoides*
P. rendahli	*N. ater*	*D. bandata* (M)
M. splendida inornata	*N. hyrtlii*	*S. butleri* (F)
C. marianae	*M. nigrans*	*O. lineolata* (M)
C. stercusmuscarum	*P. tenellus*	
A. agrammus (F)	*A. agrammus* (M)	
A. macleayi	*D. bandata* (F)	
A. percoides	*H. fuliginosus*	
L. unicolor	*P. midgleyi* (M)	
S. butleri (M)	*T. chatareus*	
G. aprion	*H. compressa*	
G. giuris (F)	*M. mogurnda*	
S. krefftii (M)	*S. krefftii* (F)	

F = female fish only; M = male fish only

Sex ratio

Table 160 gives the seasons in which significant differences from a 1:1 sex ratio were found and indicates the more numerous sex.

Only five species showed no significant difference from a 1:1 sex ratio in all seasons (table 160). Of the species with significant differences, 80% had an unequal ratio in the 1978 Late-dry season (but only 30% of the species had unequal ratios in the 1979 Late-dry season) and 45% in the 1978–79 Mid-wet season. The highest percentage found in any season except the first was 45%, which suggests that inexperience in sexing the fish at the beginning may have accounted for at least some of the unequal sex ratios recorded. Without breaking down the sex ratio data by habitats, which would require larger sample sizes, it is difficult to determine what is happening throughout the entire system. Generally, the sex ratios found may reflect: (a) the true situation, (b) bias in sex determination, or (c) sampling bias, due either to localised movements of a species within the waterbody or to a behavioural characteristic of a particular sex.

Because of the abnormal 1979–80 Early-wet season, it was difficult to determine whether the sex ratios were changing during breeding cycles. For most species, they appeared not to be related; however, *M. mogurnda*, *H. compressa*, *A. agrammus* and three members of the family Terapontidae may have unequal sex ratios connected with their breeding cycles.

Small fish and fish caught outside their breeding season were often difficult to sex. All fish with gonad stages less than IV were termed immature; mature fish had a gonad stage of IV or above. All fish with a length greater than LFM were termed adults; those less than the LFM were termed juveniles.

There were thus six categories of fish:

Juveniles (length less than LFM)	(i)	Sexually indistinguishable
	(ii)	Male
	(iii)	Female
Adults (length greater than LFM)	(i)	Sexually indistinguishable
	(ii)	Male
	(iii)	Female

Table 160 Seasonal changes in sex ratio for 25 fish species over all habitats combined

	Sampling period						
Ratio type with fish species indicated	1978 Late-dry	1978–79 Early-wet	Mid-wet	1979 Late-wet–Early-dry	Mid-dry	Late-dry	1979–80 Early-wet
‘A’ 1:1 ratio all seasons							
N. erebi							
O. lineolata							
A. percoides							
S. butleri							
G. giuris							
‘B’ Higher ratio of males							
S. krefftii	M (ad)	M (ad)	M	M (ad)	M (ad)		
A. macleayi	M		M (all)		M		
A. agrammus	M	M					
H. fuliginosus	M						
L. unicolor	M						
P. midgleyi	M (all)						NS
G. aprion	M (all)	M (all)	M (all)				
H. compressa	M					NS	NS
M. mogurnda	M					M	NS
‘C’ Higher ratio of females							
N. ater	F			F (all)	F	F (ad)	
P. rendahli	F			F (all)	F	F	
N. hyrtlii	NS	NS	NS	F (all)		F (ad)	
M. nigrans		F (ad)	F (ad)	F (ad)		F (ad)	F (ad)
M. splendida inornata		F					
C. marianae	F				F (all)		
C. stercusmuscarum	F	F (all)			F		
P. tenellus			F	F (all)			NS
‘D’ Ratio varies throughout year							
T. chatareus	M	M	M (all)		F (all)		
D. bandata	M (all)		F (ad)	F (ad)	F (ad)	F (ad)	NS
A. leptaspis	F		F (all)		M (all)		

M = male fish dominant; F = female fish dominant; NS = no fish captured

ad = sample of adult ($\geq$LFM) fish only; equal ratio for all fish

all = sample of all male and female fish; equal ratio in adult fish only

Before development, both male and female gonads are thin and strap-like, which makes sexing difficult. The sex ratios of the immature fish are therefore tentative.

Unless squash preparations of fresh material or histochemically stained sections are prepared and the gonad checked under the microscope, it is very difficult to avoid these misidentifications, although accuracy does improve both with knowledge of the fish species and with practice. Further work might clarify whether some of the unequal sex ratios observed are due to sex misidentification, and find out why there are genuinely unequal ratios in a fish population.

Breeding season

The breeding seasons of the fish must coincide with the conditions that offer the greatest amount of protection for the eggs, and food and shelter for the newly hatched young. The duration and timing of reproductive activity are thus two critical components of an organism's life-history strategy. Factors contributing to species having different breeding seasons include: variability in the physico–chemical environment; biotic factors such as predation, and inter- and intra-species competition for breeding sites and food for the young; and the social system of the species (Kramer 1978).

Some species are aseasonal spawners, breeding continuously at intervals throughout the year (eg *Glossamia aprion*, the Melanotaeniidae [Roberts 1978], and *Craterocephalus stercusmuscarum*). Most fish species, however, breed around the onset of the Wet season. Of the 29 species in the Magela Creek system for which breeding seasons were determined, 25 appeared to have peaks in reproductive development (as indicated by mean GSI for the common species, and based on research in other areas for the less abundant species) around the Early-wet season (table 161). Fish take advantage of the extensive flooding, which often causes an increase in plankton and other foods (see fig 176). Flooding also hugely increases the area and diversity of aquatic habitats available. Many species have become largely dependent on these floods for the initiation and induction of spawning. This normally occurs when water temperatures are rising and are relatively high (Lake 1967; Lowe-McConnell 1975). The young are spawned when food is plentiful and when aquatic plant communities are most dense, affording them protection from predation. The rapid growth of that year's young contributes to a rapid increase in fish biomass. Floodplain fishes are reported to have short life-cycles — many of them mature within one year, for example — as has been found for a close relative of *Melanotaenia splendida inornata* (Beumer 1979b) and *Craterocephalus stercusmuscarum* (Llewellyn 1979).

Kramer (1978) suggests that tropical freshwater fish may be an exception to the generalisation that tropical species have longer breeding seasons than temperate species (which has been documented in many groups, including mammals, amphibians and marine invertebrates). Seasonal breeding generally occurs in areas where there are major fluctuations in physico–chemical conditions, which is the case in the waterbodies of the Alligator Rivers Region. From the limited data, it appears that 16 of the species studied have a well-defined breeding season, and that the remaining species have either an extended breeding season or breed continuously throughout the year.

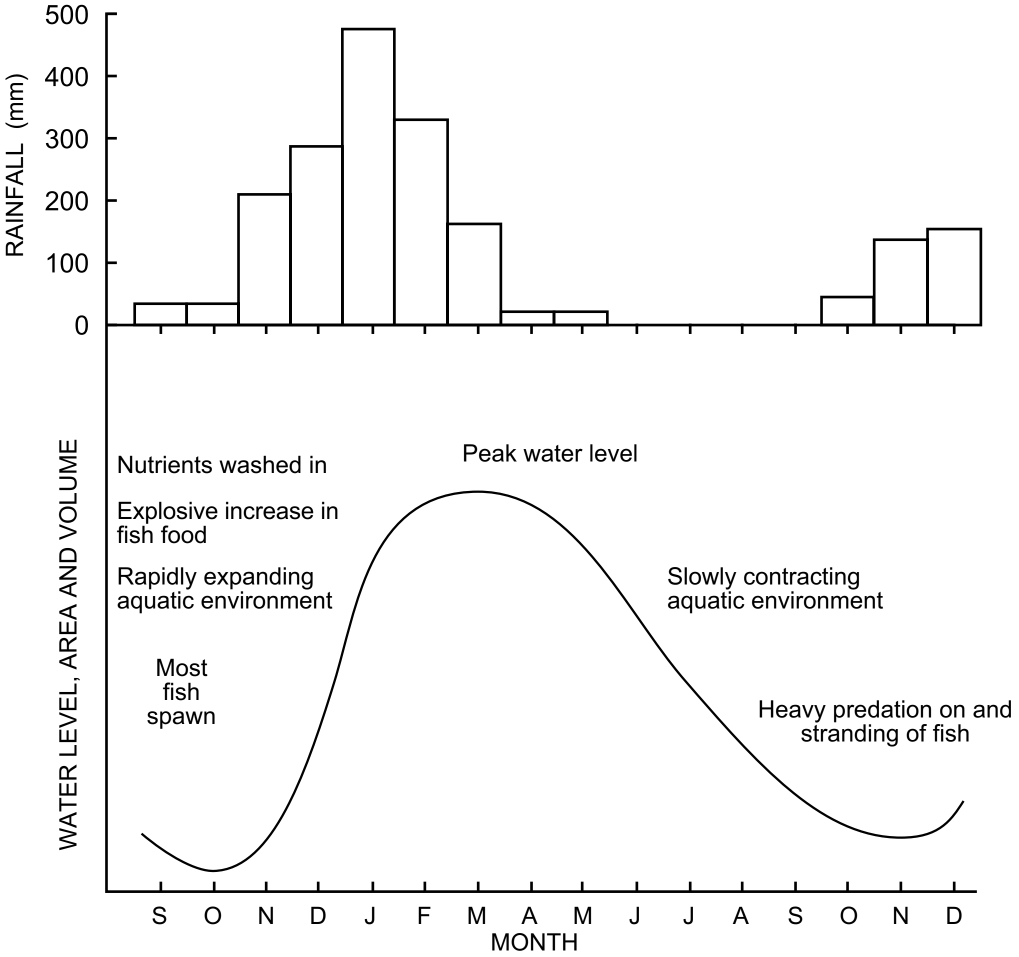
As noted, the Early-wet is the main season for reproduction of most of the species. No species appeared to breed exclusively during the Dry season, although at least three species had breeding seasons extending from the Mid-dry to the Early-wet seasons, and seven species that are aseasonal spawners had high mean GSIs at that time. Ten species appeared to have either an extended breeding season or to breed continuously throughout the year. These species all showed a peak in reproductive development during the Early-wet season.

Table 161 Breeding seasons of the more abundant species of the Magela system as indicated by the mean gonadosomatic index (GSI) for each sampling period (adult males and females combined)

	Sampling period						
Fish species and season	1978 Late-dry	1978–79 Early-wet	1978–79 Mid-wet	1979 Late-wet–Early-dry	1979 Mid-dry	1979 Late-dry	1979–80 Early-wet
A Early-wet season							
M. cyprinoides							
N. ater		>3.9				1–1.9	3–3.9
N. hyrtlii	NS	NS	NS				2–2.9
P. rendahli		2–2.9					3–3.9
L. calcarifer *							
H. fuliginosus *							
L. unicolor		>3.9					3–3.9
P. midgleyi		>3.9					NS
S. krefftii *							
B Late-dry–Early-wet season							
S. jardinii *							
A. leptaspis	1–1.9	1–1.9				2–2.9	
A. agrammus	2–2.9	>3.9				1–1.9	>3.9
A. percoides	1–1.9					1–1.9	2–2.9
S. butleri	>3.9	3–3.9				2–2.9	>3.9
T. chatareus	1–1.9	3–3.9				1–1.9	3–3.9
L. alata *							
C Late-dry season							
G. giuris	1–1.9					2–2.9	NS
D Mid-dry to Early-wet season (ie extended)							
M. nigrans	1–1.9	3–3.9			1–1.9		2–2.9
M. splendida inornata	1–1.9	2–2.9			1–1.9	1–1.9	2–2.9
A. macleayi	1–1.9	2–2.9			1–1.9	1–1.9	1–1.9
E Mid- to Late-wet season							
H. compressa			>3.9	2–2.9		NS	NS
F Early- to Mid-wet season							
M. mogurnda							NS
G Aseasonal							
N. erebi	2–2.9	2–2.9	1–1.9	1–1.9	2–2.9	2–2.9	>3.9
C. marianae	2–2.9	>3.9	1–1.9	3–3.9	2–2.9	3–3.9	>3.9
C. stercusmuscarum	2–2.9	>3.9	2–2.9	1–1.9	2–2.9	3–3.9	2–2.9
P. tenellus	1–1.9	3–3.9	2–2.9	1–1.9	1–1.9	2–2.9	NS
D. bandata	1–1.9	>3.9	2–2.9	1–1.9	1–1.9	2–2.9	NS
G. aprion	3–3.9		1–1.9		2–2.9		
O. lineolata **	1–1.9	1–1.9		1–1.9	1–1.9	1–1.9	NS

* less common species; data from other studies used, as no GSI figures were obtained in the present study

** mean female GSI only; NS no fish sampled



Actual month depends on rainfall and time taken for water to travel down to lower reaches

	Fish movements	
Upstream: (corridor and floodplain) Downstream: (escarpment) Lateral: (floodplains)	Disperse into lowlands and across floodplains	Movement back into dry season refuge areas via creekbed channels
	Fish biomass	
Production of young	Very rapid growth	High mortality
	Fishing/predation	
Destructive for migratory species	Difficult as fish dispersed; much cover	Intensive – fish confined and concentrated in refuge areas

Figure 176 Season cycle of events for fish in the lower reaches of Magela Creek

The precise regulatory role of environmental factors on the reproductive cycles in fish is not known; it has been studied in only about 50 of the 20 000 or so species of fish in the world. It has been suggested that an endogenous reproductive rhythm is triggered approximately annually by environmental factors so that reproduction can occur at the best time of the year (Bangalore et al 1978).

Site of spawning

Table 162 shows the spawning sites for 29 species. Although general breeding sites may be indicated by the presence of running-ripe, mature and spent fish, it is not known in which microhabitats within those sites they actually spawn.

Since no fish in breeding condition were found throughout its entire range, species were selecting certain areas in which to spawn in preference to other areas. Some sites, such as Radon Springs (RS), were monitored mainly by underwater observation and therefore do not show up in the general biological data as potential spawning sites.

The escarpment area and sandy creekbed habitats were the most usual spawning sites for at least 14 species. *Melanotaenia nigrans*, which spawned in the small escarpment perennial streams, was the only species that appeared to spawn exclusively within the escarpment area, while *H. fuliginosus*, *C. marianae* and *P. midgleyi* apparently spawned only in the escarpment streams and the lowland sandy creekbed habitats. *Syncomistes butleri* bred mainly in the escarpment and lowland sandy creek areas, but may also spawn further downstream in the corridor billabongs.

Other species that appeared to breed in the escarpment area and sandy creekbed habitats were *M. mogurnda* and *T. chatareus*, which also bred in lowland backflow billabongs. Species such as *C. stercusmuscarum*, *M. splendida inornata*, *A. percoides*, *N. ater* and *S. krefftii* also bred in backflow billabongs. *Arius leptaspis* and *S. jardinii* appeared to spawn in the escarpment area, although *A. leptaspis* possibly breeds mainly in the lower reaches and *S. jardinii* also spawns in some of the floodplain billabongs.

Only two species — *A. agrammus* and *A. macleayi* — apparently spawned in the lowland sandy creekbed habitats, but were not recorded as also spawning in the escarpment area, although the adults of these species were found there.

The most important spawning habitat was the lowland backflow billabongs, where 19 species showed evidence of spawning. Four species apparently breed at no other location and therefore may be totally dependent on these billabongs; these are *N. erebi*, *L. unicolor*, *N. hyrtlii* and *P. rendahli*.

Although our data indicate that *L. alata* may possibly spawn in the lowland backflow billabongs, there was also an indication that at least part of the population had made a spawning migration downstream. Such migrations have been recorded for this species in Papua New Guinea (Haines 1979).

Species that appear to breed only in the lowland backflow billabongs and floodplain billabongs are *O. lineolata*, *D. bandata*, *G. aprion* and *P. tenellus*. *Glossogobius giuris* possibly breeds only in lowland backflow billabongs and corridor billabongs. No species was apparently breeding exclusively in the corridor and floodplain billabongs.

Three species — *M. cyprinoides*, *L. calcarifer* and *L. alata* — appear to migrate downstream to the estuarine or coastal areas to spawn. Seven species apparently breed in at least four of the five habitat areas in the Alligator Rivers Region, excluding estuarine or marine areas: *A. leptaspis*, *M. splendida inornata*, *A. percoides*, *N. ater*, *S. krefftii*, *C. stercusmuscarum* and *A. agrammus*.

Table 162 Sites where running-ripe (Stage VI), mature (Stage V) or spent (Stage VII) fish were captured during each season; the species that are reported to migrate to the estuarine or coastal areas to spawn are also indicated. See appendix 1 for site codes.

	Escarpment																		
	Seasonal stream	Perennial stream		Mainchannel waterbody			Lowland sandy creekbed			Lowland backflow billabong						Corridor	Flood-plain	Lower riverine floodplain	Estuarine or coastal
Fish species	SY* NS*	RS	BS*	BD	ST*	CP*	MU	NC*	MD GD	FS	DR*	CA CL DA GL	NR*	BX*	GA GN IM	MI BO MX	ID LT JJ JA NN	WL CH	RH CC MMa MMb
M. nigrans	V/VII	VI																	
H. fuliginosus				V/VII	V/VII	VI			VI										
C. marianae				VI	VI	VI	VI		VI										
P. midgleyi			V/VII	V/VII					VI										
S. butleri				VI	V/VII	VI			VI							VI			
M. mogurnda	VII			VII			VII					VII							
T. chatareus				VI	VI	VI						VI	VI						
S. jardinii																	VII		
N. erebi										VI		VI	V/VII	VI	VI				
L. unicolor										VI		VI							
N. hyrtlii												V/VII			V/VII				
P. rendahli												V/VII		V/VII	V/VII				
O. lineolata												V/VII		V/VII	V/VII			V/VII	
A. macleayi								VI							VI				
A. leptaspis					V/VII						VI	V/VII			V/VII	V/VII	VI		
M. splendida inornata				V/VII	V/VII			V/VII	VI			V/VII			V/VII	V/VII	V/VII		
A. percoides				VI	VI				VI			VI			VI	VI	VI		
N. ater				V/VII	VI				V/VII			V/VII	VI		V/VII	VI	VI	VI	
S. krefftii					VI				VI			VI	VI		VI	V/VII			
C. stercusmuscarum				VI			VI	VI	VI			VI					VI		

Table 162 continued

	Escarpment																		
	Seasonal stream	Perennial stream		Mainchannel waterbody			Lowland sandy creekbed			Lowland backflow billabong						Corridor	Flood-plain	Lower riverine floodplain	Estuarine or coastal
Fish species	SY* NS*	RS	BS*	BD	ST*	CP*	MU	NC*	MD GD	FS	DR*	CA CL DA GL	NR*	BX*	GA GN IM	MI BO MX	ID LT JJ JA NN	WL CH	RH CC MMa MMb
A. agrammus									VI			VI	VI	VI	VI		VI		
G. giuris											V/VII					V/VII			
D. bandata										V/VII		V/VII					V/VII		
G. aprion												V/VII			V/VII		V/VII		
H. compressa																	V/VII	V/VII	
P. tenellus													V/VII				V/VII		
M. cyprinoides																			VI
L. calcarifer																			VI
L. alata																			VI
Sub total	**2**	**1**	**1**	**10**	**9**	**4**	**3**	**3**	**10**	**2**	**2**	**16**	**6**	**4**	**12**	**7**	**11**	**3**	**3**
Total per habitat	**2**	**2**		**12**			**12**			**19**						**7**	**11**	**3**	**3**

* = Nourlangie catchment

Breeding strategy

The breeding strategy is determined by such factors as variability in the physico–chemical environment, predation, and inter- and intra-species competition for breeding sites and food for the young. The type and numbers of eggs laid, stage of development at hatching and measures to protect the newly hatched young have been selectively evolved to achieve maximum survival for the species.

Each of the more common species has been put into one of the following broad, sometimes overlapping, categories of breeding strategies:

- bear live young
- incubate in mouth
- build nest and/or guard territory
- attach eggs to aquatic vegetation
- scatter eggs at depth
- spawn pelagic eggs

Table 157 summaries the reproductive variables for all the common species.

A high proportion of the species studied appear to exhibit some form of parental care (ovoviviparity, buccal incubation, guarding of nests). This strategy may have evolved in response to the variable conditions imposed by the extreme Wet and Dry seasons, and to the strong competition for food and other 'niche variables' in this tropical freshwater region with its high species richness and biomass.

Live-bearing species

The most specialised strategy found in the evolution of fishes is the production of live young that do not pass through a larval stage (ie they are viviparous or ovoviviparous). The female is fertilised internally by the male, which has specially developed organs ('claspers') on the pelvic or anal fins, and often an elongated urinogenital papilla.

At least four families represented in the Region have members that bear live young: Carcharhinidae (*Carcharhinus leucas,* Boeseman 1964), the Pristidae (*Pristis microdon,* also from New Guinea) (Roberts 1978; Haines 1979), the Dasyatidae (Breder & Rosen 1966) and the Hemiramphidae (*Zenarchopterus,* also from New Guinea) (Haines 1979).

Buccal-incubating species

The eggs, generally few in number, are incubated in the mouth by the male or female parent (rarely both). Typically large and yolky, they have a long incubation period and the hatched larvae are usually relatively large and well developed. Mouth-brooding has the advantage over egg-laying in tropical environments in that the mouth-breeding parent can avoid areas of low dissolved oxygen or other detrimental water conditions, and protect the young from predators.

Three species caught in the Region are mouth-brooders: *S. jardinii* (female broods), *A. leptaspis* (male) and *G. aprion* (male).

Scleropages jardinii and *A. leptaspis* were two of the largest fish caught in the Region, yet were amongst the least fecund species observed (mean number of eggs laid were 90 and 42 respectively). However, these eggs were the largest recorded (8.4 and 13.8 mm), and had very large yolks. The incubation periods are longer than one week, and the newly hatched young are well-developed alevins (the yolk-attached larvae transform directly into juveniles [Hubbs 1943]).

Glossamia aprion has a higher fecundity (220 eggs), with a smaller mean egg diameter of 1.5 mm. Lake (1978) recorded eggs with diameters of 3 mm and a two-week incubation period — depending on temperature — for this, or a closely related, species in Queensland. The newly hatched young are about 6 mm long and are quite well developed.

These three mouth-brooding species did not all breed during the same season: *A. leptaspis* and *S. jardinii* have well-defined breeding periods around the Early-wet season, while *G. aprion* appears to breed almost continuously throughout the year.

Nest-building and/or guarding species

Most fish that use this breeding strategy are multiple spawners, producing batches of eggs at intervals throughout the breeding season. Some, however, are aseasonal breeders. Producing several batches of eggs ensures that at least some survive when water levels fluctuate. It is usually the male that selects either a site for nest building, or a territory, generally in shallower water. The site is usually in a cave or hollow log, or amongst gravel or litter, which he protects against intruders or predators. These species often make rapid fin movements to aerate the eggs and supply them with additional oxygen, bring fresh water around the nest and remove metabolic waste from it. Nest builders often have complex courtship behaviour, which helps synchronise spawning — this is important, as the broods are small — and they do not make extensive migrations (Lowe-McConnell 1975). The eggs vary in size and shape between species and are often adhesive. The incubation period is generally less than a week, and the larvae are poorly developed, although usually better developed than those of pelagic spawners. The male, after hatching the eggs, often spawns again and then protects the next batch of eggs. They generally do not guard the larvae.

Other workers studying the same species or closely related species in other areas found that a high proportion of the species found in the Region exhibit some sort of nest-building or territorial-guarding behaviour. These include the family Plotosidae (Davis 1977a; Breder & Rosen 1966), probably some members of the Terapontidae (Breder & Rosen 1966), the family Gobiidae (Breder & Rosen 1966), and the family Eleotrididae (Breder & Rosen 1966; Llewellyn 1971; Pollard 1974; Auty 1978; Lake 1978).

Almost all members of these families in the Region have a large number of small (usually less than 1 mm diameter) demersal eggs, which may or may not be adhesive. The incubation periods are all less than one week and the larvae at hatching are not well developed. In all cases it is believed that nests are constructed or a territory is selected and guarded during spawning and incubation.

This type of breeding strategy, while affording greater protection from predators, and in some cases from low dissolved-oxygen concentrations, is at risk from changes in water level. The short incubation time and the numerous eggs laid in a number of separate spawnings may overcome this disadvantage.

Species that attach eggs to aquatic vegetation

This group lays fewer and larger eggs than the nest builders. The eggs hatch into well-developed larvae after an incubation period greater than a week.

The disadvantage of producing a smaller number of offspring from each spawning may be partly offset by the advanced stage of development of the newly hatched young. They are good swimmers, efficient feeders and fast growers. Also, the non-pelagic larvae, unlike planktonic larvae, do not have to expend energy on returning upstream.

The eggs are attached by adhesive threads or tendrils to aquatic plants and other objects in the water, which hide them from predators. However, the eggs are subject to desiccation if the water level drops or to dispersal if there is a flood.

The melanotaeniids increase the chances of some eggs surviving by spawning repeatedly throughout the year. The reproductive strategy of *S. krefftii* is not known, but other members of the genus attach their large eggs to aquatic vegetation, and they have a long incubation.[251]

Species that scatter demersal eggs over the substrate

Two strategies are used by fish in this category.

1 A small number of relatively large eggs, which usually adhere to substrates, are scattered over the bottom, sinking between rocks and amongst the vegetation. The large, well-developed larvae probably have an increased chance of survival, which may offset the species' low fecundity.

2 A large number of smaller eggs are scattered as in (1), but the incubation period is short and the hatched larvae are poorly developed. The short incubation period decreases the risk of desiccation when water levels drop. The poor development of the newly hatched fry is counterbalanced by the large number of eggs.

Scattering the eggs reduces the chance of the whole brood being destroyed simultaneously. However, the eggs may be susceptible to detrimental changes in the physico–chemical environment, such as a decrease in dissolved oxygen.

The atherinids exhibit strategy type (1). Members of this family are generally aseasonal spawners, probably breeding throughout the year.

Leiopotherapon unicolor, an example of a species exhibiting strategy (2), also scatters its eggs demersally. However, unlike atherinids it has a well-defined breeding season, high fecundity and a small egg diameter. The incubation period is short (about two days; Llewellyn 1973; Lake 1978; Merrick 1980) and the larvae at hatching are small (about 2.2 mm) with poorly developed eyes and fins (Llewellyn 1973).

Species that deposit eggs on surface waters (pelagic)

This strategy is usually adopted by 'total spawners' (Lowe-McConnell 1975): all the eggs ripen at one time each year. These are seasonal spawners and may make extensive breeding migrations. Generally, their fecundity is very high and the pelagic eggs are small. At the end of a short incubation period, poorly developed, planktonic larvae emerge.

Megalops cyprinoides and *L. calcarifer* migrate to the estuarine or coastal areas to breed (Roberts 1978; Haines 1979). *Megalops cyprinoides* spawns in estuarine or shallow inshore waters and the eggs hatch into leptocephalus-type larvae, approximately 12 mm long and with poor fin development. The larvae undergo metamorphosis and the young fish do not attain full adult appearance until they are about 300 mm long (Wade 1962).

Lates calcarifer has a complex life history, which involves a protandrous sex change and a seasonal catadromous breeding migration. The species is reported to spawn up to 16.8 x 10^6 eggs, with diameters of 0.7 by 0.8 mm (Reynolds 1978). Conflicting reports suggest that eggs are pelagic (Moore 1979) or demersal (Reynolds 1978). The newly hatched larvae are 4 mm long (Reynolds 1978).

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[251] Smith (1998) indicated that *S. krefftii* have been observed spawning within macrophyte beds along the shore of Lake Moondarra in north-western Queensland.

Toxotes chatareus and *N. erebi* also have high fecundities and very small eggs. These two species breed within the Magela Creek system, although both have also been recorded as breeding in estuarine waters (Roberts 1978; Haines 1979). *T. chatareus* breeds during the Early-wet season. Its pelagic larvae have been collected from flooded lowland backflow billabongs. *Nematalosa erebi* has a very high fecundity and very small eggs, but may breed aseasonally, although a peak in reproductive development was observed during the Early-wet season.

Dispersal of the species is also facilitated by its having pelagic eggs. These, however, are very susceptible to damage by high stream velocities as they float on the surface, but the enormous numbers of eggs generally produced may counteract this loss.

Future studies

The Early-wet season appears to be the most important period for reproduction: the reproductive activity of 25 species peaks at this time. A second Wet season sampling is needed to confirm and expand the reproductive data collected in the present study.

In ecological studies, it is important to understand the problems that arise in relation to reproduction. The methods a species uses, and their success or failure in a given setting, can be the key to understanding an ecological complex. Conversely, the effects of the reproductive pattern on the ecological complex in which a species is involved may have a profound influence on the continued existence of other forms (Breder & Rosen 1966).

Apart from extending and confirming the existing data, the reproductive strategies of species should be further studied to assess any impact of mining activity on the communities. Information on habitat requirements for spawning, the type of egg spawned and the duration of the incubation period is essential to determine the effects of mining activity on this biologically critical parameter.

Fluctuations in water level, the abundance and distribution of aquatic plants and the type of substrate found in the waterbody may affect breeding success. All of these variables should be monitored closely and any changes in their natural ranges should be kept to an absolute minimum. Because food availability is a critical factor in initiation of spawning and spawning success, the invertebrate fauna, aquatic plants and smaller fish species that constitute food for organisms at higher trophic levels must be maintained at their natural levels.

Increased silt loads in the water from areas of disturbed land may affect fish reproduction indirectly by interfering with aquatic plants, nesting sites and food availability, or directly by interfering with visual cues that may be essential in courtship behaviour and spawning.

Chemical pollutants can enter the Alligator Rivers Region waterbodies by controlled or uncontrolled discharges of water containing mining treatment wastes, organic pollutants from sewage treatment works, pesticides from the township, or fertilisers from the revegetating areas of the mine site or town gardens. These pollutants may affect reproduction in many different ways. Teratological development of embryos may result in deformed or malfunctioning larvae that do not survive hatching. There may be behavioural changes in the adults during the mating season. The production of eggs and sperm, the secretion of egg membranes, egg shells and production of egg nutrients may all be affected by changes in hormone function and enzyme activity. Changes in the ecosystem may influence reproductive success when vitellogenesis is directly influenced by the availability of food (Davis 1972).

Chronic exposure to toxic chemicals throughout the various stages of a fish's life history has been regarded as the best means of estimating long-term, safe concentrations of toxicants for fish. The early stages of embryonic development are far more sensitive than later stages to pollution by irradiation (Davis 1972).

The effects of pollutants on behavioural aspects of reproduction have hardly been touched on by any of the investigators in this field, and the physiological effect of pollution on reproduction and on the development of embryos and larvae, including metamorphosis, is little understood (Davis 1972).

More work on the effects of pollutants and the synergistic and antagonistic effects of various pollutants, both singly and combined, on the reproduction and life history of species in the Region is urgently required to enable safe concentration limits to be determined.[252]

4.4 Feeding habits

The main components of the diet of the fish collected during the study are summarised in the pie diagrams in each species section in chapter 3 of this report.

Similarity of feeding habits [253]

Polythetic agglomerative (MULCLAS in figure 177) analysis (CSIRO Taxon Library) was undertaken on the relative abundances (quantitative estimated volume data) of items in the overall diets of fish species. Discussion in the following section progresses from top to bottom on the dendrogram in figure 177.

Syncomistes butleri, P. midgleyi and *L. alata* were grouped separately from most of the other species, as they ate primarily algae and detritus. The two upstream escarpment zone terapontids and the mullet, which was mainly found in corridor and floodplain billabongs, were classified in earlier sections as herbivores/detritivores. *Hephaestus fuliginosus,* which is usually found associated with these terapontids, was grouped separately because of the abundance of aquatic and terrestrial insects in its stomachs. A large gap separated these species from the following, more carnivorous, species.

The plotosid catfishes were generally combined together in one large group. However, the 'colour-type' *Neosilurus* sp. A was grouped separately because an abundance of unidentified organic material and conchostracan microcrustaceans was found in the stomachs. Possibly the organic material was unidentified due to our inexperience in the early stages of the study, and the size of the conchostracan component may have been due to seasonality in the availability of food in the study period when the 'colour-type' classification used. The plotosid catfishes ate mainly dipteran insect larvae (mostly chironomids) and cladoceran microcrustaceans (all the plotosids were classified as meiophagic benthic carnivores).

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[252] Biological testing of mine waste waters using reproductive parameters has subsequently been developed (see Holdway 1991).

[253] Nine feeding guilds are identified within the species-account section and this analysis: herbivores/detritivores (3 species), microphagic omnivores (2 species), meiophagic omnivores (4 species), macrophagic omnivores (4 species), microphagic carnivores (6 species), meiophagic carnivores (6 species), meiophagic insectivore (1 species), macrophagic insectivore (1 species), and macrophagic piscivore/carnivores (6 species). There is clearly substantial discrimination in respect to the trophic level of foods utilised (ie herbivore/detritivores, omnivores, carnivores, piscivores, etc) and the size of the food (ie microphagic, meiophagic and macrophagic, etc), which relates to the body size of the particular fish species. In contrast to these results, a study (Pusey et al 1995b) into the feeding ecology of freshwater fishes from two rivers in the Australian wet tropics revealed only five trophic guilds discriminated primarily on the basis of body size of the constituent fish species.

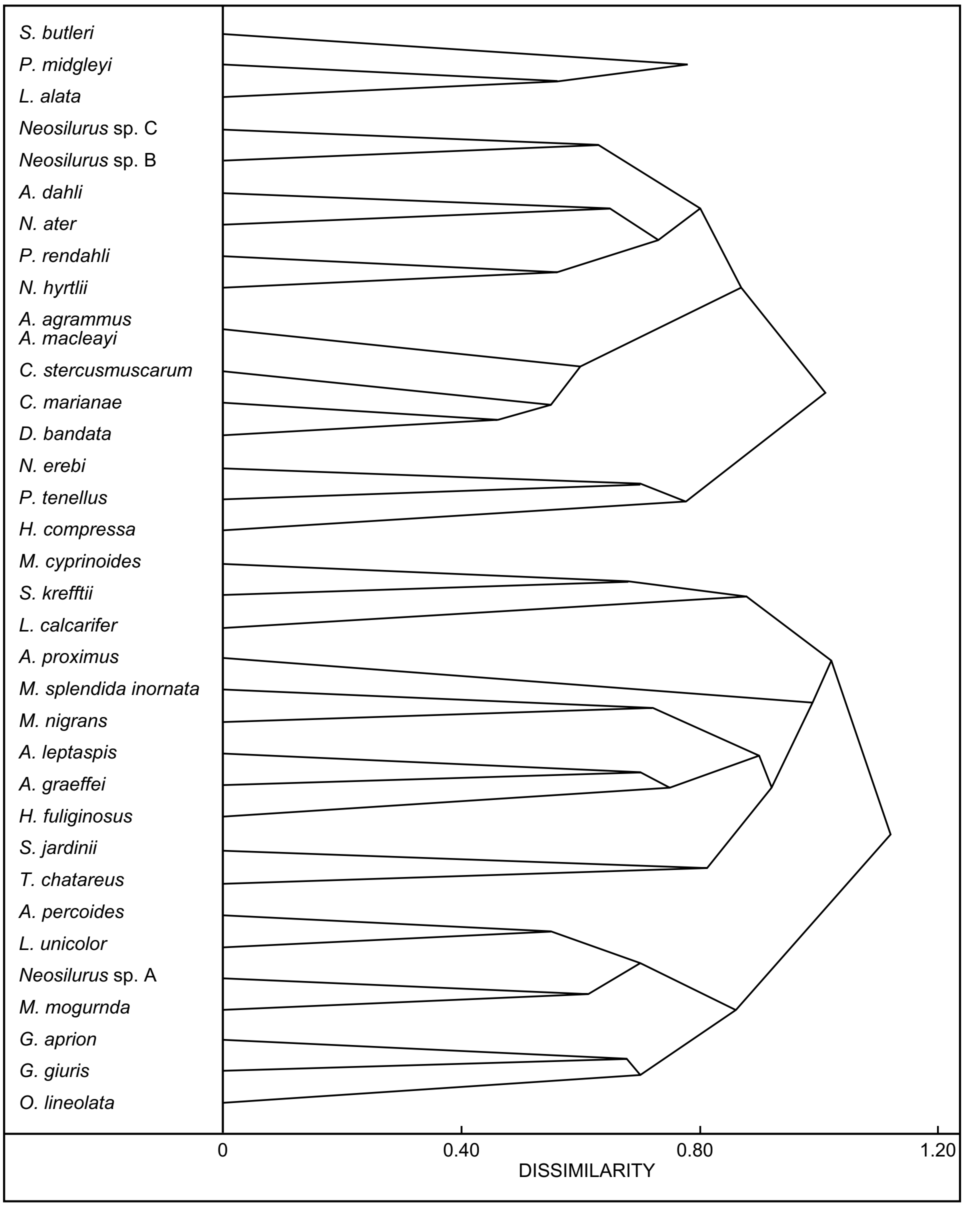

Figure 177 MULCLAS analysis of the relative abundance of stomach contents items in the overall diets of fish species captured in this study period

The small ambassids (*A. agrammus, A. macleayi* and *D. bandata*) and atherinids (*C. stercusmuscarum* and *C. marianae*) were grouped together, as their diets were based on aquatic dipteran insect larvae and microcrustaceans. The diets of the two *Ambassis* species were very similar (mainly cladocerans), but *D. bandata* was grouped more closely with the atherinids, because of the strong chironomid component in its diet. Both *Ambassis* and *Craterocephalus* species were classified as microphagic carnivores feeding in littoral benthic or midwater habitats or both; *D. bandata* was considered to be a meiophagic carnivore that feeds in similar zones.

Nematalosa erebi and *P. tenellus* were grouped together because of the common presence of algae, detritus and, to a lesser extent, cladocerans and unidentified matter in their diets. The occurrence of the unidentified component caused *H. compressa* to be incorrectly grouped with these species. *Nematalosa erebi* and *P. tenellus* were classified as microphagic omnivores (*N. erebi* more specifically as a detritophage/planktivore feeding in mid- and benthic waters, and *P. tenellus* feeding in littoral benthic waters). *Hypseleotris compressa* was classified as a microphagic carnivore that is occasionally omnivorous. A large gap separated these species from the next group, which consisted of carnivores that were generally more predatory.

Macrophagic piscivores/carnivores (*M. cyprinoides, S. krefftii* and *L. calcarifer*) were placed together in the first group of a larger set of groups. (*Carcharhinus leucas*, which was excluded from the analysis because the few specimens captured were not from the regular sampling sites, would have been placed in this group, as it was entirely piscivorous.)

The next six species to some extent displayed omnivorous feeding habits. (The grouping position of *A. proximus* [a macrophagic omnivore] was possibly not very meaningful, as only a few specimens were examined.) The melanotaeniids (meiophagic omnivores) were grouped together, as they usually fed on aquatic insects, terrestrial insects and filamentous algae. *Melanotaenia nigrans* fed over many substrate types and from the water's surface, and *M. splendida inornata* fed opportunistically throughout most waterbody zones. The other two ariid catfishes (*A. leptaspis* and *A. graeffei*) were classified as macrophagic omnivores that feed in benthic and midwater zones, so they are grouped together. *Hephaestus fuliginosus* (a predominantly escarpment-zone terapontid) was grouped near them, as it also was considered to be a macrophagic omnivore.

Scleropages jardinii and *T. chatareus* were grouped together, as they commonly fed on insects, both terrestrial and aquatic, but *T. chatareus* ate mainly terrestrial insects, and *S. jardinii* also ate some teleosts. *Scleropages jardinii* was classified as a macrophagic carnivore/insectivore, and *T. chatareus* as a meiophagic insectivore.

The remaining terapontids (*A. percoides* and *L. unicolor*) were placed together in the next group. These species were meiophagic omnivores and fed extensively in benthic and midwater zones. They were both opportunistic feeders, eating aquatic insects, crustaceans, algae, hydrophytes and terrestrial plant material.

The remaining species (except for the plotosid 'colour type' *Neosilurus* sp. A) had varied carnivorous diets. *Mogurnda mogurnda* and *G. giuris* were classified as meiophagic carnivores that feed in benthic and midwater zones, primarily on aquatic insects and crustaceans. *G. giuris* was an opportunistic feeder. *Oxyeleotris lineolata* and *Glossamia aprion* were classified as macrophagic carnivores, feeding on crustaceans, teleosts and aquatic insects, also in the benthic and midwater zones.

Sharing of food resources

Fishes in Amazonian tributary streams apparently do not generally have distinct specialisations in the foods they eat; the stomach contents of the various fish families present are rather uniform because most species have a more or less varied diet (Knoppel 1970). Lowe-McConnell (1975) explained that this apparent contradiction (in view of the adaptive radiations of characoids in the Amazon basin) seems to arise from only omnivorous (eurytrophic) fishes being able to penetrate to the headwater streams. The same effect is seen in the present study, where about 50% (table 163) of species in escarpment perennial streams and terminal mainchannel waterbodies were omnivores, while only 20 to 30% in lowland, corridor and floodplain habitats were.[254] Omnivorous species include the melanotaeniids, *L. unicolor* and *H. fuliginosus*. Two terapontid herbivores/detritivores (*S. butleri* and *P. midgleyi*) are also found in the escarpment zone in the study area (table 163); their specialised ability to feed upon periphyton on submerged bedrock, particularly in terminal mainchannel waterbodies, as well as their ability to reach and occupy these upstream habitats in the Wet season, appear to be the main reasons for their successful colonisation of such habitats.

Lowe-McConnell (1975) stated that omnivorous fish species that penetrate to the headwaters are usually the most widely distributed, and suggested that their particular feeding specialisations may be more useful in downstream areas throughout the year, or possibly in some seasons, or that they may have been more significant in the past when the fish species were evolving. *Leiopotherapon unicolor* and *M. splendida inornata* were the only upper escarpment zone species also found abundantly in lowland, corridor and floodplain habitats in the present study.

Specialisations may be more advantageous in the middle and lower reaches of rivers, where so many species coexist (Lowe-McConnell 1975). In the present study many closely related species found in lowland, corridor and floodplain habitats had very similar diets in sites where these species were captured together, eg the main forage fish species, including the ambassids, melanotaeniids, plotosids and atherinids, and some terapontids (*L. unicolor* and *A. percoides*). The diets of the main predatory species (*L. calcarifer*, *A. leptaspis*, *S. krefftii* and *M. cyprinoides*) also overlapped: their stomach contents were rather uniform, as Knoppel (1970) found in Amazon tributary fishes; however, there were differences between families (eg plotosids fed mainly on benthic dipteran larvae, while ambassids fed mainly on microcrustaceans), so specialisation may occur more at the family rather than the species level.

There are great seasonal variations in pressure on food resources in rivers. In Costa Rica, fish diets overlapped least in the Dry season, when food is most scarce and competition probably strongest (in accordance with Gause's competitive exclusion principle) (Zaret & Rand 1971). In Zaire, however, Matthes (1964) found that fishes ate similar food in the Dry season when mainly bottom detritus was available. In the Rupununi savanna district of British Guiana, Lowe-McConnell (1963) found a similar uniformity in the Dry season. She suggested that

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[254] In the study of Pusey et al (1995b) which focused on the feeding ecology of freshwater fishes from two rivers in the Australian wet tropics, dietary overlap was highest at sites characterised by high water velocities, coarse substrates and dense riparian canopy. This equates to escarpment habitats in the Alligator Rivers Region (ARR). A high level of dietary overlap is expected in escarpment areas given the dominance of omnivory. The omnivorous feeding habitats are likely to be beneficial in habitats where food availability is low. Pusey et al (1995b) found dietary overlap to be least in areas characterised by low water velocities and sandy substrates, an equivalent of corridor habitats in the ARR. Pusey et al suggested that the low dietary overlap was driven by low food availability in such habitats. In contrast, food availability is likely to be high in ARR corridor habitats as they act as a staging area for migrating taxa in the wet season and function as a depositional area for taxa washed down from the lowland sandy creek habitat. Pusey et al did emphasise that dietary overlap varied within and between the two rivers they studied.

trophic specialisations here would come into play in the Wet season, which is the main feeding period.

The pressure on resources is apparently greatest when water levels fall after the Wet season and the number of species rises as they leave the contracting Wet season environments. This is the period when unique feeding habits would be most beneficial; *T. chatareus,* for example, would have an obvious specialist advantage.

Detailed analyses of the seasonal variation in food overlap between species were not undertaken in the present study; however, such analyses in future studies could ascertain the degree of stress caused by the lack of food resources and its repercussions on body condition.

Trophic relationships

The energy pool available in the biomass of primary producers (microorganisms, periphyton, hydrophytes and phytoplankton) is ultimately the only food available for fish production unless it is supplemented by a supply of allochthonous material. In freshwaters, Lowe-McConnell (1975) argued that two alternative chains run: either from bottom detritus through microorganisms to detritus-feeding invertebrates (and/or fish) to invertebrate-eating fish to several levels of piscivores; or (in the pelagic zone) from phytoplankton to zooplankton to zooplankton-feeders and then to one or more levels of piscivores. She noted that in river systems the detrital chain appears to be more important. Bottom detritus tends to be allochthonous in origin in the upper reaches and derived from hydrophytes in the lower reaches.

The Purari River System of Papua New Guinea has low primary productivity, virtually no plankton, few filamentous algae and rooted hydrophytes, opaque water (due to the heavy silt load), rapid flow, and frequent fluctuations in water level (Haines 1979). The notable feature of the Purari fish fauna is the paucity of herbivores and lack of planktonic feeders, which is attributable to the lack of hydrophytes and plankton. The sources of nutrition in this system were thought to be allochthonous materials from terrestrial plant communities becoming bottom detritus. Some fish ate the terrestrial material directly (or, at the next trophic level, in the form of insects), others were detritophages, but most ate detritophagic prawns, which predominated in this system.

The nutrient cycle and trophic relationships between fishes in our study area appeared to be different from those of the Purari River; however, the source of nutrition in the upper Magela and Nourlangie systems is likely to be the same as in the Purari system — from allochthonous terrestrial plant material via detritus. The main difference is that in lowland and floodplain billabongs nutrients appear to be recycled from bottom detritus. This detritus mainly comes from (a) the decomposition of hydrophytes, and (b) phytoplankton (Dry season benthic waters of these habitats have been classified as mesotrophic [Hart & McGregor 1978] and eutrophic [Walker & Tyler 1979]). Zooplankton populations develop, perhaps in part because more nutrients become available when large amounts of organic material decompose and become more concentrated by evaporation after the seasonal flow has ended. More niches may therefore be available for microphage- or plankton-feeding fishes and herbivorous fishes than in the Purari River System. We found seven species of microphagic fishes (atherinids, *H. compressa*, *N. erebi*) in the study area, no strictly herbivorous species (except the upstream terapontids in the escarpment zone), but many omnivorous species (eg *L. unicolor, A. percoides, M. splendida inornata*). No strictly detritophagic fish species were found, although *L. alata* had a detrital component in its stomach contents. The main trophic group appeared to be the carnivores (15 species), which generally fed on aquatic insects and crustaceans. It is notable that the Purari fauna had few species similar in size to most of the microphagic feeders in our study area.

Table 163 Percentage frequencies of the total number of fish species occupying various trophic niches in a longitudinal array of habitats in the Magela Creek catchment

	Escarpment			Lowlands				Overall
Trophic niche	Terminal main-channel	Perennial stream	Mainchannel	Sandy creek	Backflow billabong	Corridor billabong	Floodplain billabong	
Piscivores/ carnivores	–	–	7.1 (1)	18.1 (2)	10.5 (2)	13.6 (3)	15.8 (3)	10.7 (3)
Carnivores	–	22.2(2)	50.0 (7)	54.5 (6)	57.8 (12)	54.5 (12)	57.9 (11)	53.5 (15)
Omnivores	50.0 (2)	55.6 (5)	35.7 (5)	27.2 (3)	31.5 (6)	22.7 (5)	21.1 (4)	25.0 (7)
Herbivore/ detritivores	50.0 (2)	22.2 (2)	7.1 (1)	–	–	9.1 (2)	5.3 (1)	10.7 (3)
Total number of abundant species	4	9	14	11	19	22	19	28

(Number of fish species shown in parentheses)

The features typical of freshwater fish faunas of the other three tropical continents (Asia, Africa and South America) were summarised (Lowe-McConnell 1975) as (1) the importance of allochthonous plant material as direct food for fish species, (2) the important role of insects as fish food, (3) the important role of mud and detritus as direct food for some species, and (4) the presence of large numbers of individuals and kinds of piscivorous fishes. The Alligator Rivers Region fish fauna did not appear to closely follow the above pattern. Allochthonous plant material was only directly important to a few species in the escarpment zones of the catchment; however, some omnivores ate this material in the lower reaches during the Dry season. Terrestrial insects and aquatic insect larvae were important fish foods, but crustaceans were of comparable importance in the aquatic component of the diets. Mud and detritus as food was fairly important to only a few species. There are relatively few primarily piscivorous fish species in the freshwaters of the Region, and their populations appeared small.

The percentage frequency of the total number of abundant fish species from various trophic niches in a longitudinal array of habitats in the Magela Creek catchment is shown in table 163. The greatest numbers of species overall were classified as carnivores, followed by omnivores, piscivores/carnivores and then herbivores/detritivores. Carnivorous species were found most often in floodplain and lowland billabongs, followed closely by corridor billabongs and sandy creekbed habitats and then escarpment mainchannel waterbodies. Many more niches are available in the lower reaches of tropical rivers, which have more bottom mud, phytoplankton and hydrophytes, providing more food sources for the generally more diverse communities (Lowe-McConnell 1975).

Compared with other habitats, there were few carnivores in escarpment perennial streams in the Alligator Rivers Region (probably because there are no, or very few, zooplankton to support microphagic carnivores [pers obs]). No carnivores (except for occasional *Crocodylus johnstoni*) were found in escarpment terminal mainchannel waterbodies. The highest frequency of omnivorous fish species was found in escarpment perennial streams and terminal mainchannel waterbodies (see earlier sections for explanation), decreasing to the lowest frequency in corridor and floodplain billabongs. All omnivorous fish had very high mean fullness indices. Piscivore/carnivore species were most common in lowland sandy creekbeds (these species preyed upon forage fish, which used these habitats as migration routes in the Wet season), followed by floodplain and corridor billabongs, then lowland billabongs and escarpment mainchannel waterbodies; none were found abundantly in escarpment perennial streams (except in the Nourlangie catchment, where *M. cyprinoides* was observed) and terminal mainchannel waterbodies. All piscivorous/carnivorous fish had very low mean fullness indices. The highest frequency of herbivore/detritivore species was found in escarpment terminal mainchannel waterbodies and perennial streams (the specialised terapontids), followed by corridor billabongs (where *S. butleri* and *L. alata* were captured), escarpment mainchannel waterbodies and floodplain billabongs. All herbivore/detritivore fish species had very high mean fullness indices.

The percentage frequencies of the major feeding categories of the total numbers of abundant fish species from various trophic niches in the Purari River catchment in Papua New Guinea and in the three tropical South American waterbodies mentioned are shown in tables 164 and 165, respectively. Herbivore/detritivore fish species occurred most often in the Purari River catchment tributary springs and least often in the most downstream freshwater delta habitats (as in our study area); omnivores were rare in the catchment and, unlike our study, none were collected in spring-fed streams entering the river; carnivores were common in the river and the freshwater delta, and also in tributary springs (unlike in our study); piscivores/carnivores appeared to be more diverse than in the Alligator Rivers Region.

Table 164 Percentage frequency of the total number of fish species occupying various trophic niches in the Purari River catchment, Papua New Guinea (after Haines 1979) (number of fish species shown in parentheses)

Trophic niche[1]	Springs off river		River above delta		Freshwater delta	
Piscivores/carnivores	11.1	(1)	15.8	(6)	19.2	(5)
Carnivores	44.4	(4)	42.1	(16)	57.6	(15)
Omnivores	–		7.9	(3)	3.8	(1)
Herbivore/detritivores	44.4	(4)	34.2	(13)	19.2	(5)
Total number of abundant species	9		38		26	

1 Trophic niches redesignated by present authors

Table 165 Percentage frequency of the total numbers of fish species occupying various trophic niches in the present study area and in three tropical South American waterbodies (number of fish species shown in parenthesis)

Trophic niche	Overall habitats in present study		Tributary forest streams [1]		Lowland lake [2]		Oxbow lagoon [3]	
Piscivores/carnivores	11.1	(3)	5.0	(2)	12.5	(5)	19.6	(11)
Carnivores	55.5	(15)	30.7	(12)	45.0	(18)	21.0	(12)
Omnivores	25.9	(7)	26.6	(10)	25.0	(10)	21.0	(12)
Herbivore/detritivores	7.4	(2)	38.4	(15)	17.5	(7)	37.5	(21)
Total number of abundant species	27		39		40		56	

Trophic niches designated (or redesignated) by present authors:

1 Amazon tributaries near Manaus (specimens collected by Fittakau) (Knoppel 1970)

2 Lake Redondo in the Amazon River catchment (Marlier 1967)

3 Oxbow lagoons of the seasonally flooding Middle Parana–Paraguai River system (Ringuelet et al 1967)

The trophic niches of the fish species in forested Amazonian tributary streams (Knoppel 1970) were similar in the fish communities of the escarpment mainchannel waterbodies we studied, the main differences being the relative numbers of omnivores and herbivores/detritivores. The fish communities examined by Marlier (1967) in Lake Redondo, Amazon River system, were also similar to those in the escarpment waterbodies. The high diversity of herbivores/detritivores and piscivores/carnivores in an oxbow billabong of the middle Parana–Paraguai River system (Ringuelet et al 1967) resulted in the trophic structure of these fish communities being vastly different from any communities examined in the present study.

Food chains

A tentative food chain (based on the examination of stomach contents) for the freshwater fishes of the Alligator Rivers Region is shown in figure 178. The return pathways of energy and nutrients have not been shown on this figure. The main pathways by which the energy is fixed from allochthonous material into the detrital chain, recycled (especially in the lower reaches of the catchment) by the primary producers, and eventually transferred to the fish and via some fish species to humans, is thus tentatively shown for the aquatic ecosystems in the Region.

Food chains are very complex, although some may be based on relatively few sources. In the rocky shore habitat of Lake Malawi (Africa), numerous species depend on only aufwuchs (organisms that are closely associated with or attached to a submerged surface but do not penetrate into it); however, in sandy inshore habitats of the same lake numerous species depend on plankton, terrestrial insects, aufwuchs on *Vallisneria*, *Vallisneria* itself, and bottom detritus and algae (Fryer 1959). Lowe-McConnell (1975) noted that, as in any food chain, there are rarely more than four or five links, as longer chains are expensive bioenergetically (80 to 90% of potential energy is lost at each successive stage).

The Alligator Rivers fish fauna appears to utilise a broad range of food resources; however, most do so indirectly (particularly via aquatic invertebrates). Only three species solely utilised the first trophic level (the escarpment terapontids and *L. alata*); however, many partially used it (the most important being *N. erebi* and the melanotaeniids). *Toxotes chatareus* mainly (and *H. fuliginosus* and *S. jardinii* partially) utilised allochthonous material in the form of terrestrial insects and (in the case of *H. fuliginosus*) plant material.

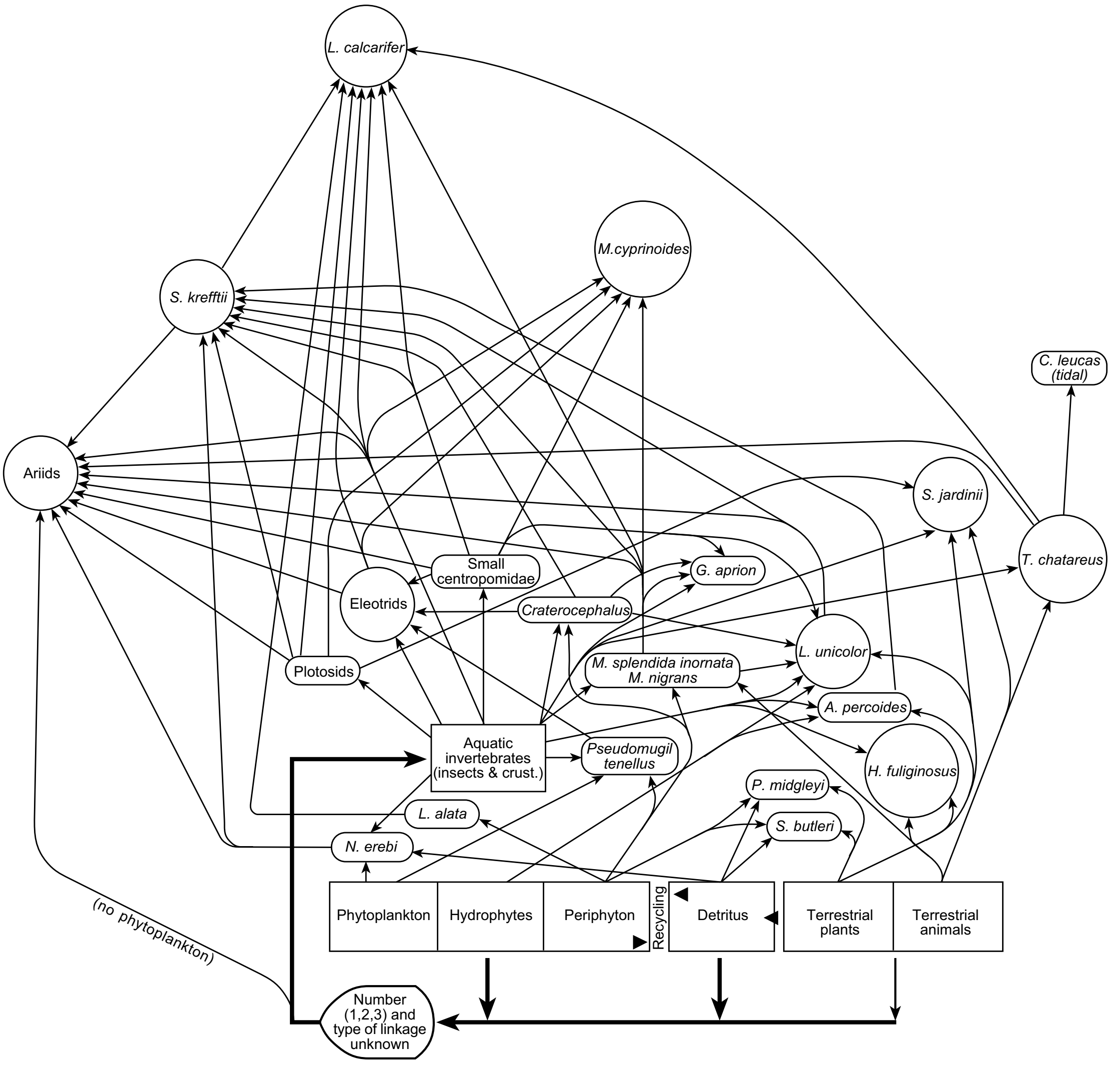

Figure 178 Pathways of energy and nutrient transfer between various trophic levels. Circles indicate that the species is eaten by humans in the tropics.

The main transfer of energy from the primary producers (the first trophic level, including microorganisms on the detritus) to the fish fauna thus appears to be via invertebrates — mainly aquatic insects and crustaceans in the benthic/substrate zone, and mainly microcrustaceans (zooplankton) in the pelagic open-water zone. The number of links in the chain between the primary producers and the invertebrates (primary and possibly secondary consumers) in tropical Australian freshwater ecosystems is unknown. A major source of food for macroinvertebrates may be, as Marchant (1980) suggested, organic detritus (macrophytes themselves do not seem to be a source) within the littoral zone of lowland billabongs in the Magela Creek system (the guts of ephemeroptera and trichoptera larvae were often full of detritus); much of this detritus appeared to be decomposing leaves of *Pandanus aquaticus*, *Barringtonia acutangula* and *Melaleuca*.

The aquatic invertebrates (secondary and possibly tertiary consumers) are eaten by a variety of smaller fish species: ambassids and atherinids ate mainly zooplankton, and plotosids and eleotrids ate mainly aquatic insects and larger crustaceans. The trophic relationships are very complex at these levels, as the opportunistic feeding habits of most species result in frequent overlaps in the food items; many of the fish species partially utilise lower trophic levels (eg the atherinids, melanotaeniids and the more downstream terapontids); some of the fish species also prey upon other smaller fish species (so are partly piscivorous; eg some eleotrids, *G. aprion*, *L. unicolor*); and the larger, predominantly piscivorous fish species may also prey upon larger invertebrates (notably *Macrobrachium*). In New Guinea, such freshwater prawns appear to fill the detritophagic niche that is occupied by fishes in other continents with true or primary division freshwater fish faunas (Haines 1979).

The smaller fish species are eaten by three primarily piscivorous fish species (and also fish-feeding waterbirds and reptiles): *L. calcarifer*, *M. cyprinoides* and *S. krefftii*. The first species is that most frequently eaten by humans in the Region. Fish species that utilise the lowest trophic levels appear to be of minor importance (with invertebrates possibly being of more secondary importance) to these primarily piscivorous species. The macrophagic omnivorous ariid catfishes (*A. leptaspis* and *A. graeffei*) ate large volumes of smaller fishes in the Wet and Late-wet seasons. By following various pathways of energy and nutrient transfers, the primarily piscivorous fish species can be classified as feeding from the third to the seventh trophic levels, though possibly most commonly at the fourth to fifth levels.

In the Purari system, ariid catfishes dominate in both biomass and number of species (Haines 1979). They occupied virtually all trophic niches available; Haines (1979) concluded that the lack of a ‘true’ (ie primary division) freshwater fish fauna allowed the adaptive radiation of this predominantly marine family to take place in estuaries and rivers. In the Alligator Rivers Region, the ariid catfishes also dominate the biomass in the lower reaches of the catchments and occupy all available trophic levels (fig 178). The same may apply to *L. unicolor* in the upper reaches of the catchments in the Region.

Plasticity of fish diets

Most fishes, according to Lowe-McConnell (1975), display great dietary plasticity: they eat different foods as they grow and change their biotope. Different foods become seasonally available or they actively select preferred foods; this is particularly true of riverine fishes in the more seasonal rivers. The diet of *Lates niloticus* in Lake Chad changed with size of fish, biotope, season and year (Hopson 1972); this species could not be assigned to a particular narrow trophic niche because of the great variation in its feeding habits.

The following sections summarise the main changes in the feeding habits of the Alligator Rivers fish fauna with seasons and habitats. The data collected in the present study will be analysed at a later time to describe changes in feeding habits in relation to size of fish, time of day and year.

Seasonal changes

Marchant (1980) recorded the greatest number of macroinvertebrate taxa, and the highest density of individuals, in the littoral zone of lowland billabongs and corridor billabongs of the Magela Creek system in the Late-wet–Early-dry seasons; both the number and density fell for the rest of the Dry season but rose rapidly in the Early-wet season.

Terrestrial insects appeared more frequently in the diets of most carnivorous and omnivorous fish species during the 1978–79 Early-wet season. These insects would have been washed into creekbeds and hence into billabongs as the Wet season flows covered previously dry land. *Arius leptaspis*, *M. splendida inornata*, *M. nigrans*, *H. fuliginosus* and *T. chatareus* ate large quantities of these insects in this season. *Toxotes chatareus* may have eaten washed-in insects, but, as a result of inundation by flood waters, this species could also move close to terrestrial vegetation and eat insects that were not in contact with the water. Anuran larvae were abundant in littoral waters during the Early-wet season and were eaten frequently by *O. lineolata* and occasionally by *L. calcarifer*.

The Early-wet to Mid-wet seasons saw a resurgence of microcrustaceans, including copepods and cladocerans (pers obs), and conchostracans and ostracods (recorded by Marchant 1980). The microcrustacean component of the diets of the plotosids and the ambassids, *N. erebi*, *A. percoides*, *L. unicolor*, *P. tenellus*, *M. mogurnda*, *H. compressa*, *G. giuris* and *G. aprion* increased markedly during the Early-wet season as the microcrustaceans became available in the billabongs. Also, ostracods were abundant in the diets of *C. marianae*, *C. stercusmuscarum* and *D. bandata* during the Wet season.

Aquatic insect larvae also showed peak abundances in the billabongs during the Wet season; the most notable was the emphemeropteran *Cloen* sp. A ('Baetidae' in stomach contents tables) recorded by Marchant (1980). *Cloen* sp. A became abundant in the billabongs in the Early-wet season, which was reflected by its abundance in the stomachs of the plotosids and of *G. aprion* and *L. unicolor*. Chironomid larvae were most abundant in the billabongs towards the end of the Wet season, and many fish species (notably the plotosids) ate them.

Macrobrachium spp. disappear during the Wet season; Marchant (1980) suggested they migrate (probably downstream). Likewise, *Macrobrachium* virtually disappeared in the Wet season from the diets of fish species (*G. aprion* and *O. lineolata*) that frequently ate them in the Dry season.

Hydrophytes grew extensively in the billabongs during the Wet season but virtually disappeared from most of them by the end of the Dry season. The amounts of hydrophytes in the stomachs of *A. leptaspis*, *L. unicolor* and *A. percoides* peaked in the Late-wet–Early-dry season.

More fish appeared in the stomachs of *L. calcarifer*, *M. cyprinoides*, *A. leptaspis*, *G aprion*, *L. unicolor* and *O. lineolata* during the Wet season, and particularly towards the Late-wet–Early-dry season. The numbers of fish species captured in the billabongs also peaked in the Late-wet–Early-dry season. Although *S. krefftii* also ate many fish in the Wet season, its fish-feeding peaked towards the Early-wet (and even the Late-dry) seasons.

More algae were eaten during the Mid-wet and Late-wet–Early-dry seasons by a number of fish species. *Liza alata*, *S. butleri* and *P. midgleyi* grazed more commonly on filamentous green algae, while *N. erebi*, *P. tenellus* and to a lesser extent *C. stercusmuscarum* more commonly ate phytoplankton.

Habitat differences

Marchant (1980) did not find marked differences in the macroinvertebrate taxa of lowland billabongs and corridor and floodplain billabongs in the Magela Creek system. However, as seasonal fluctuations in the numbers and density of taxa in corridor billabongs were not as marked as in other billabongs, he considered the corridor billabongs to be reservoirs for some species that are not found in the Dry season in other, shallower, billabongs. Marchant (pers comm) found marked differences between the macroinvertebrate communities of lowland sandy creekbed pools and escarpment mainchannel waterbodies, and also of those in the other billabongs he studied in greater detail.

Chironomid larvae (together with oligochaetes) were the dominant taxon Marchant (1980) found in the billabongs. Not surprisingly, they were also the dominant taxon in the stomachs of the smaller carnivorous and omnivorous fish species in these billabongs. Dipteran larvae were the main fauna captured on the muddy substrates in the deeper areas of billabongs examined by Marchant. Plotosid catfishes, which are thought to feed predominantly in these areas, had larger dipteran larvae components in their diets than other species (except perhaps *D. bandata*).

Primarily piscivorous fish species apparently ate fish mostly in the floodplain and corridor billabongs; however *M. cyprinoides* and *S. krefftii* frequently ate fish in lowland sandy creekbed channels. *Arius leptaspis*, *L. unicolor* and *G. aprion* appeared to eat fish mostly in lowland billabongs.

Species collected over sandy substrates (eg *C. marianae*, *C. stercusmuscarum*, *L. unicolor*, *A. percoides* and *N. erebi*) appeared to eat more microcrustaceans in the corridor and lowland zones than in the escarpment zone. Species such as ambassids, plotosids, *M. splendida inornata*, *G. aprion* and *L. unicolor* captured over muddy substrates in lowland, corridor and floodplain billabongs ate more microcrustaceans than those captured over sandy substrates. Similarly, some gobiid and eleotrid species (eg *G. giuris*, *M. mogurnda* and *O. lineolata*) ate more crustaceans in downstream habitats than in upstream areas. These differences presumably reflect the relative abundances of crustaceans in the upper reaches (usually sandy) and downstream reaches (usually muddy) of the creek system. The quantities of nutrients and detritus available in the waterbodies (affecting microcrustacean abundance) may be the cause of these apparently longitudinal effects.

More terrestrial insects were eaten by fishes (eg *T. chatareus*, *M. splendida inornata*, *L. unicolor* and *S. jardinii*) in escarpment habitats than by the same species in more downstream habitats. This may be because there is more overhanging terrestrial vegetation around most escarpment habitats than around downstream habitats (also aquatic insects appear to be less abundant [pers obs] in escarpment habitats).

Hydrophytes grew extensively in lowland backflow billabongs and floodplain billabongs during the Wet season. Some fish species (eg *A. leptaspis*, *A. percoides* and *L. unicolor*) ate more hydrophytes in those billabongs than they did in sites with sparse hydrophyte cover.

Phytoplankton was more common in the stomachs of small fish species (eg *C. stercusmuscarum*, *P. tenellus* and *M. splendida inornata*) found in lowland billabongs, corridor billabongs and floodplain billabongs than in other habitats. *Nematalosa erebi* fed more extensively on phytoplankton in the downstream muddy substrate habitats; over sandy substrates in escarpment mainchannel waterbodies this species fed extensively on diatomaceous periphyton. Filamentous green algae were found more frequently in the diets of *M. splendida inornata* captured in clearwater streams such as escarpment mainchannel waterbodies and lowland sandy creekbeds.

Main feeding seasons and habitats

The following resume is based on Lowe-McConnell's (1975) summary of the annual sequence of events in seasonal tropical rivers. The production and biomass of most fish foods (except zooplankton) increase rapidly when water levels rise with the onset of Wet season flow. When terrestrial Dry season lands are covered by Wet season floods, the water is greatly enriched in nutrient salts from the breakdown of organic matter; this leads to explosive growth of bacteria, algae and zooplankton (in most tropical seasonal rivers zooplankton develops best in still-water pools while the waters are subsiding after the Wet season), which in turn support a rich macroinvertebrate fauna. The high-water time is the main feeding, growing and fattening season for most tropical fish species. Small fish are susceptible to predation by piscivores when the flood waters subside and billabongs contract as the Dry season progresses. Fish populations are thus geared to this expansion and contraction of their environment and resources. Fishes in tropical seasonal rivers have been known to make long migrations between feeding and spawning areas. As the nutrients are depleted and the water level falls, the fish move to the main river channels. The first to move are the predators, which lurk around the mouths of the channels down which abundant young fish pass on their way back to the main stream.

Macroinvertebrate communities in the littoral zone of lowland billabongs in the Magela Creek catchment were found to have a similar pattern of resurgence in numbers and density of taxa during the Wet season (Marchant 1980). The resurgence peaked in the Early-wet season in lowland billabongs (to two-fold that recorded in corridor billabongs). The highest densities and numbers of taxa were recorded in the Late-wet–Early-dry season due to the concentrating effects of falling waters. The density of taxa decreased slightly in the Early- to Mid-wet season when the floodwaters peak. There was a secondary resurgence between the Mid-dry and Late-dry seasons in the corridor billabongs.

Zooplankton were abundant during the 1978–79 Early-wet season in the first floodwaters from lowland sandy creekbeds and lowland backflow billabongs (pers obs), which is in contrast to Lowe-McConnell's (1975) observation; however, zooplankton were also abundant towards the end of the Wet season.

The season of the greatest feeding activity (based on fullness indices) of fish species in the study area (table 166) was, as other research workers in tropical seasonal rivers have found, the Wet season.

The mean number of species most actively feeding per season per habitat increased dramatically into the Early-wet season from a low in the Late-dry season. By the Mid-wet season feeding activity had peaked (nearly five-fold that in the Late-dry season), and then began to decrease slightly by the Late-wet–Early-dry season. During the Mid-dry season feeding activity returned to a slightly higher level than in the previous Late-dry season.

The mean number of species feeding most actively per habitat per season was far greater in habitats downstream than upstream of the Ranger Uranium Project Area (RUPA).

Upstream of RUPA the highest feeding activity occurred in escarpment mainchannel waterbodies, followed by lowland billabongs and then lowland sandy creekbeds. In all of these habitats, the greatest feeding activity was in the Mid-wet season; however, some fish in escarpment mainchannel waterbodies feed extensively throughout the year.

Downstream of RUPA the highest feeding activity was recorded in lowland billabongs and then floodplain billabongs. Possibly floodplain habitats are more important feeding areas than lowland billabongs because of their higher volume of water during the Wet season; however, large numbers of fish from down- and upstream areas (many species from Magela Creek migrate upstream in response to flow)[255] enter the lowland billabongs during the Early-wet season, where they remain in large densities throughout the Wet.

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[255] This has been confirmed in subsequent studies (Bishop et al 1995) on fish movement dynamics in the Region.

Table 166 Habitats and seasons of greatest feeding activity of fish species in the study area (RUPA: Ranger Uranium Project Area)

Habitat	Sampling seasons					Mean number of species per habitat
	Late-dry	1978–79 Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	
Escarpment mainchannel waterbody	*C. marianae* *C. stercusmuscarum*	*M. mogurnda* *M. nigrans*	*M. mogurnda* *M. nigrans* *C. marianae* *C. stercusmuscarum* *H. fuliginosus* *M. splendida inornata*	*M. splendida inornata* *A. percoides* *H. fuliginosus*	*M. splendida inornata* *A. percoides*	3.0
Lowland sandy creekbed (upstream of RUPA)	*C. marianae*	*M. mogurnda*	*M. mogurnda* *C. marianae* *M. splendida inornata*	*M. splendida inornata* *A. percoides*	*A. percoides*	1.6
Lowland backflow billabong (upstream of RUPA)	*A. agrammus*	*M. mogurnda* *G. aprion*	*M. mogurnda* *L. unicolor* *D. bandata* *G. aprion* *M. splendida inornata*	*M. splendida inornata* *L. unicolor*		2.0
Lowland sandy creekbed (downstream of RUPA)	*C. marianae*		*C. marianae* *S. krefftii* *M. splendida inornata* *M. cyprinoides*	*A. leptaspis* *S. krefftii* *M. splendida inornata* *A. percoides*	*M. splendida inornata*	2.0
Lowland backflow billabong (downstream of RUPA)	*A. macleayi* *A. agrammus*	*T. chatareus* *G. aprion* *O. lineolata* *A. agrammus* *N. hyrtlii* *P. rendahli* *L. unicolor* *S. krefftii*	*T. chatareus* *N. hyrtlii* *O. lineolata* *S. krefftii* *C. stercusmuscarum* *G. aprion* *D. bandata* *M. splendida inornata*	*T. chatareus* *N. hyrtlii* *O. lineolata* *S. krefftii* *M. splendida inornata* *L. unicolor* *M. cyprinoides* *A. leptaspis*	*O. lineolata* *M. splendida inornata* *A. percoides*	9.2

Table 166 continued

	Sampling seasons					
Habitat-type	Late-dry	1978–79 Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Mean number of species per habitat
Lowland backflow billabong (downstream of RUPA) *(cont'd)*			*M. cyprinoides* *L. unicolor* *A. leptaspis* *A. percoides* *P. rendahli*	*P. rendahli*		
Corridor billabong	*A. macleayi* *G. giuris* *N. ater*	*T. chatareus* *L. alata* *G. giuris* *A. macleayi* *S. butleri*	*T. chatareus* *M. splendida inornata* *S. krefftii* *S. butleri*	*T. chatareus* *P. tenellus* *N. ater* *S. krefftii* *M. splendida inornata*	*P. tenellus* *S. krefftii* *N. ater* *M. splendida inornata* *G. giuris*	4.2
Floodplain billabong		*L. alata* *G. aprion* *H. compressa* *O. lineolata* *A. agrammus* *P. rendahli*	*L. alata* *N. hyrtlii* *H. compressa* *S. krefftii* *O. lineolata* *M. splendida inornata* *C. stercusmuscarum* *G. aprion* *D. bandata* *T. chatareus* *M. cyprinoides* *A. leptaspis* *L. unicolor* *P. rendahli* *A. percoides*	*L. alata* *N. hyrtlii* *P. tenellus* *S. krefftii* *N. ater* *O. lineolata* *M. splendida inornata* *M. cyprinoides* *A. leptaspis* *P. rendahli*	*P. tenellus* *N. ater* *O. lineolata* *M. splendida inornata*	7.0
Mean number of species per season	1.25	2.86	5.88	4.5	1.75	

The lowest mean numbers of species feeding with greatest activity per habitat occurred in lowland sandy creekbeds. This habitat had the highest proportion of piscivores/carnivores with high fullness indices (mainly in the Mid-wet and Late-wet–Early-dry seasons) of any habitat in the catchment. The lowland sandy creekbeds may be used mainly as a migration channel for fish in the Wet season.[256]

Corridor billabongs were apparently much less important feeding areas than floodplain and lowland billabongs, but more important than sandy creekbed pools or any other habitat upstream of the Ranger Uranium Project Area. The number of species with highest mean fullness indices per season in this habitat varied only slightly throughout the year; the greatest activity occurred in the Late-wet–Early-dry and Mid-dry seasons. These observations correlate with those of Marchant (1980), who found the numbers and types of macroinvertebrate taxa (ie fish food) to vary less markedly in this habitat than in lowland billabongs; he also reported a small resurgence of macro-invertebrates in this habitat from the Mid-dry to Late-dry seasons. Corridor billabongs may be used by fish mainly as a migration channel in the Wet season,[256] and as a refuge in the Dry season.

4.5 Parasites and predators

Parasites and predators of the freshwater fishes of the Alligator Rivers Region exploit the highest trophic niches available in the aquatic systems.

Parasites

The parasites (identified by Dr L Cannon, Queensland Museum) found infecting freshwater fish species of the region, or known from other studies to infect them, are listed in table 167. The taxonomy of these parasites is not clear primarily because many of them have complex life cycles. Summaries (Cannon, pers comm) of the life cycles of some groups are given below:

Nematodes (roundworms)

Thynnascaris and **Contracaecum** Larvae are passed from copepods to small zooplankton-feeding fishes and then to more predatory fish. *Thynnascaris* matures in the predatory fish, while *Contracaecum* matures in fish-eating birds (Cannon 1977).

Philometra Adult females form cysts in fish; they extend the posterior of their body into the water and disgorge young, which may be eaten by zooplankton and thence by fish.

Eustrongylides The larvae of this genus are usually found in a variety of fishes. The adult host is a piscivorous bird. The first intermediate host is thought to be an arthropod, and probably a crustacean. One of the effects of this nematode on its fish hosts is that the females do not lay eggs when the cyst is in the ovary or vent (Pollard 1973b).

Physalopteroids The larvae may end up in water monitors, file snakes or frogs. Related subfamilies occur in amphibians and reptiles.

Trematodes (flukes)

Clinostomum The large and well-developed fluke lies in thin-walled cysts in fishes; when warmed, as in the mouth or throat of a water bird eating the fish, the cercaria quickly leaves the fish and attaches itself to the bird’s throat.

Cestodes (tapeworms)

The effects of cestodes on host fish may include a loss of body condition, an inhibition of gonad maturation and an inhibition, during the reproductive season, of movements to spawning areas.

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[256] This has been confirmed in subsequent studies (Bishop et al 1995) on fish movement dynamics in the Region.

Table 167 Parasites found or known to infect some freshwater fish species of the Region

Fish host	Parasite	Affected tissue
Nematalosa erebi	Trematode metacercariae	Intestine
Arius spp.	Ascaridoid nematodes	
	Contracaecum sp. (?)	Stomach
	Thynnascaris sp. (4th stage)	Stomach
	Spiruroid nematode (immature)	
	Philometra sp. (?)	Stomach wall
	Trematode metacercariae	
	Clinostomum sp. (?)	Adipose
	Ptychobothriid cestode (adult)	
	Senga sp. (?)	Body cavity
Plotosidae	Spiruroid nematode (immature)	
	Philometra sp. (?)	Gonad
	Physalopterids	Gonad and intestines
	Caryophyllidean cestode (monozoic)	
	Notolytocestus sp.	Stomach
Strongylura krefftii	Spiruroid nematodes (immature)	
	Philometra sp. (?)	Body wall and cavity
	Encysted nematodes	
	Eustrongylides sp.	Body wall
Melanotaenia splendida inornata and *M. nigrans*	Hirudinae (leech)	Body wall
	Spiruroid nematode (immature)	
	Philometra sp. (?)	
Craterocephalus stercusmuscarum	Porohalacarid arachnid	
	Astacopsiphagus parasiticus (?)	Stomach
Ambassis agrammus	Spiruroid nematode (immature)	Stomach
Lates calcarifer	*Philometra* on *Lates* in India (Rasheed 1965)	Body wall
	Trematode *Transversotreme laruei* (Velasquez 1961) may develop to progenetic metaceraria	
	Trypanorhynch cestodes (Coulter 1959)	
Amniataba percoides	Cestode pleuroceroid (immature)	
	Senga sp. (?)	Body cavity
	Brachiuran crustacean	
	Argulus sp.	Stomach
Leiopotherapon unicolor	Spiruroid nematode (immature)	
	Physalopterids	Body cavity
	Philometra sp. (?)	Body cavity
	Camallanid nematode (Merrick 1974)	
	Procamallanus sp.	Intestine and stomach
	Cestode cysticercoid (immature)	Gonad
	Cestode pleuroceroid (immature)	
	Senga sp. (?)	Body cavity
	Crytogonomia trematodes (Watson 1980)	Stomach
Oxyeleotris lineolata	Encysted nematodes	
	Eustrongylides sp.	Body wall

Notolytocestus Transmitted to a fish when it eats aquatic oligochaetes infected with the immature cestodes.

Senga (Ptychobothriidae) Previously only recorded from no closer to Australia than Sri Lanka. When the host is alive, this cestode lives healthily in the host's intestine; when the host dies it may crawl anywhere within or outside the host.

Hirudinae (leeches)
Previously recorded to be parasitic on fishes.

Porohalicaridae
Only one porohalicarid species has been previously recorded from Australia. It was found in the gillchamber of a freshwater crayfish in Queensland (Williams 1968).

Brachiura (fish lice)
Argulus Blood-sucking on fish and amphibians; usually outside or in gill chamber. There are only a few records of such brachiurans occurring on Australian freshwater fish (eg on *Mogurnda australis* and *Mugil* sp. from the Murray River [Riek 1946]). It may have been introduced through infested exotic aquarium fishes (Williams 1968). This genus was found in the present study in the stomach of *A. percoides*, a species that was observed cleaning other fish species by pecking over their bodies and particularly around their gill chambers.

The seasonal incidence of macroscopic parasite infestations in various fish species from the study area is shown in table 168.

Table 168 Seasonal percentage frequency of the incidence of macroscopic parasite infestations in various fish species examined during the study period

	Sampling period							Across all seasons	
Fish species	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	N	Mean
C. leucas	20.0							13	7.6
M. cyprinoides				5.5				151	0.6
N. erebi	1.2							1493	0.2
A. leptaspis	54.9	6.7	9.2	5.3	6.5	16.0	50.0	633	18.3
A. dahli	18.1							22	14.8
N. ater	40.0	2.5	8.0	9.0	12.5	69.2	12.5	317	18.3
P. rendahli	1.4	20.5		7.6	5.6	24.1	10.0	426	7.3
S. krefftii	12.7	11.8	71.2	94.1	84.6	88.0	25.0	215	61.8
M. nigrans	9.5	10.8	41.9	7.4	7.1	11.9	15.0	206	15.0
M. splendida inornata	17.4	3.4	24.4	24.3	25.2	21.7	9.7	1109	20.1
C. stercusmuscarum	0.7	1.2	4.0			1.6		766	1.7
P. tenellus		12.9				3.0		189	2.7
A. agrammus	2.7	3.8	12.0	15.4	6.9	6.1	10.0	736	6.9
A. macleayi	2.2				4.4	4.5		519	2.3
D. bandata	0.9	6.2	2.4		1.7	3.3		477	2.0
L. calcarifer	22.2	88.8	20.0					35	54.3
A. percoides	32.0	10.5	1.1	5.4	5.3	20.4	28.6	484	13.4
L. unicolor	40.0	5.2	33.9	6.1	33.9	40.9	100.0	371	26.1
G. aprion	5.8	4.2	3.4		5.8	1.6		557	3.6
T. chatareus	7.1							236	0.4
G. giuris		7.1						117	1.7
M. mogurnda	22.4	33.3	17.0		14.2	77.7		163	23.3
O. lineolata	20.0		33.3	10.0	17.2	16.7	50.0	133	16.5

The mean overall incidence of such infestations was highest in *S. krefftii*, *L. calcarifer*, *L. unicolor*, *M. mogurnda*, *M. splendida inornata*, *A. leptaspis*, *N. ater* and *O. lineolata*. The incidence of infestation of *A. leptaspis*, *N. ater*, *P. rendahli*, *A. percoides*, *M. mogurnda* and *O. lineolata* (all primarily benthic species) appears to be lower in the Wet season, increasing towards the end of the Dry season. *Leiopotherapon unicolor* had a secondary peak of infestation in the Mid-wet season. *Melanotaenia nigrans*, *M. splendida inornata*, *S. krefftii* and *Ambassis* spp. (mid-water and surface-dwelling species) had an increasing incidence of parasite infestation during the Wet season and a decreasing incidence towards the end of the Dry season.

The incidence of macroscopic parasite infestations in fish species from various habitats in the study area are shown in table 169. The highest incidence in most fish species was in samples taken from lowland backflow billabongs and floodplain billabongs (this may be related to the occurrence of zooplankton populations, which may be the initial hosts for many parasites); however, *A. leptaspis*, *M. nigrans*, *L. unicolor* and *O. lineolata* were exceptions to this generalisation. The lowest incidence of infestations was generally in samples from lowland sandy creekbeds and corridor billabongs.

The incidence of parasitic infestations appears therefore to vary between species, seasons and habitats, and possibly with many other factors. Severe infestations can affect body condition, migration and the reproductive success of some species, just as adverse environmental conditions can.

Table 169 Percentage frequency of the incidence of macroscopic parasite infestations in fish species from various habitats examined in the study area

	Escarpment habitat		Lowlands habitat				
Fish species	Main channel	Perennial stream	Sandy creekbed	Backflow billabong	Corridor	Floodplain	N
M. cyprinoides						3.4	151
N. erebi				0.3			1493
A. leptaspis	20.0		12.5	9.1	19.1	13.3	633
N. ater	42.8			100.0	72.5	17.6	317
P. rendahli				14.8		4.1	426
S. krefftii	50.0		55.5	59.0	50.0	55.5	215
M. nigrans	83.3	25.5	18.5				206
M. splendida inornata	14.1		10.5	32.6	11.6	14.6	1109
C. stercusmuscarum	4.9		0.7	1.7	1.8	1.6	766
P. tenellus				3.7		1.0	189
A. agrammus			3.7	8.7	6.7	8.0	736
A. macleayi	3.1		16.6	3.3		2.2	519
D. bandata				3.0	1.1	3.5	477
L. calcarifer					88.8	20.0	35
A. percoides	12.5		8.3	15.7	36.6	41.4	484
L. unicolor	20.0	50.0	10.0	31.9		16.7	371
G. aprion				1.7	1.7	6.3	557
T. chatareus			3.3		20.0		236
G. giuris	12.5				2.3		117
M. mogurnda			6.7	38.9	14.2		163
O. lineolata			40.0	20.0	14.2	6.7	133

Predators

Predators of freshwater fishes in the Alligator Rivers Region include six species of reptiles (9 species if some estuarine species are included), at least 31 species of birds, and humans. The known feeding habits of these species are summarised below.

Birds

A list of piscivorous birds found on the Arnhem Land plains (after M. Ridpath, derived from published literature) is given in table 170. Little or nothing is known about which fish species they eat, and in which habitats and seasons.

Table 170 Fish-eating birds found on the Arnhem Land plains (after M Ridpath[3*])

Species	Common name
Tachybaptus novaehollandiae	Little grebe
Pelecanus conspicillatus	Australian pelican
Phalacrocorax sulcirostris	Little black cormorant
Phalacrocorax varius	Pied cormorant
Phalacrocorax melanoleucos	Little pied cormorant
Anhinga melanogaster	Darter
Ardea sumatrana	Great-billed heron
Ardea pacifica	White-necked heron
Egretta novaehollandiae	White-faced heron
Ardea picata	Pied heron
Butorides striatus	Mangrove heron
Ardea alba [1*]	Large egret
Egretta garzetta	Little egret
Egretta intermedia [2*]	Intermediate egret
Nycticorax caledonicus	Nankeen night heron
Ixobrychus flavicolis	Black bittern
Ephippiorhynchus asiaticus	Black-necked stork
Threskiornis molucca	Australian white ibis
Platalea regia	Royal spoonbill
Platalea flavipes	Yellow-billed spoonbill
Haliastur indus	Brahminy kite
Haliaeetus leucogaster	White-bellied sea eagle
Pandion haliaetus	Osprey
Larus novaehollandiae	Silver gull
Chlidonias hybridus	Whiskered tern
Sterna nilotica	Gull-billed tern
Sterna caspia	Caspian tern
Alcedo azurea	Azure kingfisher
Alcedo pusilla	Little kingfisher
Todiramphus sanctus	Sacred kingfisher
Todiramphus chloris	Mangrove kingfisher

1* The stomach of one specimen contained 1 'mullet' (105 mm) and 4 other 'fish' (24–37 mm) (M Ridpath pers comm)

2* The stomach of one specimen contained 11 'perch' (47 mm in length) (M Ridpath pers comm);

3* Nomenclature from Christidis and Boles (1994)

Large numbers of *Pelecanus conspicillatus* (Australian pelican) were observed feeding on plotosid catfishes in the Magela Creek catchment towards the end of the 1978 Dry season. Many of the birds suffered torn bills from the pectoral and dorsal spines of these fish. Over 40 *Haliastur sphenurus* (whistling kites) and *Haliaeetus leucogaster* (white-bellied sea eagles) were observed feeding on fish carcasses (mainly *L. alata*) on the banks of Leichhardt Billabong after a fishkill in the 1978–79 Early-wet season.

Reptiles

***Acrochordus javanicus* (file snake)** This species was occasionally observed attacking fish captured in gillnets. The published literature records that this species eats fish, but does not record which species it most commonly eats. Aboriginal people living in the study area frequently eat this species of snake.

***Acrochordus granulatus* (little file snake)** This is a coastal and estuarine species that is common around the coast of Kakadu. It relies heavily on fish in its diet.

***Cerberus rynchops* (Bockadam)** A water snake which is found in coastal and wetland areas usually associated with mangroves. This is a fish eating species.

***Fordonia leucobalia* (white-bellied mangrove snake)** Like the bockadam, this species is common amongst the mangroves of Kakadu. Eats largely crustaceans and also fish.

***Enhydris polylepis* (Macleay's water snake)** A freshwater species which in certain situations can be abundant. This snake feeds on frogs, tadpoles and fish.

***Chelodina rugosa* (northern snake-necked tortoise)** This species was readily lured to dead fish left in the water. Aboriginal people of the area also frequently eat this species.

***Varanus mertensi* (water monitor)** This species was frequently observed in escarpment perennial streams with mainly small fish. It was observed feeding on *Melanotaenia* spp. and *Craterocephalus* spp. at the upstream end of an escarpment mainchannel waterbody (Jim Jim Creek catchment) during the 1980 Mid-dry season (pers comm, Ian Morris, Australian National Parks and Wildlife Service).

***Crocodylus johnstoni* (Johnston's freshwater crocodile)** The feeding habits of this species in the upper escarpment reaches of the Mary River, Northern Territory, is being studied by G Webb (pers comm). His study, based on regurgitated stomach contents, has showed that fish predominate in the diet during the Wet season and particularly towards its end when the flow decreases and the fish populations concentrate as they move to Dry season refuge areas. Generally, this species ate small schooling species such as the melanotaeniids, ambassids and the smaller plotosids, as well as some terapontids and, on one occasion, an individual was seen capturing a specimen of *S. butleri.*

***Crocodylus porosus* (saltwater or estuarine crocodile)** The feeding habits of this species in freshwater environments are not known. Taylor (1979), who examined the stomach contents of sub-adult (less than 180 cm TL) specimens from coastal areas of Arnhem Land and Melville Island, found that they had eaten mainly crabs, *Macrobrachium* and terrestrial insects. The virtual absence of fish (*Pseudogobius* sp. was the only species eaten regularly in small quantities) is astonishing; however, larger specimens ate more vertebrates than did the smaller specimens. C. Limpus (pers comm) observed that larger specimens of this species in freshwater rivers of north-eastern Queensland eat fish of all sizes.[257]

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[257] Griffin (1994) undertook radio tracking studies on *L. calcarifer* in the Mary River in 1991/92. The loss of one tagged individual was explained by predation from *C. porosus*.

In the St Lucia estuary in South Africa, *Crocodylus niloticus* is oriented at certain times of the year to intercept migrating populations of sea mullet (*Mugil cephalus*) as they enter narrows in the estuary (Whitfield and Blaber 1979).

Humans [258]

The fish species eaten by Aboriginal and non-Aboriginal people in the Alligator Rivers Region and adjacent catchments are listed in table 171.

Thirteen fish species are eaten: twelve by Aboriginal people and eight by non-Aboriginal people. *Lates calcarifer* is the most important fish species eaten by humans in the region. Amateur anglers target this species in all rivers of the region except for the West Alligator, with most effort being concentrated in the South and East Alligator Rivers.[259] Amateur anglers regularly fish for *Lates calcarifer* downstream of the Ranger uranium project area in the Magela Creek system and downstream from corridor billabongs in the Nourlangie Creek system.

Table 171 Fish species eaten by Aboriginal and non-Aboriginal people in the Alligator Rivers Region and adjacent catchments

	Aboriginal people			Non-Aboriginal people	
Fish species	Magela Creek near Jabiru *A	Other areas in Region*B	Featured in regional art	Amateur	Commercial
Nematalosa erebi	+	–	–	–	–
Scleropages jardinii	–	+	–	–	–
Arius leptaspis	+	+	+	+	–
Plotosidae spp.	+	+	+	–	–
Lates calcarifer	–	+ *1	+	+	+
Leiopotherapon unicolor	+	+ *2 *3	–	–	–
Hephaestus fuliginosus	–	+	–	+	–
Toxotes chatareus	–	+	–	–	–
Liza alata	–	–	–	+	–
Oxyeleotris lineolata	–	+ *4	–	+	–
Strongylura krefftii	–	+	+	+	–
Polynemus sheridani (estuarine)	–	+ *5	–	–	+
Eleutheronema tetradactylum (estuarine)	–	+ *5	–	–	+

+ eaten; – not eaten

*A Local Aboriginal family (Peter), traditional owners

*B Senior Murrumbur elder (pers comm), traditional owner and cultural advisor to Parks Australia

*1 Local Aboriginal people at Cannon Hill removed and ate most of this species from Precarious Billabong as it was drying out in the 1979 Dry season.

*2 Harris (1975) describes local Aborigines capturing this species from escarpment streams in Arnhem Land. Dams are made out of woven *Pandanus* and sheets of *Melaleuca* bark. The fish are coralled behind the dams and then funnelled into narrow channels from which they are captured.

*3, *4 Anbarra people capture these species (in Gidjngali language: An-gayapadja [or Gurrayurraba] and Bilerra [or Wadakurdorrk], respectively) from the freshwater swamp, Djibadjirra, between the Liverpool and Blyth Rivers in Arnhem Land.

*5 Piers Barrow (pers com), project officer, Natural Resource Management, Kakadu National Park

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[258] Other piscivorous mammals include the bottle-nosed and Irrawaddy dolphins which are found around the coast and in the estuaries of the Alligator River Region. Information from Greg Miles, Public Relations Officer, Kakadu National Park.

[259] Surveys of the *L. calcarifer* and *S. jardinii* populations of Yellow Waters Billabong on the South Alligator River (Griffin 1993, 1995, 1997 & 1998) indicate high population densities for these species.

The other species shown in table 170 to be eaten by non-Aboriginal people are rarely targeted by amateur anglers. They are caught occasionally and some of those caught are eaten. Other species such as *Scleropages jardinii* and the catfish are rarely, if ever, eaten by non-Aboriginal people. If caught, they are generally released.

Commercial fishing is prohibited throughout Kakadu National Park. Large areas are also closed to recreational fishing, including the whole catchment of the West Alligator River and all the country to the south and east of the Kakadu Highway. This area includes all of the sandstone country, containing the permanent pools that are the dry season refugia for many fish species. The area also contains the majority of the habitat of species such as *Hephaestus fuliginosus* — an excellent sport and food fish keenly sought by some amateur fishers in the top end of the Northern Territory. Consequently the pressure on this species from recreational angling is currently negligible due to the fishing closures.

4.6 Movements

Many tropical freshwater fishes migrate upriver as the water level rises, and then move out onto the flooded plain when conditions permit (Lowe-McConnell 1975). Their reactions to water flow are thus complex and, as yet, have been little investigated. Migration, particularly in freshwater fishes, is often regarded as an adaptive phenomenon for increasing growth, survival and abundance, all of which may increase production. Like many other seemingly obvious generalisations in ecology, there is by no means a mass of well-documented and conclusive evidence in its support.

Fortuitously, during the 1978 Late-dry season, an unusual event enabled us to note which small fish species are the first to move upstream out of lowland billabongs when flow begins. Groundwater was pumped (at 0.1 m^3 s^{-1}) and allowed to flow (via site IF) into a close-by lowland backflow billabong (II) adjacent to Magela Creek and downstream of the Ranger Uranium Project Area. Six fish species — *M. splendida inornata*, *Craterocephalus stercusmuscarum*, *A. agrammus*, *D. bandata*, *Glossamia aprion* and *M. mogurnda* — were found in site II before flow started (table 171); as flow entered the billabong, large numbers of *A. agrammus*, *M. splendida inornata* and somewhat fewer *D. bandata* moved upstream through the newly created riffle area towards the groundwater pump. What was the stimulus? Whitehead (1979) described changes in hydrological conditions of the Nzoia River, Kenya, during floods; he found that no single factor could be isolated as the stimulus for fish migration, since all these changes are almost simultaneous. Van Someren (1963), however, suggested that the initial movement of fish is stimulated by a complex set of factors, including water height and velocity, but that the fish themselves must be in a physiologically receptive state before the changing external conditions will affect them.

The most dramatic effect of fish movements in the present study was the recolonisation of lowland sandy creekbeds and lowland backflow billabongs after the Dry season when the Wet season flow began. The biomass of catches increased rapidly in lowland backflow billabongs when these became connected to the inundated lowland sandy creekbeds (these habitats are important migration routes), and thence to corridor and floodplain billabongs. During the 1978–79 Early-wet season in Gulungul Billabong (table 172), typical Late-dry season fish species (eg *P. rendahli*, *A. agrammus*, *G. aprion*, *M. mogurnda* and *O. lineolata*) were replaced (or they spread out as the volume of water in the lagoon increased) by larger-bodied fish species (eg *N. erebi*, *A. leptaspis* and *T. chatareus*, some of which were in breeding condition) and smaller fish species (eg *C. stercusmuscarum*, *P. tenellus*, *A. macleayi* and *L. unicolor*). Presumably, most of these fish moved upstream from corridor and floodplain billabongs when these were connected to the main creek channel; however, this speculation requires verification. Upstream movement of fish species is also detectable in escarpment perennial streams during the Wet season.

Table 172 Abundance and total weight of fish caught in samples from habitats where water had just started to flow

	Site code and date						
	II	IF	GL				MJ
	18 Sept 1978		5 Dec 1978		18 Dec 1978		13 Dec 1979
Fish species	Abund. (*n*)	Abund. (*n*)	Abund. (*n*)	Wt (g)	Abund. (*n*)	Wt (g)	Abund. (*n*)
N. erebi	0	0	0	0	1	270.0	0
A. leptaspis	0	0	0	0	16	12465.0	0
P. rendahli	0	0	15	220.6	0	0	0
M. nigrans	0	0	0	0	0	0	1
M. splendida inornata	43	71	0	0	0	0	145
C. marianae	0	0	0	0	0	0	2
C. stercus-muscarum	2	5	0	0	15	11.9	0
P. tenellus	0	3	0	0	2	0.5	0
A. agrammus	43	371	79	90.1	0	0	0
A. macleayi	0	0	0	0	17	22.2	1
D. bandata	58	12	0	0	0	0	0
A. percoides	0	0	0	0	0	0	62
L. unicolor	0	0	0	0	3	1.4	3
G. aprion	1	0	2	47.2	0	0	0
T. chatareus	0	0	0	0	9	1710.0	0
M. mogurnda	11	0	2	4.5	0	0	0
O. lineolata	0	0	1	13.1	0	0	0
Total	**158**	**462**	**102**	**375.5**	**63**	**14481.0**	**212**
No of species	**6**	**5**	**5**		**7**		**6**

Some fish appear to move downstream from Dry season refuge areas in escarpment habitats (once again, this requires verification). During the 1979–80 Early-wet season, several species (mainly *M. splendida inornata* and *A. percoides*, and some *L. unicolor*, *C. marianae* and *M. nigrans*) were present in the first-flowing water that reached as far downstream as MJ (table 171, also see map in appendix 8) near the Ranger Uranium Project Area. Also, throughout the Wet season typical escarpment-dwelling fish species (eg *H. fuliginosus*, *P. midgleyi*, *S. butleri* and *M. nigrans*) were found in lowland sandy creekbed habitats.

Recolonisation of temporary streams by fish and invertebrates in Illinois, USA, was studied by Larimore et al (1959). Larimore found that most of the fish species withstood the extreme drought conditions in at least a few parts of the stream. Re-establishment of the populations began as stream flow resumed. Fish moved upstream, with the result that within two weeks, 21 of the 29 regularly occurring species moved into most of the stream course — a rate similar to that observed in the present study.

As a result of the great diversity of freshwater fishes in tropical regions (Fryer & Illes 1972), there are special forms of feeding migrations, the most common of which is associated with the seasonal inundation of river floodplains (Welcomme 1974, 1975): the adults, and the young which have hatched out in areas along flooded rivers, migrate laterally into rich feeding habitats (Roberts 1972; Petr 1974, 1975). This strategy, which is followed by many tropical freshwater fishes, is to rapidly exploit a temporarily rich food source brought about by flooding and washing in of terrestrial resources and the upsurge of nutrients. The young of some tropical fishes remain to feed at or near where they were spawned for some time before migrating to their main feeding area.

The spawning migrations of most tropical freshwater fishes are within rivers and their floodplains or from lakes into rivers. These migrations seem to be aimed at enabling the adults and young to exploit the rich resources that result from flooding (Northcote 1978). This type of migratory activity was also apparent in our study area: many large-bodied fish species in breeding condition appeared in lowland billabongs during the Wet season after these were connected to corridor billabongs via inundated lowland sandy creekbeds. The occurrence of high proportions of sexually maturing (or just matured) fish in the sandy creekbed habitats and corridor billabongs (section 4.3) supports these observations. Many small juveniles (eg those of *T. chatareus*) were observed to be washed downstream in creekbed channels during the Wet season, which would explain why many juveniles of species normally found in the lowlands in the Dry season (eg *T. chatareus*, *L. unicolor*, *A. percoides*) were found in floodplain habitats in the Wet season.

The migrations of many tropical fishes back to lakes or to mainstream rivers to avoid being trapped in lateral marshes and side channels (Santos 1973; Lowe-McConnell 1975) minimises mortalities from predation and from desiccation of aquatic habitats during the Dry season. The migratory activity of fish in the present study appeared to be at a high level in lowland sandy creekbed channels during the Late-wet–Early-dry season when water levels were receding.[260]

Migrations of fish from marine feeding areas to freshwater spawning habitats do not seem to be nearly as common in tropical waters as in temperate and arctic regions (Northcote 1978). In the present study no anadromous species were captured, but three apparently catadromous species (*L. calcarifer*,[261] *M. cyprinoides* and probably *L. alata*) were found. They appeared to

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[260] Dramatic upstream movements of a considerable range of fish species were subsequently documented during studies on fish movement dynamics reported by Bishop et al (1995). The movements were considered to be a part of refuge-seeking migrations. Bishop (1987) utilised these migrations in Magela Creek to demonstrate avoidance responses of the fish to releases of waste waters from the Ranger Uranium Mine.

[261] There has subsequently been a number of investigations into the movements of *L. calcarifer*. From radiotracking work in the Mary River, Griffin (1994) concluded that *L. calcarifer* was a roving predator rather than a 'lie in wait' predator. In freshwater reaches the overall mean distance travelled per day was 3.9 km (SE=1.3). Greater speeds (up to 42 km/day or 1.8 km/hr) were observed over time periods of a few hours. Griffin (1987) undertook tagging work in the Daly River between 1980 and 1984. Downstream movement was apparent in the Dry season months of July and August. Russell and Garrett (1988) undertook tagging work on juvenile barramundi in tidal creeks of two NE Queensland coastal bays. Within their first year most juveniles were recaptured at the original tagging location in the creeks. After this they moved out to the main estuary and dispersed into adjacent streams and coastal habitats. Distances of 7.6 to 23 km were involved. Moore and Reynolds (1982) studied the migration patterns of barramundi in PNG. Adult *L. calcarifer* released in inland waters migrated to coastal spawning grounds and then returned to the inland areas. Distances up to 622 km were involved. Juveniles left coastal nursery swamps when about 6 months old and became distributed throughout coastal and estuarine regions. A general easterly movement from the Gulf of Papua was apparent. During their second and third year they moved into inland waters.

migrate in the Late-wet–Early-dry season in western drainage channels of the Magela Creek floodplain. A study of upstream fish movements through a central Queensland coastal fishway (within the tidal influence of the Fitzroy River) (Kowarsky & Ross 1981) suggests that more species in the Alligator Rivers Region may be diadromous. The following species used the fishway: mullet (several species including *M. cephalus*), *N. erebi*, *H. compressa*,[262] *Arius* sp., *Melanotaenia* sp., *M. cyprinoides*, *Neosilurus* sp., *A. agrammus*, *S. krefftii*, *A. percoides*, *C. stercusmuscarum* and *G. aprion*.[263] The diversity of fish species was greatest in the summer, as was the peak use by mullet and *N. erebi*, which were generally the most abundant species using the fishladder. *Nematalosa erebi* is frequently observed in freshwater streams after rises in flow, aggregating in large shoals at the base of obstructions such as weirs and rapids (Grant 1978). This behaviour was observed in the present study in Magela Creek just downstream of culverts beneath the Oenpelli Road during the 1978–79 Early-wet season.

The diversity of fish communities decreased with increasing elevation of regular sites (Bishop et al 1990, section 4.2, pp 75–8). The most obvious cause of this reduction in diversity was species dropping out during upstream movements because they could not surmount obstacles in escarpment cascades during the Wet season. The successful species were *M. mogurnda*, *L. unicolor*, *H. fuliginosus* and *M. nigrans*, all of which are frequently found in the upper reaches of escarpment perennial streams. *Syncomistes butleri* and *P. midgleyi* must have comparable migratory abilities, as they are commonly found in escarpment terminal mainchannel waterbodies. Plotosid catfishes are often found upstream in large migrating schools during the Late-wet–Early-dry season in some escarpment habitats.

Migration may be one of the most important survival strategies for fishes in the study area. It is probably an adaptation of major significance in the production of freshwater fish, especially in environments subject to sharp fluctuations or to marked spatial patchiness in habitat fertility. Studies are needed to determine more precisely the degree to which phases of migration regulate the species and size composition of fish communities and the extent to which they would affect the value of ecological monitoring surveys of freshwater fishes in the Region. Only when fishes are in Dry season refuges in pools cut off from rivers and creeks is the composition of the communities relatively stable, at least until predation becomes significant.

Tagging studies of selected fish species (eg *L. unicolor*, *M. splendida inornata* and *N. ater*) from Magela Creek and other sites on its tributaries adjacent to the Ranger Uranium Project Area are required to define the degree of independence of upstream sites from populations downstream of the project area.

4.7 Mortality

The mortality of freshwater fish appears to be greatest at the end of the tropical Wet season when water levels are receding; many fishes are then stranded in drying pools and predation is at a maximum (Lowe-McConnell 1975). Mortality, caused primarily by deoxygenation, desiccation and reduced cover, is also very high in Dry-season billabongs.

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[262] Massive upstream migrations of *H. compressa* have subsequently been reported (Bishop 1993) at the estuary-freshwater interface of the Bellinger River, coastal NSW.

[263] Further studies (Stuart 1997) on a modified version of the same fishway additionally recorded the following species: *A. graeffei*, *M. cyprinoides*, *L. calcarifer*, *C. stercusmuscarum*, *P. rendahli*, *N. hyrtlii*, *L. unicolor* and *O. lineolata*. The bulk of the biomass (70%) was made up of *A. graeffei* of which 81% were immature.

The length-frequency distributions of various fish species in the present study (see biological sections) suggested that for only a few species was adult mortality a seasonal phenomenon. Adults of *A. percoides*, *D. bandata*, *M. nigrans* and *M. splendida inornata* decreased in abundance in samples between the 1979 Late-dry and the 1978–79 Mid-wet seasons; adults of *C. stercusmuscarum* disappeared after the Late-wet–Early-dry season. However, as these effects may result from adult migration to unsampled habitats, further studies are required.

Fish kills at the beginning of the Wet season are common in the tropical coastlands of the Northern Territory. Bishop (1980) related fish kills in Magela Creek at the beginning of the 1978–79 tropical Wet season to physical and chemical changes (mainly low dissolved-oxygen levels); this is just one possible mechanism for natural fish mortality in tropical freshwaters of northern Australia.[264] Bishop (1980) stressed that differentiation between human-induced and natural mortalities is very difficult owing to our scant knowledge of the factors and mechanisms that affect fish survival in such waters.[265]

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[264] Discussing fish kills in the Alligator Rivers Region, Bishop and Forbes (1991) argued that a complex of factors is surely responsible for kills. Which factor is dominant probably depends on annual climatic phenomena such as the severity of the Dry season and the amount of rainfall and hence how rapidly the first flows cover the floodplains in the Early-wet season. It is easy to understand why most fish kills occur in the Early-wet season, as this is when fish are most stressed from deteriorating environmental conditions over the Dry season, and when they are most exposed to terrestrial toxicants that reach waterbodies in concentrated form with first flows. The ability of a species to avoid toxic waters in the first flow period is likely to be the most positive strategy to ensure survival and thus breeding opportunity later in the season.

[265] An example of the complexities involved arises from Bishop's (1994) investigation of a large fishkill in the Middle Fly River of Papua New Guinea in October 1994. Hypoxia was considered to be the primary fishkill mechanism. The major predisposing factors for the kill appeared to be a rapid drop of water levels and a large volume of deoxygenated water present on the floodplain. Conditions leading to the development of the large volume of deoxygenated water were considered to be quite complex. It was considered possible that the deoxygenation could have been induced by the large-scale release of sediments from the Ok Tedi mine further upstream. The sediments could have altered the structure of the river's levees thus altering their hydrology, particularly the rate at which they drain. Greatly enhanced densities of aquatic plants on the floodplains could also have resulted from the sediment inputs. This too would affect the levee formation as well as creating a large additional biomass which would decay and subsequently adversely affect the dissolved oxygen climate of floodplain waters.

5 Conclusions/Synthesis

As identified in Section 1.2, the essential objective of the study was to identify the locations and timing of activities critical in the life cycles of the fish species considered. By cross-relating such knowledge to information on the locations and timing of potential mining-induced physical and chemical (abiotic) impacts, the life-cycle components of those species most at risk can be identified, an important task in impact risk assessment. Clearly, knowledge of the species which might potentially be exposed to abiotic impacts is fundamentally important in the process of understanding and ameliorating resultant biological impacts.[266] Such knowledge is also vitally important when designing and interpreting monitoring investigations which aim to assess the effectiveness of management actions.[267] Such investigations are a fundamental component of any adaptive stream management strategy.[268]

Primary biological/ecological information was obtained and analysed for each of the 37 freshwater fish taxa found in the Alligator Rivers Region in relation to the following generic species-account structure: size composition, environmental associations, reproduction and feeding habits. Each of these components revealed complementary information on the location and timing of activities critical in the life cycles of the fish taxa considered.

5.1 Size composition

Location

Smaller juveniles of the largest number fish species were found in lowland backflow billabongs and floodplain billabongs. These two habitats appear to be particularly important as nursery areas. 'Reservoirs' of large adults of many species were found in floodplain, corridor, escarpment mainchannel and (larger/deeper) lowland backflow billabongs.

Timing

Three types of juvenile recruitment were apparent: Type A: recruitment usually limited to a single season; Type B: continuous recruitment with a few peaks occurring during the year; Type C: continuous recruitment with no apparent peaks (applicable to only one species). Type A recruitment was mainly apparent in the larger fish species. Juveniles of most of these species recruited to their adult populations during the Early-wet and Mid-wet seasons. Type B recruitment was mainly apparent in the smaller fish species. For most of these species the primary recruitment occurred in the Mid-wet season. The secondary recruitment occurred in the Mid-dry season for most, but across all such species it extended from the Late-wet–Early-dry season to the Late-dry season.

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[266] Smith and Pollard (1996) indicated that there are two conceptually distinct elements in fisheries management – the management of the resource itself, and the management of the users (ie the impactors). They further state that resource management activities include research on and regulation of the resource, and fundamentally require a knowledge of the biology and ecology of the fish species involved.

[267] Apart from ensuring the sensitivity of monitoring, through the identification of the potentially most-vulnerable fauna and their lifecycle components, Underwood (1997) indicated that biological information has key importance in developing well-focused hypotheses and selecting the most appropriate statistical procedures (to analyse monitoring data), given that there will be shortcomings if their specific requirements and assumptions are not met.

[268] Sensu Walters (1986)

An examination of variations in body condition indicated that most species obtained their best condition from the Mid-wet to the Mid-dry season, with a peak in the Late-wet–Early-dry season. Seasonal trends in the number of species with poorest body condition were complex, being complicated by the presence of recently-spent individuals in the Early-wet season.

5.2 Environmental associations

Useful information indicative of the environmental associations of 32 fish species was obtained. Three main groups of species were distinguished by characteristic combinations of associated environmental factors: species that typically inhabited the escarpment area (although making incursions to the lowlands in the Wet season), species that typically inhabited the lower reaches of the catchment, and those widely distributed species found in both of these areas. Escarpment associated species were usually associated with low temperature, high DO concentration, low conductivity, low turbidity and coarse substrate. These species therefore displayed a generally 'clean water' association. Accordingly, when they make incursions to the lowlands in the Wet season, or are trapped therein throughout the Dry season, they are potentially the most vulnerable component of the fish fauna to mining induced abiotic impacts. They are therefore likely to be the most useful candidates for monitoring and biological testing.[269]

5.3 Reproduction

Six breeding strategies were exhibited by the fishes studied:

- live-bearing: only the river whaler shark
- buccal incubating: the saratoga, ariid catfishes and mouth almighty
- nest building/guarding (demersal and/or adhesive eggs): the plotosid catfishes, some terapontids, gobiids and eleotrids
- aquatic vegetation attachment (adhesive eggs): melanotaeniids, ambassids, blue-eyes, longtom
- scattering over the substrate (demersal eggs): atherinids and a terapontid
- deposited in the water column (pelagic eggs): tarpon and barramundi in the estuarine or coastal waters, bony bream and archer fish in freshwaters

Species which lay demersal eggs are most prone to impacts associated with siltation, and/or the release of toxic materials from sediments when anoxic conditions develop at depth within waterbodies. Accordingly, such species are therefore likely to be the most useful candidates for monitoring and biological testing.

Location

The most important spawning habitat was the lowland backflow billabongs where 19 species showed evidence of spawning. Four species apparently breed at no other location and are therefore totally dependent on these billabongs. The escarpment area and lowland sandy creekbed habitats were the usual spawning sites for at least 14 species.

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[269] This view was also expressed by Bishop (1987) who examined an extended time series of fish-community data from the Alligator Rivers Region. Bishop also examined the movements of fish within Magela Creek in relation to the effects of the release of mine waste waters. Escarpment-associated species were found to avoid a plume of waste water in the creek, while other species were attracted to the plume.

Timing

Most fish species (25) bred around the onset of the Wet season. This is the time when initial flooding hugely increases the area and diversity of aquatic habitats available as well as initiating major increases in plankton and other foods. No species appeared to breed exclusively during the Dry season, although at least three species had breeding seasons extending from the Mid-dry to the Early-wet seasons. Ten species appeared to have an extended breeding season or to breed continuously throughout the year. These species all showed a peak in reproductive development during the Early-wet season.

5.4 Feeding habits

Nine feeding guilds were identified:

- herbivores/detritivores: two terapontids and Ord River mullet
- microphagic omnivores: bony bream and the blue-eye
- meiophagic omnivores: melanotaeniids and two terapontids
- macrophagic omnivores: ariid catfishes and one terapontid
- microphagic carnivores: ambassids, atherinids and one eleotrid
- meiophagic benthic carnivores: plotosid catfishes, gobiids and one eleotrid
- meiophagic insectivore: archerfish
- macrophagic carnivore/insectivore: saratoga
- macrophagic carnivore/piscivore (peak carnivores): river whaler shark, tarpon, longtom, barramundi and sleepy cod

If biomagnification effects are the focus of future investigations then the peak carnivores are the most suitable candidates for monitoring. Similarly, if exposure to disturbed contaminated sediments is a key factor, then the herbivore/detritivores, omnivores and/or benthic carnivores are the most suitable candidates.

Location

Downstream of the Ranger Uranium Mine (RUM) the highest feeding activity was recorded in lowland backflow billabongs followed by floodplain billabongs. Upstream of RUM the highest feeding activity was recorded in escarpment mainchannel waterbodies followed by lowland billabongs.

Timing

The season of greatest feeding activity was, as other researchers in tropical seasonal rivers have found, the Wet season. Feeding activity increased most dramatically between the Late-dry season and the Early-wet season. By the Mid-wet season feeding activity had peaked, and then decreased slightly by the Late-wet–Early-dry season.

5.5 Importance of lowland backflow billabongs

A finding from the study that stands out is the crucial importance of lowland backflow billabongs to the ecology of the majority of the freshwater fish fauna. They function as key breeding sites during the Wet season,[270] particularly the Early-wet season, for a large range of fish species. Accordingly, they function as important nursery areas through this season. Feeding activity of juveniles and adults is also focused on these billabongs and this continues into the Late-wet–Early-dry season.[271]

5.6 Wider application of the study findings

The detailed information presented in this report constitutes a major contribution to the autecological knowledge of the freshwater fish fauna of the Alligator Rivers Region. Because many of the species have a wide distribution, the information will be valuable to researchers across Australia,[272] especially those working in the Timor Sea, Gulf of Carpentaria and north-east coast drainage divisions (map 3; sensu Lake 1978). It will also be of considerable value in Papua New Guinea and Irian Jaya, as a high proportion of the tropical fish fauna of Australia are also found in these countries. Insights gained into the processes 'driving' the ecology of this tropical riverine fish fauna also have world-wide application.

Importantly, the information arising from the present study will have considerable application when assessing the nature and magnitude of impacts arising from a range of freshwater-associated developments, and particularly those in the mining arena. The risk of errors in such assessments is minimised if i) the necessary background biological/ecological information is available, and ii) if serious efforts are made to source and effectively utilise best-available information.[273]

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[270] The importance of the Wet season flooding cycle can not be over emphasised as highlighted by Bishop et al (1986, 1990) and Bishop and Forbes (1991). Herbert et al (1995) stated that the Wet season flooding cycle was of vital importance to the freshwater fish fauna at Cape York Peninsula – floods rejuvenate habitats, allow colonisation, breeding and migrations of many species.

[271] The high value of lowland backflow billabong habitats to the Alligator Rivers Region's freshwater fish fauna was also emphasised by Bishop and Forbes (1991). In studying the fish movement dynamics within Magela Creek during the Wet season, Bishop et al (1995) concluded that lowland billabongs play a significant role in providing recruits to upstream dry-season refuges – a key ecological process in this seasonally flowing stream. Unfortunately, in 1996, a large lowland billabong system well connected to the Magela Creek mainchannel (the Djalkmara/Indium complex, see DA and IM in Appendix 8) was isolated from the creek system by a bund wall in order that the Ranger Uranium Mine could exploit their Ore Body No 3. The crucial importance of billabong/lagoon systems to the freshwater fish fauna of Cape York Peninsula was emphasised by Herbert et al (1995).

[272] The value of the autecological information is evidenced by its citation (as a draft manuscript) on 57 occasions within Merrick and Schmida's book *Australian freshwater fishes: biology and management*, published in 1984. The Alligator Rivers Region (ARR) studies represent the single largest contribution to autecological information on Australian freshwater fishes ever made. From diffuse sources, there have been gradual, piecemeal additions to knowledge relevant to ARR fish since the time the work was undertaken. The ARR studies were undertaken at a time when there was a research 'culture' favouring investigations aiming to understand key aspects of the biology and ecology of aquatic biota. This culture went 'out of fashion' in the early 1980s, and as a result, more recent contributions to the knowledge of the basic biology/ecology of aquatic biota are quite rare. The current research culture favours investigations into biological patterns and processes using sophisticated experimental designs and associated statistical analyses. Ironically, to be sensitive and well-focused, such investigations require a spectrum of basic biological and ecological information in order to select target biota, develop meaningful hypotheses and designs, select appropriate statistical procedures, and finally, make ecological interpretations of the findings. Given the rarity of such detailed biological and ecological information, the present research culture appears to have 'put the cart before the horse'. Fortunately, this is now not the case for present-culture investigations into the freshwater fish fauna of the Alligator Rivers Region.

[273] A prime example of a situation where such errors can have drastic consequences arises from the Ok Tedi Mining operation in the Fly River catchment of Papua New Guinea, where hundreds of kilometres of the river system has been destroyed by the release of tailings and waste rock. In a review of available biological and ecological information on fauna from the river system, Smith (1998) stated that 'overall the current state of knowledge of the population, community and ecosystem biology of the Fly River system is poor, and this will severely limit the potential for making predictions of the responses of the species assemblages to the Fly River stressors'.

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Appendices

Appendix 1 Sampling site codes

Sampling sites

The following sampling sites are listed alphabetically by site code. Sites AJ, AK, AO and AT, those sampled by Midgley (1973) and referred to in the figures and tables of this volume, are included here.

Further site details are given in volume 1. Table 4 of volume 1 (pp 16–18) lists the sampling sites by catchment and includes information on zones, stream order, map references, grid references, latitude and longitude, elevation above sea level and distance from the estuary. Table 5 of volume 1 (p 19) lists the regularly and occasionally sampled sites, and groups them by drainage system and habitat type.

Code	Site name	Code	Site name
AJ	above Jim Jim Falls	FS	Fishless Billabong
AK	above Kolondjarluk Falls	FX	Flying Fox
AM*	Nabarlek Dam		
AT	above Twin Falls	GA	Goanna Billabong (on Baralil Ck)
AO	above Koolpin Gorge	GD	Magela bed
AU	Adgibongololo Ck	GL	Gulungul Billabong
		GN	Georgetown Billabong
BC	Birraduk Creek	GU	Magela bed
BD	Bowerbird Billabong		
BF	Magela Falls base	ID	Island Billabong
BM	Mt Brockman	IF	Magela riffle
BO	Buffalo Billabong	II	Surshar Billabong
BS	Baroalba Springs	IM	Indium Billabong
BX	Malabanbandju Billabong		
BY	Baroalba stream	JA	Jabiluka Billabong
		JD	Jim Jim Falls base
C1*	Costean 1	JJ	Ja Ja Billabong
C2	Coonjimba 2		
C3	Coonjimba 3	KD	Kolondjarluk (on Kolondjarluk Ck)
C4	Coonjimba 4		
CA	Coonjimba Billabong	LC	Little Coonjimba
CC	Cahills Crossing	LT	Leichhardt Billabong
CD	Bullwidgi Billabong		
CH	Cannon Hill Billabong (on anabranch)	MA	Muriella Park
CL	Corndorl Billabong	MD	Magela bed
CP	Camp 1 (on Kolondjarluk Ck)	MG	Magela bed
DA	Djalkmara Billabong	MI	Mudginberri corridor
DR	Deaf Adder	MJ	Magela bed

* artificial structure

Code	Site name	Code	Site name
MMa	Magela mouth	RS	Radon Springs
MMb	Tidal creek	RT*	Retention Pond 2
MU	Magela upstream		
MX	Magela Crossing	SD	Camp 2 (on Kolondjarluk Ck)
MY	Maybangul Billabong	SR	Namandi
		ST	Sawcut Gorge
N2	Nourlangie 2	SY	Tributary pools (on Hickey Ck)
N3	Nourlangie 3	SZ	Tributary pools (on Hickey Ck)
NC	Nourlangie crossing 2		
NE	Nourlangie East	TD*	Tailings dam
NN	Nankeen Billabong	TF	Magela Falls top
NR	Anbangbang Billabong	TW	Twin Falls
NS	Noranda pools (on Noranda Ck)		
NY	Nourlangie crossing	UU	Magela upstream
RF	Radon Falls	WL	Western Red Lily Billabong (on anabranch)
RH	Rock Hole		
RO*	Retention Pond 1	ZZ*	Bore site

* artificial structure

Appendix 2 Genus species data card B

Genus species card (type B)

The following variables are recorded on the genus species card. Columns on data card (80 columns wide) are shown in parentheses.

Sample reference code (1–17)
Date, time, sampling site, sampling method and mesh size.

Genus and species (18–54)
Generic and specific names follow the usage of the Australian Museum.

Total number (55–58)
Total number of fish per species per sample.

Total weight (59–64)
Total weight (in g x 10^{-1}) of fish per species per sample.

Length: minimum (65–68), maximum (69–72)
Minimum and maximum length (mm, TL or LCF) of fish per species per sample.

Species code (73–77)
Australian Museum fish family codes are used for fish captured during the study or recorded from 'freshwater' habitats. These codes are provided on the following pages and the names are as they appear in the data files.

Card type (80)
Genus species card coded as B.

Code	**Family**	**Genus and species**	**Common name**
00801	Carcharhinidae	*Carcharhinus leucas*	River whaler or bull shark
02301	Pristidae	*Pristis microdon*	River sawfish
03501	Dasyatidae	*Dasyatis fluviorum*	Brown river stingray
05402	Megalopidae	*Megalops cyprinoides*	Tarpon or ox-eye herring
08501	Clupeidae	*Nematalosa erebi*	Bony bream
08502	Clupeidae	*Nematalosa come*	Bony bream
08503	Clupeidae	*Hilsa kelee*	Black-spotted bream
08801	Osteoglossidae	*Scleropages jardinii*	Saratoga
18801	Ariidae	*Arius leptaspis*	Lesser salmon (forktailed) catfish
18803	Ariidae	*Arius leptaspis* *(= Hexanematichthys* sp. A*)*	Lesser salmon (forktailed) catfish
18804	Ariidae	*Arius proximus* *(= Hexanematichthys* sp. B*)*	Grey (forktailed) catfish
18805	Ariidae	*Arius graeffei* *(= Hexanematichthys* sp. C *= Arius australis)*	Blue (forktailed) catfish
19201	Plotosidae	*Anodontiglanis dahli*	Toothless catfish
19202	Plotosidae	*Neosilurus* sp. A	Eel-tailed catfish
19203	Plotosidae	*Neosilurus* sp. B	Eel-tailed catfish
19204	Plotosidae	*Porochilus obbesi*	Obbes' catfish

Code	Family	Genus and species	Common name
19205	Plotosidae	*Neosilurus* sp. C	Eel-tailed catfish
19211–3	Plotosidae	*Neosilurus ater* (3 colour types)	Narrow-fronted tandan, butter jew or black catfish
19214–6	Plotosidae	*Neosilurus hyrtlii* (3 colour types)	Hyrtl's catfish
19217–9	Plotosidae	*Porochilus rendahli* (3 colour types)	Rendahl's catfish
23401	Hemirhamphidae	*Zenarchopterus caudovittatus*	Garfish
24501	Melanotaeniidae	*Melanotaenia nigrans*	Black-banded rainbow fish
24502	Melanotaeniidae	*Melanotaenia splendida inornata (= Melanotaenia maculata)*	Chequered rainbowfish
24503	Melanotaeniidae	*Melanotaenia splendida australis (= Melanotaenia australis)*	Red-tailed rainbowfish
24600	Atherinidae	*Craterocephalus* sp.	Hardyhead
24601	Atherinidae	*Craterocephalus marianae (= Craterocephalus marjoriae)*	Mariana's hardyhead
24602	Atherinidae	*Craterocephalus stercusmuscarum*	Fly-specked hardyhead
24603	Pseudomugilidae	*Pseudomugil tenellus*	Dainty blue-eye or delicate blue-eye
28501	Synbranchidae	*Ophisternon gutturale*	Swamp eel or one-gilled eel
31001	Ambassidae	*Ambassis agrammus*	Sail-fin perchlet or sail-fin glassfish
31002	Ambassidae	*Ambassis macleayi*	Reticulated perchlet or reticulated glassfish
31003	Ambassidae	*Denariusa bandata*	Pennyfish
31004	Centropomidae	*Lates calcarifer*	Silver barramundi
31005	Ambassidae	*Ambassis elongatus*	Yellow-fin perchlet or elongated glassfish
31006	Ambassidae	*Ambassis* sp.	Perchlet or glassfish
32101	Terapontidae	*Amniataba percoides*	Black-striped grunter or banded grunter
32102	Terapontidae	*Hephaestus fuliginosus*	Black grunter or bream
32103	Terapontidae	*Leiopotherapon unicolor*	Spangled grunter
32104	Terapontidae	*Syncomistes butleri*	Sharp-nosed grunter or Butler's grunter
32105	Terapontidae	*Pingalla midgleyi (= Pingalla* sp.*)*	Black-blotched anal-fin grunter or Midgley's grunter
32701	Apogonidae	*Glossamia aprion*	Mouth almighty
35901	Toxotidae	*Toxotes lorentzi*	Primitive archerfish
35902	Toxotidae	*Toxotes chatareus*	Common archerfish
35903	Toxotidae	*Toxotes jaculator*	Archerfish
36301	Scatophagidae	*Scatophagus* sp.	Butter fish or scat
38101	Mugilidae	*Liza alata (= Liza diadema)*	Ord River mullet
38102	Mugilidae	*Liza parmata*	Green-backed mullet
38103	Mugilidae	*Rhinomugil nasutus*	Mud mullet
38104	Mugilidae	*Liza macrolepis*	Mullet
42801	Gobiidae	*Glossogobius giuris*	Flathead goby
42802	Gobiidae	*Glossogobius aureus*	Golden goby

Code	Family	Genus and species	Common name
42901	Eleotrididae	*Hypseleotris compressa* *(= Hypseleotris compressus)*	Northern carp gudgeon or empire gudgeon
42902	Eleotrididae	*Mogurnda mogurnda*	Purple-spotted gudgeon
42903	Eleotrididae	*Oxyeleotris lineolata*	Sleepy cod
42904	Eleotrididae	*Prionobutis microps*	Small-eyed sleeper or gudgeon
42905	Eleotrididae	*Oxyeleotris selheimi*	Black-banded gudgeon
45101	Belonidae	*Strongylura krefftii*	Freshwater longtom
46201	Soleidae	*Aseraggodes klunzingeri*	Tailed sole
46202	Soleidae	*Brachirus salinarum*	Salt-pan sole
46301	Cynoglossidae	*Cynoglossus heterolepis*	Tongue sole

Appendix 3 Biology data card C

Biology card (type C)

The following variables are recorded on the biology card. Columns on data card (80 columns wide) are shown in parentheses.

Sample reference code (1–17)
Date, time, sampling site, sampling method and mesh size.

Species code (18–22)
See Appendix 2.

Fish numbers (23–25)
In each sample, for each species, fish were numbered individually up to 100; these columns record the individual's number. For samples with more than 100 fish per species, 100 fish were randomly subsampled for measurement.

Genus and species (26–58)
See Appendix 2.

Fish length (59–62)
Length of each fish (LCF or TL in mm)

Fish weight (63–68)
Weight of each fish, in g x 10^{-1}

Sex (69)
M = male; J = juvenile or indeterminate; F = female; H = hermaphrodite

Gonad weight (70–75)
Gonad weight recorded (in g) to two decimal places for larger species and to three decimal places for small species.

Gonad stage (76)
Stages I–VII: I (immature virgin); II (developing virgin/recovering spent); III (developing); IV (maturing); V (mature); VI (ripe); VII (spent). The stages are described in detail in the Materials and Methods section in this volume.

Fullness (77)
Coded as follows (adapted from Ball, 1961):

0 = empty; 1 = ¼ full; 2 = ½ full; 3 = ¾ full; 4 = full; 5 = distended and full; 6 = distended, remnants only

Number of stomach contents cards (78–79)
Number of stomach contents cards (type D) used per specimen recorded on biology card

Card type (80)
Biology data card coded as C

Appendix 4 Stomach contents data card D

Stomach contents card (type D)

The following variables are recorded in the stomach contents card. Columns on data card (80 columns wide) are shown in parentheses.

Sample reference code (1–17)
Date, time, sampling site, sampling method and mesh size (if applicable).

Species code (18–22)
See Appendix 2.

Fish numbers (23–24)
See Appendix 3.

Item (25–48, 52–76)
Stomach contents food items. Taxonomic item prefixes (25–27, 52–54) as follows:

Item prefix	Taxon	Item prefix	Taxon
KIN	Kingdom	SBF	Subfamily
SPP	Superphylum	TRI	Tribe
PHY	Phylum	GEN	Genus
SBP	Subphylum	SPG	Supergenus
SPC	Superclass	SBG	Subgenus
CLA	Class	SPS	Superspecies
SBC	Subclass	SPE	Species
DIV	Division	SBS	Subspecies
SPO	Superorder	Miscellaneous:	
ORD	Order	EMP	empty
SBO	Suborder	DEC	decomposed
SEC	Section	DAM	damaged
SPF	Superfamily	LIQ	liquid
FAM	Family	MAT	material

Percentage (49–51, 77–79)
Percentage volume of each food type in stomach contents recorded to nearest 5%.

Card type (80)
Stomach contents data card coded as D.

Appendix 5 Key to length-frequency distributions showing habitat preferences

Shading	Habitat type	SITES	
		Magela Creek	**Nourlangie Creek**
	Escarpment area waterbodies		
▧	Mainchannel waterbodies	BD	ST
	Lowland habitats		
▒	Sandy creekbed sites upstream of RUPA*	MU, MJ, MG	
▨	Sandy creekbed sites downstream of RUPA	GD, MD	NC, NY
▓	Shallow backflow billabongs upstream of RUPA	FS	
▥	Shallow backflow billabongs downstream of RUPA	CL, GL, CA, DA	
◍	Shallow backflow billabongs		NR
░	Channel (deep & steep-sided) backflow billabongs	GN, IM, GA	BX
	Corridor waterbodies		
▩	Sandy mainchannel billabongs	MI	NE, SR
▤	Muddy anabranch billabongs	BO	FX
	Floodplain waterbodies		
■	Floodplain billabongs	ID, JJ, LT, JA, NN	N3

RUPA – Ranger Uranium Project Area

* The position relative to RUPA is not relevant for Nourlangie Creek sites.

Site codes are shown in appendix 1.

Appendix 6 *In situ* means, standard errors and ranges (with sample sizes) of physico-chemical parameters (except visibility) in which various fish species were captured during the study

		Temperature (ºC)				Dissolved Oxygen (mg/L)				pH				Conductivity µS/cm	
Fish species		Range	Mean	Standard error	N	Range	Mean	Standard error	N	Range	Mean	Standard error	N	Range	N
No catch	S	26–41	30.9	0.13	409	1.0–9.7	5.7	0.08	374	4.8–8.6	6.20	0.04	378	2–1600	377
	B	23–34	28.7	0.10	406	0.0–6.7	3.6	0.12	336	4.5–7.4	5.90	0.03	345	2–1600	351
M. cyprinoides	S	23–34	29.8	0.31	76	1.9–9.7	6.2	0.23	68	5.3–9.1	6.45	0.11	69	2–200	68
	B	23–34	28.0	0.27	76	0.2–7.4	2.8	0.27	62	5.2–7.1	6.03	0.06	66	4–280	66
N. erebi	S	23–38	31.0	0.13	229	2.7–9.7	6.3	0.10	189	5.1–8.6	6.21	0.10	200	2–500	195
	B	23–35	28.8	0.17	226	0.2–9.5	3.9	0.14	199	4.8–6.8	5.86	0.14	180	6–480	186
S. jardinii	S	23–33	28.2	0.41	35	3.0–6.8	5.8	0.26	27	4.1–6.8	5.90	0.12	29	6–80	29
	B	23–31	27.3	0.38	35	1.7–6.8	3.8	0.49	14	4.5–6.5	5.80	0.09	26	6–58	24
A. leptaspis	S	26–34	30.3	0.18	248	0.1–9.7	5.8	0.12	201	4.8–9.1	6.10	0.05	230	2–498	226
	B	23–32	28.3	0.14	245	0.2–7.4	2.9	1.68	301	4.3–7.1	5.75	0.04	220	4–478	224
A. proximus	S	29–34	30.0	0.69	7	5.3–7.8	6.7	0.37	7	5.7–6.3	6.20	0.09	17	10–70	7
	B	26–31	26.7	0.69	7	2.0–4.9	3.5	0.41	7	5.2–5.9	5.70	0.12	17	10–58	7
A. graeffei	S	28–31	29.3	0.34	15	4.4–6.5	5.6	0.24	15	6.1–7.0	6.64	0.07	15	10–160	16
	B	27–31	28.7	0.39	15	0.6–4.9	3.2	0.42	15	6.1–7.0	6.60	0.07	15	10–160	16
A. dahli	S	27–33	30.2	0.41	19	4.4–7.4	5.8	0.23	17	5.4–7.0	6.20	0.12	17	6–24	17
	B	26–32	28.6	0.43	19	0.6–6.8	4.5	0.48	17	5.1–7.0	6.11	0.11	17	6–47	17
Neosilurus sp. A	S	22–35	31.3	0.18	102	0.1–8.8	5.8	0.18	74	4.8–8.1	5.90	0.06	88	2–160	86
	B	25–34	29.4	0.18	98	0.4–6.8	3.5	0.19	70	4.5–6.8	5.65	0.18	81	4–234	82
Neosilurus sp. B	S	26–37	29.9	0.18	30	3.3–7.4	5.8	0.23	22	4.5–6.5	5.80	0.11	26	6–58	27
	B	26–30	28.2	0.31	29	0.9–7.4	5.2	0.48	19	5.3–6.5	5.82	0.11	24	6–58	24
Neosilurus sp. C	S	27–41	30.9	0.38	45	3.8–8.8	6.1	0.16	34	4.3–8.8	6.37	0.19	36	6–230	36
	B	27–34	28.9	0.25	44	0.5–6.0	3.3	0.24	28	4.5–7.4	5.97	0.16	31	6–280	32
N. ater	S	23–33	28.5	0.37	55	2.7–8.2	5.5	0.21	50	4.0–7.2	6.10	0.08	49	2–120	48
	B	23–32	27.3	0.33	55	0.6–6.2	3.4	0.25	44	5.3–7.0	5.92	0.40	45	2–70	44
N. hyrtlii	S	25–37	29.4	0.41	45	0.2–9.5	6.5	0.36	36	4.0–8.6	6.30	0.14	36	4–620	37
	B	23–36	27.2	0.39	45	1.0–9.7	3.7	0.43	27	5.2–7.3	6.02	0.08	32	4–620	33
P. rendahli	S	26–38	30.1	0.38	58	1.0–9.7	5.6	0.41	36	4.8–7.7	6.15	0.09	37	2–620	36
	B	23–34	28.0	0.35	58	2.0–9.5	3.8	0.53	26	5.2–7.3	5.98	0.10	26	10–600	28
S. krefftii	Si	24–38	30.4	0.22	113	3.7–9.1	6.3	0.17	76	4.5–8.6	6.42	0.09	75	6–98	78
	B	24–34	28.7	0.21	111	0.2–7.0	3.9	0.27	60	4.5–7.3	6.01	0.07	52	4–78	69

Appendix 6 continued

Fish species		Temperature (ºC)				Dissolved Oxygen (mg/L)				pH				Conductivity µS/cm	
		Range	Mean	Standard error	N	Range	Mean	Standard error	N	Range	Mean	Standard error	N	Range	N
M. nigrans	S	23–35	28.2	0.37	46	3.7–7.2	5.7	0.21	27	3.9–6.7	5.11	0.17	27	4–180	29
	B	23–32	27.5	0.32	42	5.0–6.8	5.6	0.31	6	3.9–6.2	5.30	0.02	15	4–12	20
M. splendida inornata	S	23–40	30.6	0.19	210	0.9–8.2	5.8	0.13	86	4.6–8.3	6.14	0.08	93	2–220	100
	B	23–36	29.5	0.17	207	2.0–6.8	4.9	0.43	22	4.5–7.3	5.92	0.13	36	2–64	40
C. marianae	S	25–40	30.5	0.32	54	3.2–8.2	6.2	0.17	39	4.3–8.3	6.35	0.15	34	4–160	38
	B	23–35	29.6	0.35	53	5.2–6.8	6.2	0.29	6	5.4–7.0	6.15	0.23	6	2–64	14
C. stercusmuscarum	S	25–43	30.9	0.21	144	0.9–8.2	5.7	0.18	48	4.0–8.1	6.14	0.11	56	4–220	60
	B	24–36	29.7	0.19	144	2.5–6.8	5.3	0.45	8	5.1–7.0	6.12	0.19	10	2–110	15
P. tenellus	S	27–38	31.4	0.44	49	5.0–7.8	6.6	0.25	13	5.0–7.1	6.02	0.18	12	6–120	14
	B	25–36	30.1	0.40	48	5.2–5.9	5.5	0.35	2	–	–	–	0	12	1
A. agrammus	S	25–41	31.3	0.27	117	1.3–7.8	5.9	0.18	46	4.8–9.1	6.40	0.11	63	4–220	55
	B	24–38	29.7	0.24	116	2.5–6.8	4.4	0.57	8	4.5–6.7	5.98	0.18	12	6–62	13
A. macleayi	S	25–38	30.6	0.30	88	1.0–9.1	6.2	0.27	35	4.8–7.7	6.19	0.10	44	2–620	42
	B	23–34	29.3	0.28	88	0.5–9.5	4.6	0.46	26	5.3–7.0	6.07	0.09	32	2–620	33
D. bandata	S	25–38	30.0	0.28	87	3.7–7.8	5.9	0.23	25	4.8–8.1	6.36	0.13	31	4–220	31
	B	25–38	29.7	0.27	87	2.9–6.2	4.3	0.97	3	4.5–6.7	6.09	0.27	8	8–60	7
L. calcarifer	S	26–35	30.3	0.63	18	3.0–6.8	5.0	0.33	11	4.0–7.7	6.08	0.27	13	4–160	14
	B	24–33	28.2	0.54	17	0.0–6.8	3.3	0.73	9	5.1–6.3	5.90	0.14	10	4–110	10
Ambassis spp.	S	27–36	30.9	0.39	34	3.7–6.6	5.3	0.34	8	5.5–7.2	6.30	0.52	12	6–160	12
	B	25–35	29.8	0.36	33	5.2	5.2	0.0	1	–	–	–	0	12–170	3
A. percoides	S	23–40	30.2	0.22	177	3.9–9.7	6.2	0.10	116	5.0–8.6	6.25	0.06	129	2–160	129
	B	23–35	28.9	0.19	177	0.2–9.5	4.8	0.20	82	4.5–7.3	6.03	0.04	104	2–230	107
H. fuliginosus	S	23–34	28.2	0.43	43	3.8–7.4	6.0	0.19	31	4.0–6.7	5.57	0.14	17	6–80	30
	B	23–24	27.6	0.43	41	5.0–7.4	6.4	0.26	12	4.5–6.5	5.65	0.15	5	6–12	21
L. unicolor	S	23–40	30.2	0.25	156	0.9–9.1	6.3	0.15	98	4.0–8.6	6.12	0.08	100	6–620	100
	B	23–35	28.9	0.22	156	0.2–9.5	4.5	0.33	60	4.5–7.3	5.84	0.07	72	4–620	76
S. butleri	S	23–34	28.9	0.53	38	5.0–7.4	6.2	0.19	31	4.5–6.7	5.95	0.09	31	2–50	31
	B	23–34	28.4	0.48	37	3.8–7.2	5.7	0.27	20	4.5–6.7	5.71	0.19	27	2–60	29
P. midgleyi	S	23–35	27.6	0.42	41	3.8–8.2	5.9	0.22	28	4.0–7.1	5.40	0.17	26	2–80	29
	B	23–35	27.4	0.43	41	5.0–7.4	5.9	0.25	11	4.5–7.0	5.67	0.18	19	2–64	21
G. aprion	S	25–38	30.6	0.20	158	1.3–9.7	6.2	0.19	73	4.9–8.1	6.30	0.07	84	2–620	86
	B	23–35	29.0	0.19	158	0.2–9.6	4.8	0.37	40	4.5–7.3	5.90	0.09	49	2–100	53

Appendix 6 continued

Fish species		Temperature (ºC)				Dissolved Oxygen (mg/L)				pH				Conductivity µS/cm	
		Range	Mean	Standard error	N	Range	Mean	Standard error	N	Range	Mean	Standard error	N	Range	N
T. chatareus	S	26–36	30.8	0.22	142	4.3–9.7	6.3	0.11	91	4.6–7.2	6.13	0.05	97	2–420	100
	B	24–34	29.5	0.21	139	0.2–7.4	4.1	0.24	74	4.8–7.3	5.84	0.08	83	2–440	86
T. lorentzi	S	29–34	30.2	1.07	6	6.2–7.4	6.9	0.36	3	5.3–6.5	5.70	0.38	3	2–14	3
	B	29–32	29.5	0.67	6	7.4	7.4	0.0	1	5.3–6.5	5.70	0.38	3	10–14	3
L. alata	S	27–35	30.7	0.74	14	0.1–8.0	4.8	0.98	8	5.1–7.4	6.31	0.29	10	8–160	9
	B	26–34	29.7	0.74	14	0.4–3.2	2.4	0.42	6	5.1–7.3	5.94	0.31	7	8–230	8
G. giuris	S	23–38	30.6	0.47	38	5.4–7.4	6.4	0.17	14	5.6–8.3	6.50	0.17	17	4–56	22
	B	23–35	29.7	0.43	38	5.2–6.8	6.3	0.53	3	5.1–6.7	6.20	0.16	5	6–36	8
G. aureus	S	29–36	31.5	1.23	6	6.1	6.1	0.0	1	6.8	6.80	0.0	4	24–160	4
	B	28–33	30.0	0.93	6	–	–	–	–	–	–	–	–	24	1
H. compressa	S	28–36	30.8	0.49	19	3.7–7.8	6.1	0.67	6	5.0–9.1	6.90	0.38	12	4–160	10
	B	27–33	29.9	0.35	15	–	–	–	–	–	–	–	0	18	1
M. mogurnda	S	25–36	30.1	0.31	46	3.0–7.8	5.6	0.24	28	3.9–8.3	5.90	0.23	28	6–200	28
	B	24–35	28.9	0.30	42	2.9–5.5	4.8	0.49	6	3.9–6.7	5.14	0.33	8	4–60	8
O. lineolata	S	26–38	31.1	0.37	63	1.0–9.1	5.9	0.41	23	4.8–9.1	6.36	0.20	24	4–500	25
	B	23–35	29.3	0.36	62	1.7–9.5	4.6	0.56	13	4.5–7.1	6.09	0.19	14	2–480	16

S : surface B : bottom

Appendix 7 Visibility (ranges, means and standard errors with samples sizes) and *in situ* percentage dominance of substrates and hydrophyte types at sites in which various fish species were captured during the study period

	Visibility (cm)*				Substrates								Hydrophytes					
Fish species	Range	Mean	SE	N	Boulder/ bedrock	Rock	Gravel	Sand	Mud	Clay	Leaf litter	N	Emer-gent	Submer-gent	Floating attached	Floating un-attached	N	Veg Occ Index
No catch	1–270	64.7	3.9	332	0.0	3.4	4.2	21.2	39.4	28.6	3.2	1261	25.0	40.2	26.8	8.1	410	69.7
M. cyprinoides	4–270	86.2	7.0	63	3.9	2.2	1.7	16.0	35.9	36.4	3.9	231	20.9	50.0	23.6	5.5	76	78.5
N. erebi	1–360	65.0	4.4	208	0.2	1.5	5.1	17.6	38.0	33.0	4.6	669	24.6	45.4	25.6	2.4	225	73.9
S. jardinii	4–360	130.0	28.0	14	11.9	11.9	0.9	42.2	10.1	13.8	9.2	109	15.7	44.7	28.9	10.5	34	62.2
A. leptaspis	1–360	76.0	4.8	234	0.4	1.4	2.1	11.3	43.6	40.6	1.65	729	24.0	44.6	25.3	6.0	247	79.5
A. proximus	90–210	130.0	20.7	7	0.0	0.0	0.0	0.0	51.0	49.0	0.0	21	3.6	60.7	21.4	14.3	8	100.0
A. graeffei	15–190	117.0	18.8	15	0.0	0.0	0.0	71.1	13.3	15.6	0.0	45	28.5	42.9	14.3	14.3	15	20.0
A. dahli	3–210	136.3	15.8	17	0.0	3.5	0.0	57.9	24.6	7.0	7.0	57	9.1	63.6	27.3	0.0	9	21.1
Neosilurus sp. A	1–270	93.2	7.8	92	0.6	0.3	1.6	31.9	30.3	7.2	7.2	304	35.0	42.3	18.7	4.1	134	70.8
Neosilurus sp. B	15–250	136.0	18.6	15	8.6	19.3	2.2	47.3	5.4	7.5	9.7	93	9.1	22.7	27.3	40.9	29	30.0
Neosilurus sp. C	3–150	41.7	5.8	40	4.4	0.0	6.7	8.9	49.6	25.2	5.2	135	27.7	38.8	26.6	6.6	45	63.6
N. ater	2–360	94.8	12.7	39	0.0	0.0	1.8	24.0	21.7	39.8	3.6	166	24.6	41.5	26.2	8.5	54	65.0
N. hyrtlii	1–170	39.9	6.7	37	1.5	3.0	6.0	14.2	41.8	28.4	5.2	134	21.0	42.5	32.8	3.7	50	64.4
P. rendahli	1–170	31.1	5.1	51	0.0	0.0	6.7	6.7	57.8	28.9	0.0	180	27.2	41.7	25.6	5.5	55	89.8
S. krefftii	1–360	72.1	8.4	80	2.0	2.8	7.1	23.9	36.4	22.7	5.1	352	29.1	43.1	26.1	1.7	115	74.2
M. nigrans	30–200	136.0	31.4	5	22.0	17.0	2.1	39.7	4.3	0.0	14.9	141	32.0	34.0	20.0	14.0	45	23.4
M. splendida inornata	1–270	44.0	4.2	95	3.3	5.4	4.8	32.5	24.7	19.8	9.5	628	34.4	42.6	18.8	4.1	211	72.1
C. marianae	1–130	44.3	13.2	11	0.6	8.1	1.8	62.1	5.6	4.3	17.4	161	34.4	50.8	13.1	1.6	53	46.3
C. stercusmuscarum	2–190	48.0	4.9	67	1.1	5.5	5.0	37.2	21.0	21.0	9.4	438	34.1	44.5	17.8	3.5	148	78.8
P. tenellus	3–360	49.6	14.2	26	1.4	8.3	3.4	12.5	34.0	38.9	1.4	144	37.8	39.4	16.3	6.4	50	91.8
A. agrammus	1–360	32.0	5.4	78	1.0	1.0	4.1	32.1	42.0	10.6	9.2	293	36.6	35.4	24.7	5.0	115	80.2
A. macleayi	1–150	47.6	5.8	59	0.7	3.6	7.8	29.0	27.0	20.4	5.8	279	34.4	41.6	19.1	5.0	82	76.4
D. bandata	1–110	34.8	4.4	52	0.0	0.0	3.0	18.6	43.0	31.6	3.8	263	30.6	43.5	20.7	5.2	86	93.2
L. calcarifer	3–120	54.2	10.2	17	2.6	0.0	0.0	19.2	46.2	26.9	5.1	78	43.1	40.3	12.5	4.2	26	88.9
Ambassis spp.	1–190	36.6	9.6	22	0.0	9.6	1.9	18.3	39.4	24.0	6.7	104	31.1	45.5	20.3	2.1	36	80.0
A. percoides	1–360	111.7	8.2	101	2.5	7.1	3.6	42.8	20.0	15.5	8.6	523	26.4	45.6	22.4	3.6	175	54.2
H. fuliginosus	90–360	180.0	33.5	7	22.3	21.5	2.3	40.0	0.0	0.0	13.9	130	43.5	26.1	4.3	26.1	45	14.6

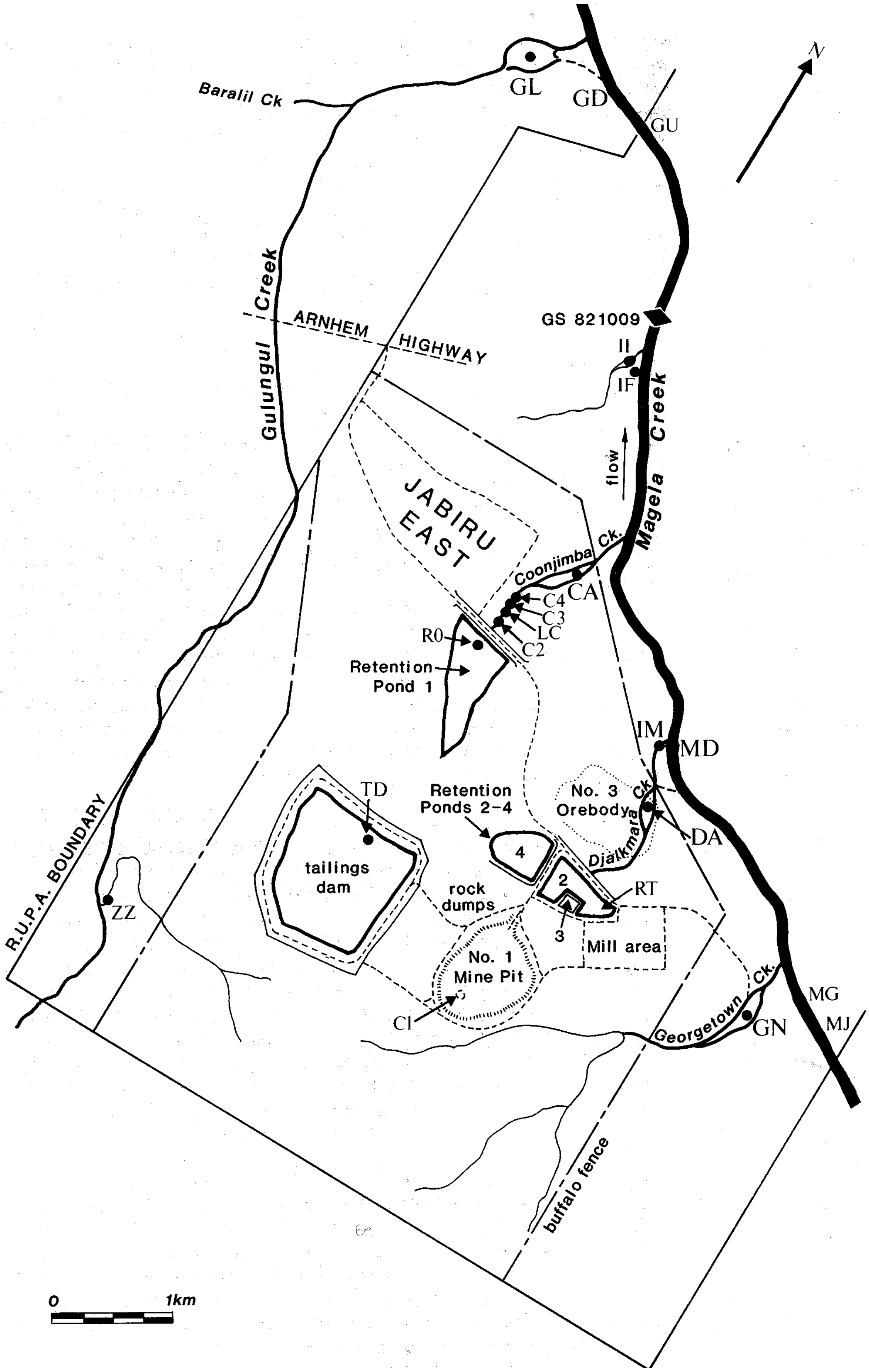
Appendix 7 continued

Fish species	Visibility (cm)*				Substrates								Hydrophytes					
	Range	Mean	SE	N	Boulder/ bedrock	Rock	Gravel	Sand	Mud	Clay	Leaf litter	N	Emer-gent	Submer-gent	Floating attached	Floating un-attached	N	Veg Occ Index
L. unicolor	1–360	62.0	8.0	80	6.7	7.9	7.5	30.3	22.5	17.5	7.5	479	30.1	44.2	22.6	3.1	155	62.7
S. butleri	50–360	171.2	19.4	16	10.6	19.5	0.8	48.0	0.0	11.4	9.8	123	63.2	21.1	0.0	15.8	38	40.0
P. midgleyi	100–360	188.0	46.0	5	20.3	20.3	3.3	45.5	0.0	0.0	10.6	123	17.8	35.7	7.1	39.3	42	27.9
G. aprion	1–200	40.6	4.0	106	2.8	4.0	3.8	22.7	38.2	23.8	4.7	471	30.0	43.6	21.6	5.0	155	86.8
T. chatareus	1–360	82.8	6.5	99	2.1	5.2	5.3	31.7	25.1	21.8	8.7	426	35.1	40.3	21.7	2.8	140	67.8
T. lorentzi	60–130	95.0	35.0	2	22.2	5.6	11.1	50.0	0.0	5.6	5.6	18	0.0	100.0	0.0	0.0	6	17.0
L. alata	1–150	32.8	12.2	13	3.5	1.8	0.0	12.3	66.7	15.8	0.0	57	44.3	40.9	9.8	4.9	20	94.7
G. giuris	1–360	75.8	26.3	13	1.7	11.1	2.6	53.0	11.1	6.8	13.6	117	38.9	45.3	10.5	5.3	44	66.0
G. aureus	10–110	58.3	21.7	6	4.8	14.3	0.0	66.7	9.5	0.0	4.8	21	24.1	48.3	13.8	13.8	6	83.3
H. compressa	3–110	24.6	6.8	17	0.0	8.7	3.5	10.5	56.1	17.5	3.5	57	32.0	46.4	16.0	5.6	19	100.0
M. mogurnda	1–190	24.5	6.8	31	5.8	5.3	2.4	22.2	35.3	20.3	8.7	207	32.0	44.0	17.6	6.5	66	75.4
O. lineolata	1–100	26.3	4.3	46	0.0	2.2	6.4	15.9	49.7	22.8	3.2	189	29.1	44.3	21.0	5.7	63	80.0
Statistics across all sites		66.0	25.7	2218	4.1	6.3	4.0	39.1	29.8	20.8	6.6		27.7	39.5	27.2	5.6		

*Reading here is for 'non-M' visibility

SE = Standard error

Appendix 8 Layout of Ranger Uranium Project Area



Layout of Ranger Uranium Mine Project Area (as at 1979–80) in relation to the Magela Creek drainage system, showing locations of sampling sites not included on map 2. Regular sampling sites are identified by larger type, occasional sites by smaller type.