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Temporal and spatial variations in the macroinvertebrate communities of the seasonally flowing portions of Magela Creek, Northern Territory

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TEMPORAL AND SPATIAL VARIATIONS IN THE MACROINVERTEBRATE COMMUNITIES OF THE SEASONALLY FLOWING PORTIONS OF MAGELA CREEK, NORTHERN TERRITORY.

By

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DECLARATION OF ORIGINALITY

I certify that the substance of this thesis has not been accepted for the award of any other degree or diploma in any university and, to the best of my knowledge and belief, contains no material previously published or written by another person except where due reference and acknowledgement is made.

Emmanuel Tripodi

ABSTRACT

The variations in the macroinvertebrate communities of non-permanent water bodies have received little attention in the past. Those studies which had been conducted were basically descriptive in content and pertained only to the wet-dry transition period. This is the first study (to the best of my knowledge) to describe changes in the benthic macroinvertebrates throughout the tropical wet-season in the Alligator Rivers Region in northern Australia.

The temporal and spatial variations of the macroinvertebrate communities of Magela Creek in Kakadu National Park, Northern Territory were examined over the 1995-96 wet season. Three habitats were sampled (sandy tracts of stream bed, areas of macrophytic growth and leaf litter clumps) at three sites along the seasonally flowing portions of the creek using a modified semi-quantitative, rapid assessment technique employed by the Australian Monitoring River Health Initiative. Several sources of variation were identified. These included the environmental variables of macrophytic, detrital and integrated root mat abundance throughout the area of sampling transects, all of which were found to be significantly affecting the community indices used to describe the benthos (Simpson's Index of Diversity, number of taxa and total abundance). The highly variable flow regime and frequent spates which affected the creek during the study were the likely sources variation in the benthos. Multivariate analyses were used to determine the similarity between macroinvertebrate communities of different habitats, which were found to comprise of two major communities. The generalist detritivores which inhabited the macrophytes and leaf litter packs, and the highly specialised sand inhabiting community.

Although the physical, morphological characteristics of the channel structure of each study site were not recorded, these are believed to be the overall major cause for the variations observed between sites.

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CHAPTER 1: INTRODUCTION

In the past, researchers concerned with variation in the macroinvertebrate communities of freshwater systems have often focussed their attention on permanent water bodies, such as permanent lotic streams and lentic billabongs, lakes and wetlands (e.g., in the Alligator Rivers Region of the Northern Territory; Marchant, 1982; Outridge, 1988; Malipatil and Sharley, 1992). Relative to these studies, seasonal and temporary streams have often been overlooked. However, a reasonable number of reports do exist. These include studies of macroinvertebrates from an Arizona desert stream after flooding (Gray, 1981; Fisher *et al.*, 1982); a temporary "wadi" stream in Iraq (Carl, 1989); a temporary stream in West Algeria (Gagneur and Chaoui-Boudghane, 1991). Australian studies include spate induced disturbance in a tropical temporary stream in Queensland (Smith and Pearson, 1987), the ecology and the over-summering refuges of two intermittent streams in Victoria by Boulton (1989) and Boulton and Lake (1992) respectively.

However, in order to have a sound understanding of the dynamics of an ecosystem, it is fundamental to investigate the temporal and spatial variations which occur in each (or at least most) of the separate components of which it is comprised. In the Alligator Rivers Region for example, it is important to understand not only the dynamics and functions of the residual billabongs which persist after wet season flows have ceased, but also to understand the function of the links which join them and their role in the dynamics of the system as a whole. In this way, conclusions may be reached pertaining to the complete hydrological cycle and faunal variations throughout an entire year or optimally, several years.

In September 1993, at the Alligator Rivers Region Research Institute's (ARRRI)

Biological Monitoring Workshop in Canberra, the attendees drew attention to the lack of knowledge of intermittent streams (and other water bodies) in the region and recommended additional studies be undertaken to redress this issue. At that time, results from biological monitoring programmes were derived from sampling only at a very restricted part of the flow period and from permanent water bodies.

Ecologically, the flow regime of temporary streams is important because it has a significant impact on the life-cycles and behavioural strategies of the invertebrates that utilise it. During the wet season flows, vast areas of the stream bed are reopened for habitation (recolonisation), significantly increasing the size of the available aquatic habitat. For example, the major billabongs in the Magela Creek (Northern Territory) catchment, Bowerbird (7 ha), Mudginberri (5 ha), Coonjimba (14 ha), Djalkmara (26 ha), Georgetown (9 ha), Jabiluka (18 ha) and Leichhardt Billabongs (15 ha) (Outridge, 1988; Finlayson *et al.*, 1994), contribute only a fraction of the total area available for macroinvertebrate habitation when compared to the area along 30-40 km of sandy stream bed during wet season flows. Annual macrophytic growth and fresh leaf litter washed into the channels are made available for colonists and probably provide a release from the intense competition for resources in the confined environment of the billabongs. It is likely that the life-cycle strategies of macroinvertebrates would take advantage of this expansion of the habitat. Predators of macroinvertebrates can also take advantage of the overall proliferation in macroinvertebrate abundance. For example, species of juvenile rainbow fish synchronise their annual upstream migration with this period in the Alligator Rivers Region. In Magela Creek alone, their numbers regularly exceed one million individuals per hour (personal communication, R. Pidgeon, 1996) and prey intensively on macroinvertebrates (personal communication, W. McFarlane, 1996). Barramundi also migrate upstream at this time, taking advantage of both the reestablished links to permanent upstream water-bodies and the increased abundance of food required for juvenile fish. Conversely, when the stream flow

ceases, the size of the habitat shrinks dramatically and often very quickly. Newly established macroinvertebrates must emigrate from the tracts of sand beds or employ other strategies for survival (e.g., diapause and emergence).

Seasonal flooding of a temporary stream after the dry season provides an excellent opportunity to study recolonisation and the temporal and spatial variation of macroinvertebrate colonists, but there have been few such studies. The majority have been largely descriptive, documenting the species present when flow resumes and then speculating on the possible causes of recolonisation (e.g., Harrison, 1966; Hynes, 1975; Williams, 1977; Carl, 1989).

When a temporary stream ceases to flow, aquatic macroinvertebrates must adopt physiological or behavioural strategies to survive and avoid desiccation (Boulton *et al.*, 1992). Most of these strategies are behavioural; stream inhabitants take refuge in permanent bodies elsewhere. When flow resumes the stream is recolonised via four major pathways; drift, vertical migration from the substrate, aerial colonisation and upstream migration (Williams and Hynes, 1976).

Drift, the downstream transport of animals in the current, is likely to be important where permanent water bodies persist upstream. For example, a temporary stream arising from snow melt in the Rocky Mountains of Utah was colonised primarily by the drift from established benthic communities upstream (MacArthur and Barnes, 1985).

Vertical migration from the substrate includes the emergence of resting stages from the dry substratum, as well as colonization from the hyporheic zone. In a temperate intermittent stream in Canada, vertical migration from the substrate was found to be the most important source of recolonisation (Williams, 1977). Morrison (1990) sampled Scottish streams following drought, and concluded that the

majority of colonists had emerged from either aestivating stages in the dry sediment, or in the case of oligochaetes, from the hyporheic zone. In a temporary stream in Victoria (Australia), half of the 91 invertebrate species over-summered in the dry creek bed in refuges that did not hold free water (Boulton, 1989).

Upstream migration has not been investigated in any detail in the literature reviewed.

In contrast, neither Harrison (1966) in Rhodesia nor Hynes (1975) in Ghana found any evidence of resting stages of aquatic insects. Both authors suggested that repopulation by flying insects was responsible for most of the recolonisation in the tropical streams they studied. The "aerial reserve" was also deemed the dominant recolonisation source in Arizona streams after flooding (Gray, 1981, Fisher *et al.*, 1982); in a temporary "wadi" in Iraq (Carl, 1989); in a temporary stream in West Algeria (Gagneur and Chaoui-Boudghane, 1991) and; in a tropical temporary stream in Queensland, Australia (Smith and Pearson, 1987).

Although it may be that the area of the aquatic habitat suitable for recolonisation increases during the wet season flows in tropical streams, the habitat itself is often harsh and unstable. Surges in discharge (spates) are frequent in such flows in northern Australia following monsoonal downpours, and macroinvertebrates have evolved mechanisms to avoid being washed downstream. Although permanent attachment to the substrate would be a sure strategy to avoid involuntary drift, most stream animals move freely. Permanent attachment carries the risk of becoming stranded during the low flow periods of fluctuating water levels and animals which do use this strategy (e.g., freshwater sponges), only survive in areas which are permanently immersed (Moss, 1988). Mobility gives animals the ability to avoid such causes of desiccation, although with greater risk of displacement. For other animals (e.g., mayfly nymphs and beetle larvae), flattened and streamlined

bodies reduce friction with the moving water and claws provide a means of gripping the substrate. The long tails of mayfly and stone fly nymphs help in directing the insects so that they face the current head on, thus minimising the drag created by the flow. Animals such as leeches and snails have an attachment mechanism to secure a hold on the substrate, whereas others possess silk glands which are used to spin pads on the substrate for attachment via small hooks or spines; Lepidoptera and blackfly larvae, respectively (Moss, 1988).

Despite these mechanisms of attachment, displacement and drift downstream is common. The susceptibility and utilization of drift differs for each species, and the complexity of these patterns suggest that drift may not merely be a consequence of living in streams; it may have some adaptive advantages. It results in the rapid recolonisation of newly wetted channels after droughts and tracts denuded by violent spates; drift is also relatively high at times when food supplies are scarce. Hildebrand (1974) showed that drift in animals feeding on algae attached to stones was high when the algae were scarce, allowing dispersal to potentially richer sites downstream. Drift rates of a net-spinning caddisfly (*Plectrocnemia conspersa*) and a 'leafpack inhabiting' stonefly (*Nemurella picteti*) were exceptionally high in a southern English stream when densities of the former were so high (100 m^{-2}) that net-spinning sites were very scarce, and again in summer when leafpacks for the latter were few. In contrast, drift rates were low for another stonefly nymph *Leuctra nigra*, during the same period when its food supply was abundant (Townsend, 1980).

Most of the food and energy flow of upland streams is comprised of the organic detritus washed into the streams, largely as leaf litter from the catchment (Vannote *et al.*, 1980). The litter is then processed by microbes and other animals into progressively finer particles. This is normally the case in the catchments of deciduous woodland forests (Cushing *et al.*, 1983), but in other areas (e.g. the

grazed grasslands of Britain) where forests have been removed or do not occur, shade is replaced by sunlight and macrophytes and epilithic algae provide the majority of the food resource (Moss, 1988).

This study consisted of a series of systematic macroinvertebrate collections from three evenly spaced sites along the sandy, intermittently flowing areas of Magela Creek during the wet season flows. The study sites were all situated along the section of the creek between the western Arnhem Land escarpment and the Magela Creek Floodplain. Benthic samples were taken from three habitats common to each of the study sites, and in areas of the creek which were not immediately downstream of any of the residual billabongs. This was done in order to avoid direct contamination of the samples by macroinvertebrates typical of billabong communities.

The specific objectives of the this study were:

i) to document temporal and spatial variations in the structure of the macroinvertebrate communities in the seasonally flowing portions of Magela Creek (sand channels) during the 1995-96 wet season.

ii) to identify environmental factors that affect the structure of these communities, and

iii) to make recommendations on ways in which biological monitoring designs in seasonally-flowing streams of northern Australia using benthic macro-invertebrates might be refined and improved.

Through the collection of data pertaining to the temporal and spatial variations of the macroinvertebrate communities during the wet-season, and viewing these results in conjunction with wet-dry transition data already collected for the Alligator Rivers Region, a more complete interpretation of the ecological dynamics of the region may be attained.

CHAPTER 2: MATERIALS & METHODS

2.1 Study area

Magela Creek (12° 35′ S, 132° 52′ E) is situated in Kakadu National Park, 250 km east of Darwin in the Northern Territory of Australia, and forms part of the Alligator Rivers Region (ARR) as a major tributary of the East Alligator River. The Magela Creek catchment has an area of about 600 km^2, and consists of a largely undisturbed catchment of sandstone escarpments, open *Eucalyptus*-forested lowlands, floodplains and estuarine wetlands (Outridge, 1988). The area receives an mean annual rainfall of 1560 mm and has an average annual discharge of 420 X 10^6 m^3 (Vardavas, 1988). Average annual evaporation is 2400 mm (Fry, 1979). The creek water is generally very soft and slightly acidic, and natural levels of heavy metals and suspended solids are low (Vardavas, 1988). The creek flows intermittently, usually from mid-December to May, reflecting the heavy monsoonal summer rainfall and a winter drought characteristic of the wet-dry tropics. During wet-season flows, the water levels in the creek fluctuate greatly over short periods of time.

The creek arises in the sandstone plateau of western Arnhem Land, flows over the escarpment into a gorge and then continues through extensive lowlands as an anastomising sandy bottomed stream. Approximately 30 km from the gorge, the stream enters a broad, seasonally inundated floodplain with disjointed drainage lines until finally discharging into the East Alligator River estuary. This study was conducted entirely in the course between the gorge and the floodplain (Figure 1).

Typical of streams found in the ARR, Magela Creek is permanent in the escarpment gorge, but ceases to flow during the dry season (approximately 6 months) within a short distance of entering the lowlands. Its course from the gorge to the floodplain

is dotted with a number of persistent water bodies. These include "backflow billabongs" separated from the sandy stream by a low natural levee, "channel billabongs" positioned in the main channel of the creek, and "floodplain billabongs" which occur in depressions or remnant channels on the floodplain. Further detail and descriptions of geography, climate and major characteristics of the streams of the ARR may be found in Humphrey *et al.* (1990).

Each of the study sites was a 50 m long section of braid(s) which contained a suitable number of habitats within the site from which to collect samples. This was important because it permitted sampling without targeting the same position within the site on consecutive visits. Each site was surrounded by a common riparian zone, composed of the dominant paperbark trees (*Melaleuca viridifolia* Sol. ex Gaertner and *M. nervosa* (Lindley)), white apple trees (*Syzygium* spp.), the freshwater mangrove (*Barringtonia actutangula* (L.) Gaertner) and the western Arnhem Land endemic *Lophopetalum arnhemicum* Byrnes. The dominant shrub around the watercourse was the river Pandanas (*Pandanas aquaticus* F. Muell.) (Brennan, 1992). The stream was homogeneous in its 'fine' sand particle size (400 µm median diameter) (Roberts, 1991).

Aquatic macrophytes emerged and became more prolific as the wet season developed, and included the following; Hydrocharitaceae: *Blyxa* spp., *Maidenia rubra* W.Fitzg. ex. Rendle, *Vallisneria* spp., Xyridaceae: *Xyris* spp., Scrophulariaceae: *Limnophila* spp., Cyperaceae: *Cyperus* spp., *Eleocharis* spp., Eriocaulaceae: *Eriocaulon* spp., Haloragaceae: *Myriophyllum* spp., and Juncaginaceae: *Triglochin procerum* R.Br. (Brennan, 1992). The terrestrial grass (*Pseudoraphus spinescens* (R. Br.) Vick.) was also present in some of the early inundated macrophytic habitats in littoral zones. Three study sites along the course of Magela Creek were selected, representing the upper, middle and lower sections of the creek between the western Arnhem Land escarpment and the Magela Floodplain.

Sites were selected in portions of the creek which would not become contaminated by macroinvertebrates exiting nearby billabongs. The anastomising stream consists of multiple braids which fork (or split) and rejoin one another. Occasionally one of these braids would be temporarily connected to a 'backflow billabong' at times of high flow, when the natural levee which normally separates the braid from the billabong is breached. Therefore, the sampling sites were located either in a braid of the creek running adjacent to 'backflow billabongs' (as for the Fishless and the Georgetown sites), or upstream of 'channel billabongs' (as for the Mudginberri site).

Sampling began as soon as the first sampling site (Fishless) was re-inundated with the first wet season flow. The 1995-96 wet season began earlier than normal (usually commencing mid-December), with Fishless resuming flow on 21st November, 1995. Flow did not commence at the Georgetown and Mudginberri sites until the 12th and 13th of December (1995) respectively, and continued through to mid May 1996, at all sites.

2.1.1 The Fishless study site

The first site (Fishless; **FL**: 12° 43′ 11″ S, 133° 00′ 36″ E) was located approximately 9 km downstream from the escarpment gorge in a braid of the creek north of Fishless Billabong. This was the most upstream of the three study sites and possessed high levees (2-3 m from the stream-bed) and a single narrow channel (12-15 m wide) in comparison to other sites.

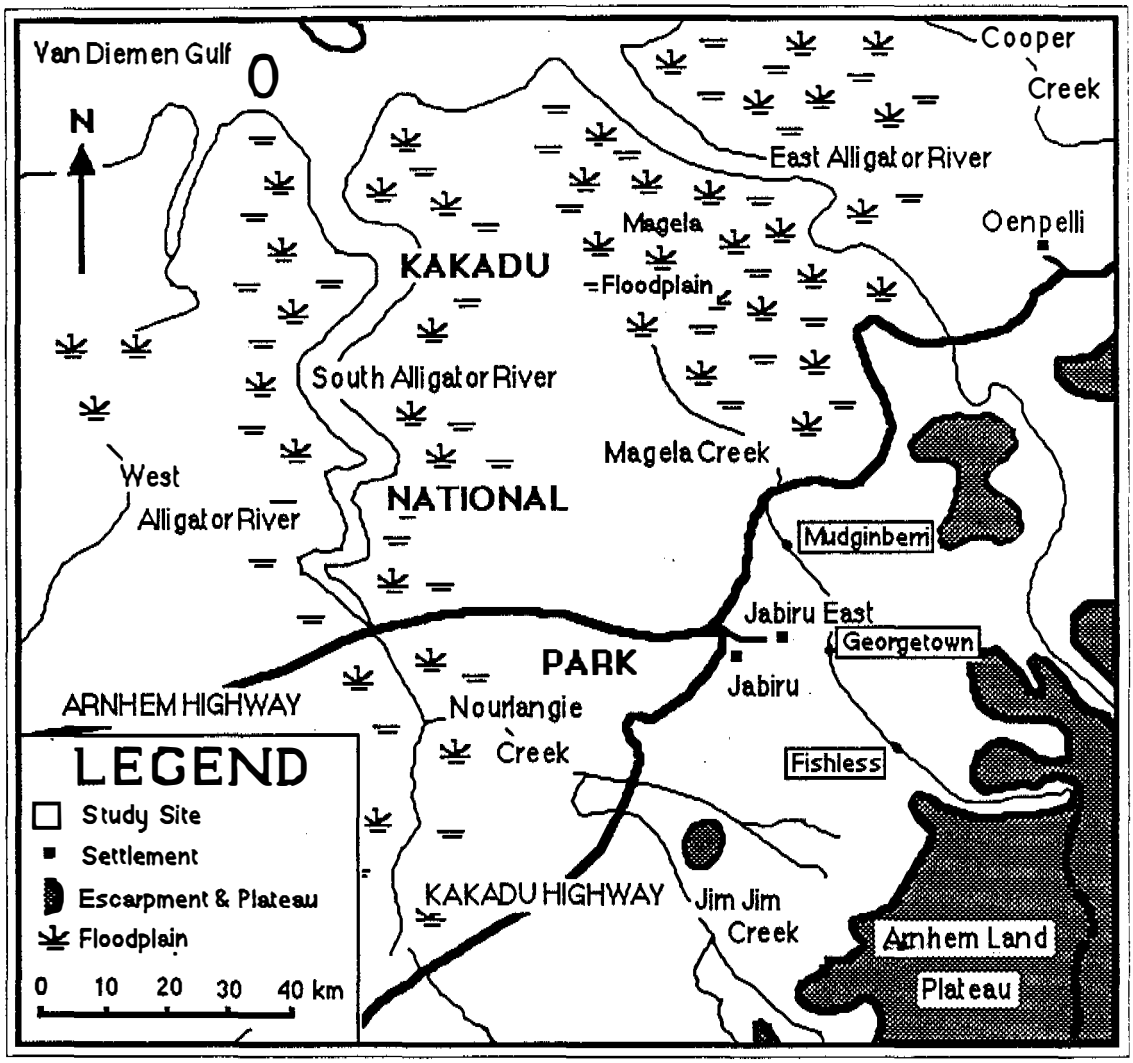


Figure 1: The Alligator Rivers Region.

2.1.2 The Georgetown study site

The second site (Georgetown; **GT**: 12° 40′ 33″ S, 132° 55′ 45″ E) was situated 12 km further downstream from the Fishless site, near Georgetown Billabong. Again, sampling at this site was restricted to the northern braid so that samples would not be contaminated with billabong macroinvertebrates during high flow. The site possessed anastomising braids which were only inundated during spates, and had no levees as such; the banks sloped gently. The width of the study site varied from 12-25 m (which incorporated the intermittently inundated braids or 'side channels'). Georgetown is the overflow point for the ERA's (Environmental Resources Australia, Ltd) Ranger Uranium Mine's retention pond no. 1, and the Office of the Supervising Scientist (OSS) is responsible for monitoring these overflows. As a result, the Georgetown Creek-side Monitoring Station (GCMS) has been established with a permanent gauge marker, used to measure gauge height.

2.1.3 The 'Mudginberri' study site

The third of the study sites (Mudginberri; **MD**: 12° 35′ 55″ S, 132° 52′ 25″ E) was again located 12 km downstream of the Georgetown site, approximately 200 m upstream of Mudginberri Billabong. The main channel was deeper than those at other sites (usually 0.8 m during the wet season compared to 0.35 m at the other sites), and the site possessed anastomising braids and gently sloping banks which functioned similarly to those at Georgetown during spates. The study site had a width which varied between 20 and 35 m, depending on the flow regime.

2.2 Access and travel to study sites

Transport from ERISS to the study sites was via four-wheel drive vehicle, four-wheel drive quad-runner, boat or canoe, depending on the water level and flow conditions, and the condition of the tracks running along-side the creek. A field assistant was always required for the collection of samples and as a 'look-out' for salt-water crocodiles (particularly at Mudginberri).

2.2.1 Fishless

When the water level was high, it was possible to take a small (3m long) flat bottomed boat (or "punt," equipped with two 3 m lengths of rope, buoyancy-vests and oars) from the Georgetown Creek-side Monitoring Station boat-ramp and then 12 km upstream to the Fishless site. The flat bottom was essential for negotiating shallow waters and fallen logs submerged in the deeper portions of the creek. Its small size was also essential to allow access between mid-stream trees and the bank, and to allow it to be dragged over sand bars. The trees throughout the area were marked with flagging tape to assist in finding the site for future visits.

When the water level was low, the punt could not be taken due to a lack of navigable water; instead a quad was required for negotiating the winding, boggy and flooded track on the south side of the creek for sampling at Fishless. A further difficulty in accessing Fishless was the strong growth of spear grass (Poaceae: *Sorghum* spp.), which often concealed the track. To avoid becoming lost, a portable Global Positioning System (GPS) unit with a 'tracking mode' (a Garmin® 450), and in case of an accident or machine failure, a floating emergency satellite beacon were also carried.

2.2.2 Georgetown

Access to the Georgetown site was seldom a problem as the sealed road leading to the Ranger Uranium Mine was only two kilometres from the study site, which could then be reached by one of two tracks, using either the four-wheel drive vehicle or the quad. When water conditions were high however, a canoe was used to cross the main channel and reach the opposite bank, mid-stream 'islands', and other braids.

2.2.3 Mudginberri

The Mudginberri site was reached by four-wheel drive vehicle, taking the Oenpelli Road junction of the Arnhem Highway 5 km west of Jabiru and then turning onto a

dirt track leading to the Mudginberri Aboriginal camp. Another track branching north from the first, led to the study site. The main channel here was deeper than those at the other sites (usually 0.8 m during the wet season), and combined with the nearby location of Mudginberri Billabong and the resident salt-water crocodiles, made the use of a canoe more of a precautionary safety measure than a necessity.

2.3 Methods

2.3.1 Sampling protocol

The sampling strategy was to collect from three macroinvertebrate habitats at the three sites, each with three replications. The collection of macroinvertebrate samples for each site began one day after the particular site resumed flow, with consequent samples being collected on days 3, 7, 14, 21, and fortnightly thereafter, until the recessional flow period (when discharge ceased to fluctuate). Samples from each habitat were collected using a modified semi-quantitative, rapid assessment technique, similar to that employed in the national Monitoring River Health Initiative (MRHI). This technique is currently being used at ERISS in its broader monitoring study. Accompanying physico-chemical data and information on habitat structure were also gathered.

Samples were then stored until processed for examination in the laboratory. Processing of samples involved sub-sampling the larger samples so that they could be examined in a reasonable amount of time (2-3 hours), and the laboratory examination involved the sorting and the identification of specimens from the collected samples.

2.3.2 Measuring physical variables

For each replicate collected, corresponding physical variables were also recorded. Air and water temperature (°C) were measured at the time of sample collection

(using an ethanol based thermometer). Estimates of percentage (%) macrophytic cover, exposed substrate, integrated root mats, and detritus cover in the transect area were also collected for each sample replicate by comparing the cover of each variable to a botanical 'percent foliage cover' aid. This was simply a page of squares, each becoming more and more crowded with dots or blotches than the previous box. The corresponding value of percentage cover was printed below each box.

A field guide to aquatic plants (Saintly & Jacobs, 1994) of tropical fresh-water habitats was used to identify the macrophytes. Surface flow rate as seconds per metre (s/m) was measured by timing a plastic float as it passed by a 1 m metal rod with a wrist stopwatch. This was repeated twice and the average recorded. Average depth (cm) was measured to the nearest 5 cm using the aluminium handle of the net. Gauge height (m) was recorded at the GCMS, from a set of three sequential gauge markers spanning 6 m from highest to lowest recordable gauge heights. These were converted to discharge values by reading the corresponding discharge figure from the ERA "Magela02" table (Appendix IV), by incorporating the cross-sectional area of the creek and the stream velocity when the water was at a particular gauge height. Rainfall figures for Jabiru were collected from the Bureau of Meteorology, Darwin (Appendix V).

2.3.3 Water chemistry sampling

Water sampling was conducted on six occasions and at all three sites during the 1995/96 wet season flows. The following chemical variables were analysed at a National Association of Testing Authorities (NATA) registered laboratory (OSS Interim Report File No: JR-OS-203; Laboratory Job no.: 95026, 96002): pH, conductivity, alkalinity,, turbidity, bicarbonate, sodium, ammonium, potassium, chloride, nitrate, magnesium, sulphate, calcium, orthophosphate, total phosphorus, Total Organic Carbon (TOC), and Dissolved Organic Carbon (DOC). The dissolved

oxygen was not analysed as it was suggested (personal communication Humphrey, 1996) that this variable was consistantly high during the wet season flows.

2.3.3.1 Preparation of bottles for water chemistry sampling

Prior to the collection of water samples in the field, it was necessary to ensure that the sampling bottles did not contain residual materials which would contaminate the samples collected. The treatment and type of sampling bottle taken into the field are shown below (Table 1).

TABLE 1: Water chemistry bottle preparation and storage.

Analyte(s)	Bottle type	Treatment	Storage
pH, conductivity, turbidity, alkalinity, bicarbonate	1L polyethylene bottle.	Soak bottle in Decon®, 10% HNO_3 was, rinse well with deionised water. Fill bottle at sample site.	Store refrigerated.
Na, K, Ca, Mg, $NH\text{-}N_4$, and Cl, $NO_4\text{-}N$, SO_4 (for HPLC)	50 mL Nalgene polyethylene bottle HPLC vials.	Soak vials & bottle in Decon®, rinse well with deionised water. Fill bottle at sample site. Filter sample using Terumo syringe pump & 0.45µm Millex® filter into 2 HPLC vials.	Store bottles vials frozen.
Orthophosphate-P	50 mL Nalgene Polyethylene bottle.	Soak bottle in Decon®, 10% HNO_3 wash, rinse well with deionised water. Filter 50 mL sample from collection bottle & transfer to bottle.	Store frozen.
Total-P	50 mL Nalgene polyethylene bottle.	Soak bottle in Decon®, 10% HNO_3 wash, rinse well with deionised water. Fill bottle at sample site.	Store frozen.
Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC)	200 mL amber glass bottle. McCartney bottles.	Fill bottle at sample site. Fill McCartney bottles according to method (1 total, 1 filtered).	Store frozen.

2.3.3.2 Methods for water analyses

The methods for analysing chemical variables are summarised in Table 2 below. All analyses were performed in a National Association of Testing Authorities (NATA) Australia registered laboratory.

TABLE 2: Water chemistry analyte and corresponding method of analysis.

Analyte(s)	Method of analysis	Reference*
pH	Electrometric	APHA 4500-H+
Conductivity	Electrometric	APHA 2510-D
Alkalinity, Bicarbonate	Acidimetric titration.	APHA 2320-B
Turbidity	Nephelometric	APHA 2130-B
Na, NH4+-N, K, Cl, NO3--N	Ion chromatography	in house (1)†
Mg, SO4, Ca	Ion chromatography	in house (2)††
Orthophosphate-P	UV-Visible spectrophotometric	APHA 4500-PE
Total Phosphorus	Acid Digestion and UV-Visible spectrophotometric and Molybdenum Blue	APHA 4500-PB & APHA 4500-PE
Total Organic Carbon,	Oxidation, IR detection	APHA 5310-D
Dissolved Organic Carbon.	Acidimetric, IR detection	APHA 5310-D

* In: APHA (1994). † In: Noller & Currey (1990). †† In: le Gras (1993).

2.3.3.3 Collection of water chemistry samples

Each water chemistry bottle taken into the field was filled at surface level by immersing the bottle in the middle of the stream and allowing the water to flow through the aperture without any bubbles being formed. Once filled, the bottle's lid was replaced whilst the bottle was immersed to ensure no air was contained in the sample.

2.3.4 Macroinvertebrate sampling

Samples were collected from three habitats at each study site using a triangular headed net (head: 25 cm x 25 cm x 25 cm; netting: 250 µm gauge mesh, 60 cm long, tapering to a rounded point) fastened to a 2 metre long tubular aluminium handle. The handle of the net was notched every 5 cm and was used to measure the sampling transect length (2 m) and water depth (cm) in the field.

The creek's banks and bottom were characterised by three distinct habitats, each of which were sampled during this study (Figure 2). These were (i) the fine to coarse-grained sandy areas of the creek bottom (the *Sand* habitat); (ii) the macrophytic areas which occur at riffle zones and along stretches of the creek bank (macrophytic edge habitat, or more simply *Edge* habitat) and; (iii) the clumps of leaf litter and other organic detritus which accumulated in long masses and deep clumps, usually in areas of very low water velocity, backwaters and eddies (leaf litter habitat, or *Leaf* habitat).

2.3.4.1 Sampling technique

Each of the three habitats required a variation of the basic sampling technique (i.e., collection via the use of a net) for two reasons. Firstly, in order to keep the equipment load light and to remain unencumbered for remote work, it was decided that only one net or sampling device would be used (i.e., the sampling net). Secondly, this decision led to two of the three habitats being sampled quantitatively (the sand and edge habitats), and the third (Leaf habitat) being sampled qualitatively. This was because the sand and edges were usually long and rather flat substrates, whereas the leaf litter often only accumulated in small, deep piles, typically 30-40 cm diameter and 1-10 cm in depth. Thus, the quantitative transects of the sand and edge habitats (which were 2 m x 25 cm = 0.5 m^2) were in contrast to the 'half-filled net' quantification of the leaf litter samples.

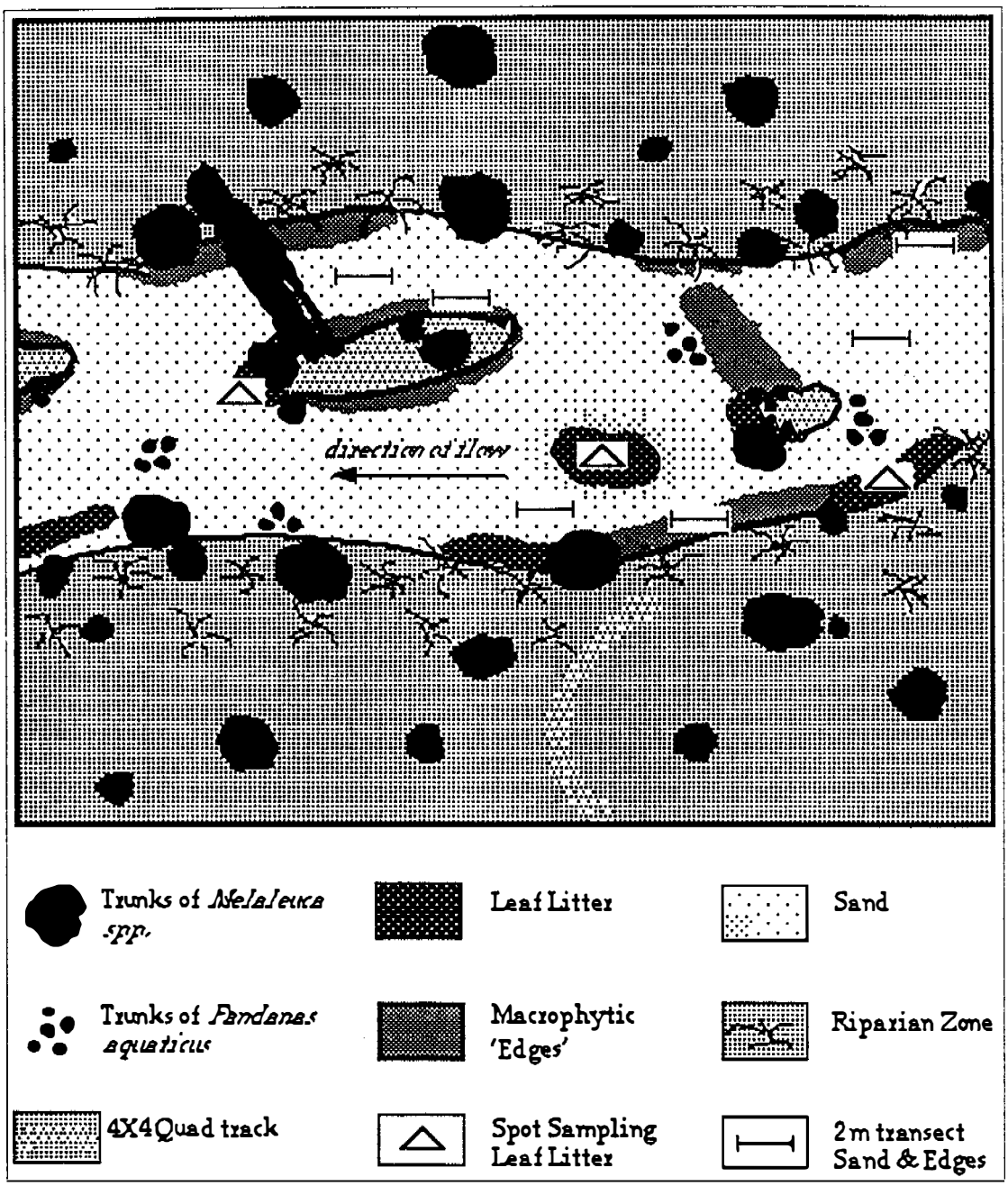


Figure 2: Fishless habitat sampling map.

Samples were collected from areas anywhere within the site which could accommodate a 2 m transect in the required habitat type (for Sand and Edge samples) or a 'spot' sample of anywhere which possessed a leaf litter clump. The Fishless site possessed banks 2-3 m high from the stream-bed and numerous small 'islands'.

2.3.4.2 Collection of sand habitat samples

Representative sand habitat samples were collected from water of varying depths, velocities and organic contents, in order to fully represent its diversity. The collection of the sand samples was achieved by selecting a 2 m long transect of sandy creek bottom, which was any continuous length of that habitat type. The net was held inverted with both hands and the net head was thrust into the sand, moved back slightly and then held until the water flow carried the disturbed substrate into the net. This was repeated 20 to 30 times along the transect and took approximately one minute to complete.

Once collected, the substrate was transferred into a 14 litre plastic bucket of creek water and vigorously agitated. The sand sank to the bottom of the bucket and the invertebrates suspended in the moving water were poured through a nest of two sieves (mesh: 4 mm and 250 μm; 30 cm diameter; brass). A second bucket was used to refill the first and the procedure was repeated another four times (5 in total).

The invertebrates, substrate and detritus caught in the sieve were carefully transferred into a plastic storage pot (10 cm diameter, 12 cm tall, with screw top lids) using a plastic squeegee bottle filled with 70% ethanol as a preservative. The storage pots were labelled to include site, habitat, date and replication number.

2.3.4.3 Collection of macrophytic edge habitat samples

Samples representing the macrophytic edge habitat were collected from random locations within the site boundary which supported continuous stands of macrophytes. Such conditions occurred in riffle zones, on stream banks and the banks of 'islands' between braids. Samples were collected from a 2 m long transect. The inverted net was held with one hand while the other hand uprooted plants and disturbed the substrate. This material was carried by the current into the net.

Once collected, the substrate was transferred into a large plastic bucket of creek water and then agitated vigorously. The macrophytes were transferred to the second bucket and the water and detritus poured through the nest of sieves. The now empty first bucket was refilled and poured into the second containing the macrophytes. This procedure was repeated an additional four times.

The invertebrates, substrate and detritus caught in the sieve were carefully washed down the sides and mesh of the sieve into a storage pot, using a plastic 'squeegee' bottle filled with 70% ethanol. The contents of the 4 mm sieve were also examined for the larger macroinvertebrates (such as the odonates) which could not pass through it or were strong enough to cling to other material caught in that level of the sieve nest. The storage pots were labelled to include site, habitat, date and replication number.

2.3.4.4 Collection of leaf litter habitat samples

Samples representing the leaf litter habitat were restricted to areas where the litter had accumulated. This was in areas of slow or no flow, backwaters with negative flow, and deep eddies. Samples were collected by placing the net beside the leaf clump and pushing a large mass of it into the net. The net was then raised from the water. The net was half-filled on each occasion in an attempt to standardise samples.

Once collected, the leaf litter was transferred into a bucket of water and agitated vigorously. The larger leaves and twigs were transferred to a second bucket and the water poured through the nest of sieves. The first bucket, now empty, was refilled and poured into the second containing the leaves and twigs, which was re-agitated. The procedure was repeated four more times before the leaves and twigs were discarded (except in the case where they were collected-see below).

The invertebrates, substrate and detritus caught in the sieve were transferred into a labelled storage pot and preserved in 70% ethanol. As with the macrophytic edge samples, the 4 mm sieve was examined for larger macro-invertebrates which did not pass through into the 250 μm sieve below.

2.3.4.5 Quantifying leaf litter samples

To quantify the leaf litter samples, the 13 samples collected (one sample taken on each of 13 separate occasions) were kept and stored in a plastic bag after the macro-invertebrates had been removed. These were returned to the laboratory for drying in a thermostatically controlled oven (105 °C) for a minimum of 24 hours, or until constant weight had been achieved. They were separated into fractions of 'leaf' and 'woody material'; each fraction was then weighed on an electronic pan balance to 1 decimal place.

2.3.5 Laboratory procedures

The laboratory procedures were conducted at ERISS and the University of New England (UNE), NSW. Sub-sampling was conducted in the Sample Preparation Laboratory (SPL) at ERISS, while sorting and identifications of the sample contents were conducted at both ERISS and UNE.

2.3.5.1 Sub-sampling

Before sorting and identification, voluminous samples and samples with large numbers of macroinvertebrates were sub-sampled into $^1/_2$, $^1/_4$, $^1/_8$, or $^1/_{16}$ fractions of the original sample (through repetitive sub-sampling) using a Geo-splitter (Figure 3).

The Geo-splitter (named 'Geo' because it was originally designed to divide samples of terrestrial substrates) is a metal box with a grilled top and two drawer-type traps; the spaces between each grill have baffles which are alternately arranged, so

that any material which passes through the top of the Geo-splitter is diverted equally into one of two 'traps' or drawers, effectively separating the sample into two 50% sub-samples.

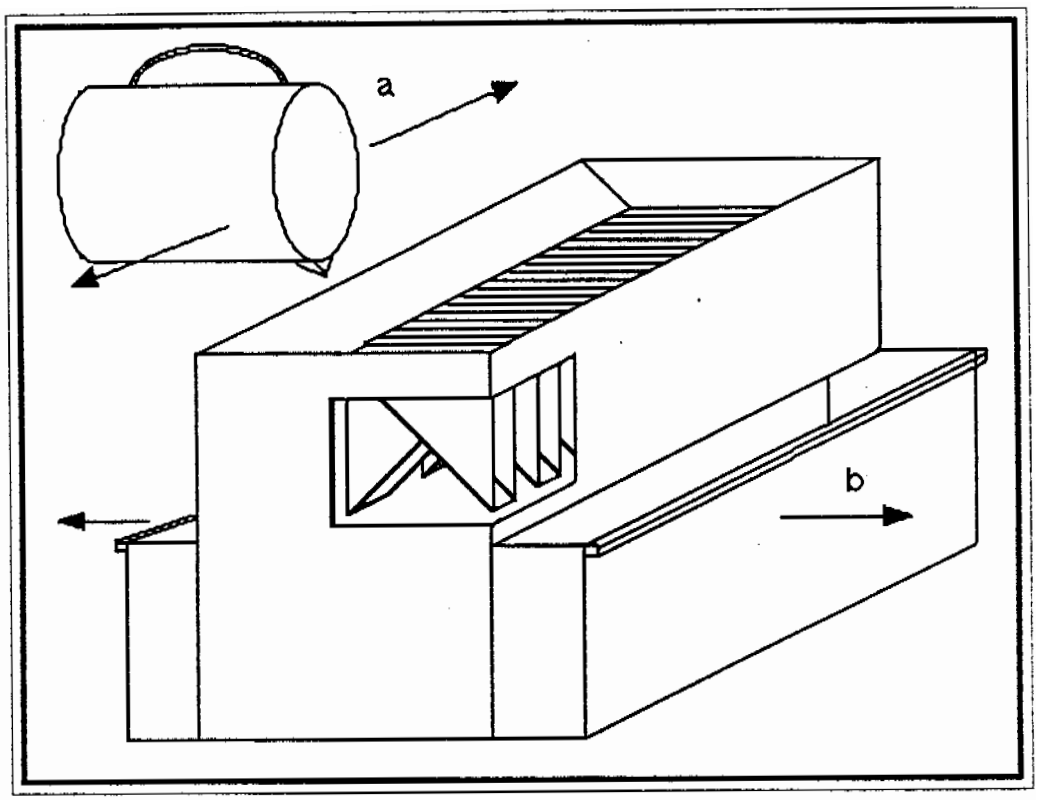


Figure 3: Geo-splitter diagram.

The Geo-splitter is a sub-sampling device. The contents of a macroinvertebrate sample is placed into a large jug (a) with water and then poured over the grill from side to side (a arrows); baffles (see cut-away section) direct the sample contents evenly into two drawers (b), which can the be withdrawn (b arrows) to collect a 50/50 split sub-sample.

The Geo-splitter is placed within a large sink. Samples were then washed out of the storage pot with a hose into a large plastic jug so the mixture could be poured through the grill. To ensure samples were divided accurately, it was necessary to keep the pouring of the sample flowing over different sections of the grill by gently sweeping the jug from side to side. The grill was then washed down with the hose and water so that all the baffles were clear of clinging materials. The Geo-splitter was removed from the sink and the drawer traps withdrawn. This process was repeated until the appropriate fraction of the original sample was obtained (i.e., $^1/_4$, $^1/_8$, or $^1/_{16}$).

A minimum of 100 macroinvertebrates was to be represented in any sub-sample, with a maximum of approximarely 200, so that the time sorting each sample ranged from 2 to 3 hours. This method allowed quantitative values for number of macro-invertebrates per metre squared (m^2) to be reported for the sand and edge habitats, and number of macroinvertebrates per kilogram (kg) of detritus for the leaf litter habitat.

2.3.5.2 Sorting of macroinvertebrate samples

All macroinvertebrates were sorted under a Leica™ stereo dissecting microscope (x10 to x30 zoom magnification) fitted with an external dial controlled light box. Samples were sorted whilst in plastic 'mazes' to avoid overlooking any part of the sample material. These were moulded plastic sorting trays that possessed a winding trough in which the sample material was contained, narrow enough to allow high magnification and still maintain the entire trough 'width' within the microscope's field of view (Figure 4). Two pairs of forceps were required to collect macroinvertebrates from the trays; one for collecting and a second pair for teasing apart algal strands which had become tangled into masses. Sorted macroinvertebrates were stored in small, plastic screw-cap glass vials and labelled with sample number, date of collection, habitat, replication number, and site.

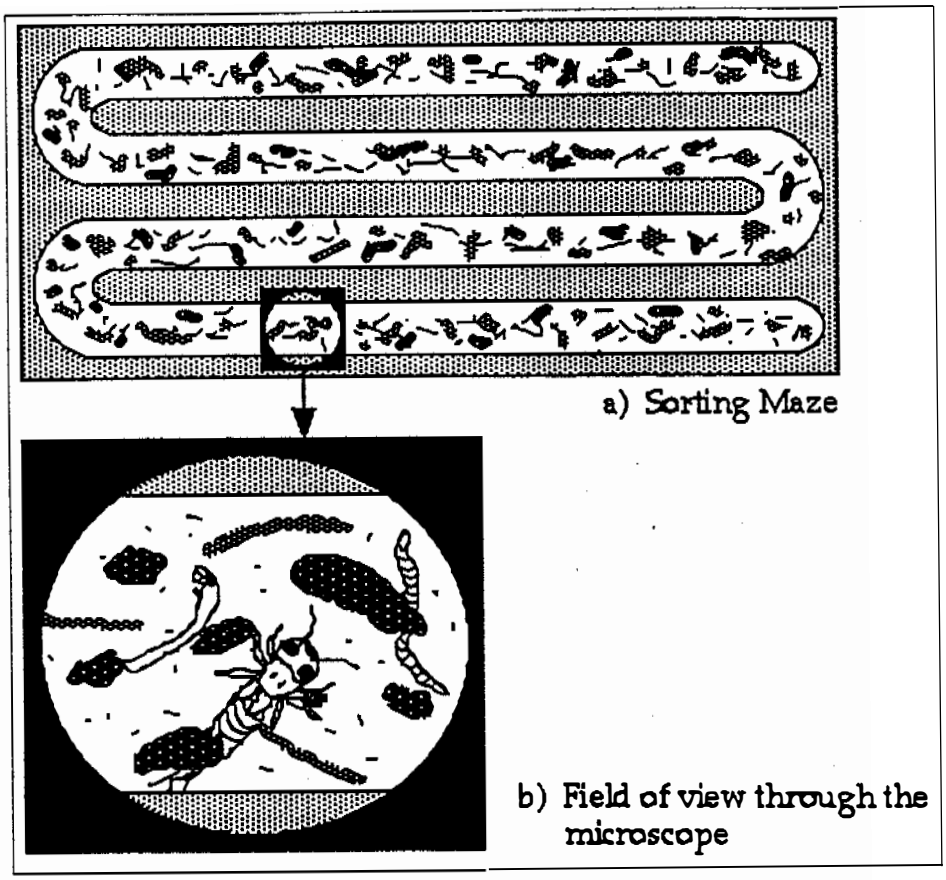


Figure 4: a) Sorting Maze diagram; b) Field of view

The sorting maze (a) was used to sort through macroinvertebrate samples under a dissecting microscope without missing any part of the sample (by following the maze. The field of view through the microscope contained the entire width of the trough whilst being powerful enough to identify macroinvertebrates.

2.3.5.3 Identification of macroinvertebrates

All macroinvertebrates were identified using the appropriate keys (listed below) and with the assistance of colleagues at ERISS. Every new species encountered was identified to the lowest taxonomic level possible in order to properly assess the total number of taxa present. Thereafter, the macro-invertebrates were identified and recorded at the family level.

2.3.5.3.1 Key to the macroinvertebrate Orders

Williams (1980) was used to identify the Insecta and Crustacea and was used to identify macroinvertebrates into orders. A variety of reference material was used depending on the Order of Insecta, outlined below.

2.3.5.3.2 Keys to Insecta Families

2.3.5.3.2.1 Coleoptera

Hawking (1995) was used to identify beetles to the family level. Lawrence (1992) was used to identify the Carabidae, Chrysomelidae, Gyrinidae adults (to genus) and larvae (to family), Hydraenidae adults and larvae (to family), Hydrochidae adults and larvae (to family), and Microsporidae larvae (to family). Dytiscidae were identified using Watts (1978) for adults and Watts (1963) for larvae. Watts (1992) was used to identify the Elmidae adults (to genus) and Glaister (1991) was used to identify Elmidae larvae (to species). ERISS has a Voucher Collection of 10 species of *Austrolimnius* adults, and *Coxelmis, Simsonia* and *Stenelmis* collected from the ARR. Hydrophilidae adults were identified (to genus) using Watts (1992); larvae (to family) in Lawrence (1992).

2.3.5.3.2.2. Diptera

Williams (1980) and Cranston (unpublished, 1995) were used to identify dipterans to family level. The Ceratopogonidae and Empididae have no formal key, however an ERISS Voucher Collection of Ceratopogonidae was used to identify un-

recognised or unnamed species. Chironomidae larvae were identified using Cranston (1991), and the Culicidae in Russell (1993). Simuliidae larvae were identified using Mackerras & Mackerras (1948). The larvae of the Stratiomyidae, Syrphidae, Tabanidae and Tipulidae were identified to family using Cranston (1995).

2.3.5.3.2.3. Ephemeroptera

Hawking (1995) was used to identify the mayfly families. The larvae of the families Baetidae, Caenidae and Leptophlebiidae were identified (to species) in Suter (1992).

2.3.5.3.2.4 Hemiptera

The Belostomatidae have no formal key. Williams (1980) was used to name the Corixidae (to genus). The genera *Agraptocorixa* and *Diaprepocoris* could be named to species using Knowles (1974); *Cymatia* (to species) in Lansbury (1983); *Micronecta* (to species) in Chen (1965); *Sigara* (to species) in Lansbury (1970).

Gerridae were identified to genus using Hungerford & Matsuda (1960). The family Hebridae was identified to species in Lansbury (1990), the Hydrometridae (to genus) in Andersen (1977). The Mesoveliidae has only 1 aquatic genus, *Mesovelia*, with no key to species available. The Naucoridae could be identified to genus in Lansbury (1985); for the ARR, Lansbury (1991). The family Nepidae were named to genus using Williams (1980); the genera *Goondnomdanepa* (to species) in Lansbury (1978) and *Ranatra* (to species) in Lansbury (1972). The family Pleidae has only 1 genus in Australia; *Plea*. The Veliidae were identified to family using Williams (1980); with the genus *Microvelia* identified to species using Malipatil (1980).

2.3.5.3.2.5 Lepidoptera

Only 1 aquatic family is known to be present in Australia; Pyralidae.

2.3.5.3.2.6 Neuroptera

Aquatic lace-wings were identified to family with Williams (1980).

2.3.5.3.2..7 Odonata

Hawking (1995) was used to identify odonates to the family level. All nymphs could be identified (to species) using Hawking (1993) except for the following genera: Aeshnidae-*Anax;* Libellulidae-*Nannophlebia.*

2.3.5.3.2..8 Trichoptera

The caddisfly families Calamoceratidae, Helicopsychidae, Hydropsychidae, Philopotamidae, Hydroptilidae and Psychomyiidae (1 species recorded) could all be identified to species, and all Ecnomidae (to genus) and Polycentropodidae (to 2 monospecific genera) in Wells (1991). The Leptoceridae genera *Leptocerus* (1 species), *Leptorussa* (1 species), *Oecetis* (to species) and *Triplectides* (to species) are also covered in Wells (1991), although *Triaenodes* has no formal key.

2.3.5.3.3 Keys to Hydracarina Families

The families of Hydracarina were identified using the ERISS Voucher Collection for water mites, with the assistance of ERISS colleges, and Harvey (unpublished).

2.3.5.3.4 Keys to Crustacea

The reference for Crustacea (to family/genus) was Williams (1980).

2.3.5.3.4.1 Decapoda

Families of the Decapoda are described in Williams (1980). The families Atyidae and the Palaemonidae could be identified to species with Horwitz (1995).

2.3.5.3.4.2 Isopoda

Isopod families are described in Horwitz *et al.* (1995), and there is a Phreotoicidae voucher specimen at ERISS which could be referenced.

2.3.5.3.5 Keys to Mollusca

Aquatic snails (Gastropoda) were identified to genus in Williams (1980) and Smith & Kershaw (1979), with the Bivalvia identifiable to genus in Williams (1980).

2.3.5.3.6 Oligochaetae

All oligochaetes were classed at the Order level because identification to family level is difficult and time consuming, thus no key for worms was required.

2.3.6 Data analysis

Prior to any of the statistical analyses being conducted, all data were converted to quantitative measures of macroinvertebrate abundance according to the habitat sampled. Firstly, all sub-sampled samples were multiplied by the inverse of their respective sub-sample fraction to give numbers equating to a full sized sample (e.g., counts relating to $^1/_2$ sub-samples were multiplied by 2). Thereafter, for the sand and macrophytic edge habitat samples, raw data were multiplied by two to convert macroinvertebrate numbers in the sample (equivalent to 0.5 m^{-2}) to numbers per metre squared (m^{-2}); for the leaf litter habiat, macroinvertebrate numbers were multiplied by 4.42 in order to convert them from numbers per sample to numbers per kilogram of detritus (kg^{-1} leaf litter) (see Appendix I). Finally, all data were $\log_{10}$ transformed to normalise the distribution of the populations.

Analyses to determine the spatial variation in the macroinvertebrate communities comprised of samples from all three sites, habitats and 3 points in time. These samples were also used to observe temporal changes, however, in order to gain

results for the temporal variations at 'higher resolution' through time, the Georgetown site samples were analysed across 7 points in time. The reasons for this were two-fold. Firstly, the observed temporal changes for data sets pertaining to 3 points in time over the wet season meant that each group of samples were separated by approximately 65 days. This was considered to be too long to uncover successional changes and the appearance or dissappearance of particular taxa in the samples. Secondly, the stream morphology and flow characteristics at Georgetown were more applicable to the course of Magela Creek as a whole. It was not narrow, with high levees and without anastomising braids which only became inundated during spates as Fishless was, and it was not immediately upstream of a large channel billabong as Mudginberri site. Hence, the Georgetown site was considered to be morphologically 'neutral' to the effects of physical and chemical variations in flow regimes.

2.3.6.1 Statistical analyses

Three forms of statistical analyses of data were used to determine the spatial and temporal variation of the Magela Creek samples. These were Correlations, one-way repeated measures ANOVA and PATN® multivariate analysis, each of which is described below.

2.3.6.2 Correlation of physical variables & community indices

The correlation of the physical variables to community indices were computed using MINITAB®. The physical variables measured corresponded to each replicate collected in the field, so no averaging of the community indicie data was required. Physical variables were compared to the corresponding Simpson's Index of Diversity, number of taxa and abundance values for each replication collected.

2.3.6.3 Correlation of chemical variables and community indices

The correlation of the chemical variables to the community indices were computed using MINITAB®. In order to properly configure the data for the correlation, it was necessary to calculate the mean values for Simpson's Index of Diversity, number of major taxa, and mean total abundance for each habitat, at each of the 3 sites, and for each of the 3 sampling dates. Thus the final matrix for correlation consisted of an equal number of rows (i.e., 9 rows of data; 3 habitats at 3 times at 3 sites).

2.3.6.4 One-way repeated measures ANOVA and community indices

One-way repeated measures ANOVA was used on the data of each habitat and at each of the three sites and times, to find significant temporal and spatial variations of the macroinvertebrate community indices. This technique produced figures which indicated whether there were significant differences between sites, times, or if there were any significant Site*Time interactions.

2.3.6.5 Multivariate analyses: PATN®

PATN® was used to explore patterns in data of the major taxa in each of the three habitats from one site (Georgetown) at 7 points in time during the 1995-96 wet season. This was done because it was believed that in order to properly observe successional changes that may have occured during the study period (if any), three points in time (i.e., every 65 days) were insufficient.

Belbin and McDonald (1993) compared three clustering algorithms and concluded that PATN® (as a Flexible-UPGMA algorithm) was the most accurate in determining the 'true' ordination of a fabricated data set (when compared to TWINSPAN® and ALOC®). The Bray-Curtis coefficient was used to generate an association matrix and cluster analysis used UPGMA (ß=-0.1) to generate a dendrogram (Figure 10). Ordination of the association matrix used semi-strong hybrid multidimensional scaling (SSH) a non-metric algorithm, to ordinate the data

in 3 dimensions (2 dimensions presented Axis 1 and Axis 2) and 50 random starting configurations were used (Figure 9).

The principle components correlation (PCC) was used to produce ordination vectors of the major taxa found to be most strongly correlated with the observed patterns.

CHAPTER 3: RESULTS

3.1 Physical variables

The measurements of physical variables were recorded for each replicate collected. These measures were correlated with the calculated community indices (i.e., Simpson's Index of Diversity, number of taxa and abundance) for each replicate using MINITAB®. The physical variables correlation coefficients are presented in Appendix II. It should be mentioned however, that with 79 degrees of freedom in the physical variables data set, all significant physical variables correlations should be considered as being weak since they are all very likely to be significant (personal communication, S. Cairns, 1996). Raw data is presented in Appendix IX.

3.1.1 Air and water temperature

Although the data pertaining to air and water temperature (Appendix IX) were incomplete and could not be analysed in conjunction with other data sets, both air and water temperatures recorded from the 4th of January to the 1st of May (1996) were consistently between 30.0°C and 36.0°C and were not likely to be a source of significant variation in community indices.

3.1.2 Percentage macrophytic cover

Percentage macrophytic cover was positively correlated to all three community indices. Simpson's Index of Diversity was significantly correlated at the 5% level ($P<0.05$, DF=79, $r>0.220$), and both number of major taxa and mean total abundance were significantly correlated at the 0.1% level ($P<0.001$, DF=79, $r>0.361$).

3.1.3 Percentage exposed substrate

Percentage exposed substrate was also positively correlated for all three community indices, each significant at the 1% level ($P<0.001$, DF=79, $r>0.361$).

3.1.4 Percentage root mat cover

Percentage root mat cover was found to be significant for the number of major taxa at the 0.1% level ($P<0.001$, DF=79, $r>0.361$) and mean total abundance significant at the 5% level ($P<0.05$, DF=79, $r>0.220$).

3.1.5 Percentage detritus cover

Percentage detritus cover was found to be positively correlated to Simpson's Index of Diversity at the 0.1% level ($P<0.001$, DF=79, $r>0.361$).

3.1.6 Discharge at Georgetown (and corresponding rainfall)

The gauge height data are presented in Appendix III. Rainfall figures are presented in Appendix V. Although there were no significant correlations between community indices and discharge, the discharge graph demonstrates the frequency and severity of spates in Magela Creek induced by monsoonal rainfall. The figures for discharge and rainfall are graphed in Figure 5.

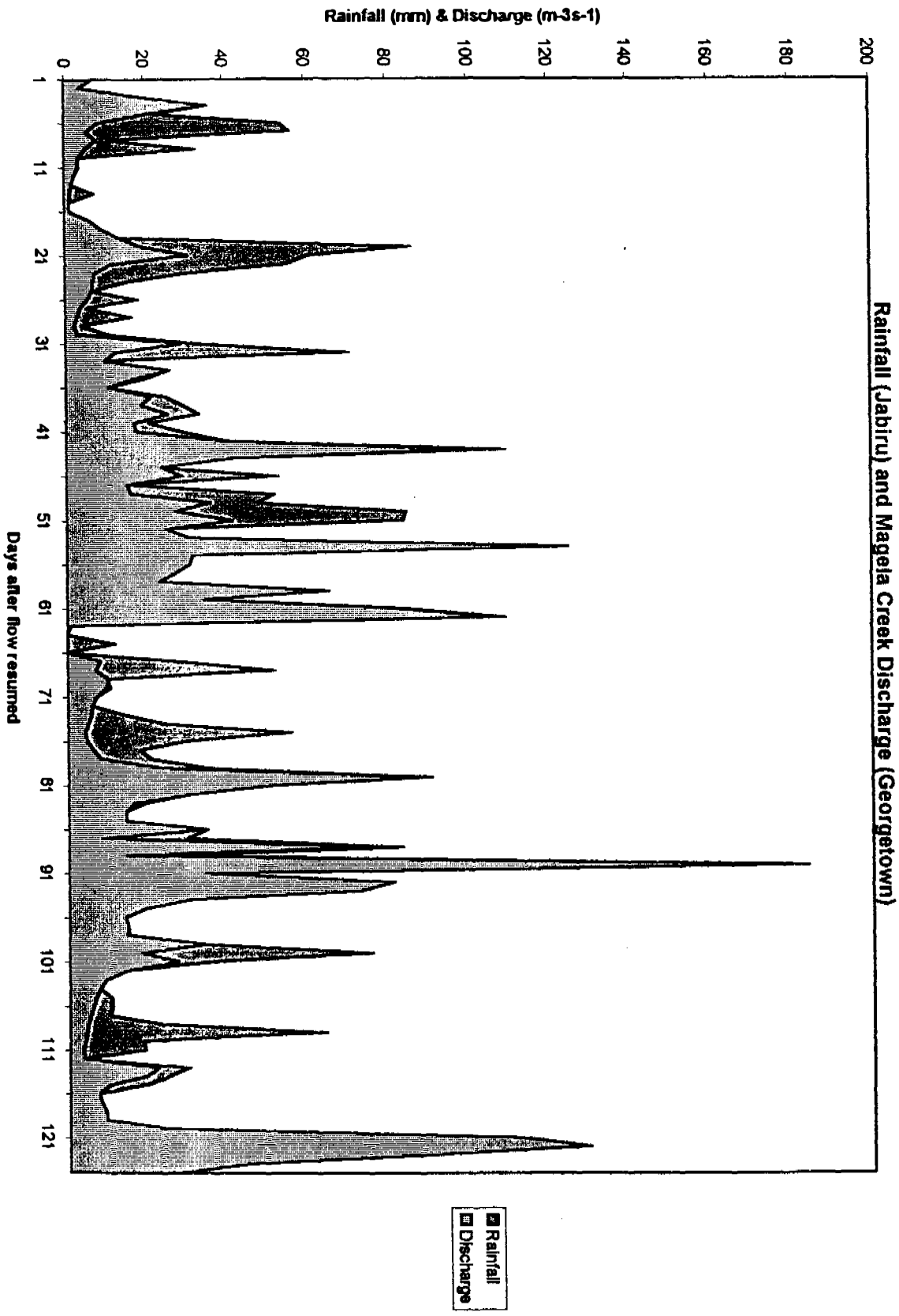


Figure 5: Rainfall (at Jabiru) & discharge (at Georgetown Creek-side Monitoring Station).

3.2 Chemical variables

The results for the chemical variables were received from the NATA laboratory and are presented in Table 3. These results were correlated with the averaged macroinvertebrate data (i.e., for Simpson's Index of Diversity, number of taxa and abundance) for each of the corresponding sampling dates using MINITAB®. The chemical variables correlation coefficients are presented in Appendix VI.

TABLE 3: Changes in chemical variables in the Magela Creek flows during the study (Dec 22, 1995 - May 1, 1996).

Study Site	**Fishless**			**Georgetown**			**Mudginberri**		
Days after flow	1	64	141	1	64	141	1	64	141
pH	6.0	5.3	6.3	6.2	5.8	6.6	6.3	6.2	6.6
Conductivity (µS/cm)	14	12	11	21	9	19	19	12	19
Alkalinity (mg/L $CaCO_3$)	1.1	<0.2	1.9	2.9	0.7	3.2	2.4	1.6	4.6
Bicarbonate (mg/L HCO_3)	1.30	<0.20	2.30	3.50	0.85	3.90	2.90	2.00	5.60
Turbidity (NTU)	1.1	0.0	0.0	2.5	0.0	0.0	2.6	0.0	0.0
Sodium (mg/L Na)	1.0	0.8	1.2	1.2	0.7	1.3	1.2	0.9	1.9
Ammonium (mg/L N)	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potassium (mg/L K)	0.16	0.14	0.06	0.36	0.14	0.05	0.38	0.24	0.11
Chloride (mg/L Cl)	2.1	1.6	1.7	2.3	1.2	1.9	2.3	1.5	2.1
Nitrate* (mg/L N)	3.50	7.44	0.00	0.00	0.54	0.00	0.00	1.54	0.00
Magnesium (mg/L Mg)	0.42	0.32	0.46	0.53	0.22	0.57	0.70	0.37	0.88
Sulphate(mg/L SO_4)	0.15	0.08	0.66	0.25	0.04	0.23	0.97	0.21	1.27
Calcium (mg/L Ca)	0.09	0.06	0.14	0.31	0.14	0.41	0.41	0.24	0.48
Ortho-P (mg/L P)	0.00	0.00	0.006	0.00	0.00	<0.002	0.00	0.00	0.00
Total-P (mg/L P)	0.000	0.000	0.015	0.002	0.000	0.002	0.070	0.057	0.000
TOC (mg/L C)	3.0	2.1	17	4.8	4.4	3.3	4.5	4.0	2.4
DOC (mg/L C)	1.9	2.0	18	3.8	4.3	3.5	3.8	4.1	2.3

* samples were regarded as contaminated and nitrate was not statistically analysed for correlations.

The results of the MINITAB® correlations were significant ($P<0.05$) when $r>0.666$ (DF=7). The only positive correlations found to be significant were between alkalinity (and the alkaline derivatives of bicarbonate and sulphate) and the mean total abundance of macroinvertebrates in the leaf litter habitat. Otherwise, results

show that the concentrations of chemical variables were low (Table 3).

3.3 Macroinvertebrate communities of Magela Creek

At the end of the sampling phase of the study, a total of 306 samples had been collected (Appendices VII and VIII). Of these, 117 were sub-sampled (where required), sorted and identified. 50 macroinvertebrate families and three higher taxa were identified from the field. Of these, 10 families were from the order Coleoptera; 5 families from the order Diptera; 3 from Ephemeroptera; 2 from Hemiptera; 1 from Lepidoptera; 5 from Odonata; 6 from Trichoptera; 2 from Copepoda; 3 from Malacostraca; 2 from Ostracoda and; 11 families of the sub-order Hydracarina. In addition, 2 classes of Mollusca and Nematoda were recognised.

3.3.1 Grouping of taxa

Macroinvertebrates of different orders were identified to different taxonomic levels, depending on the availability of keys, condition of the specimens and the time allotted for identification of specimens (e.g., mounting of chironomids was not contemplated for identification beyond the sub-family level). Table 4 lists the 119 minor taxa of macroinvertebrates identified during the study, and shows the 16 major taxa groupings which were used both for the one-way repeated measures ANOVA and PATN analyses. The macroinvertebrates were analysed at higher taxonomic levels (shown below) than that to which they were initially identified, because the raw data sets were too variable at lower taxons to give reliable results (Gauch, 1982).

Table 4: The 16 major and 119 minor macroinvertebrate taxa recognised.

Insecta	Family	Genus/species
COLEOPTERA	(sub-) Bidessinae	*Bidessus* spp.
	Curculionidae	
	Dytiscidae	OSS 3A, 4A, 6A, 8A, 9A, 11A
		Antiporus spp.*, (incl. OSS 11A)
		Costonectes spp.
		Hyderodes shuckardi
		Hydraticus spp.*, (incl. OSS 4L, 6L)
		Hydravatus spp.
		Lancetes spp.
	Elmidae	*Austrolimnius* spp.*, (incl. OSS 1L, 2L, 3L, 4L, 8L)
	Gyrinidae	*Macrogyrus* spp., OSS 1A
	Haliplidae	*Halipus* spp.
	Hydrophilidae	*Berosus* spp.*, OSS 1L, OSS 5L
	Noteridae	OSS 1A, OSS 1L
	Staphylinidae	
	Scirtidae	OSS 1L, OSS 2L

Diptera	Family	Sub-family	Genus/species
	CHIRONOMIDAE	Aphroteniinae	
		Chironominae*	
		Orthocladinae	*Pseudosmittia* spp.
		Tanypodinae*	
	CERATOPOGONIDAE*		(incl. OSS 1L, 2L, 3L, 5L, 6L, 8L, 9L, 10L)
	SIMULIIDAE		*Simulium* spp*, (incl. *S. papuense*)
	Tabanidae‡		*Tabanus* spp.*, OSS 1L
	Tipulidae‡*		(incl. OSS 1L, 2L, 4L, 5L)

Ephemeroptera	Family	Genus/species
	BAETIDAE	*Baetis* spp.*, OSS 1N, OSS Genus C sp. 1
		Cloeon fluviatile
	CAENIDAE	*Tasmanocoenis* spp.*, (incl. OSS sp. D, E, H, L)
		Wundacaenis dostini
	LEPTOPHLEBIIDAE	*Bibulmena* spp.*, (incl. OSS 2N)
		Jappa spp.

HEMIPTERA	Family	Genus/species
	Corixidae	*Micronecta micra*
	Gerridae*	(incl. OSS 4N)

Lepidoptera‡	Family	Genus/species
	Pyralidae*	(incl. OSS 1L, 9L)

ODONATA	Sub-order	Family	Genus/species
	Anisoptera	Aeshnidae	
		Gomphidae*	(incl. *Ictinogomphus australis, Antipodogomphus neophytus, Austrogomphus mjobergi*)
	Zygoptera	Isostictidae*	(incl. *Rhadinosticta handshini, Eurysticta kununurra*)
		Coenagrionidae	*Pseudagrion microcephalum*
		Corduliidae	*Hemicordulia* spp.*, (incl. *H. intermedia*)

Table 4: *Continued...*

Trichoptera (ALL NON-LEPTOCERIDAE)	**Family**	**Genus/species**
	Calamoceratidae	*Anisocentropus muricatus*
	Ecnomidae	*Ecnomus* spp.*, (incl. *E. veratus*)
		Ecnomina spp.*
	Hydropsychidae	*Cheumatopsyche* spp.*, (incl. *C. suteri*)
	Hydroptilidae	*Hellyethira* spp.*, (incl. *H. forficata, H. eskensis, H. cubitans, H. ramosa*)
		Orthotrichia spp.*, (incl. *O. turrita, O. velata*)
		Oxyethira spp.*
		Tricholeiochiton spp.
	LEPTOCERIDAE	*Oecetis* spp.*
		Leptorussa spp.*
		Triaenodes spp.*, (incl. OSS 1L)
		Triplectides spp.*, (incl. T. helvolus, T. cuiskus)
	Philopotamidae	*Chimarra* spp.
Annelida	**Class**	
	Hirudinea‡*	
	OLIGOCHAETA*	
	Polychaeta‡ †	

CRUSTACEA	**Order**	**Family**	**Genera/species**
Copepoda*		Calanoidae	
		Cyclopoidae	
Malacostraca	Decapoda	Atyridae*	(incl. *Paratya* spp.)
		Palaemonidae	(incl. *Macrobrachium rosenbergii*)
		Sundatelphusidae	*Holthusiana transversa*
	Cladocera*	Daphniidae*	(incl. *Daphnia* spp.)
Ostracoda*		(incl. Darwinulidae)	

HYDRACARINA	**Family**	**Genus/species**
	Aturidae*	
	Hydrophantidae*	
	Hygrobatidae*	(incl. *Australibates* sp.)
	Limnesiidae*	(incl. *Limnesia* sp.)
	Mideopsidae*	
	Oribatidae*	
	Oxidae*	(incl. *Oxus* spp., *Frontipoda* sp.)
	Prostigmatidae	
	Torrenticolidae	(incl. *Torrenticola* sp.)
	Trombidioidae	
	Unionicolidae*	(incl. *Unionicola* spp., *Recifella* spp.)

MOLLUSCA	**Class**	**Family**	**Genus/species**
	Bivalvia*		(incl. *Ferrissia* spp.)
	Gastropoda	Lymnaeidae	*Lymnaea* spp. and *Amerianna* spp.
NEMATODA*			

* multiple genera/species noted during identifications.

† freshwater polychaete worms have only been recorded in southern Australia (Williams, 1980).

‡ taxa were omitted from the data sets due to low representation in the samples analysed.

OSS= Species label code in the ERISS Voucher Specimen collection: A=adults, L=larvae, N=nymphs.

3.4 Temporal and spatial variation of macroinvertebrates

To identify the temporal and spatial variations which occurred over the seasonally flowing portions of Magela Creek, the macroinvertebrate samples of three corresponding calendar dates were analysed for each site. These dates are shown in Table 5 below.

TABLE 5: Sampling dates and corresponding 'days after flow resumed'

Study Site	Dates examined	Days after flow resumed
FISHLESS	12th Dec, 1995	21
	13th Feb, 1996	84
	29th Apr, 1996	161
GEORGETOWN	12th Dec, 1995	1
	14th Feb, 1996	64
	30th Apr, 1996	141
MUDGINBERRI	13th Dec, 1995	1
	15th Feb, 1996	64
	1st May, 1996	141

* Calendar dates were used to select the times to be analysed because flow began at the Fishless site after the first falls of the wet season (late November). However, because the rain spell was sporadic and lacked follow up falls, the flow did not reach Georgetown and was absorbed by the sandy creek bed somewhere in between. It was not until mid December that the creek began to flow properly, hence the inconsistency in the 'Days after flow resumed' column.

One-way repeated measures analysis of variance (ANOVA) was used to compare Simpson's Index of Diversity, number of taxa and mean total abundance of macroinvertebrates at each site and habitat at the three sampling times (early, mid and late wet season). Those results which were statistically significant at the 5% level are reported below (Table 6).

3.4.1 Sand habitat

One-way repeated measures ANOVA of the macroinvertebrate community indices in the sand habitat produced two significant results, outlined in Table 6.

3.4.1.1 Simpson's Index of Diversity (D): sand

The one-way repeated measure ANOVA results are presented in Table 6, and are presented graphically in Figure 6a.

TABLE 6: Sand: Summary of ANOVA results; Simpson's Index of Diversity (D) for three sites (FL, GT and MD) and three times (Days 1, 64 and 141).

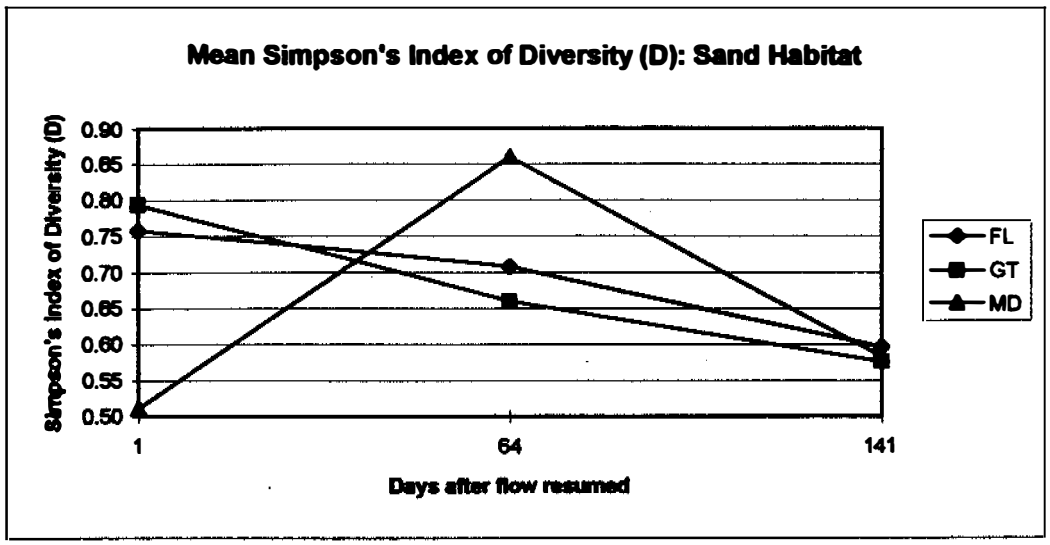
Source	DF	SS	F	P
Site	2	0.00604	0.20	0.820
Repli (Site)	6	0.08852	0.98	0.477
Time	2	0.11446	3.82	0.052
Site*Time	4	0.20282	3.38	0.045*
Error	18	0.17986		
Total	26	0.59171		

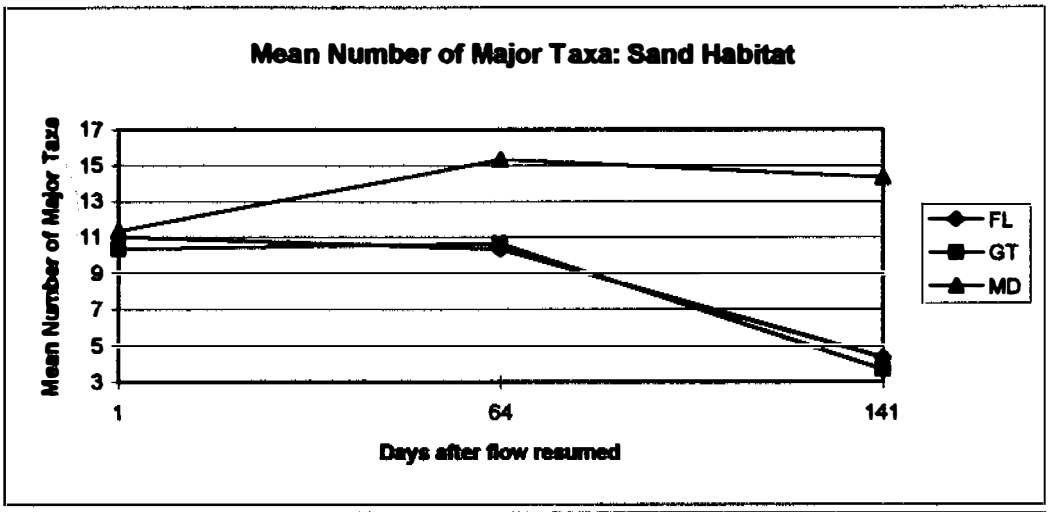
* Significant result ($P<0.05$).

Table 6 shows that there was no significant difference in Simpson's Index of Diversity (SID) over time or at different sites. There was however, a significant Site*Time interaction. It is difficult to speculate on the cause(s) of this interaction, however Figure 6a shows that while SID declined at FL and GT, it 'peaked' at MD in late February. Possible causes for these trends are discussed in Chapter 4.

3.4.1.2 Number of major taxa: sand

There were no significant differences in the number of major taxa in the sand habitats of FL, GT or MD at any of the three sampling times examined. Although the differences observed were not significant, it should be noted that the number of major taxa decreased at FL and GT, and increased and remained high at MD (Figure 6b).





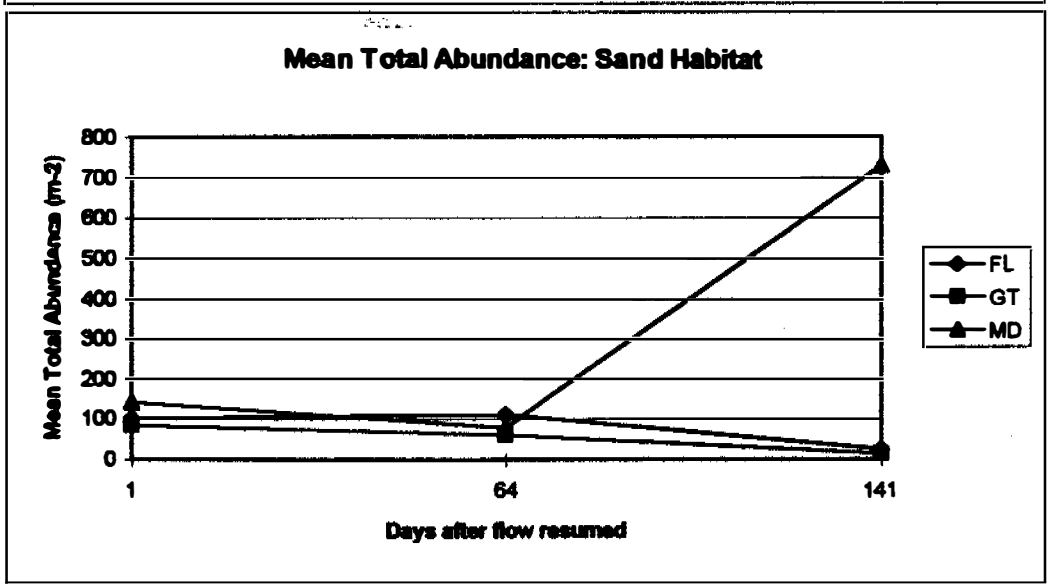


Figure 6: Community Indices: Sand Habitat

a) Mean Simpson's Index of Diversity (D)
b) Mean Number of Major Taxa
c) Mean Total Abundance

3.4.1.3 Mean total abundance: sand

Table 7 shows the only significant difference in the mean total abundance between the 3 sites and 3 times occurred at the Site*Time interaction.

TABLE 7: Sand: Summary of ANOVA results; mean total abundance for three sites (FL, GT and MD) and three times (days 1, 64 and 141).

Source	DF	SS	F	P
Site	2	108.723	2.46	0.165
Repli (Site)	6	132.354	2.50	0.083
Time	2	6.252	0.35	0.708
Site*Time	4	121.556	3.45	0.043*
Error	12	105.735		
Total	26	474.620		

* Significant result ($P<0.05$).

Mean total abundance in the sand habitat was found to be highest in the early to mid wet season at each site (Figure 6c). Although the mean total abundance at FL and GT decreased in the sand habitat with time, it steadily increased at MD.

Therefore in the sand habitat, the only two significant variations were both at the Site*Time interaction, for SID and mean total abundance. These community indices both decreased at FL and GT over time, whereas at MD they increased. This trend is presented in Table 14.

3.4.2 Macrophytic edge habitat

One-way repeated measures ANOVA of the macroinvertebrate community indices in the sand habitat produced four significant results (Table 8). Time and site were both found to be the causes of these variations in the edge habitat.

3.4.2.1 Simpson's Index of Diversity (D): edge

There were no significant differences in the SID between the edge habitats of FL, GT and MD at any of the three sampling times examined (Figure 7a).

3.4.2.2 Number of major taxa: edge

Large variations in the number of major taxa were observed at the different sites and over time. This is shown in Figure 7b and Table 8

TABLE 8: EDGE: Summary of ANOVA results; number of major taxa for three sites (FL, GT and MD) and three times (days 1, 64 and 141).

Source	DF	SS	F	P
Site	2	191.63	12.68	0.007**
Repli (Site)	6	45.33	0.50	0.796
Time	2	327.19	10.87	0.002**
Site*Time	4	166.81	2.77	0.077
Error	12	180.67		
Total	26	911.63		

** Highly significant ($P<0.01$).

Significant variations in the number of major taxa in the macrophytic edge habitat occurred both over time and at each site. All sites possessed low numbers of taxa in the early stages of the wet season. The number of major taxa remained fairly constant at FL, 'peaked' at GT in late February, but steadily increased during the wet season at MD.

3.4.2.3 Mean total abundance: edge

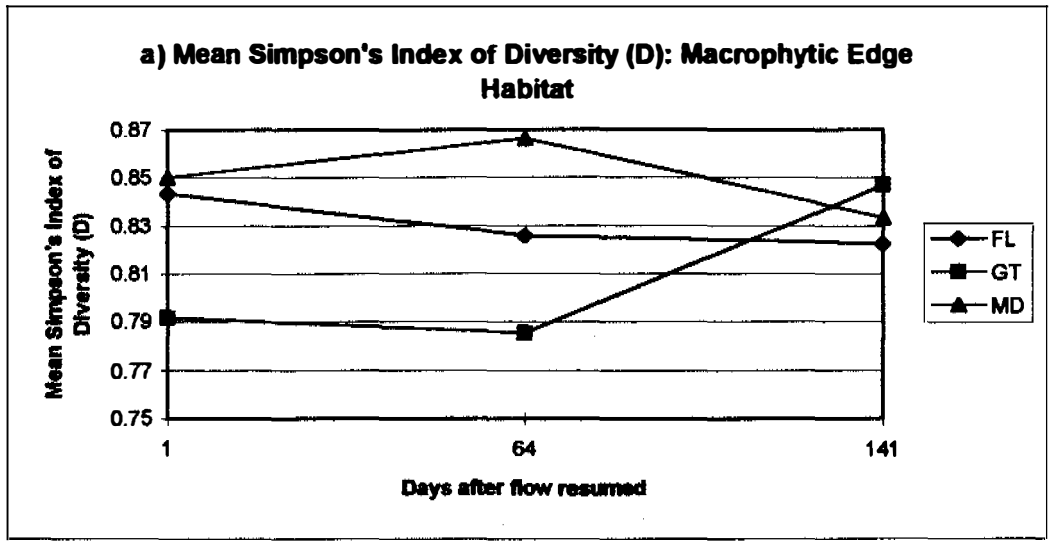
Two significant variations occurred in the mean total abundance, both at the different sites and over time. These changes are illustrated in Figure 7c and Table 9.

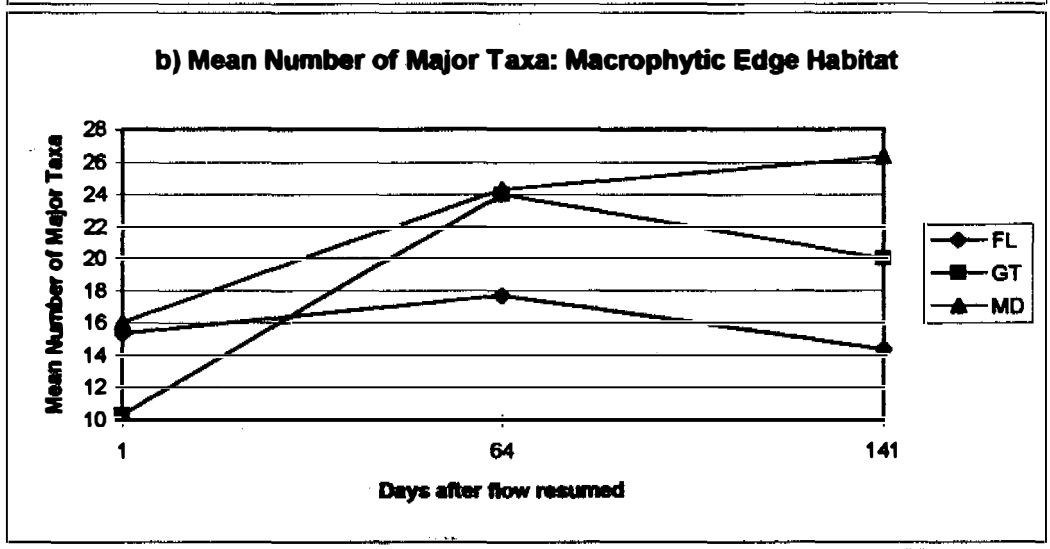
TABLE 9: Edge: Summary of ANOVA results; mean total abundance for three sites (FL, GT and MD) and three times (days 1, 64 and 141).

Source	DF	SS	F	P
Site	2	282.90	52.22	0.000***
Repli (Site)	6	15.95	0.10	0.996
Time	2	591.35	10.58	0.002**
Site*Time	4	207.76	1.86	0.183
Error	12	335.49		
Total	26	1433.44		

** Highly significant ($P<0.01$). *** Very highly significant ($P<0.001$).

Highly significant variations in mean total abundance were found for at the different sites and over time. The mean total abundance at FL remained fairly constant during the wet season. At MD, the mean total abundance increased during the early to mid wet season and remained fairly constant thereafter. However, at GT the mean total abundance steadily increased, mainly due to large numbers of Simuliid larvae which dominated the late wet season edge samples.





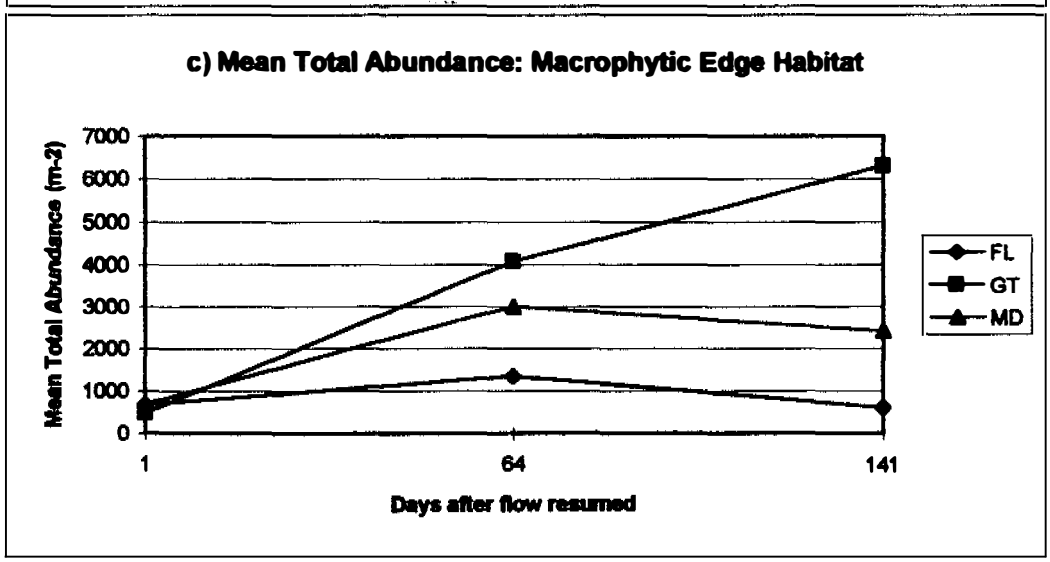


Figure 7: Community Indices: Macrophytic Edge Habitat
a) Mean Simson's Index of Diversity (D)
b) Mean Number of Major Taxa
c) Mean Total Abundance

3.4.3 Leaf litter habitat

One-way repeated measures ANOVA of the macroinvertebrate community indices in the leaf litter habitat produced five significant results, outlined in Table 10.

3.4.3.1 Simpson's Index of Diversity (D): leaf litter

One source of significant variation in SID was found to have occurred in the leaf litter habitat. This is illustrated in Figure 8a and summarised in Table 10 below.

TABLE 10: Leaf: Summary of ANOVA results; Simpson's Index (D) for three sites (FL, GT and MD) and three times (days 1, 64 and 141).

Source	DF	SS	F	P
Site	2	0.05328	8.18	0.019*
Repli No (Site)	6	0.01955	0.30	0.927
Time	2	0.02809	1.28	0.314
Site*Time	4	0.01145	0.26	0.898
Error	12	0.13191		
Total	26	0.24427		

* Significant result ($P<0.05$).

Significant site differences in SID were noted in the leaf litter habitat. FL had the highest SID at day 1, remained fairly constant towards the mid wet season, but then decreased in the late wet season. At GT, SID steadily decreased as the wet season progressed, and at MD SID remained fairly constant.

3.4.3.2 Number of major taxa: leaf litter

Three significant variations for number of major taxa were found in the leaf litter habitat. These are illustrated in Figure 8b and summarised in Table 11.

TABLE 11: LEAF: Summary of ANOVA results; number of major taxa for three sites (FL, GT and MD) and three times (days 1, 64 and 141).

Source	DF	SS	F	P
Site	2	81.407	6.14	0.035*
Repli (Site)	6	39.778	0.74	0.625
Time	2	156.963	8.81	0.004**
Site*Time	4	277.481	7.79	0.002**
Error	12	106.889		
Total	26	662.518		

* Significant result ($P<0.05$). ** Highly significant result ($P<0.01$)

A great deal of variation in number of major taxa was observed to occur in the leaf litter habitat. At FL, the number of major taxa 'peaked' during the mid wet season then decreased. The number of major taxa remained fairly constant at GT, and at MD, number of major taxa was observed to steadily increase over time.

3.4.3.3 Mean total abundance: leaf litter

Variations in mean total abundance of the leaf litter communities are illustrated in Figure 8c and Table 12.

TABLE 12: Leaf: Summary of ANOVA results; mean total abundance for three sites (FL, GT and MD) and three times (days 1, 64 and 141).

Source	DF	SS	F	P
Site	2	150.86	4.16	0.074
Repli (Site)	6	109.15	1.00	0.466
Time	2	66.02	1.82	0.204
Site*Time	4	422.57	5.83	0.008**
Error	18	326.51		
Total	26	965.96		

** Highly significant ($P<0.01$)

The variations in the mean total abundance in the leaf litter habitat were highly significant for the Site*Time interaction. At FL and GT, the mean total abundance in the early wet season were high compared to MD. Thereafter however, the mean total abundance decreased at FL over time, remained fairly constant at GT, but steadily increased at MD.

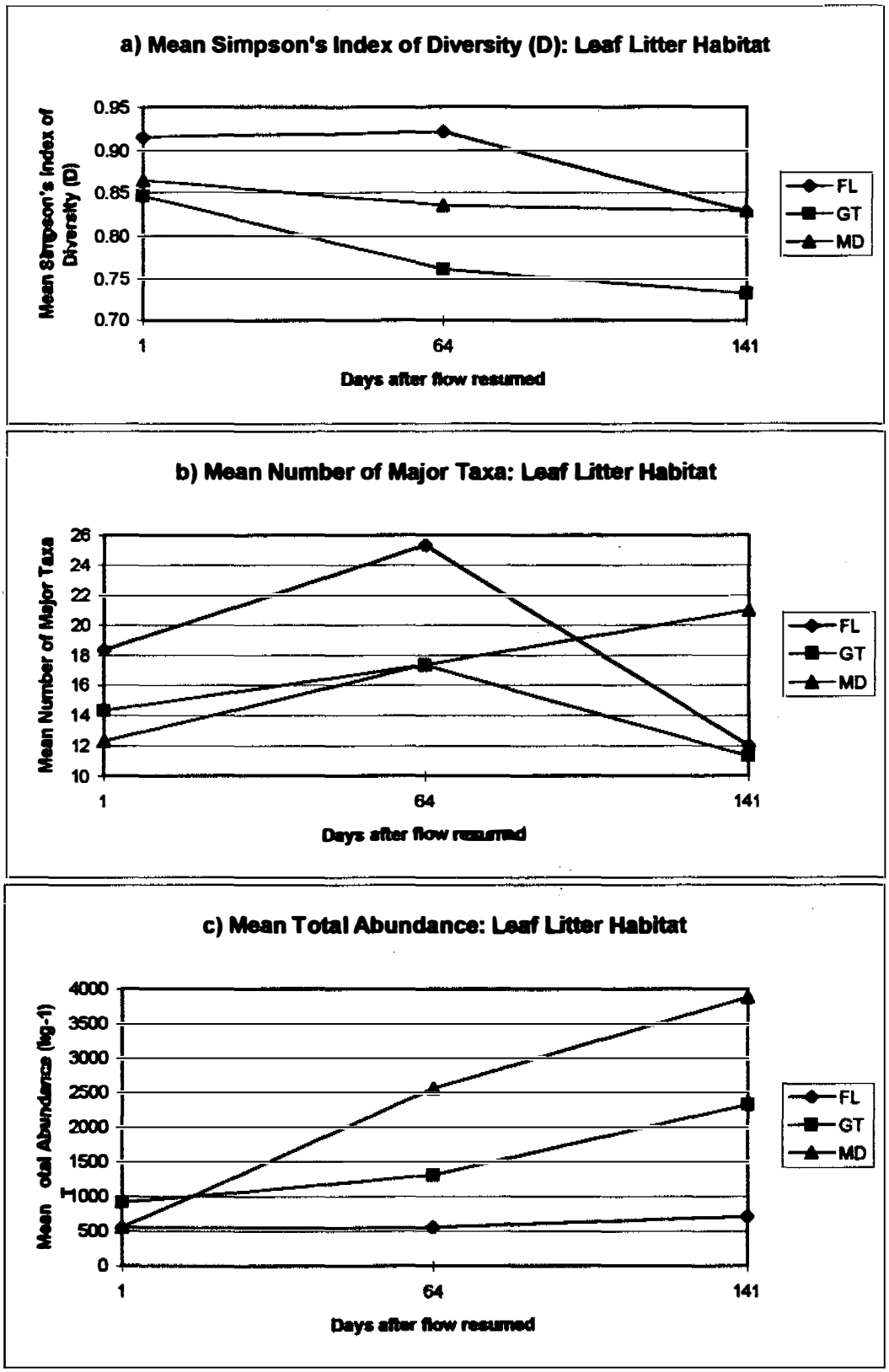


Figure 8: Community Indices: Leaf Litter Habitat
a) Mean Simpson's Index of Diversity (D)
b) Mean Number of Major Taxa
c) Mean Total Abundance

3.4.4 Summary of temporal and spatial variation

Table 13 is a summary of the one-way repeated measures ANOVA's results, conducted to determine the spatial and temporal variations in each of the three habitats investigated in this study. It illustrates an overall trend in the variation of the community indices longitudinally.

TABLE 13: Summary of the overall trends in the three community indices used to describe temporal and spatial variation of macroinvertebrates.

Trends Over Time:	SID (D)	Number of major taxa	Mean total abundance
FISHLESS			
Sand	decreased(-)	steady(0)	decreased(-)
Edge	steady(0)	peaked(+ -)	steady(0)
Leaf	decreased(-)	peaked(+ -)	decreased(-)
Overall Trend (4-)			
GEORGETOWN			
Sand	decreased(-)	steady(0)	decreased(-)
Edge	steady(0)	peaked(+ -)	increased(+)
Leaf	decreased(-)	steady(0)	steady(0)
Overall Trend (2-)			
MUDGINBERRI			
Sand	peaked(+ -)	steady(0)	increased(+)
Edge	steady(0)	increased(+)	increased(+)
Leaf	steady(0)	increased(+)	increased(+)
Overall Trend (5+)			

'steady(0)' indicates that the respective community indice remained fairly constant through time. (0)=no overall change.
'peaked(+ -)' indicates that although the value for the respective community indice increased from early to mid wet season, it decreased significantly toward the end of the wet season.
(+ -)=increasing then decreasing trend (overall trend is neutral; 0).
'increased(+)' indicates that the community indice steadily increased as the wet season developed.
(+)=increasing trend.
'decreased(-)' indicates that the community indice steadily decreased as the wet season developed.
(-)=decreasing trend.

The trends in the community indices illustrated in Table 14 are best recognised when each of the three study sites are observed individually and then compared to one another. By assigning the 'trends' with a descriptive signature value (+), (-), (0) or (+ -), it is possible (by summing the signs) to illustrate what the overall longitudinal changes in the community indices are for the seasonally flowing portions of Magela Creek studied. For Fishless, the overall trend value is (4-), indicating that initial colonists were rapidly emigrating from the site. Georgetown also demonstrated a negative overall trend (2-), indicating that emigration from this site was also occurring, but to a lesser degree than at Fishless. For Mudginberri, the opposite overall trend is observed (5+). This indicates that Mudginberri was continually gaining macroinvertebrates, either through drift, ovideposition, vertical migration or upstream migration from Mudginberri Billabong.

3.5 Multivariate analyses of the major taxa at Georgetown

The similarity of the composition of the major taxa at Georgetown for 7 sampling dates were computed using PATN®. Raw data are presented in Appendix VIII. The dates and the corresponding 'days after flow resumed for the Georgetown samples are listed in Table 15.

TABLE 14: Sampling date and the corresponding number of 'days after flow resumed' for the Georgetown macroinvertebrate samples.

Time	Dates examined	Days after flow resumed
1	12th Dec, 1995	1
2	19th Dec, 1995	8
3	3rd Jan, 1996	23
4	14th Feb, 1996	64
5	15th Mar, 1996	95
6	3rd Apr, 1996	114
7	30th Apr, 1996	141

3.5.1 Ordination of Georgetown macroinvertebrate samples

The ordination of the macroinvertebrate samples is illustrated in Figure 9a. The figure shows that the macroinvertebrate community in the sand habitat (top right of the plot) was distinctly different to those of the edge and leaf litter habitats (centre and bottom left of the plot). The edge and leaf litter habitat samples were intermixed, indicating that there was little difference in the composition of these macroinvertebrate communities.

3.5.2 Principle Components Correlation (PCC) for physical and chemical variables

Neither the physical nor the chemical variables were strongly correlated with the composition of the macroinvertebrate communities ($r<0.6$), hence no further analyses on the physical or chemical variables were conducted.

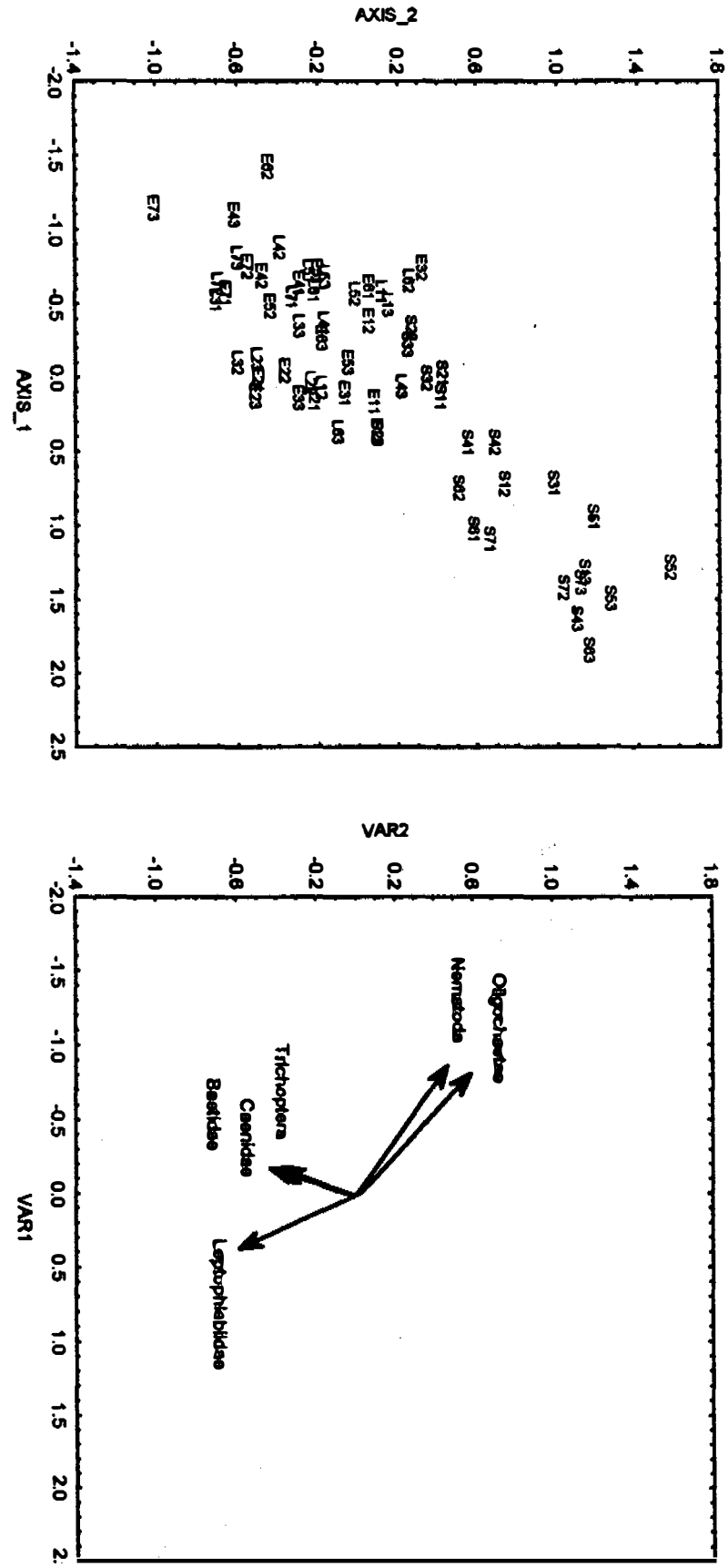


Figure 9: a) Ordination of Georgetown macroinvertebrate samples.
b) Principle Components Correlation (r>0.6).

3.5.3 Principle Components Correlation (PCC) for major taxa at Georgetown

The PCC of the major taxa showed that the Oligochaetae, Nematoda, Trichoptera, Baetidae, Caenidae and Leptophlebiidae ($r>0.6$) were the most strongly correlated groups which defined different macroinvertebrate communities. The PCC vectors are illustrated in Figure 9b, indicating in which direction the individual major taxa directed the ordination plot of samples in which they occurred (refer to Figure 9a). The dendrogram (Figure 10) shows how the individual Georgetown macroinvertebrate samples were clustered in the ordination. By observing the patterns of major 'splits' in the dendrogram and then referencing the individual samples in each 'split' to the ordination, it is possible to separate the clusters into the differing macroinvertebrate assemblages and hopefully recognise which taxa are responsible for that clustering.

3.5.4 Patterns of the community indices over time: Georgetown

At the Georgetown study site, variations in the three community indices were examined on 7 separate sampling occassions during the wet season (Figure 11). Fishless was narrower than other the other sites and did not possess the typical braids which only became inundated when flow peaked during spates. The Mudginberri site was 200 m upstream of a channel billabong which again was not typical of the other sites. Therefore, the Georgetown macroinvertebrate samples were considered to be more indicative of the whole course of Magela Creek than Fishless or Mudginberri in regards to stream morphology and flow characteristics.

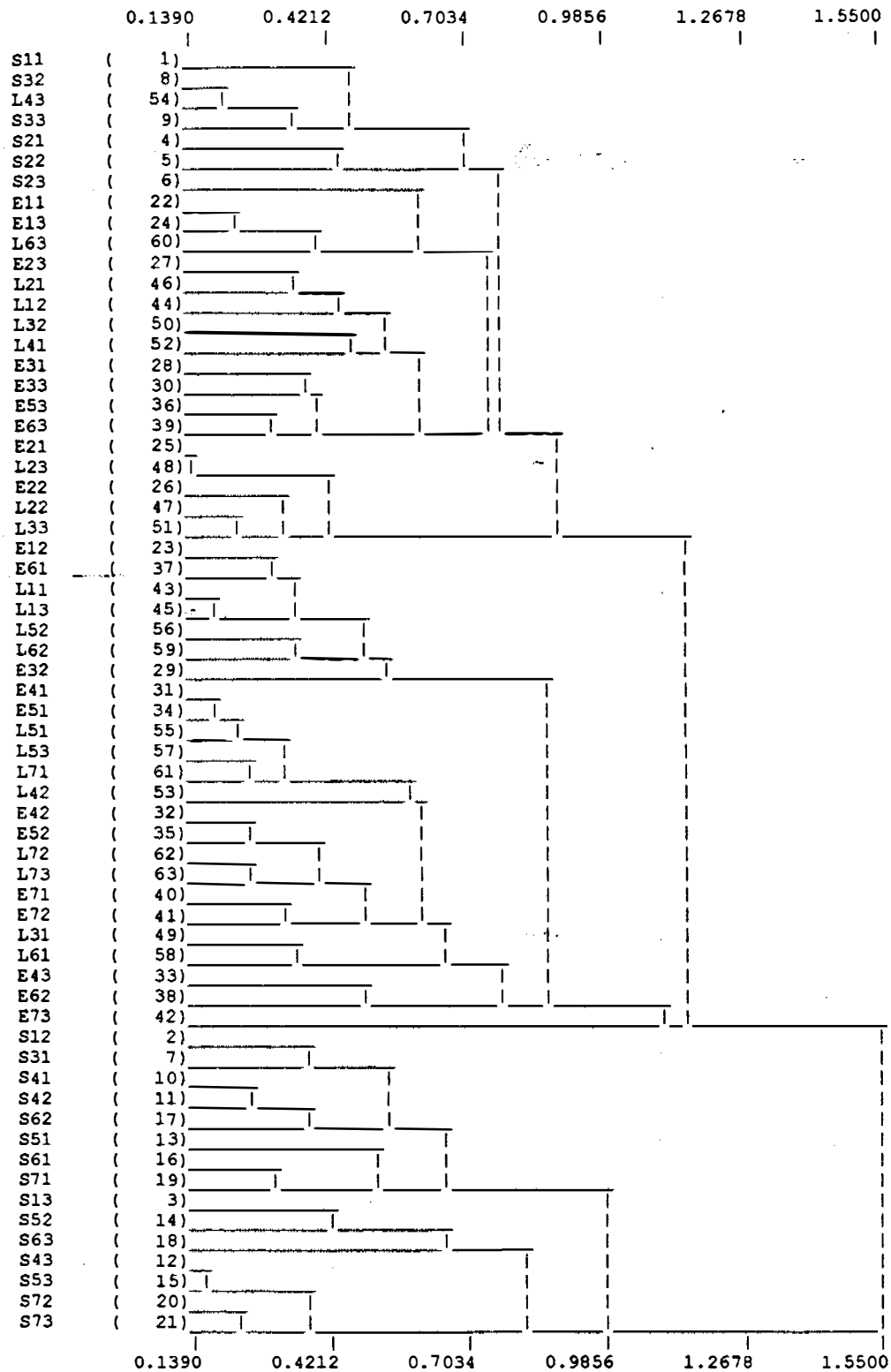
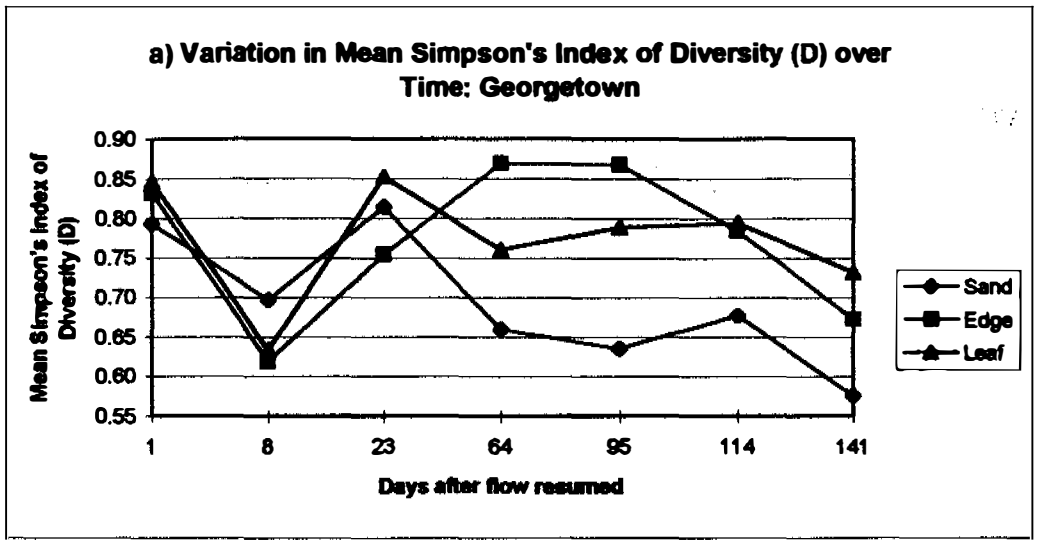
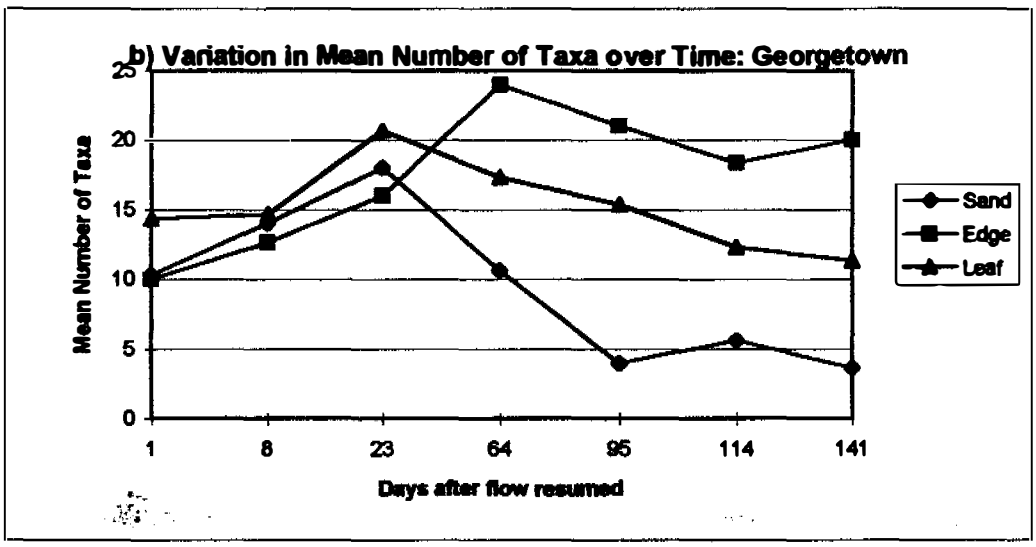


Figure 10: Dendrogram of the Georgetown macroinvertebrate samples.
S=Sand habitat sample, E=Macrophytic Edge sample, L=Leaf litter sample.
First Digit=sampling Time (i.e., 1-7), Second Digit=sample replication number.





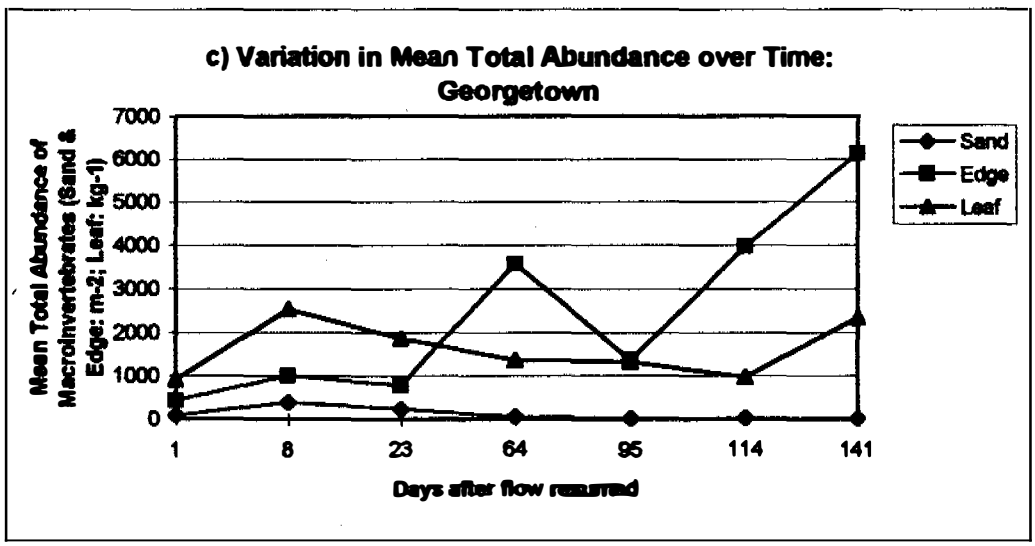


Figure 11: Variation of Community Indicies over Time: Georgetown
a) Mean Simpson's Index of Diversity (D)
b) Mean Number of Taxa
c) Mean Total Abundance

3.5.6 Family level taxa which display site preferences

The data compiled for community indices ANOVA's and the PATN® analyses (Appendices VII and VIII) were averaged over sites and habitats to determine if there were any taxa which were site specific, or showed site preference. These were the taxa which displayed a marked higher or lower incidence at any particular site and are presented in Table 15. The complete macroinvertebrate family level by site listing are presented in Appendix X as box and whisker plots.

TABLE 15: Taxa which displayed site preferences (approximate mean number of individuals collected from each site per sampling occasion).

Major Classification	Taxa Name	Site		
		Fishless	Georgetown	Mudginberri
COLEOPTERA	Elmidae	45	~0	2
	Hydroptilidae	4	12	35
	Hydropsychidae	6	12	2
CRUSTACEA	Ostracoda	9	54	72
	Cladocera	~0	60	50
	Decapoda	0	0	12
DIPTERA	Simuliidae	40	400	0
	Tanypodinae	20	120	130
EPHEMEROPTERA	Caenidae	50	160	300
HYDRACARINA	Hygrobatidae	5	8	26
	Mideopsidae	2	10	12
	Oribatidae	50	230	100
	Unionicolidae	8	8	25
MOLLUSCA	Gastropoda	0	0	9
	Bivalvia	0	0	8
NEMATODA	Nematoda	12	42	25
ODONATA	Zygoptera	2	12	4
OLIGOCHAETA	Oligochaeta	40	90	145

The macroinvertebrate taxa displayed above show distinct preference for certain local site conditions. These patterns are addressed in the next chapter.

Appendix II: Physical Variables Correlation Coefficients (from MINITAB® v.9).

	% Macro	% Expos	%RtMt	%Detr	SFlow	Depth	Taxa	Abund
% Expos	-0.308							
% RtMt	0.778	-0.258						
%Detr	-.0384	-0.661	-0.258					
SFlow	-0.276	-0.346	-0.211	0.548				
Depth	-0.147	0.092	-0.092	-0.030	-0.246			
Taxa	0.496	-0.526	0.388	0.171	-0.090	-0.063		
Abund	0.415	-0.412	0.240	0.080	0.011	-0.151	0.416	
SID	0.224	-0.554	0.163	0.385	0.075	-0.075	0.512	0.210

81 rows; DF=79; $P<0.05$: r>0.220

$P<0.01$: r>0.286

$P<0.001$: r>0.361

CHAPTER 4: DISCUSSION

4.1 Environmental sources of variation in macroinvertebrate communities

All studies of macroinvertebrate assemblages in freshwater ecosystems are accompanied by data pertaining to the environmental variables which are believed to influence them. Hence, many references are available when discussing the effects that these variables have on zoobenthic communities. Environmental variables which were found to be significant through data analyses (Chapter 3) are discussed below. The environmental variables which were not found to be significant but nonetheless characterise the ecology of tropical intermittent streams are also addressed.

4.1.1 Physical variables

Analysis of the physical variables data produced four significant results relating to variation in the macroinvertebrate assemblages in Magela Creek. These were percentage macrophytic cover, percentage exposed substrate, percentage root mat cover and percentage detritus cover of the transects or spot samples collected. Each of these physical variables are discussed below.

4.1.1.1 Percentage macrophytic cover

The presence of macrophytes has often been associated with increased abundance and diversity (or richness) in macroinvertebrate assemblages by many researchers (see citations below). The benthic assemblages of Magela Creek were no exception. Increases in the community indices of diversity, number of taxa and abundance, were all significantly related to an increase in the percentage macrophytic cover. For example, Lillie and Evrard (1994) found a significant positive correlation between macroinvertebrate density and macrophytic biomass in temporal and permanent prairie potholes in Wisconsin. In a catchment study in the southern

Appalachians, Wohl *et al.*, (1995) found similar patterns. A study by Balla and Davis (1995) showed that the highest macroinvertebrate biomass was recorded in wetlands with both cyanobacterial blooms and abundant macrophytes present, and Hargeby *et al.* (1994) found that in a eutrophic lake in Sweden, a gradual decline in phytoplankton over many years led to an increased biomass of submerged macrophytes. This in turn, allowed macroinvertebrate abundance to increase which in time, was responsible for increased numbers of resident waterfowl and fish.

Cogerino *et al.* (1995), in a study of the macroinvertebrates in aquatic banks of a large European river, found that the microhabitats of aquatic vegetation (macrophytes and algae) contained the richest fauna in terms of both mean specific richness and mean density. Similarly, Malmqvist and Maki (1994) concluded that macroinvertebrate assemblages in north Swedish streams were strongly associated with drainage area, elevation, water quality (in terms of alkalinity, colour and phosphate), and the presence of macrophytes. Thus richness and abundance community indices have been observed to increase concurrently with increased macrophytic presence.

As the wet season developed, the stands of macrophytes in Magela Creek were observed not only to increase in size (through vertical growth), but also increase in the total benthic area covered (i.e., macrophyte beds became more extensive through lateral expansion). These two types of macrophytic development in Magela Creek were observed to be more pronounced in the downstream sites. After the commencement of recessional flows at Fishless and Georgetown, macrophytic beds decreased in area, however at Mudginberri the water persisted, as did the associated macrophyte beds. Oertli and Lachavanne (1995) found that the older shoots of an emergent macrophyte (*Typha latifolia*) supported higher mean annual richness, abundance and biomass of macroinvertebrates, as they provided a

wider range of microhabitats on the plants. Older aquatic plants of other species showed similar trends. Therefore, maintenance or increases in the diversity of macroinvertebrate assemblages at Mudginberri could be associated with the persistence and expansion of macrophytic areas.

As the wet season progressed, there was a distinct succession in the emergence and change in the composition of macrophyte species in Magela Creek (the data was not presented due to time constraints but was recorded on field data sheets). In a study of a lowland river in Tasmania with artificially controlled water levels, the macroinvertebrate assemblages of *Myriophyllum simulans, M. variifolium, Triglochin* sp. and *Eleocharis* sp. were investigated; different species of macrophyte typically supported different macroinvertebrate assemblages (Humphries *et al.*, 1996).

Thus, the size, age, diversity and abundance of aquatic higher plants and algae has been shown to be positively correlated to increased abundance and diversity of macroinvertebrate assemblage which commonly utilise the resources within this habitat. Similar trends were observed in Magela Creek during the course of this study.

4.1.1.2 Percentage exposed substrate

The percentage exposed substrate was also found to be significantly correlated with declining abundance and diversity of macroinvertebrates in Magela Creek. Cogerino *et al.* (1995) reported that the fewest species occurred in sand in a large European river. Naturally, the percentage of exposed substrate was rarely less than 100% in sand habitat samples; the particle size of the sandy tracts (c. 400 µm) results in extremely small interstitial spaces that only highly specialised fauna would be able to inhabit. Chironomidae, Ceratopogonidae and Oligochaeta were the most common taxa found in the sand, accompanied by extremely small (1st or 2nd instar) caenid nymphs in the slower waters of Mudginberri. Other taxa (e.g.,

Nematoda) examined in the sand samples were most likely composed of fauna which were obligate hyporheos (Williams and Hynes, 1976; Moss 1986)).

4.1.1.3 Percentage root mat cover

Root mats were a relatively minor component of the transect area of samples in the early wet season however, as the sand tracts became scoured by spates, the percentage of the transect area comprised of exposed root mats increased. No references to the function or effect of root mats on macroinvertebrate assemblages were found in the works by other authors. In Magela Creek, diversity was significantly higher in samples containing this substrate. For example, root mats were favoured by the filter-feeding blackfly larvae *Simuliium* spp.; the high surface flow conditions in these areas were favoured this taxa which otherwise appeared only as a minor component in samples without root mats. Fishless and Georgetown were the most extensively 'scoured' sites.

4.1.1.4 Percentage detritus cover

The significance of detritus in regard to macroinvertebrate community structure has been well documented in the works of many authors (see citations below), as detritivores are often a major component of freshwater ecosystems. In the Magela Creek benthos, increased percentage of detritus cover was significantly correlated to increases in the diversity of macroinvertebrate assemblages. Leaf litter samples were composed primarily of detritus in the form of leaves from *Melaleuca* spp. and *Pandanus aquaticus* , accompanied by woody twigs and seed capsules. These forms of detrital matter were often tough and pliable Generalist detritivores are the most abundant functional feeding group for the assemblages of macroinvertebrates collected at Magela Creek (Outridge, 1988) Therefore, the factors which influence the biomass and condition of organic detritus entering the systems must also be considered to fully understand the ecological dynamics which occur in regard to the large assemblage of detritivores in Magela Creek.

For example, densities of most macroinvertebrate taxa studied in a monsoonal stream in Hong Kong were correlated with detrital standing stock (Dudgeon, 1993). Similar relationships between detritus and macroinvertebrate assemblages were observed by Wohl *et al.*, (1995) in the southern Appalachians of the United States. In another U.S. study, Maloney and Lamberti (1995) found that macroinvertebrate densities within decomposing leafpacks increased steadily. These variations in density were relative to the remaining mass of the leaf litter; as decomposition of the leaves progressed, the mass of the remaining leaf litter decreased, as did the number of macroinvertebrates it contained. However, since the density of macroinvertebrates increased relative to the remaining mass of the leaf litter, , the overall density ('per unit remaining mass') increased. The detritivores contained in the leaf litter consisted predominately of two taxa; Chironomidae (54%) and Hydropsychidae (44%). Processing rates of detritus (leaves) were among the highest observed for North American streams, which may be attributed to high microbial activity at summer water temperatures, good nutritional status of the leaves, and high macroinvertebrate numbers. Outridge (1988) has associated microbial activity with leaf litter breakdown in Magela Creek, however, a full study of this aspect of the stream ecology has not been undertaken to date.

France (1995), following a study of the Canadian Shield Lakes, also showed that allochthonous detritus contributed more toward the total lake standing crop of the littoral zoobenthos in over half of all comparisons conducted. The amount of organic input to the systems is important, both for macroinvertebrates and other fauna which depend on them. For example, modification of the amount of terrestrial vegetation supplied to the littoral regions of lakes has the potential to affect the number of macroinvertebrates which are available to resident fishes (France, 1995). Denuded riparian zones were linked with increasingly depauperate levels of abundance and diversity in British creeks running through pasture land (Moss, 1986).

Other studies indicate that the rate of leaf litter processing by macroinvertebrates is attributable to the decompositional state of organic matter. 'Conditioned' leaves (leaves affected by the initial stages of decomposition) are known to be preferred by many macroinvertebrates. For example, the consumption and digestibility of both alga and higher vascular plants (macrophytes)by detritivores increases after preliminary decomposition has taken place (Kornijow *et al.*, 1995). This was believed to be so because in the decomposed or 'conditioned' state, allelochemical defence mechanisms of macrophytes function at a reduced capacity. Furthermore, Oertli (1993) showed that fluctuations in macroinvertebrate densities, especially on *Chara* (a macrophyte) and leaves, were also attributed to modifications in the condition of the substrate, such as the surface availability and stage in the decomposition or senescence processes. Mudginberri, previously mentioned as a depositional site for organic nutrients and macroinvertebrate drifters, would therefore have been constantly replenished with leaf litter from upstream sources in the recessional stage after each spate. This is reflected in the results for the community indices; Simpson's Index of Diversity remained constant and both the number of major taxa and total abundance in leaf litter increased.

The relationship between temperature and leaf litter breakdown has been investigated by Irons *et al.* (1994) through comparisons between sites of differing latitude; they concluded that warmer (tropical) waters depend more on microbial conditioning of detritus than the action of macroinvertebrate shredders. Although microinvertebrates were not investigated in this study, the function of microbes in the decomposition of organic detritus in Magela Creek play an important role in the 'conditioning' of sclerophyllous leaves (Outridge, 1988). Basaguren and Pozo (1994) found that in the headwater sites of a stream in Spain, leaves from the alder tree *Alnus glutinosa* were the preferred food source when compared to the leaves of *Eucalyptus globulus*. *Eucalyptus* leaves were tougher and decomposed more slowly.

Other factors such as pH, are important in influencing the decomposition rate of detrital matter. Kok and Van Der Velde (1994) reported that the decomposition of the leaves of *Nymphaea alba* and *Betula pubescens* were slower in acidic waters. The diversity of detritivorous macroinvertebrate fauna on the leaf litter of both species was extremely low in the acid pond. This is in contrast to findings at Magela Creek; pH was observed to be slightly acidic (from 5.3 to 6.6) during this study, and the diversity of the zoobenthos of Magela Creek was observed to be high (current study; Outridge, 1987).

The presence, biomass and 'conditional' state of detrital matter are therefore important considerations when investigating the dynamics of aquatic ecosystems, especially in Magela Creek which is predominately composed of generalist detritivores.

4.1.1.5 Depth

Although depth was not found to be a significant physical variable with regard to the diversity, number of taxa or abundance in Magela Creek, 85% of the samples collected were from areas not deeper than 40 cm. In a study of a French stream, Maridet *et al.* (1996) found that macroinvertebrate density and taxonomic richness decreased with depth; 70-90% of the individuals were found in the first 15 cm. Similarly, macroinvertebrate densities in the aquatic banks of the Upper Rhone River were approximately four times higher than in deeper sections of the channel (Cogerino *et al.*, 1995). Therefore, the effects depth were not reflected in the macroinvertebrate assemblages of Magela Creek because the depths from which the macroinvertebrate samples were collected were all relatively shallow.

4.1.1.6 Discharge

Discharge was not found to be significantly correlated to macroinvertebrate abundance. However, the non-significant result may have primarily been due to

the way the data were entered for the analysis. Only the discharge figure for the particular day on which sampling took place was entered. This method may have been valid for streams with a relatively consistent flow rate, but for intermittent streams subject to spates, it does not consider the significant fluctuations in discharge that occurred over the days prior to sampling. Hence, the analysis was never likely to produce a significant result.

Upon observing the rainfall/discharge plot (Figure 5), it becomes immediately apparent that the macroinvertebrate assemblages sampled on any particular day were probably affected by the duration and intensity of the most recent spate. The time for recovery from the effects of the most recent spate would have also been important in regards to the composition of the macroinvertebrate assemblages which were collected. Another important factor which was not addressed in this study were the morphological characteristics of the sampling site (e.g., channel width, depth, and the width to depth ratio). These site specific morphological factors were found to be important in the temporal and spatial distributions of macroinvertebrates in a French mountain stream (Maridet *et al.*, 1996). It is very likely that the morphological characteristics of the Magela Creek sites would have affected the composition of their respective macroinvertebrate assemblages. The influence of spate induced disturbances on each of the respective sites and community indicies are discussed in detail below (4.3.1)

4.1.2 Chemical variables

The changes in water chemistry which occurred over the wet season in Magela Creek were not found to have significant effects on macroinvertebrate assemblages. Although the chemical variables of alkalinity, bicarbonate and sulphate were found to be significantly correlated to the mean total abundance of the leaf litter community, it is difficult to determine why this was be the case. This could be explained as a function of reduced buffering capacity of relatively stationary waters

in which leaf litter habitats develop due to a lack of mixing via water movement. Alternatively, it could be explained to be an effect due to the decomposition of the leaves, where carbonic compounds (such as bicarbonate) are released through the action of microbes and other invertebrates. Whatever the cause for these significant correlations, these results should be viewed with caution because water samples were not collected for each and every replication. One water sample was collected for each site, hence the water chemistry results are of a more general nature for the chemical status of the creek. Hence, a significant correlation to the mean total abundance of the leaf litter community (the water chemistry of which was not analysed) seems invalid. It is suggested that in order to seriously investigate the effects of water chemistry on macroinvertebrate assemblages, samples should be taken in conjunction with each macroinvertebrate sample and at the same depth at which the sample was collected. This is especially important in stagnant or relatively stationary waters were the chemical characteristics of the water may change dramatically after only a short distance.

Finally, it should be mentioned that the results from the NATA laboratory deemed that water samples used for the analysis of nitrate were contaminated in most instances (Table 3). Typically, nitrate levels in Magela Creek were low; nitrogenous compounds (NO_x) are usually associated with eutrophic or polluted waters (Moss, 1986). Gallardo and Prenda (1994) found that most taxa prefer sites with high nitrate and low nitrite concentrations. Thus, through the work of others, it seems unlikely that nitrate levels would have been an important variable in Magela Creek.

4.2 Macroinvertebrate community composition in Magela Creek

The amount of work conducted in the past relating to tropical intermittent streams is in stark contrast to the paucity of studies pertaining to permanent, lentic water bodies (namely lakes, billabongs and wetlands). Hence, references for this section

of the chapter are few in comparison to those of the environmental variables discussed above.

4.2.1 Temporal and spatial variations of macroinvertebrate community indices

The temporal and spatial variations in the community indices (mean values for Simpson's Index of Diversity, number of major taxa and total abundance) were presented on a per habitat basis (Figures 6, 7 and 8) for reasons stated previously (Chapter 2). The changes in the respective community indices are summarised in Table 13.

Results significant for Time, and results significant for Site, can both be easily explained. A significant Time result is interpreted as showing that through the wet season, the respective community indicies changed in the same way for all three sites. Conversely, a significant Site result indicates that there were differences between the sampling sites, but these differences were consistent throughout the wet season. However, significant Site*Time interactions are difficult to explain. The source of this type of variation could be due to a number of factors, each of which are partly responsible for the inconsistent differences between sites and times. In order to identify the (significant) variables directly attributing to these changes, a exhaustive study would be required. Thus, intuitive explanations (hypotheses) will be expressed to explain significant Site*Time interactions. The presence of typical 'macrophytic taxa' in the sand habitat is an example of a significant Site*Time interaction; very small caenid nymphs occurred in vast numbers the sand habitat at Mudginberri late in the wet season. Normally, this taxa is not associated with sand habitation (Marchant, 1982).

Significant Site*Time interactions (refer to ANOVA Tables 6, 7, 11 and 12) were observed in two habitats; sand and leaf litter. These two habitats were very unstable in comparison to the macrophytic edges. Areas of the creek supporting

macrophytes were more stable for two reasons. Macrophytes and integrated root mats held the substrate in place and probably provided a 'protectional' effect against the current, especially during times of high flow. The 'protectional' effects of filamentous algae were observed in a study of a lake in Denmark (Brodersen, 1995). Spates scoured the tracts of sand bed and swept piles of leaf litter away to areas downstream, and most likely did the same to the macroinvertebrate assemblages within them, although this has been found to be dependent on morphological and tactile characteristics particular taxa (Robinson *et al.*, 1993). Therefore, assemblages with significant Site*Time interactions were highly unpredictable and were mainly a function of when the sampling took place in relation to the severity and the time for recovery from the last surge in discharge.

Conversely, the macrophytic edges were more stable than either the sand or leaf litter habitats due to the presence of macrophytic and riparian root systems. Macroinvertebrate assemblages in macrophyte habitats were thus able to develop with time (significant results were gathered through ANOVA analyses for number of taxa and mean total abundance in this habitat), predominately because the size, age and diversity of stands of macrophytes developed as the wet season progressed.

4.2.1.1 Other sources of temporal and spatial variation in the benthos

Other sources of temporal and spatial variation in the macroinvertebrate assemblages (such as drift, emergence, vertical and upstream migration) were not investigated in this study. However, macroinvertebrate drift in Magela Creek was studied during the early stages (1 to 28 days after flow resumed) of the 1991-92 wet season (Partridge, unpublished). Strong representation (i.e., from 200 to 5000 individuals m^{-3}) of several orders of macroinvertebrates were reported, including Ephemeroptera, Trichoptera, Chironomidae, Hydracarina, Copepoda and Cladocera. Coleoptera and Hemiptera were also recorded as lesser components of

the drift community (from 3 to 900 individuals m^{-3}). The same author also reported the emergence of aestivating stages (within 14 days) from artificially flooded sediments from the Magela Creek sand tracts. These included Nematoda, Oligochaeta, Copepoda, Cladocera, Ceratopogonidae, Muscidae, Tipulidae, Simuliidae, Ephemeroptera and Hydracarina.

Another possible source of drift in Magela Creek are the many side-arms which are ephemeral in flow regime. Side-arms typically possessed macroinvertebrate assemblages with a high propensity to drift, particularly in spring-summer and during spates (Cellot, 1996). Temporal changes in the macroinvertebrate densities in a woodland pond in Switzerland were strongly influenced by the life cycles of the invertebrates: presence of numerous young individuals in summer (for example *Cypriodopsis vidua, Cloeon dipterum, Caenis horaria, Ferrissia wautieri*), and emergence (for example Chironomidae in April) (Oertli, 1993).

Spatial variations in the macroinvertebrate communities between the three study sites were recognised due to site specific environmental (physical, chemical and biotic) characteristics. Although the composition of riparian habitats were consistent between sites, other variables such as channel width and the presence or absence of levees, are believed to be important factors in determining the extent and magnitude of changes in the benthos.

An important consideration applicable to the ARR, where late season burning of accumulated dry organic matter and occasional wild fires can occur has been reported in recent years by several authors. Minshall *et al.*, (1995) found that macroinvertebrate taxa richness, density and biomass all were greater in unburned streams. Results suggest that the removal of terrestrial riparian vegetation by wildfire can directly influence stream benthic assemblages by altering the inherent disturbance regime of the physical habitat templet. Similar findings were reported

by Roby and Azuma (1995); macroinvertebrate density and taxa richness were both lower in burned reached as a Californian stream than in unburned reaches. Also, transportable sediment was much higher in the burned stream. Mihuc and Minshall (1995) found that from 11 taxa studied, only one (*Paraleptophlebia heteronea*) could effectively use burnedorganic matter as a resource.

4.2.2 Similarities between macroinvertebrate assemblages of different habitats

The PATN analyses indicated that three distinct assemblages were recognised in the macroinvertebrate community of Georgetown, and the principle components correlation showed the principle taxa responsible for the positioning of samples on the ordination were Oligochaeta, Nematoda, Trichoptera, Baetidae, Caenidae and Leptophlebiidae.

Of the three macroinvertebrate assemblages described by the ordination, two were comprised of samples originating from different habitats. In Figure 9a, the 'pink' assemblage is comprised of 6 sand habitat samples, 9 macrophytic edge and 9 leaf litter samples. Similarly, the 'orange' assemblage is comprised of 12 macrophytic edge samples and 12 leaf litter samples. It can therefore be concluded that the differences between the respective macrophytic edge and the leaf litter habitat macroinvertebrate assemblages were minimal. Samples representing both habitats appeared evenly throughout the PATN® "colour" groupings. This was probably due to the predominance of 'generalist detritivores' known to originate from many taxa in the Magela Creek benthos. Both the macrophytic edge and leaf litter habitats were abundant in this resource, and consequently the spread of the detritivorous taxa was rather homogeneous between the two. The third 'yellow' assemblage consisted entirely of samples representing the sand habitat. These samples were comprised predominantly of taxa specialised for the harsh existence in this habitat. The dipteran families Chironomidae and Ceratopogonidae were the most common taxa in these samples, with Oligochaetae and Nematoda represented

as minor components of the assemblage. All of these taxa exhibit a long and very thin thread-like morphological structure which would allow the animals to work their way through the very small interstitial spaces and forage for the detritus within.

Some sand samples were grouped with the 'pink' assemblage, but these (bar one) are grouped together in a minor sub-group. These samples contained a slightly higher proportion (~20%) of Oligochaeta and Nematoda than the other 'pink' group samples, but were otherwise unremarkable.

In review, the PATN analyses showed two fundamentally different groups; the 'sand specialists' and the 'generalist detritivores'

4.3 Spate induced effects on community indices

The effects of physical variables on macroinvertebrate assemblages in permanent and intermittent water courses have been investigated by many researchers. Although a wide range of physical variables are usually recorded during these studies, the most common and significant sources of variation in the structure of macroinvertebrate communities can be attributable to specifics in flow regime, depth and water temperature. The effects of water depth on macroinvertebrate assemblages has already been addressed. Temperature was not considered to be an important physical variable in regards to the effect it has on the benthos in Magela Creek because it was consistently high during the 1995-96 wet season flows. The warm air and water temperature provides an ideal environment for the macroinvertebrate development, both for species with an obligate aquatic existence and those with aquatic stage(s) in their life-cycles. However, rapid increases in temperature has been reported as having detrimental effects on macroinvertebrate assemblages. Voelz *et al.*, (1994) reported that samples taken along the longitudinal profile of a regulated river (via deep release dam) showed that populations of

several species of caddisflies, which had been numerically abundant in previous years, were virtually eliminated after a brief period of increased water temperature. Some species of caddisflies were unaffected.

Spates and variation in the flow regime from both natural and artificial sources have often been found to be responsible for variations in macroinvertebrate assemblages (Humphries, 1996). In a study of the impact of spates on benthic invertebrates in a seasonally flowing tropical rainforest stream in Australia, Rosser and Pearson (1995) found that both density and richness were lowest following the wet season. The most common trend was a decline in density as the intensity of flow related disturbance increased. They reported that the density of some taxa (Chironomidae, *Helicopsyche*,*Oecetis*, *Cheumatopsyche* and *Ferrissia*) were particularly vulnerable to spate induced disturbance, whereas others (*Baetis* and *Simuliium*) were not. Growns and Davis (1994) found that in a comparison of the macroinvertebrate communities of an upland and lowland portions of a Western Australian stream, longitudinal changes were gradual, and the macroinvertebrate assemblages were related to local flow conditions. Similar findings were reported by Ferrington *et al.* (1995). These researchers found that longitudinal zonation in the composition of chironomids were strongly influenced by physical variations in the microhabitats that occur as discharge merged into a well defined stream with alternating pool-riffle habitats. Intense flash flooding of Sycamore Creek in Arizona eliminated algae and reduced the invertebrate standing crop by 98% (Stuart *et al.*, 1982).

The effects of the intensity of spates and flow regimes have been studied. Wolz and Shiozawa (1995) found that habitat types with comparable flow conditions were the most similar, and Gallardo and Prenda (1994) found that most taxa in two Mediterranean basins of different physico-chemical characteristics were distributed in sites with vegetation cover and moderate values of water flow.

The effect of spates on macroinvertebrate community density may also be due to indirect effects. Dudgeon (1993) found that in a monsoonal tropical stream in Hong Kong, spate induced disturbances reduced predation rates by fish which led to increased macroinvertebrate abundance. The limnology of the Magela Creek billabongs is strongly influenced by the seasonal rainfall and stream flow patterns; macroinvertebrate assemblages and other aquatic biota in the Magela system, including phytoplankton and fishes, are affected similarly (Outridge, 1988).

Variations in the effect of flow regimes were studied by Del Carmen Corigliano and Freytes (1994). These authors suggested that channel hydraulics, quantitative geomorphology of the watershed, sestonic components and other factors influencing the structure and composition of aquatic communities produce a punctuated gradient in the longitudinal distribution of macroinvertebrates. They studied a confluence and concluded that the tributary affected the abundance patterns and increased the density at the confluence, but had little effect on species richness.

Other effects caused by fluctuations in water regime have been reported in other aquatic environments. Balla and Davis (1995), in a study of wetlands with fluctuating water regimes in Western Australia reported temporal changes in the macroinvertebrate communities appeared to be related to seasonal changes in the physical and chemical characteristics of the wetlands. Changes in water levels, concentrated nutrients and chemical components, and community composition differed more between the less enriched wetlands than the highly enriched wetlands, where communities were generally similar. High species richness was associated with seasonal drying.

4.3.1 Site specific effects of spates

The effects of spates are highly modified by the morphological characteristics of channels and braids through which they run, thus in order to discern the specific effects of spate events relevant to each of the sites, a more detailed description for each site and review of results is presented below.

4.3.1.1 Fishless

At Fishless, the stream morphology differed from those of other sites, primarily because that study site possessed high natural levees and a channel significantly narrower than those at other sites. Littoral zones with steep banks are often associated with a reduced area suitable for macrophytic growth. This was true for the Fishless site when compared to other sites further downstream. Georgetown and Mudginberri both possessed gradually sloping banks that merged into the riparian zones to either side of the creek, allowing extensive stands of macrophytes to progressively develop during the wet season flows in the littoral zone. These 'channel morphology' characteristics are believed to be responsible for the overall differences in the macroinvertebrate assemblages in Magela Creek since none of the studied sites possessed taxa which occurred exclusively at one site. Channel morphology probably affected the intensity of spates because unlike at Georgetown and Mudginberri, the intensity of the water flow during spates at Fishless were not eased by the presence of adjacent braids. The increased volume of water was retained in the narrow channel by the levees and was effectively 'funnelled'.

This funnelling effect is reflected in the community indices used to describe the macroinvertebrate assemblages at Fishless. As the time after initial rewetting increased (i.e., after a continuous series of spates), Simpson's Index of Diversity, the number of major taxa and mean total abundance either remained constant or decreased in each habitat sampled. Hence, at Fishless, the macroinvertebrate assemblages were most prolific in the early wet season (i.e., from day 1 to day 8);

thereafter the community composition became more depauperate.

4.3.1.2 Georgetown

The 'funnelling' (or 'channelling') effect would not have been as severe at the next site downstream (Georgetown). The wider stream channel and the absence of levees meant that flow was less restricted (not 'funnelled') than at Fishless. Increases in water volume were accommodated laterally by the gently sloping banks and presence of adjacent braids. The pattern of change in the community indices for the unstable sand habitat were similar to those at Fishless however, the macroinvertebrate assemblages in the edge and leaf habitats were seen to be affected to a lesser degree than at Fishless. Mean total abundance of the edge and leaf habitat assemblages steadily increased through the wet season at Georgetown, whereas at Fishless they remained fairly constant and did not develop.

4.3.1.3 Mudginberri

At Mudginberri, a different pattern of change in the community indices were recognised. The trends shown for the two upstream sites from early to late wet season were negative 'overall' (see Table 14), but at Mudginberri they were positive (i.e., the values for the respective community indices increased with time). The stream's physical morphology was similar to that of Georgetown in that it did not possess levees and did possess adjacent braids which could accommodate surges in discharge laterally. However, it was also situated only 200 m upstream of Mudginberri Billabong. This channel billabong is believed to have acted as a 'barrier' to surges in flow, slowing the overall flow rate and making Mudginberri a depositional site for nutrients and macroinvertebrates drifters. Consequently, the community indicies indicated that as the wet season progressed, there was an increase in the overall mean total abundance and number of major taxa in the edge and leaf habitats at Mudginberri. Even the frequently disturbed sand habitat remained constant in the number of major taxa it supported, and increased in mean

total abundance. The increase in macroinvertebrate abundance is believed to be associated with the reduced effects of spates, the steady accumulation of flocculated organic matter (i.e., food for detritivores), and colonisation via settling of macroinvertebrate drifters. Increased floc content in the sand was especially apparent whilst collecting the samples; the 250 µm mesh sieve often became clogged with floc and the mesh had to be 'tapped' to allow water to pass through.

4.4 Taxa which displayed site preferences

Molluscs and crustaceans were collected almost exclusively from Mudginberri. Other taxa which prefer lentic water bodies, such as oligochaetes, Hydracarina and hydroptilids occurred more frequently at this site than at Fishless or Georgetown.

Elmids and simuliids preferred the upstream sites, which were more lotic in nature. These taxa were repeatedly collected from root mats.

Both of these preferences exhibited by species typically associated with either lentic or lotic water bodies emphasises the variation in the local flow regimes of each site. Once again, these patterns in the distribution of 'key' taxa (indicative of certain flow conditions) is most likely attributable to site specific channel morphology.

4.5 Summary of discussions

In summary, physical variables were important in determining the structure and composition of local macroinvertebrate communities within the seasonally flowing portions of Magela Creek system. Chemical variables were deemed to be suspect in their significance. Biotic factors (such as the presence and extent of macrophytes, root mats and detritus) and abiotic factors (temperature, local stream morphology and discharge) were likely to have had a profound effect on the macroinvertebrate assemblages whether they were found to be significant or not. For example, although the magnitude of spates was not found to be significantly correlated to

the macroinvertebrate structures observed in this study, the fact that spates occurred is fundamental to the dynamics of intermittent (temporary) stream ecosystems when compared to those of lentic (permanent) systems. For example, mobile taxa were more abundant in the seasonally flowing stream than in the permanent stream, which was dominated by sessile taxa (e.g., *Glossosoma tricaudatus* and Chironomidae) (Robinson *et al.*, 1993).

The sand and leaf habitats were unstable, except at Mudginberri where the presence of Mudginberri Billabong (a channel billabong) is believed to have acted as a barrier or 'damper' to wet season flows, effectively making the site a depositional area for organic nutrients (as floc and other forms of detritus; see Hart and Beckett, 1986) and macroinvertebrate drifters. This hypothesis is emphasised by the exclusive presence of taxa (molluscs, oligochaetes and crustaceans) which are found more commonly found in lentic water bodies.

CHAPTER 5: CONCLUSIONS

In addressing the aims of the study (see Chapter 1), it may be concluded that:

i) There were several temporal and spatial variations in the structure of the macroinvertebrate communities in the seasonally flowing portions of Magela Creek (sand channels) during the 1995-96 wet season. These included changes in the community indices used to indicate how the communities were structured. Namely, these were Simpson's Index of Diversity, the number of major taxa, and total abundance calculated for three habitats (sandy sections of channels, macrophytic areas positioned on 'edges' of banks and riffle zones, and clumps of leaf litter).

ii) Several significant environmental factors were identified which affected the macroinvertebrate community structures. These were the presence of macrophytic substrate, root mats and detritus, the frequency and intensity of spates, and the morphological characteristics stream channels (both immediate and downstream) of sampling sites.

iii) Several recommendations can be made on how to refine and improve sampling procedures;

a) the sampling method should be designed to be directly quantitave, thus negating the requirement to 'standardise' the units for each sample.

b) sampling transects of 2 m length were too large. The samples thus collected required lengthy periods of sub-sampling to reduce sample volume. Instead, a smaller sampling transect (~10 cm) which contains approximately 100 animals would have sufficed. Sub-sampling also damaged specimens which impeded identification of specimens.

c) the morphological site characteristics should be recorded so that the local effects of spate can be monitored more closely.

CHAPTER 5: CONCLUSIONS

In addressing the aims of the study (see Chapter 1), it may be concluded that:

i) There were several temporal and spatial variations in the structure of the macroinvertebrate communities in the seasonally flowing portions of Magela Creek (sand channels) during the 1995-96 wet season. These included changes in the community indices used to indicate how the communities were structured. Namely, these were Simpson's Index of Diversity, the number of major taxa, and total abundance calculated for three habitats (sandy sections of channels, macrophytic areas positioned on 'edges' of banks and riffle zones, and clumps of leaf litter).

ii) Several significant environmental factors were identified which affected the macroinvertebrate community structures. These were the presence of macrophytic substrate, root mats and detritus, the frequency and intensity of spates, and the morphological characteristics stream channels (both immediate and downstream) of sampling sites.

iii) Several recommendations can be made on how to refine and improve sampling procedures;

a) the sampling method should be designed to be directly quantitave, thus negating the requirement to 'standardise' the units for each sample.

b) sampling transects of 2 m length were too large. The samples thus collected required lengthy periods of sub-sampling to reduce sample volume. Instead, a smaller sampling transect (~10 cm) which contains approximately 100 animals would have sufficed. Sub-sampling also damaged specimens which impeded identification of specimens.

c) the morphological site characteristics should be recorded so that the local effects of spate can be monitored more closely.

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APPENDICES

Appendix I: Mass of leaf litter components (g).

Number	'leaves' + tray	'woody material' + tray	tray	'leaves'		'woody material'
1	206.5	67.0	37.6	168.9		29.4
2	221.8	52.5	37.7	184.1		14.8
3	228.2	121.1	29.4	198.8		91.7
4	293.8	117.0	38.0	265.8		79.0
5	194.7	62.5	37.7	157.0		24.8
6	175.1	76.2	38.1	137.0		38.1
7	205.9	52.3	37.9	168.0		14.4
8	230.8	102.7	37.9	192.9		64.8
9	255.3	69.2	44.8	210.5		24.4
10	225.0	67.1	45.0	180.0		22.1
11	233.7	84.3	37.7	196.0		46.6
12	218.1	91.7	37.8	180.3		53.9
13	199.8	71.4	37.7	162.1		33.7
Mean dry weight (g):				184.7	(226.1 g)	41.4
Standard deviation:				31.3		24.6

Mean dry weight for each Leaf litter sample = 226.1 g.

1000 g ÷ 226.1 g = 4.42 (conversion factor, from number of macroinvertebrates per Leaf litter sample to numbers of macroinvertebrates per kilogram of detritus).

Appendix II: Physical Variables Correlation Coefficients (from MINITAB® v.9).

	% Macro	% Expos	%RtMt	%Detr	SFlow	Depth	Taxa	Abund
% Expos	-0.308							
% RtMt	0.778	-0.258						
%Detr	-.0384	-0.661	-0.258					
SFlow	-0.276	-0.346	-0.211	0.548				
Depth	-0.147	0.092	-0.092	-0.030	-0.246			
Taxa	0.496	-0.526	0.388	0.171	-0.090	-0.063		
Abund	0.415	-0.412	0.240	0.080	0.011	-0.151	0.416	
SID	0.224	-0.554	0.163	0.385	0.075	-0.075	0.512	0.210

81 rows; DF=79; $P<0.05$: r>0.220

$P<0.01$: r>0.286

$P<0.001$: r>0.361

Appendix III: Gauge Heights of Magela Creek (Georgetown Creek-side Monitoring Station).

DAY	DEC '95	JAN '96	FEB '96	MAR '96	APR '96
1	-	12.487	12.392	12.756	11.759*
2	-	12.089*	12.492	12.492	12.341
3	-	11.949	13.330	12.220	12.282
4	-	11.925	12.503	12.165	12.045
5	-	11.924	12.493	12.167	11.954
6	-	11.848	12.427	12.563	11.977
7	-	11.763	12.355	12.001	12.015
8	-	11.709	12.898	12.995	12.029
9	-	11.669	12.546	12.171	12.393
10	-	11.721	13.032	13.662	13.255
11	-	12.457	13.205	12.549	13.363
12	11.940	12.122	11.533	13.032	13.114
13	11.772	12.043	11.240*	12.962	12.711
14	12.277	12.411	11.123	12.486	12.441
15	12.583	12.233*	11.043	12.281	-
16	12.292	12.068	11.989	12.162	-
17	11.991	12.322	11.940	12.177	-
18	11.860	12.267	12.054	12.169*	-
19	11.976	12.404	12.043	12.551	-
20	11.841	12.229	11.945	12.262	-
21	11.752	12.239	11.885	12.433	-
22	11.736	12.644	11.868	12.174	-
23	11.686	13.150	11.831	12.030	-
24	11.643	12.677	11.792	11.959	-
25	11.610	12.366	11.823	11.917	-
26	11.584	12.461	11.903*	11.879	-
27	11.582	12.189	11.986	11.842	-
28	11.892	12.212	12.369	11.811	-
29	12.020	12.580*	13.080	11.785	-
30	12.136	12.433		11.765	11.72
31	12.269	12.674		11.744	

* Reliable Estimate
- Data Not Recorded

Gauge heights are daily means as recorded at the release point on Magela Creek.

Data collected from E.R.A. (Environmental Resources of Australia LTD).

Station MAGELA 02.

Appendix IV: Conversion table for Gauge Height to Discharge ($m^3 s^{-1}$).

G.H.	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
11.20								0.0000354	0.000551	0.00198
11.30	0.00459	0.00859	0.0142	0.0216	0.0308	0.0421	0.0557	0.0715	0.0897	0.111
11.40	0.134	0.160	0.189	0.221	0.256	0.295	0.336	0.381	0.429	0.480
11.50	0.536	0.594	0.657	0.726	0.800	0.879	0.963	1.05	1.14	1.24
11.60	1.34	1.45	1.56	1.68	1.80	1.93	2.06	2.20	2.35	2.49
11.70	2.64	2.79	2.95	3.12	3.29	3.46	3.64	3.83	4.02	4.21
11.80	4.42	4.62	4.84	5.06	5.26	5.43	5.61	5.79	5.97	6.16
11.90	6.35	6.54	6.74	6.94	7.15	7.35	7.57	7.78	8.00	8.22
12.00	8.48	8.80	9.12	9.45	9.79	10.1	10.5	10.8	11.2	11.6
12.10	12.0	12.3	12.7	13.1	13.4	13.8	14.2	14.6	15.0	15.4
12.20	15.9	16.3	16.7	17.2	17.6	18.1	18.5	19.0	19.5	19.9
12.30	20.4	20.9	21.4	21.9	22.5	23.0	23.5	24.1	24.6	25.2
12.40	25.7	26.3	26.9	27.5	28.0	28.6	29.3	29.9	30.5	31.1
12.50	31.8	32.4	32.9	33.5	34.0	34.6	35.2	35.7	36.3	36.9
12.60	37.5	38.0	38.6	39.2	39.8	40.4	41.1	41.7	42.5	43.6
12.70	44.6	45.7	46.8	47.9	49.0	49.9	50.9	51.9	52.8	53.8
12.80	54.8	55.8	56.9	57.9	59.0	60.0	61.1	62.2	63.2	64.3
12.90	65.5	66.6	67.7	68.9	70.0	71.2	72.4	73.6	74.8	76.0
13.00	77.2	78.5	79.7	81.0	82.3	83.5	84.8	86.2	87.5	88.8
13.10	90.2	91.5	92.9	94.3	95.7	97.1	98.5	100.0	101	103
13.20	104	106	107	109	110	112	113	115	117	118
13.30	120	121	123	125	126	128	130	131	133	135
13.40	137	138	140	142	144	145	147	149	151	153
13.50	155	156	158	160	162	164	166	168	169	171
13.60	173	175	177	179	180	182	184	186	188	190
13.70	191	193	194	196	198	199	201	202	204	206
13.80	207	209	211	212	214	216	217	220	224	228
13.90	232	236	240	244	249	253	257	261	266	270
14.00	274	279	283	288	292	297	302	306	311	316
14.10	321	326	331	336	341	346	351	356	361	367
14.20	372	377	383	388	393	399	405	410	416	422
14.30	427	433	439	445	451	457	463	469	475	481
14.40	488	494	500	507	513	519	526	533	539	546
14.50	553	559	566	573	580	587	594	601	608	615
14.60	623	630	637	645	653*	661	670*	678*	687*	696*
14.70	705*	713*	722*	731*	740*	749*	759*	768*	777*	787*
14.80	795*	806*	815*	825*	835*	845*	854*	864*	874*	884*
14.90	895*	905*	915*	925*	936*	946*	957*	968*	978*	989*
15.00	1000*									

Notes: All rated data has been coded as reliable except where the following tags are used.

* Rating Table Extrapolated

Retabulated from Energy Resources of Australia Ltd with permission from Geoff McKenzie, ERA.

Appendix V: Rainfall figures for Jabiru (from Bureau of Meteorology: Darwin).

DAY	NOV '95	DEC '95	JAN '96	FEB '96	MAR '96	APR '96
1	0	29.0	0	12.0	0	0
2	0	31.0*	0.4	1.0	1.0	57.0
3	0	0	0	12.0	0	11.0
4	0	15.0	0	0	0	0
5	13.0	0	6.0	0	9.0	0
6	0	0	0	24.0	20.0	0
7	2.0	0	0	1.0	52.0	4.0
8	0	24.0	0	36.0	25.0	5.0
9	2.0	59.0	0	12.0	12.0	5.0
10	2.0	18.0	0	57.0	13.0	19.0
11	0	2.0	67.0	42.0	12.0	60.0
12	0	11.0	30.0	0	3.0	15.0
13	0	0	44.0	0	0.6	16.0
14	0	15.0	24.0	0	0	0
15	5.0	17.0*	9.0	0	3.0	8.0
16	0	14.0	0	0	0	0.6
17	5.0	0.4	13.0	0	0	10.0
18	0	0	2.0	0	0	0
19	2.0	9.0	14.0	0	22.0	0
20	30.0	0	2.0	0	6.0	0
21	0	0	8.0	2.0	15.0	0
22	0	3.0	4.0	3.0	0	0
23	0	0	58.0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	12.0	0	0
26	0	0	3.0	0	0	0
27	0	3.0	0	20.0	0	0
28	0	46.0	4.0	0	0	0
29	6.0	51.0	11.0	45.0	0	0
30	19.0	4.0	8.0		0.6	0
31		28.0	4.0		0	

RAINFALL READ AT 9 AM ON DATE SHOWN.

STATION: JABIRU AP AWS

NUMBER: 014198

CODE: JAAP

Appendix VI: Chemical Variables Correlation Coefficients (from MINITAB® v.9).

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MTB > corr c3-c27
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	pH	Conduct	Alkalini	Bicarbon	Turbidit	Na	NH4-N	K
Conduct	0.598							
Alkalini	0.890	0.777						
Bicarbon	0.886	0.775	1.000					
Turbidit	0.106	0.601	0.161	0.149				
Na	0.771	0.688	0.935	0.936	0.061			
NH4-N	-0.275	-0.335	-0.407	-0.421	0.021	-0.350		
K	-0.042	0.413	0.023	0.018	0.876	-0.118	-0.103	
Cl	0.399	0.687	0.569	0.564	0.316	0.604	0.050	0.058
MG	0.738	0.793	0.896	0.896	0.293	0.943	-0.377	0.134
SO4	0.555	0.253	0.715	0.719	-0.300	0.856	-0.287	-0.372
Ca	0.806	0.807	0.902	0.904	0.278	0.779	-0.500	0.225
Ortho-P	0.215	-0.297	0.013	0.009	-0.272	0.101	-0.208	-0.458
Total-P	0.193	0.035	-0.004	-0.002	0.327	-0.097	-0.309	0.557
TOC	0.182	-0.317	-0.032	-0.038	-0.106	0.016	-0.184	-0.244
DOC	0.186	-0.349	-0.028	-0.033	-0.193	0.022	-0.228	-0.312
SandTTL	0.340	0.355	0.628	0.633	-0.122	0.773	-0.149	-0.097
SandTaxa	-0.151	-0.001	0.010	0.015	0.128	0.020	0.100	0.476
SandSID	-0.375	-0.253	-0.383	-0.381	-0.018	-0.468	0.244	0.242
EdgeTTL	0.267	-0.031	0.170	0.177	-0.546	0.002	-0.096	-0.492
EdgeTaxa	0.135	-0.266	0.153	0.164	-0.664	0.147	-0.048	-0.394
EdgeSID	0.324	0.129	0.145	0.152	-0.106	0.188	-0.107	-0.014
LeafTTL	0.577	0.252	0.673	0.683	-0.462	0.625	-0.306	-0.312
LeafTaxa	-0.646	-0.308	-0.352	-0.341	-0.358	-0.143	0.161	-0.154
LeafSID	-0.515	-0.054	-0.378	-0.378	0.327	-0.152	0.229	0.355

	Cl	MG	SO4	Ca	Ortho-P	Total-P	TOC	DOC
MG	0.517							
SO4	0.424	0.682						
Ca	0.302	0.861	0.449					
Ortho-P	-0.047	-0.046	0.298	-0.213				
Total-P	-0.441	0.142	-0.227	0.266	-0.043			
TOC	-0.110	-0.096	0.220	-0.234	0.961	0.078		
DOC	-0.152	-0.103	0.246	-0.224	0.973	0.073	0.995	
SandTTL	0.334	0.721	0.820	0.525	-0.250	-0.142	-0.298	-0.281
SandTaxa	-0.065	0.109	0.110	0.101	-0.665	0.325	-0.544	-0.554
SandSID	0.151	-0.535	-0.297	-0.470	-0.296	-0.060	-0.214	-0.232
EdgeTTL	-0.251	-0.086	-0.057	0.285	-0.168	-0.160	-0.300	-0.230
EdgeTaxa	-0.405	0.071	0.330	0.235	-0.294	0.064	-0.360	-0.286
EdgeSID	-0.015	0.304	0.047	0.259	-0.058	0.593	-0.157	-0.132
LeafTTL	0.167	0.499	0.671	0.617	-0.203	-0.046	-0.296	-0.236
LeafTaxa	-0.037	-0.193	0.111	-0.380	-0.445	-0.326	-0.501	-0.477
LeafSID	0.209	-0.040	-0.105	-0.416	-0.159	0.107	-0.121	-0.168

	SandTTL	SandTaxa	SandSID	EdgeTTL	EdgeTaxa	EdgeSID	LeafTTL	LeafTaxa
SandTaxa	0.510							
SandSID	-0.261	0.432						
EdgeTTL	-0.064	-0.238	-0.157					
EdgeTaxa	0.496	0.436	-0.078	0.618				
EdgeSID	0.081	0.167	-0.036	0.108	0.239			
LeafTTL	0.690	0.336	-0.059	0.546	0.778	0.275		
LeafTaxa	0.425	0.558	0.339	-0.152	0.355	-0.061	0.135	
LeafSID	0.088	0.392	0.318	-0.817	-0.404	0.185	-0.460	0.534

APPENDIX VII (Page 1)

Raw Sample Data (Sites: 1=FL, 2=GT, 3=MD)

(Habitat 1=Sand, 2=Macrophytic Edge, 3=Leaf Litter)

Samp.No	Site	Hab	Day	Aturidae	Hygrobat	Limnesii	Mideopsi	Oribatid	Oxidae	Unionico	Cladocer	Dytiscid
859	1	1	1	0	0	0	0	2	0	0	1	0
860	1	1	1	0	0	2	0	0	0	2	2	0
861	1	1	1	2	0	8	0	0	2	14	0	0
862	1	3	1	8	8	0	0	88	0	24	8	16
863	1	3	1	0	0	8	0	8	0	0	8	8
864	1	3	1	8	0	0	0	24	0	24	16	8
865	1	2	1	8	0	16	8	160	0	48	8	0
866	1	2	1	8	0	8	0	8	0	0	8	0
867	1	2	1	0	0	8	16	16	0	0	0	0
868	2	1	1	0	2	7	0	5	0	3	0	1
869	2	1	1	0	0	5	0	1	0	3	0	0
870	2	1	1	1	0	0	0	0	0	0	0	0
871	2	3	1	0	0	0	0	16	0	0	32	0
872	2	3	1	0	0	12	0	4	0	0	8	8
873	2	3	1	0	0	0	0	16	0	0	16	0
874	2	2	1	0	0	4	0	40	0	0	0	0
875	2	2	1	0	0	16	0	96	0	0	0	0
876	2	2	1	0	0	0	0	16	0	0	0	0
877	3	1	1	0	0	5	1	5	0	7	2	0
878	3	1	1	0	0	0	0	0	0	0	0	0
879	3	1	1	0	0	0	0	0	0	0	0	1
880	3	3	1	0	0	0	0	128	0	0	16	48
881	3	3	1	0	0	16	16	80	16	0	16	0
882	3	3	1	0	0	0	0	8	0	0	0	32
883	3	2	1	0	0	0	8	8	0	0	4	8
884	3	2	1	0	0	0	0	40	0	8	0	16
885	3	2	1	0	0	0	1	82	0	2	2	0
1021	1	1	64	0	1	0	0	0	0	0	0	0
1022	1	1	64	0	2	2	0	6	0	2	0	0
1023	1	1	64	0	0	1	2	2	0	1	0	0
1024	1	3	64	0	16	0	0	8	0	4	0	8
1025	1	3	64	2	38	0	0	54	0	8	2	4
1026	1	3	64	0	28	28	0	0	4	12	0	8
1027	1	2	64	0	16	24	0	680	16	0	0	0
1028	1	2	64	0	8	0	2	28	0	0	0	0
1029	1	2	64	0	0	28	4	52	0	36	0	0
1030	2	1	64	0	1	1	3	5	0	0	1	0
1031	2	1	64	0	0	0	0	3	0	0	1	0
1032	2	1	64	0	0	0	0	1	0	0	0	0
1033	2	3	64	0	0	0	0	96	0	0	122	0
1034	2	3	64	0	0	0	8	1880	0	8	56	32
1035	2	3	64	2	12	4	4	10	0	10	6	12
1036	2	2	64	8	40	32	64	376	16	16	32	8
1037	2	2	64	0	8	0	40	328	0	8	192	24
1038	2	2	64	0	0	0	16	688	0	16	960	48
1039	3	1	64	1	7	11	2	5	2	1	6	0
1040	3	1	64	0	7	4	0	8	0	1	0	0
1041	3	1	64	0	4	0	0	2	0	0	1	0
1042	3	3	64	0	0	0	0	104	0	8	72	0
1043	3	3	64	0	0	0	0	880	16	0	96	0
1044	3	3	64	0	0	0	16	128	0	16	128	32
1045	3	2	64	8	40	0	32	256	24	24	368	8
1046	3	2	64	0	4	0	4	200	0	4	124	0
1047	3	2	64	10	36	26	30	340	8	22	26	0
1194	1	1	141	0	6	2	0	0	0	0	0	0
1195	1	1	141	0	0	0	0	0	0	0	0	0
1196	1	1	141	0	0	0	0	2	0	0	0	0
1197	1	3	141	0	0	0	0	0	0	8	0	8
1198	1	3	141	0	0	0	0	0	0	16	0	16
1199	1	3	141	0	0	0	0	8	0	0	0	32
1200	1	2	141	0	0	2	0	0	0	0	0	0
1201	1	2	141	0	8	0	0	1	1	0	0	0
1202	1	2	141	0	8	0	0	16	0	0	0	0
1203	2	1	141	0	1	0	0	0	0	0	0	0
1204	2	1	141	0	0	0	0	0	0	0	0	0
1205	2	1	141	0	0	0	0	0	0	0	0	0
1206	2	3	141	0	0	0	0	672	0	0	32	0
1207	2	3	141	16	0	0	0	784	0	0	32	0
1208	2	3	141	0	0	0	32	1184	0	0	64	0
1209	2	2	141	0	20	12	96	24	0	56	8	4
1210	2	2	141	4	104	20	4	28	0	48	0	0
1211	2	2	141	0	72	0	0	0	0	8	0	8
1212	3	1	141	0	12	16	19	3	1	6	1	0
1213	3	1	141	0	0	0	0	1	0	0	0	0
1214	3	1	141	0	34	17	27	2	0	0	0	0
1215	3	3	141	0	0	0	0	176	0	0	320	8
1216	3	3	141	0	16	0	0	256	0	24	104	8
1217	3	3	141	32	368	96	64	0	16	512	0	16
1218	3	2	141	4	16	4	4	48	4	4	12	4
1219	3	2	141	0	8	0	0	84	0	4	56	12
1220	3	2	141	8	160	16	88	40	16	16	0	0

APPENDIX VII (Page 2)

Samp.No	Elmidae	Hydrophi	Staphyln	Copepoda	Decapoda	Aphroten	Ceratopo	Chironom	Simuliid	Tanypodi
859	0	1	0	0	0	0	0	7	0	0
860	2	0	0	4	0	0	2	2	0	2
861	4	0	0	12	0	2	26	22	0	16
862	32	0	8	88	0	0	40	72	0	88
863	64	0	0	176	0	0	16	24	0	64
864	48	0	0	96	0	0	16	104	0	32
865	88	8	0	0	0	0	24	80	0	120
866	128	0	0	0	0	0	24	40	0	8
867	120	8	0	8	0	0	16	64	0	0
868	0	0	1	6	0	0	19	70	0	9
869	0	0	0	0	0	0	6	16	0	8
870	0	0	0	2	0	0	0	4	0	0
871	0	0	0	8	0	8	184	72	0	184
872	0	0	0	4	0	0	24	72	0	80
873	0	0	0	0	0	0	144	96	0	176
874	0	0	0	0	0	0	48	36	0	12
875	0	16	0	0	0	0	48	80	0	176
876	0	0	0	0	0	0	32	40	0	0
877	0	0	0	3	0	0	3	3	0	11
878	0	0	0	0	0	0	1	3	0	2
879	0	0	0	0	0	0	3	7	0	3
880	0	0	0	0	0	0	80	128	0	80
881	0	16	0	0	0	0	80	64	0	208
882	0	0	0	40	8	0	8	40	0	64
883	0	0	0	4	0	0	28	16	0	24
884	0	0	8	16	0	0	96	48	0	56
885	0	3	5	2	0	0	3	10	0	10
1021	11	0	0	0	0	0	13	14	0	0
1022	18	0	2	0	0	0	138	26	0	2
1023	15	0	1	0	0	0	24	11	0	1
1024	28	4	4	12	4	0	8	100	52	24
1025	46	0	0	0	0	0	0	122	20	20
1026	36	4	4	24	0	0	8	48	4	20
1027	192	0	0	0	0	40	56	208	8	0
1028	86	0	0	0	0	0	10	20	44	0
1029	320	12	0	0	0	0	8	60	24	0
1030	0	0	0	0	0	2	20	35	0	8
1031	0	0	0	0	0	0	33	30	2	6
1032	0	0	0	0	0	0	4	1	0	0
1033	0	0	0	72	0	8	8	72	0	112
1034	0	0	0	64	0	0	0	136	0	88
1035	2	0	0	16	0	0	6	60	0	22
1036	0	0	0	8	0	0	56	272	16	112
1037	0	0	0	48	0	8	56	928	0	128
1038	0	0	32	0	0	16	172	1616	0	288
1039	0	0	0	2	0	0	20	27	0	7
1040	1	0	0	0	0	0	16	16	0	6
1041	0	0	0	0	0	0	5	9	0	1
1042	0	0	0	0	0	0	24	480	0	152
1043	0	0	0	16	0	0	16	672	0	464
1044	0	0	0	16	0	0	48	752	0	416
1045	0	0	0	48	0	0	24	1128	0	304
1046	0	12	0	0	0	4	52	512	0	180
1047	12	4	0	16	0	0	10	376	36	128
1194	2	0	0	0	0	0	14	22	0	0
1195	0	0	0	0	0	0	11	4	0	0
1196	0	0	0	0	0	0	2	5	3	0
1197	0	0	4	32	0	0	4	84	0	16
1198	0	0	0	0	0	0	64	336	0	128
1199	0	0	0	0	0	0	40	576	0	144
1200	2	2	0	0	0	0	0	26	0	1
1201	5	0	0	0	2	0	24	92	259	14
1202	16	0	0	0	0	0	64	72	504	32
1203	0	0	0	0	0	0	12	9	0	0
1204	0	0	0	0	0	0	6	2	0	0
1205	0	0	0	0	0	0	5	3	0	1
1206	0	0	0	16	0	0	16	128	16	192
1207	0	0	0	0	0	0	64	704	16	336
1208	0	0	0	32	0	0	96	544	0	256
1209	4	0	0	0	0	0	36	740	60	596
1210	8	0	0	0	4	0	8	412	900	312
1211	16	0	0	0	0	0	24	960	9504	88
1212	1	0	0	1	0	0	47	190	0	36
1213	0	0	0	0	0	0	87	14	0	1
1214	68	0	0	0	0	0	25	74	0	17
1215	0	0	0	40	32	0	8	720	0	96
1216	0	0	0	176	120	0	8	456	0	96
1217	0	0	0	224	128	0	160	2016	0	400
1218	0	0	0	4	12	0	62	488	0	288
1219	0	0	0	16	4	0	52	476	0	296
1220	16	0	0	0	32	0	56	968	0	344

APPENDIX VII (Page 3)

Samp.No	Tipulida	Baetidae	Caenidae	Leptophl	Gastropo	Corixida	Gerridae	Pyralida	Mollusca	Nematoda
859	0	0	0	0	0	0	0	0	0	0
860	4	0	0	0	0	10	0	0	0	4
861	0	6	2	0	0	32	0	0	0	0
862	0	32	40	96	0	8	0	0	0	32
863	0	0	16	0	0	0	0	0	0	8
864	8	8	0	32	0	0	0	0	0	40
865	16	24	32	0	0	0	0	0	0	96
866	0	8	24	0	0	0	0	8	0	48
867	8	8	16	0	0	0	0	0	0	0
868	3	22	3	38	0	0	0	0	0	0
869	0	0	0	2	0	0	0	0	0	0
870	0	0	0	0	0	0	0	0	0	1
871	8	24	32	120	0	0	0	0	0	160
872	4	28	48	152	0	0	0	0	0	8
873	16	16	48	32	0	0	0	0	0	32
874	16	8	12	0	0	0	0	0	0	36
875	16	16	16	0	0	0	0	0	0	80
876	24	0	0	0	0	0	0	0	0	24
877	0	4	1	2	0	1	0	0	0	7
878	0	2	0	0	0	0	0	0	0	0
879	2	3	1	0	0	1	0	0	0	4
880	0	16	0	0	0	0	0	0	0	48
881	0	0	32	16	0	0	0	32	0	48
882	8	0	0	0	0	0	0	8	0	64
883	12	8	0	0	0	0	0	0	0	40
884	1	16	48	8	0	8	0	0	0	16
885	8	20	70	44	0	1	0	0	0	2
1021	0	1	0	2	0	0	1	0	0	0
1022	8	0	0	0	0	0	0	0	0	0
1023	2	0	0	0	0	0	0	0	0	0
1024	0	56	44	32	0	0	0	4	0	0
1025	0	178	106	2	0	0	0	0	0	0
1026	0	12	20	44	0	0	0	0	0	0
1027	48	96	80	0	0	0	0	0	0	152
1028	4	36	6	0	0	0	0	0	0	0
1029	12	164	72	0	0	4	0	4	0	0
1030	1	7	2	0	0	1	0	0	0	0
1031	0	1	1	1	0	0	0	0	0	0
1032	0	0	0	0	0	0	0	0	0	0
1033	0	56	40	160	0	0	8	0	0	24
1034	0	24	24	0	0	0	0	0	0	48
1035	0	46	4	12	0	0	0	0	0	0
1036	8	232	48	0	0	0	0	0	0	64
1037	0	160	160	0	0	40	8	56	0	80
1038	0	304	272	0	0	16	0	16	0	412
1039	0	1	14	0	0	1	2	0	0	0
1040	0	2	9	0	0	1	1	0	0	0
1041	0	0	9	0	0	0	0	0	0	0
1042	0	32	552	64	0	0	0	0	0	88
1043	0	16	80	0	0	0	0	0	0	32
1044	16	32	288	48	48	0	0	0	0	64
1045	0	80	352	8	0	8	0	8	0	24
1046	36	20	112	0	0	0	0	0	0	152
1047	6	512	322	0	0	2	0	2	0	2
1194	0	0	2	0	0	0	0	0	0	0
1195	0	0	2	0	0	0	0	0	0	0
1196	0	0	0	0	0	0	0	0	0	0
1197	0	8	52	8	0	0	0	0	0	4
1198	0	0	112	80	0	0	0	0	0	0
1199	0	0	208	8	0	0	0	0	0	0
1200	0	18	6	0	0	8	0	0	0	0
1201	3	80	165	0	0	0	0	5	0	2
1202	0	56	112	8	0	0	0	16	0	0
1203	0	0	4	0	0	0	0	0	0	0
1204	0	0	1	0	0	0	0	0	0	0
1205	0	0	0	0	0	0	0	0	0	0
1206	0	0	32	32	0	0	0	0	0	0
1207	0	0	560	112	0	0	0	0	0	80
1208	0	0	384	32	0	0	0	0	0	0
1209	0	216	668	0	0	0	0	0	0	20
1210	0	244	940	0	0	0	0	0	0	32
1211	8	120	1048	8	0	0	0	0	0	24
1212	4	1	701	0	0	3	0	0	1	2
1213	3	3	19	0	0	0	0	0	0	0
1214	0	0	542	0	0	3	0	1	0	0
1215	0	48	176	96	80	0	0	0	88	8
1216	0	32	632	136	104	0	0	0	0	0
1217	0	160	2592	16	0	64	0	0	0	0
1218	4	160	284	0	0	0	0	0	0	12
1219	4	92	332	0	0	0	0	4	4	4
1220	8	304	808	0	0	0	0	16	0	24

APPENDIX VII (Page 4)

Samp.No	Anisopte	Zygopter	Oligocha	Ost(oval)	Ost(rnd)	Calamoce	Ecnomida	Hydropsy	Hydropti	Leptocer
859	1	0	0	0	0	0	0	0	0	0
860	0	0	14	0	0	0	0	0	0	0
861	0	2	90	0	2	0	0	0	0	0
862	8	8	232	8	16	0	0	0	0	8
863	0	32	48	8	8	0	0	0	0	0
864	0	24	40	0	8	0	0	0	0	8
865	0	0	80	8	16	0	0	0	0	48
866	0	0	120	8	0	0	0	0	0	24
867	0	0	120	0	0	0	0	0	0	0
868	0	3	3	0	0	0	0	0	0	0
869	0	0	3	0	0	0	0	0	0	1
870	0	0	2	0	0	0	0	0	0	1
871	0	96	288	0	0	0	8	0	0	0
872	0	48	32	0	0	0	0	0	0	16
873	0	48	320	0	0	0	0	0	0	0
874	0	0	84	4	0	0	0	0	0	4
875	0	0	208	16	0	0	0	0	0	0
876	0	0	64	0	0	0	0	0	0	8
877	1	4	287	0	0	0	0	0	1	0
878	0	0	25	0	0	0	0	0	0	0
879	0	0	15	0	0	0	0	0	0	1
880	0	0	112	0	0	0	0	0	0	16
881	0	64	32	0	0	0	0	0	0	0
882	8	0	56	0	0	0	0	0	0	0
883	0	12	800	0	0	0	0	0	0	0
884	0	8	264	0	0	0	0	0	0	8
885	0	3	61	0	0	0	0	0	0	2
1021	0	0	0	0	0	0	0	0	0	1
1022	2	0	14	0	0	0	2	0	0	0
1023	0	0	6	0	0	0	0	0	0	1
1024	4	4	28	0	4	16	72	36	0	12
1025	2	0	36	6	0	4	10	24	4	10
1026	4	0	20	0	4	4	0	0	24	68
1027	8	0	104	144	0	0	0	0	8	96
1028	2	0	14	0	0	0	0	2	0	2
1029	8	0	36	12	0	0	4	12	8	4
1030	0	0	2	1	1	0	0	0	0	0
1031	0	0	1	0	1	0	1	0	0	1
1032	0	0	0	0	0	0	0	0	0	0
1033	16	0	200	80	56	0	0	0	0	0
1034	0	0	48	160	80	0	8	0	0	0
1035	0	0	28	2	4	2	0	0	0	8
1036	16	0	192	88	32	0	0	0	16	56
1037	16	16	192	72	64	8	8	0	0	40
1038	32	96	560	128	256	0	0	32	32	208
1039	0	0	0	1	3	0	0	0	3	4
1040	0	0	1	1	2	0	0	0	1	2
1041	0	0	1	0	3	0	0	0	0	0
1042	0	8	224	80	80	0	16	0	8	8
1043	0	0	608	128	80	0	0	0	16	16
1044	16	0	192	96	176	0	0	0	32	0
1045	8	0	304	145	200	0	8	0	96	80
1046	0	0	72	92	32	0	12	0	40	32
1047	0	2	394	34	84	0	8	20	102	154
1194	0	0	0	0	0	0	0	0	0	0
1195	0	0	0	0	0	0	0	0	0	0
1196	0	0	0	0	0	0	0	0	0	0
1197	0	0	8	0	0	4	0	0	4	12
1198	16	0	0	0	0	0	0	0	0	48
1199	8	0	32	0	0	0	16	0	8	8
1200	0	0	0	0	0	0	0	0	0	0
1201	1	0	5	0	0	0	4	32	37	6
1202	0	0	16	0	0	0	0	48	16	8
1203	0	1	0	0	0	0	0	0	0	0
1204	0	0	0	0	0	0	0	0	0	0
1205	0	0	0	0	0	0	0	0	0	0
1206	0	0	0	0	0	0	0	0	32	0
1207	0	0	48	272	0	0	0	0	48	48
1208	0	0	0	96	0	0	0	0	0	0
1209	0	0	60	4	4	0	0	4	56	32
1210	0	0	64	4	4	0	32	48	64	92
1211	0	0	56	0	0	0	64	232	72	0
1212	0	0	47	0	3	0	0	0	4	0
1213	0	0	7	0	0	0	0	0	0	0
1214	0	0	138	0	2	0	0	0	0	4
1215	0	0	8	120	0	0	8	0	24	8
1216	0	0	8	88	16	0	0	8	8	32
1217	0	16	32	0	304	16	16	16	320	112
1218	4	4	20	8	12	0	4	0	120	20
1219	0	4	8	16	24	0	8	0	144	32
1220	16	8	144	0	24	0	56	0	208	80

APPENDIX VIII (Page 1)

Raw Sample Data (Georgetown)

(Habitat: 1=Sand, 2=Macrophytic Edge, 3=Leaf Litter)

Samp.No	Site	Hab	Day	Aturidae	Hygrobat	Limnesii	Mideopsi	Oribatid	Oxidae	Unionico	Cladocer	Dytiscid
868	2	1	1	0	2	7	0	5	0	3	0	1
869	2	1	1	0	0	5	0	1	0	3	0	0
870	2	1	1	1	0	0	0	0	0	0	0	0
871	2	3	1	0	0	0	0	16	0	0	32	0
872	2	3	1	0	0	12	0	4	0	0	8	8
873	2	3	1	0	0	0	0	16	0	0	16	0
874	2	2	1	0	0	4	0	40	0	0	0	0
875	2	2	1	0	0	16	0	96	0	0	0	0
876	2	2	1	0	0	0	0	16	0	0	0	0
904	2	1	8	0	0	12	0	10	0	0	212	0
905	2	1	8	0	2	0	0	10	1	1	62	3
906	2	1	8	0	0	0	0	16	0	0	38	0
907	2	3	8	4	0	0	0	20	0	0	56	0
908	2	3	8	0	0	0	0	32	0	4	68	8
909	2	3	8	0	0	0	0	56	0	8	8	16
910	2	2	8	0	0	0	0	40	0	0	28	28
911	2	2	8	0	40	0	0	24	0	0	24	0
912	2	2	8	0	0	0	0	96	0	0	32	0
958	2	1	23	0	0	0	0	3	0	0	2	0
959	2	1	23	1	11	3	0	2	6	4	23	0
960	2	1	23	5	4	3	1	8	0	9	43	1
961	2	3	23	0	0	0	0	232	0	0	520	88
962	2	3	23	0	0	0	0	32	0	8	4	4
963	2	3	23	0	0	0	4	12	0	4	60	20
964	2	2	23	0	12	0	0	4	4	0	0	0
965	2	2	23	0	0	0	0	32	0	16	16	32
966	2	2	23	0	12	0	0	32	0	0	4	0
1030	2	1	64	0	1	1	3	5	0	0	1	0
1031	2	1	64	0	0	0	0	3	0	0	1	0
1032	2	1	64	0	0	0	0	1	0	0	0	0
1033	2	3	64	0	0	0	0	96	0	0	122	0
1034	2	3	64	0	0	0	8	1880	0	8	56	32
1035	2	3	64	2	12	4	4	10	0	10	6	12
1036	2	2	64	8	40	32	64	376	16	16	32	8
1037	2	2	64	0	8	0	40	328	0	8	192	24
1038	2	2	64	0	0	0	16	688	0	16	960	48
1057	2	1	95	0	0	0	0	2	0	0	0	0
1058	2	1	95	0	0	0	0	0	0	0	1	0
1059	2	1	95	0	0	0	0	1	0	0	0	0
1060	2	3	95	0	4	0	0	640	0	0	36	4
1061	2	3	95	0	0	0	0	304	0	0	0	24
1062	2	3	95	0	0	0	0	464	0	0	64	0
1063	2	2	95	8	8	0	8	504	0	8	80	0
1064	2	2	95	0	16	0	32	232	0	16	40	16
1065	2	2	95	0	20	4	4	72	4	8	2	4
1084	2	1	114	0	0	0	0	1	0	0	0	0
1085	2	1	114	0	0	1	0	0	0	0	0	0
1086	2	1	114	0	1	0	0	0	0	0	0	0
1087	2	3	114	8	0	0	0	72	0	8	192	16
1088	2	3	114	0	0	0	0	272	0	0	16	48
1089	2	3	114	0	0	0	0	64	0	0	0	0
1090	2	2	114	0	0	0	16	48	0	0	0	0
1091	2	2	114	0	32	0	32	544	0	0	224	0
1092	2	2	114	12	16	16	20	36	0	0	4	12
1203	2	1	141	0	1	0	0	0	0	0	0	0
1204	2	1	141	0	0	0	0	0	0	0	0	0
1205	2	1	141	0	0	0	0	0	0	0	0	0
1206	2	3	141	0	0	0	0	672	0	0	32	0
1207	2	3	141	16	0	0	0	784	0	0	32	0
1208	2	3	141	0	0	0	32	1184	0	0	64	0
1209	2	2	141	0	20	12	96	24	0	56	8	4
1210	2	2	141	4	104	20	4	28	0	48	0	0
1211	2	2	141	0	72	0	0	0	0	8	0	8

APPENDIX VIII (Page 2)

Samp.No	Elmidae	Hydrophi	Staphyln	Copepoda	Decapoda	Aphroten	Ceratopo	Chironom	Simuliid	Tanypodi
868	0	0	1	6	0	0	19	70	0	9
869	0	0	0	0	0	0	6	16	0	8
870	0	0	0	2	0	0	0	4	0	0
871	0	0	0	8	0	8	184	72	0	184
872	0	0	0	4	0	0	24	72	0	80
873	0	0	0	0	0	0	144	96	0	176
874	0	0	0	0	0	0	48	36	0	12
875	0	16	0	0	0	0	48	80	0	176
876	0	0	0	0	0	0	32	40	0	0
904	0	0	0	6	0	0	24	16	0	8
905	3	1	0	136	0	0	10	46	0	249
906	0	0	2	4	0	0	12	4	0	4
907	32	0	0	8	0	0	4	36	12	0
908	0	0	0	40	0	0	8	16	0	4
909	0	0	0	40	0	0	0	40	0	8
910	0	0	0	32	4	0	36	28	0	8
911	16	8	0	8	0	0	64	8	0	16
912	0	0	0	0	0	0	48	0	0	0
958	0	0	0	1	0	0	0	16	0	3
959	5	0	0	2	0	0	3	57	2	44
960	9	0	0	34	1	0	1	97	1	75
961	8	0	0	360	0	0	40	408	8	400
962	0	4	0	48	0	0	4	100	276	20
963	0	0	4	144	0	0	0	112	8	68
964	20	4	0	0	0	0	12	56	20	4
965	0	0	0	16	0	0	48	80	16	16
966	0	4	0	4	0	0	12	40	44	8
1030	0	0	0	0	0	2	20	35	0	8
1031	0	0	0	0	0	0	33	30	2	6
1032	0	0	0	0	0	0	4	1	0	0
1033	0	0	0	72	0	8	8	72	0	112
1034	0	0	0	64	0	0	0	136	0	88
1035	2	0	0	16	0	0	6	60	0	22
1036	0	0	0	8	0	0	56	272	16	112
1037	0	0	0	48	0	8	56	928	0	128
1038	0	0	32	0	0	16	172	1616	0	288
1057	0	0	0	0	0	0	2	4	0	5
1058	0	0	0	0	0	0	0	4	0	0
1059	0	0	0	0	0	0	3	2	0	0
1060	0	4	4	28	0	4	32	468	0	128
1061	8	0	0	32	0	0	0	88	0	112
1062	0	0	0	16	0	0	0	256	0	126
1063	0	0	0	56	0	0	40	264	0	120
1064	0	0	0	0	0	0	24	536	8	162
1065	4	0	0	6	0	0	18	66	16	52
1084	0	0	0	0	0	0	15	10	0	1
1085	0	0	0	0	0	0	20	23	0	0
1086	0	0	0	0	0	0	0	1	0	0
1087	0	8	0	400	0	0	8	416	0	104
1088	0	16	0	0	0	0	48	48	0	32
1089	0	32	0	0	0	0	16	0	0	16
1090	0	0	48	0	0	0	32	224	0	172
1091	0	16	0	48	0	0	32	5648	0	992
1092	0	0	4	0	0	0	4	176	8	108
1203	0	0	0	0	0	0	12	9	0	0
1204	0	0	0	0	0	0	6	2	0	0
1205	0	0	0	0	0	0	5	3	0	1
1206	0	0	0	16	0	0	16	128	16	192
1207	0	0	0	0	0	0	64	704	16	336
1208	0	0	0	32	0	0	96	544	0	256
1209	4	0	0	0	0	0	36	740	60	596
1210	8	0	0	0	4	0	8	412	900	312
1211	16	0	0	0	0	0	24	960	9504	88

APPENDIX VIII (Page 3)

Samp.No	Tipulida	Baetidae	Caenidae	Leptophl	Gastropo	Corixida	Gerridae	Pyralida	Mollusca	Nematoda
868	3	22	3	38	0	0	0	0	0	0
869	0	0	0	2	0	0	0	0	0	0
870	0	0	0	0	0	0	0	0	0	1
871	8	24	32	120	0	0	0	0	0	160
872	4	28	48	152	0	0	0	0	0	8
873	16	16	48	32	0	0	0	0	0	32
874	16	8	12	0	0	0	0	0	0	36
875	16	16	16	0	0	0	0	0	0	80
876	24	0	0	0	0	0	0	0	0	24
904	2	8	0	16	0	4	0	0	0	0
905	0	1	1	7	0	0	0	0	0	4
906	18	0	0	70	0	0	0	0	0	0
907	20	28	32	224	0	0	0	0	0	4
908	4	4	8	452	0	0	0	0	0	20
909	8	8	0	864	0	0	0	0	0	32
910	8	0	8	1056	0	0	0	0	0	8
911	16	0	16	544	0	0	0	0	0	40
912	16	0	16	256	0	0	0	0	0	32
958	0	0	0	6	0	1	0	0	0	0
959	0	29	5	0	0	8	0	0	0	5
960	0	36	9	0	0	24	2	0	0	2
961	4	48	88	496	0	24	0	0	0	32
962	0	68	248	180	0	0	0	0	0	20
963	4	12	12	460	0	0	0	0	0	16
964	8	24	44	12	0	0	0	0	0	16
965	16	16	0	16	0	0	0	0	0	96
966	0	60	112	96	0	0	0	0	0	0
1030	1	7	2	0	0	1	0	0	0	0
1031	0	1	1	1	0	0	0	0	0	0
1032	0	0	0	0	0	0	0	0	0	0
1033	0	56	40	160	0	0	8	0	0	24
1034	0	24	24	0	0	0	0	0	0	48
1035	0	46	4	12	0	0	0	0	0	0
1036	8	232	48	0	0	0	0	0	0	64
1037	0	160	160	0	0	40	8	56	0	80
1038	0	304	272	0	0	16	0	16	0	412
1057	0	0	0	0	0	0	0	0	0	0
1058	0	0	1	0	0	0	0	0	0	0
1059	0	0	0	0	0	0	0	0	0	0
1060	16	32	88	8	0	0	0	0	0	52
1061	0	8	24	8	0	0	0	0	0	112
1062	0	0	32	0	0	0	0	0	0	48
1063	16	80	104	0	0	0	0	0	0	176
1064	0	112	120	0	0	0	0	0	0	16
1065	2	50	40	1	0	0	4	0	0	18
1084	0	1	0	0	0	0	1	0	0	0
1085	1	0	1	0	0	0	0	0	0	2
1086	0	0	0	0	0	0	0	0	0	0
1087	16	32	32	0	0	48	0	0	0	32
1088	16	0	0	0	0	0	0	0	0	128
1089	0	0	0	0	0	0	0	0	0	48
1090	0	16	16	16	0	48	0	0	0	172
1091	0	16	976	0	0	32	0	0	0	172
1092	8	92	112	0	0	12	0	4	0	8
1203	0	0	4	0	0	0	0	0	0	0
1204	0	0	1	0	0	0	0	0	0	0
1205	0	0	0	0	0	0	0	0	0	0
1206	0	0	32	32	0	0	0	0	0	0
1207	0	0	560	112	0	0	0	0	0	80
1208	0	0	384	32	0	0	0	0	0	0
1209	0	216	668	0	0	0	0	0	0	20
1210	0	244	940	0	0	0	0	0	0	32
1211	8	120	1048	8	0	0	0	0	0	24

APPENDIX VIII (Page 4)

Samp.No	Anisopte	Zygopter	Oligocha	Ost (oval)	Ost(md)	Calamoce	Ecnomida	Hydropsy	Hydropti	Leptocer
868	0	3	3	0	0	0	0	0	0	0
869	0	0	3	0	0	0	0	0	0	1
870	0	0	2	0	0	0	0	0	0	1
871	0	96	288	0	0	0	8	0	0	0
872	0	48	32	0	0	0	0	0	0	16
873	0	48	320	0	0	0	0	0	0	0
874	0	0	84	4	0	0	0	0	0	4
875	0	0	208	16	0	0	0	0	0	0
876	0	0	64	0	0	0	0	0	0	8
904	0	2	0	0	0	0	0	0	0	0
905	0	0	46	5	1	0	0	0	0	0
906	0	0	52	0	2	0	0	0	0	0
907	0	0	56	0	0	0	0	0	0	0
908	0	16	80	0	0	0	0	0	0	4
909	8	72	48	0	0	0	0	0	0	0
910	0	60	48	0	12	0	0	0	0	0
911	0	0	184	0	0	0	0	0	0	0
912	0	16	48	0	0	0	0	0	0	32
958	0	0	0	0	0	0	0	0	0	0
959	0	0	26	0	1	0	0	0	0	2
960	10	2	29	4	20	0	1	0	0	3
961	8	80	272	16	56	0	0	0	0	0
962	0	8	84	0	36	0	0	28	8	32
963	4	32	84	8	112	0	0	0	4	4
964	0	0	96	0	0	0	0	0	0	48
965	0	0	992	0	16	0	0	0	0	16
966	0	0	76	4	0	0	0	8	0	24
1030	0	0	2	1	1	0	0	0	0	0
1031	0	0	1	0	1	0	1	0	0	1
1032	0	0	0	0	0	0	0	0	0	0
1033	16	0	200	80	56	0	0	0	0	0
1034	0	0	48	160	80	0	8	0	0	0
1035	0	0	28	2	4	2	0	0	0	8
1036	16	0	192	88	32	0	0	0	16	56
1037	16	16	192	72	64	8	8	0	0	40
1038	32	96	560	128	256	0	0	32	32	208
1057	0	0	0	3	0	0	0	0	0	1
1058	0	0	0	0	0	0	0	0	0	0
1059	0	0	0	0	0	0	0	0	0	0
1060	0	0	352	24	8	4	0	0	12	8
1061	0	0	104	24	16	0	0	8	0	8
1062	0	0	64	48	0	0	0	0	0	0
1063	0	0	272	48	32	0	0	0	16	32
1064	0	0	80	152	8	0	0	0	40	64
1065	4	0	118	10	0	0	0	10	2	12
1084	0	0	6	0	0	0	0	0	0	0
1085	0	0	14	0	0	0	0	0	0	0
1086	0	0	2	0	0	0	0	0	0	0
1087	8	0	160	40	16	0	0	0	0	8
1088	0	0	432	16	0	0	0	0	0	0
1089	0	0	64	0	0	0	0	0	0	0
1090	0	0	368	32	0	0	0	0	0	32
1091	0	0	914	48	16	0	16	0	32	112
1092	0	0	96	4	0	0	0	12	0	28
1203	0	1	0	0	0	0	0	0	0	0
1204	0	0	0	0	0	0	0	0	0	0
1205	0	0	0	0	0	0	0	0	0	0
1206	0	0	0	0	0	0	0	0	32	0
1207	0	0	48	272	0	0	0	0	48	48
1208	0	0	0	96	0	0	0	0	0	0
1209	0	0	60	4	4	0	0	4	56	32
1210	0	0	64	4	4	0	32	48	64	92
1211	0	0	56	0	0	0	64	232	72	0

APPENDIX IX

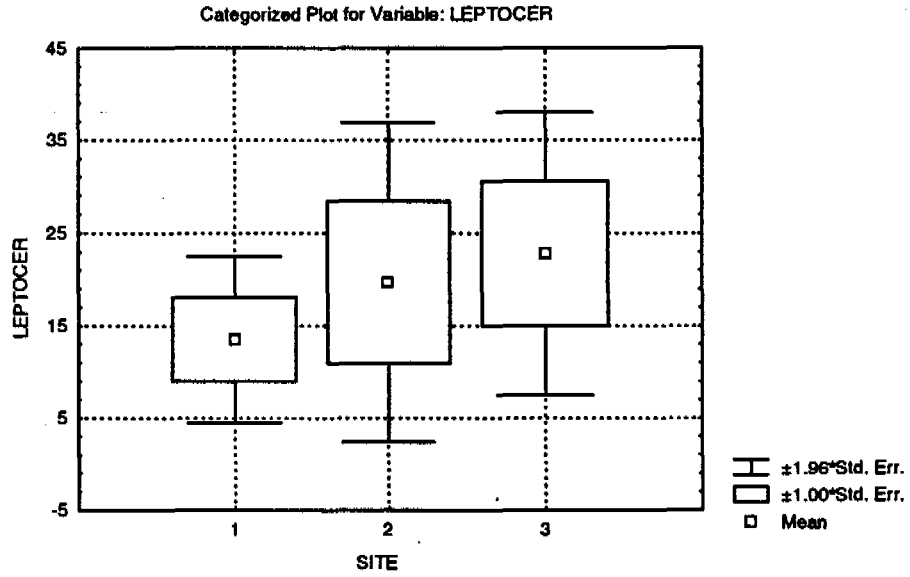
Physical Variables Data

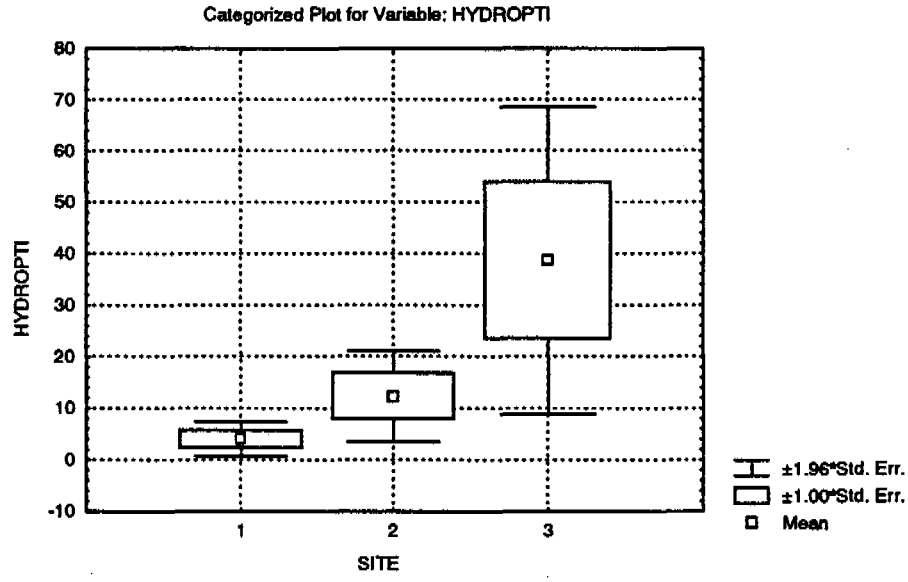
(Site: 1=FL, 2=GT, 3=MD; Habitat: 1=Sand, 2=Macrophytic Edge, 3=Leaf Litter)

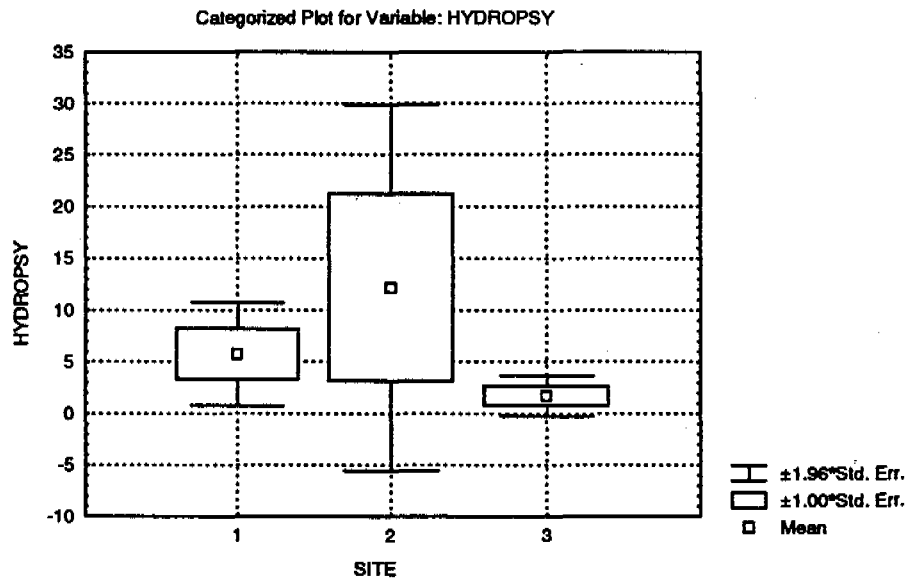
Samp.No	Site	Habitat	macro%	substr%	rootmt%	detrit%	flow s/m	depth cm	air tmp	wtr tmp
859	1	1	0	100	0	0	4	5	NC	NC
860	1	1	0	100	0	20	8	10	NC	NC
861	1	1	0	100	0	75	0	20	NC	NC
865	1	2	10	50	30	40	6	30	NC	NC
866	1	2	10	50	0	40	7	30	NC	NC
867	1	2	30	20	0	50	4	30	NC	NC
862	1	3	0	0	0	100	100	30	NC	NC
863	1	3	0	0	0	100	8	30	NC	NC
864	1	3	0	0	0	100	16	5	NC	NC
868	2	1	0	100	0	0	4	10	NC	NC
869	2	1	0	100	0	20	6	10	NC	NC
870	2	1	0	100	0	75	16	10	NC	NC
874	2	2	0	30	10	60	5	30	NC	NC
875	2	2	0	40	0	60	12	20	NC	NC
876	2	2	0	70	0	30	6	40	NC	NC
871	2	3	0	0	0	100	100	15	NC	NC
872	2	3	0	0	0	100	100	10	NC	NC
873	2	3	0	0	0	100	100	15	NC	NC
877	3	1	0	100	0	0	4	50	NC	NC
878	3	1	0	100	0	20	100	20	NC	NC
879	3	1	0	100	0	75	100	20	NC	NC
883	3	2	10	9	0	0	24	20	NC	NC
884	3	2	30	70	0	0	4	20	NC	NC
885	3	2	30	70	0	0	6	20	NC	NC
880	3	3	0	0	0	100	100	2	NC	NC
881	3	3	0	0	0	100	100	20	NC	NC
882	3	3	0	0	0	100	26	20	NC	NC
1021	1	1	0	100	0	10	6	95	36	31
1022	1	1	0	100	0	30	-10	35	36	31
1023	1	1	0	100	10	0	8	20	36	31
1027	1	2	80	10	20	0	5	30	36	31
1028	1	2	60	40	10	0	2	30	36	31
1029	1	2	60	40	5	10	2	15	36	31
1024	1	3	0	0	0	100	10	50	36	31
1025	1	3	0	10	10	100	4	30	36	31
1026	1	3	0	0	0	100	-20	45	36	31
1030	2	1	0	100	0	5	4	20	34	30
1031	2	1	5	95	0	10	4	40	34	30
1032	2	1	0	100	0	0	3	10	34	30
1036	2	2	95	5	20	0	6	10	34	30
1037	2	2	100	0	60	15	4	25	34	30
1038	2	2	70	30	10	10	4	35	34	30
1033	2	3	0	0	0	100	100	15	34	30
1034	2	3	0	0	0	100	35	15	34	30
1035	2	3	0	0	0	100	-5	50	34	30
1039	3	1	0	100	0	20	14	15	34	31.5
1040	3	1	5	95	0	10	7	65	34	31.5
1041	3	1	0	100	0	0	5	20	34	31.5
1045	3	2	70	10	20	30	10	20	34	31.5
1046	3	2	80	20	25	10	11	30	34	31.5
1047	3	2	90	10	50	10	6	40	34	31.5
1042	3	3	0	0	0	100	9	30	34	31.5
1043	3	3	0	0	0	100	-25	5	34	31.5
1044	3	3	0	0	0	100	100	20	34	31.5
1194	1	1	0	100	0	0	4	75	34	32
1195	1	1	0	100	0	15	7	15	34	32
1196	1	1	0	100	0	0	5	80	34	32
1200	1	2	85	20	80	30	15	20	34	32
1201	1	2	90	20	90	40	3	10	34	32
1202	1	2	70	25	80	0	3	25	34	32
1197	1	3	0	0	0	100	100	45	34	32
1198	1	3	0	0	0	100	10	120	34	32
1199	1	3	0	0	0	100	6	80	34	32
1203	2	1	0	100	0	0	5	15	34	30
1204	2	1	0	100	0	0	4	50	34	30
1205	2	1	0	100	10	0	4	35	34	30
1209	2	2	80	10	100	15	4	25	34	30
1210	2	2	90	10	60	10	8	10	34	30
1211	2	2	75	25	20	10	2	5	34	30
1206	2	3	0	0	0	100	100	10	34	30
1207	2	3	20	0	0	100	100	10	34	30
1208	2	3	5	0	20	100	100	5	34	30
1212	3	1	0	100	0	0	6	30	36	31
1213	3	1	0	100	0	0	4	10	36	31
1214	3	1	0	100	10	0	6	55	36	31
1218	3	2	90	10	40	20	6	15	36	31
1219	3	2	60	20	70	70	-24	40	36	31
1220	3	2	70	30	80	10	6	30	36	31
1215	3	3	0	0	0	100	100	20	36	31
1216	3	3	0	0	20	100	100	30	36	31
1217	3	3	0	0	0	100	11	35	36	31

"-" Surface Flow Rate indicates water direction was in 'backflow'

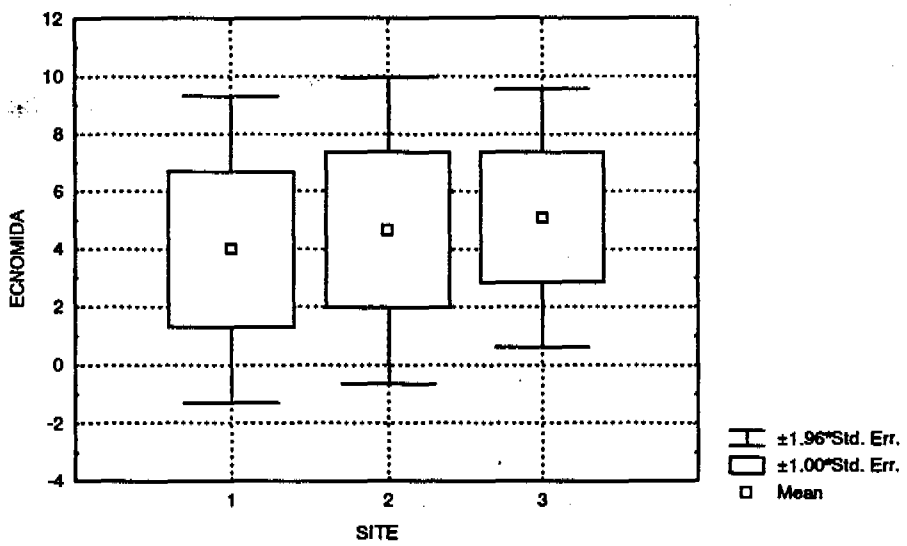
APPENDIX X


Categorized Plot for Variable: LEPTOCER
LEPTOCER
45
35
25
15
5
-5
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

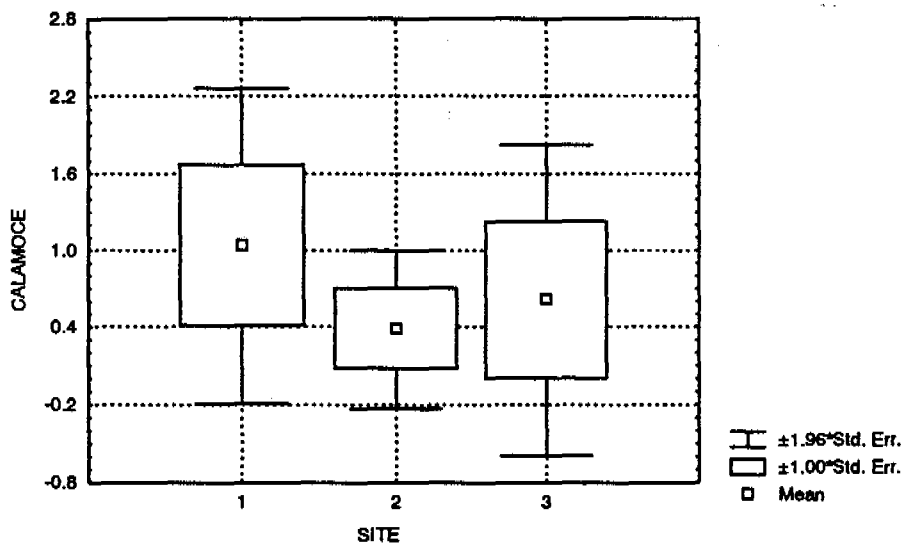

Categorized Plot for Variable: HYDROPTI
HYDROPTI
80
70
60
50
40
30
20
10
0
-10
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: HYDROPSY
HYDROPSY
35
30
25
20
15
10
5
0
-5
-10
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

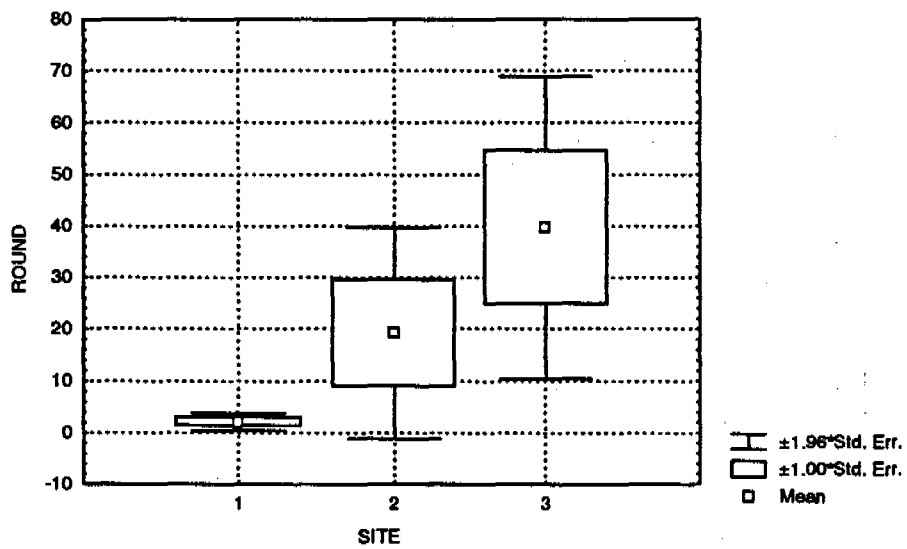
Categorized Plot for Variable: ECNOMIDA

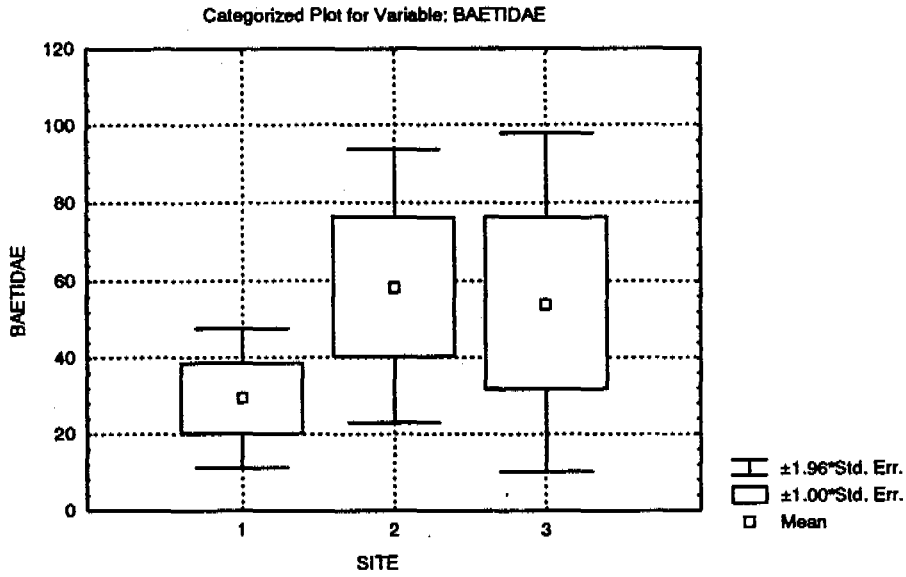


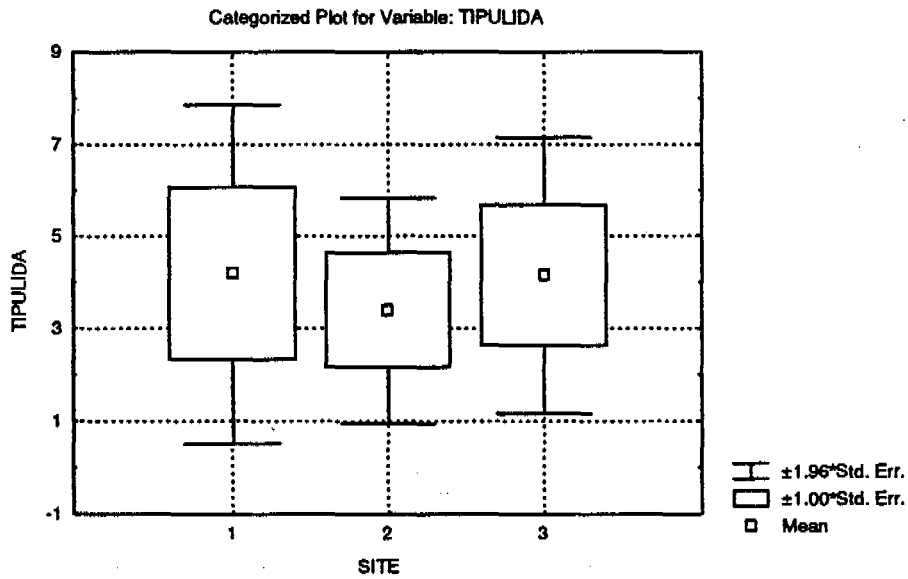
Categorized Plot for Variable: CALAMOCE

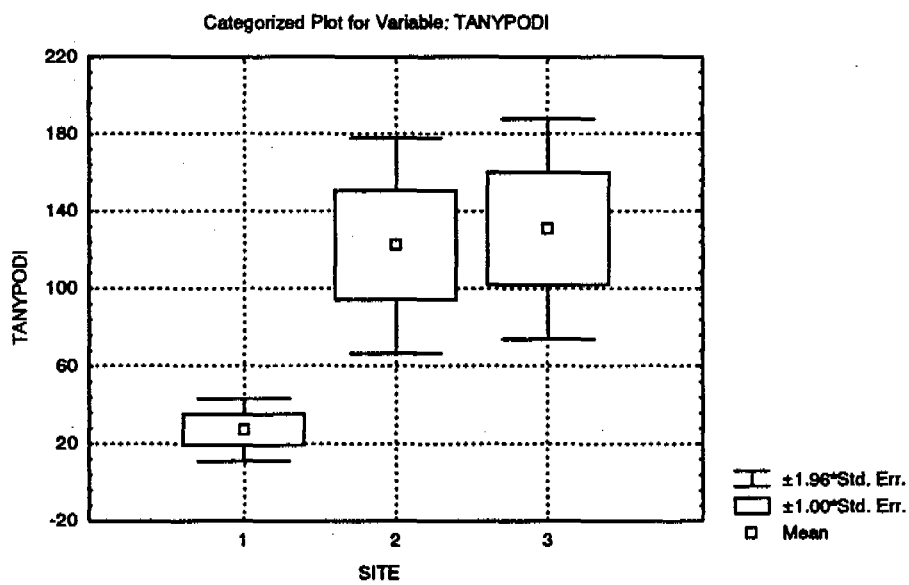


Categorized Plot for Variable: ROUND

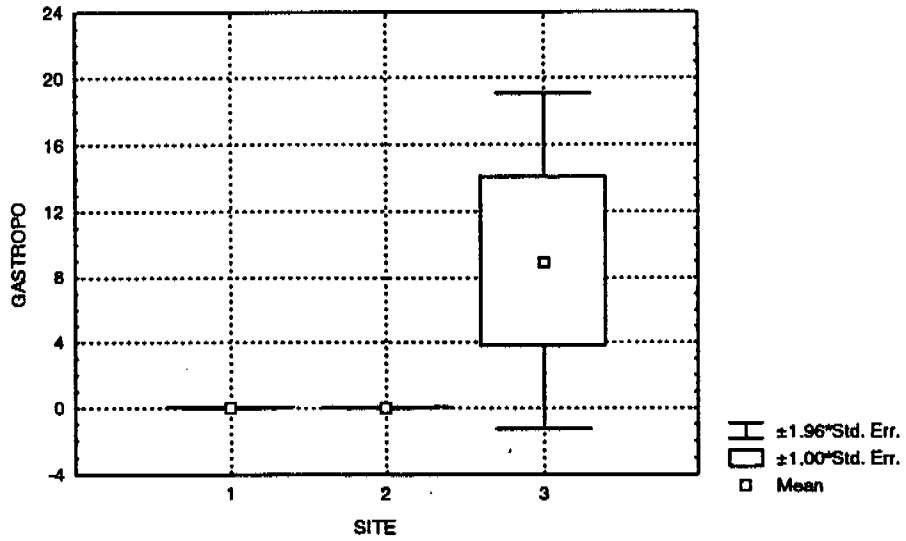



Categorized Plot for Variable: BAETIDAE
120
100
80
60
40
20
0
BAETIDAE
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

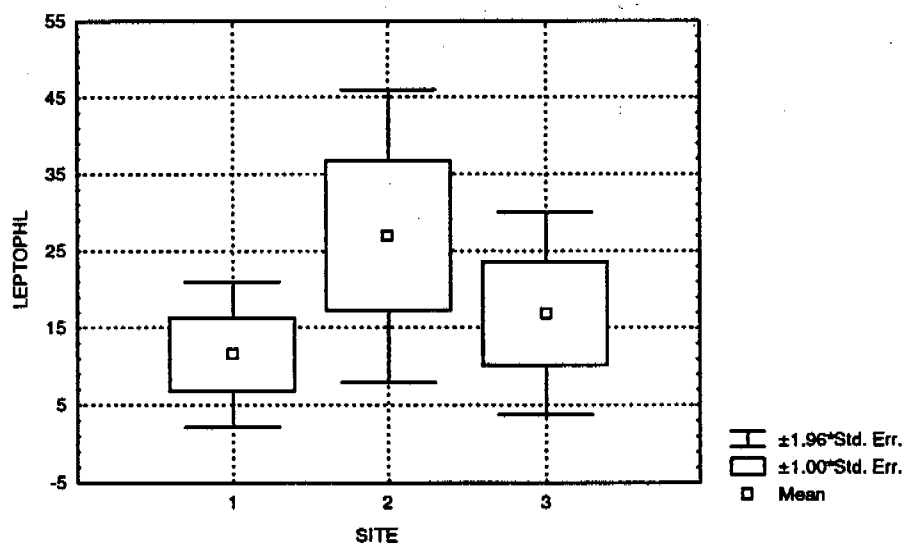

Categorized Plot for Variable: TIPULIDA
9
7
5
3
1
-1
TIPULIDA
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: TANYPODI
220
180
140
100
60
20
-20
TANYPODI
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

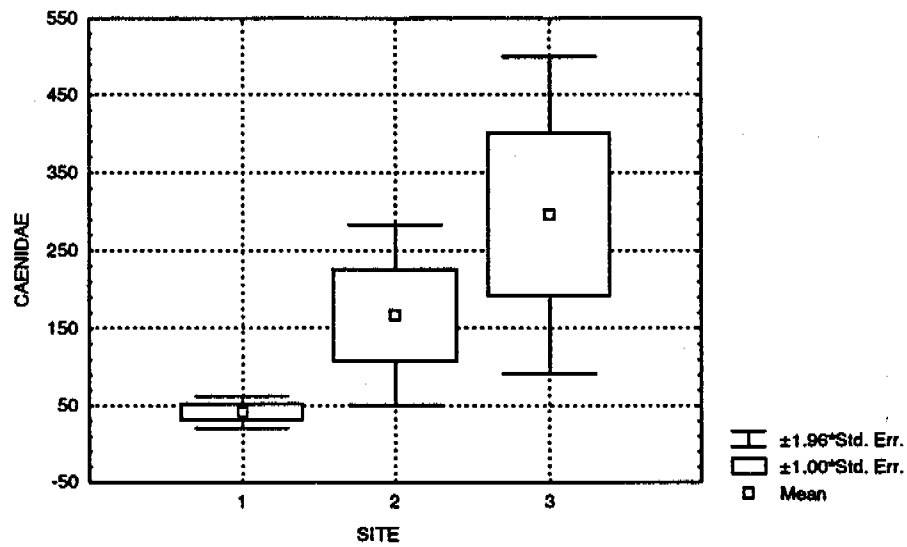
Categorized Plot for Variable: GASTROPO

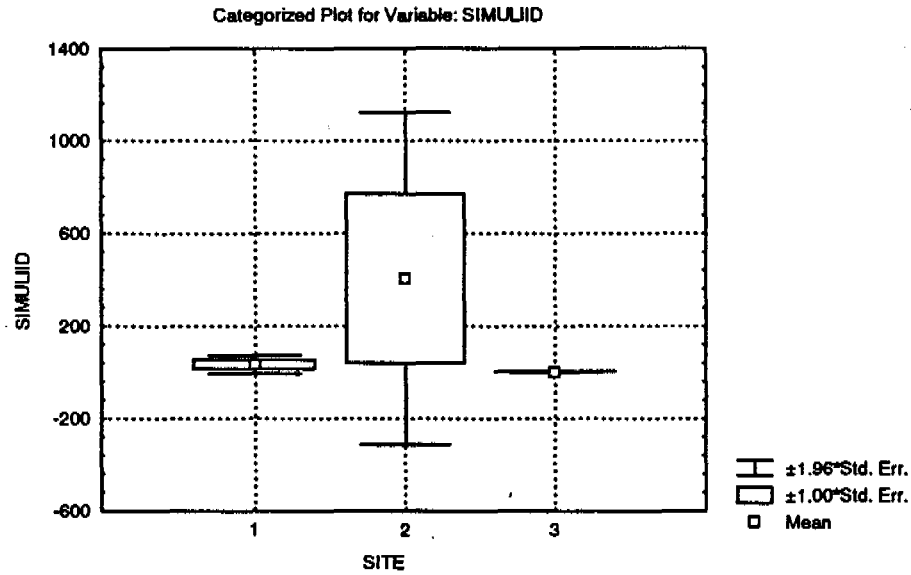


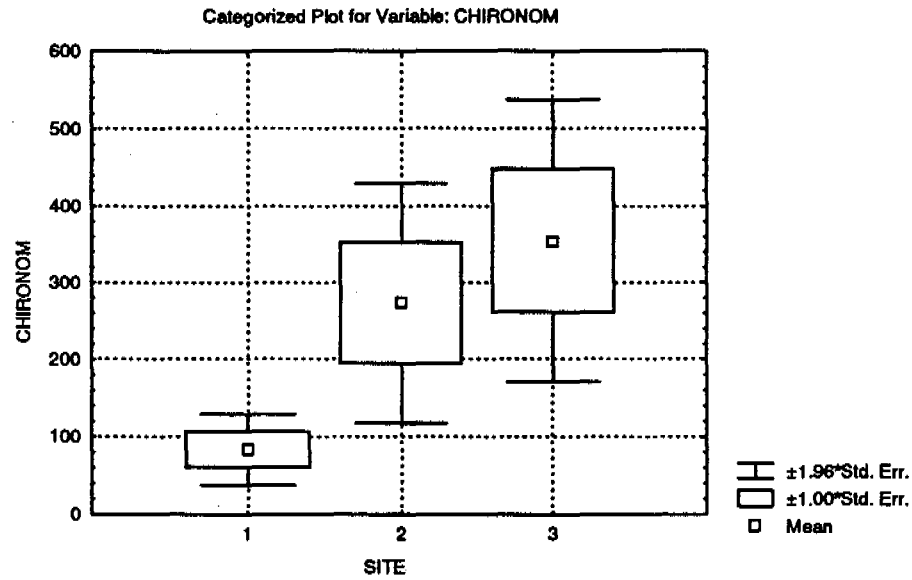
Categorized Plot for Variable: LEPTOPHL

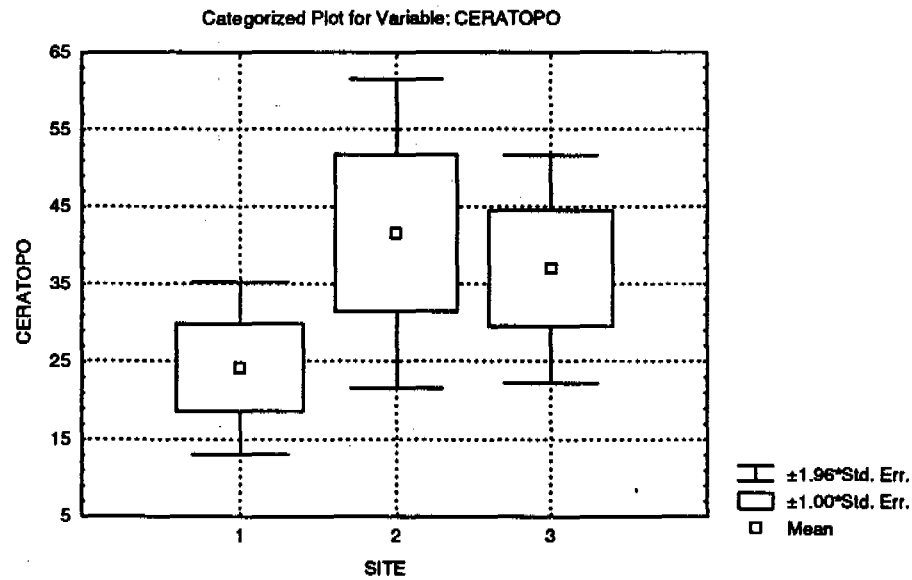


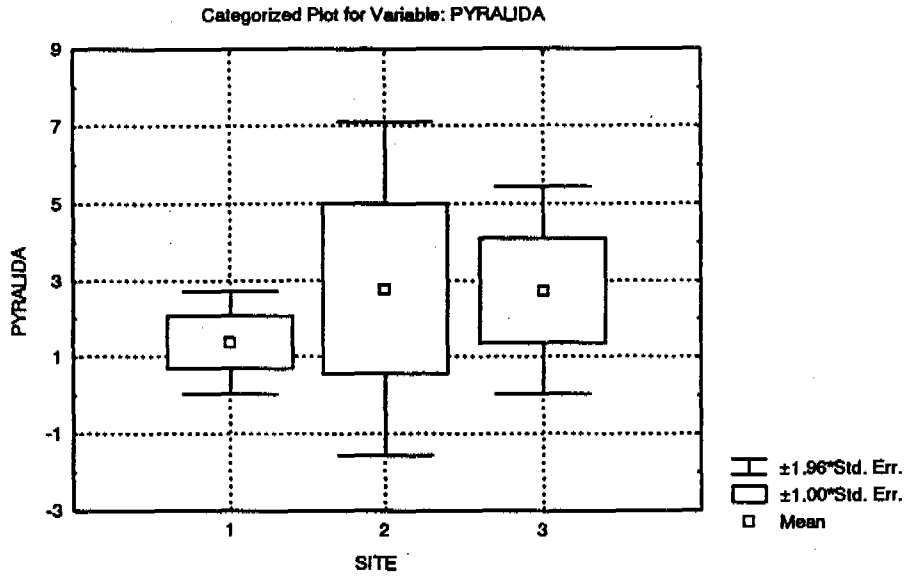
Categorized Plot for Variable: CAENIDAE

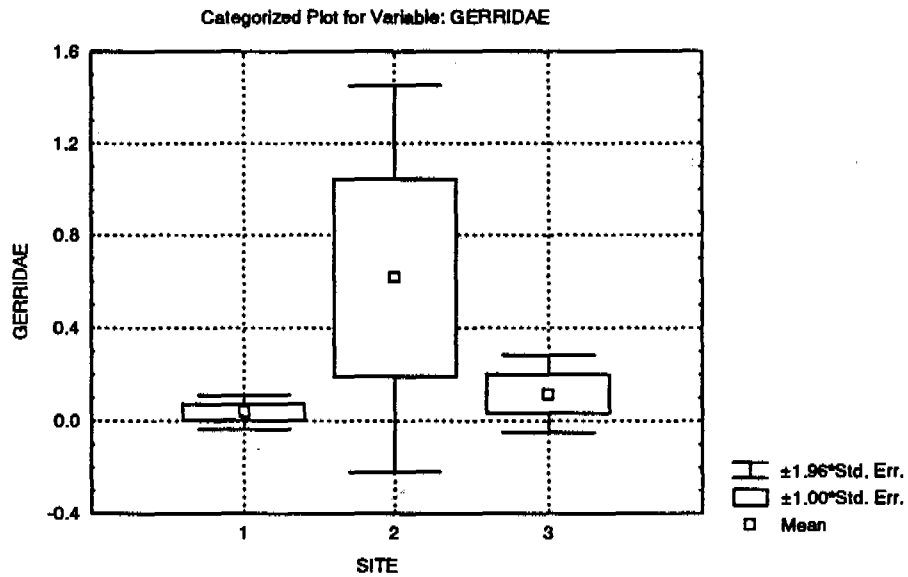


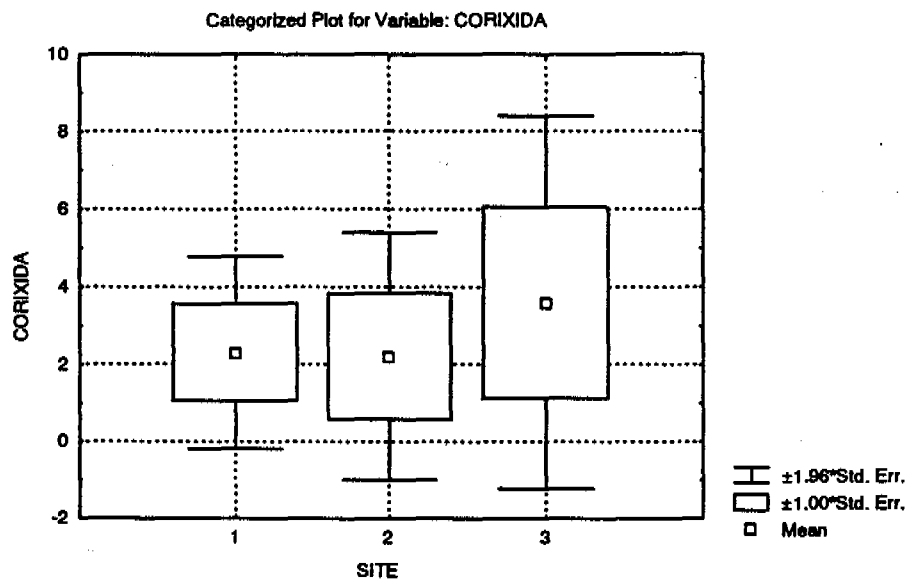

Categorized Plot for Variable: SIMULIID
1400
1000
600
200
-200
-600
SIMULIID
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: CHIRONOM
600
500
400
300
200
100
0
CHIRONOM
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

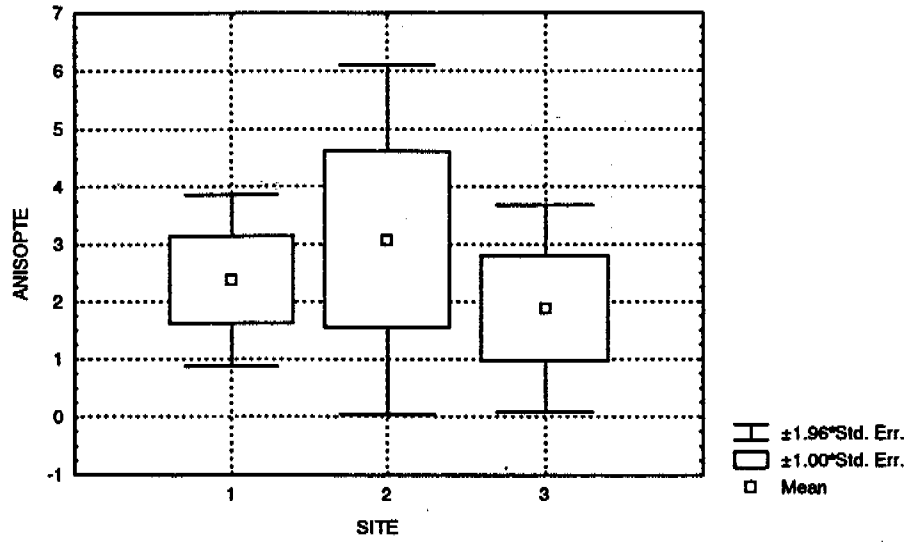

Categorized Plot for Variable: CERATOPO
65
55
45
35
25
15
5
CERATOPO
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: PYRALIDA
PYRALIDA
9
7
5
3
1
-1
-3
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

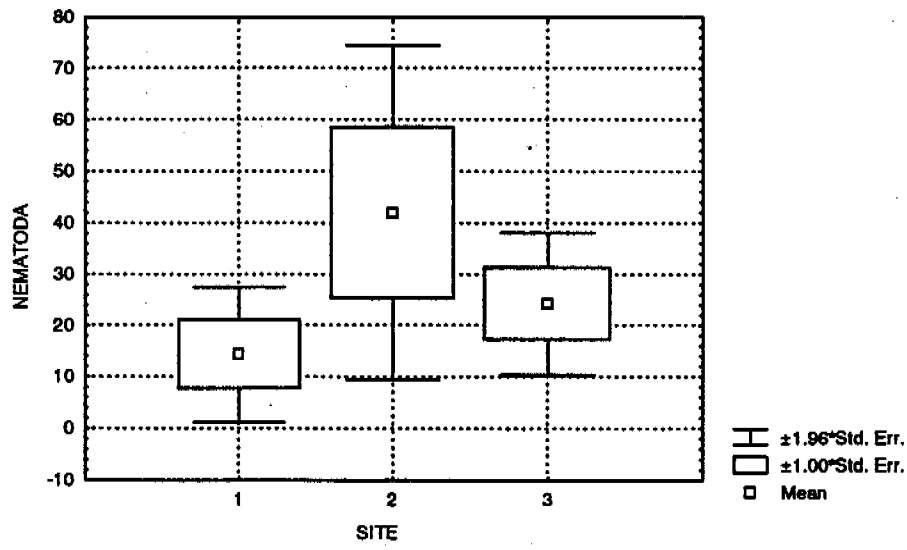

Categorized Plot for Variable: GERRIDAE
GERRIDAE
1.6
1.2
0.8
0.4
0.0
-0.4
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: CORIXIDA
CORIXIDA
10
8
6
4
2
0
-2
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

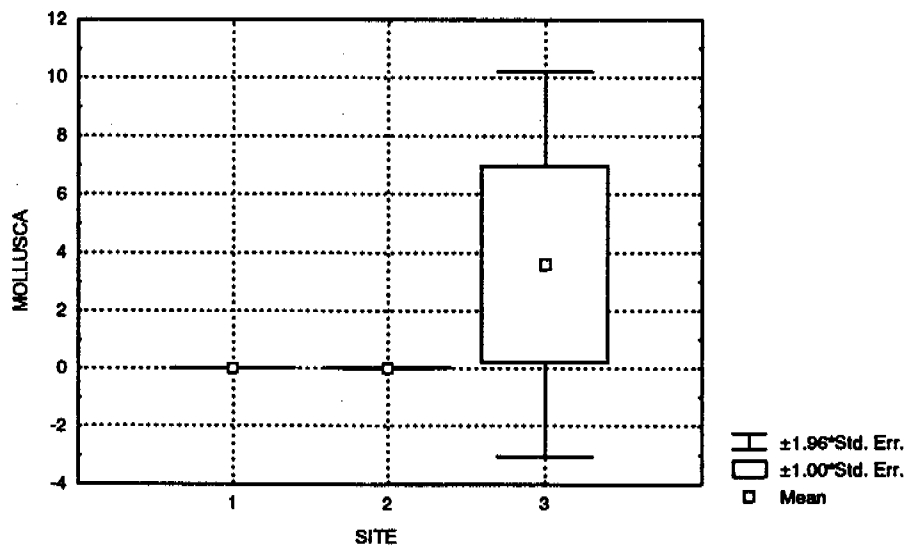
Categorized Plot for Variable: ANISOPTE

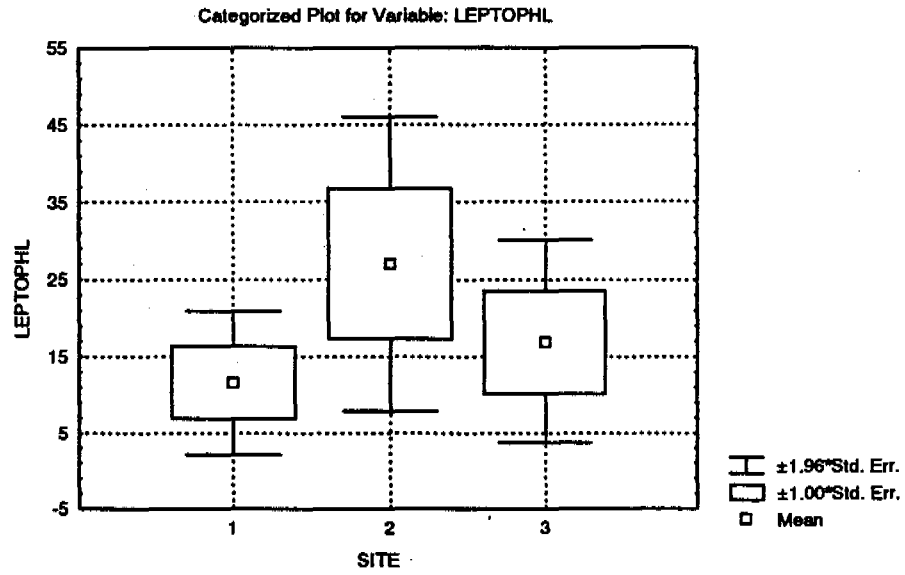


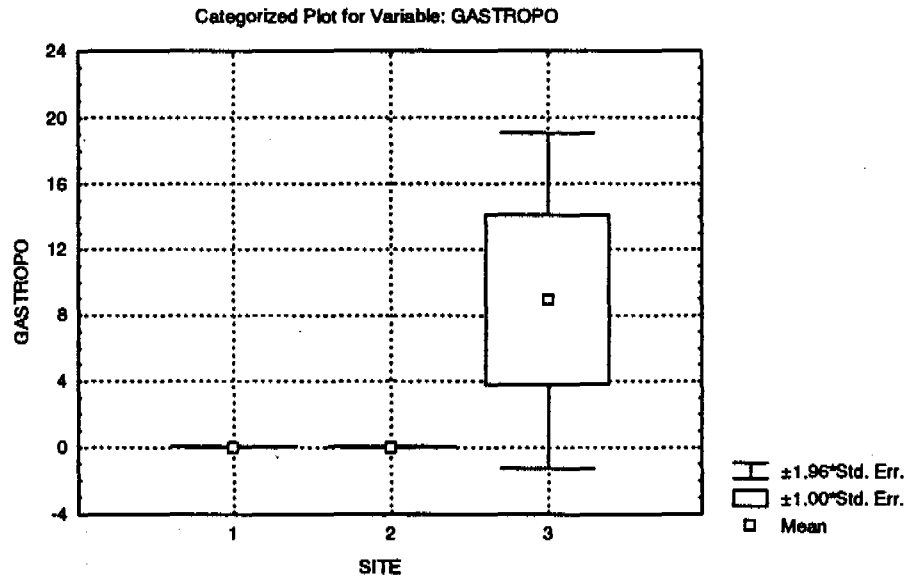
Categorized Plot for Variable: NEMATODA

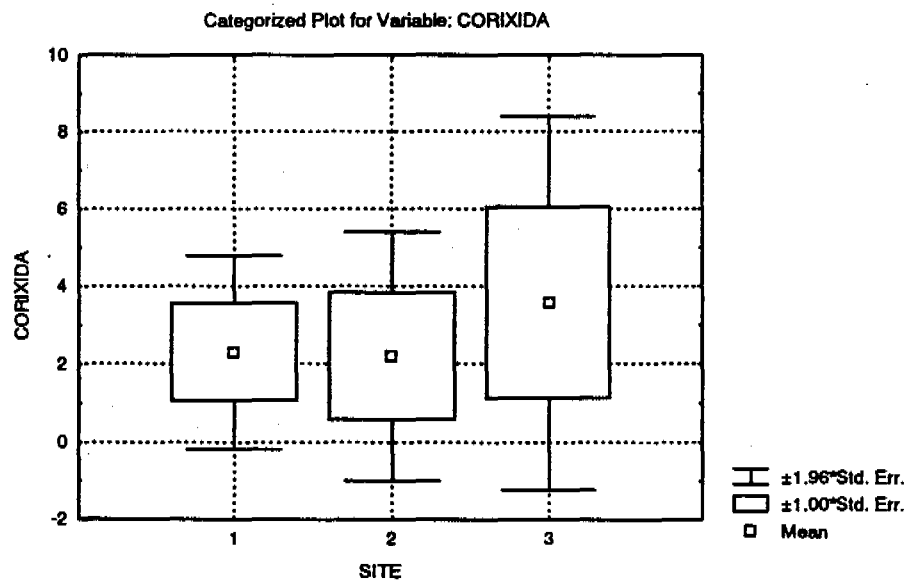


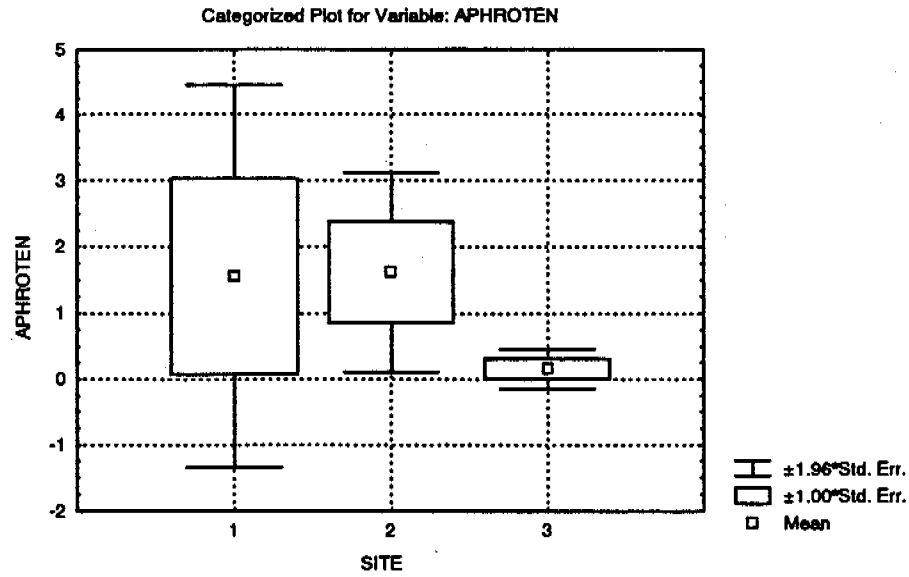
Categorized Plot for Variable: MOLLUSCA

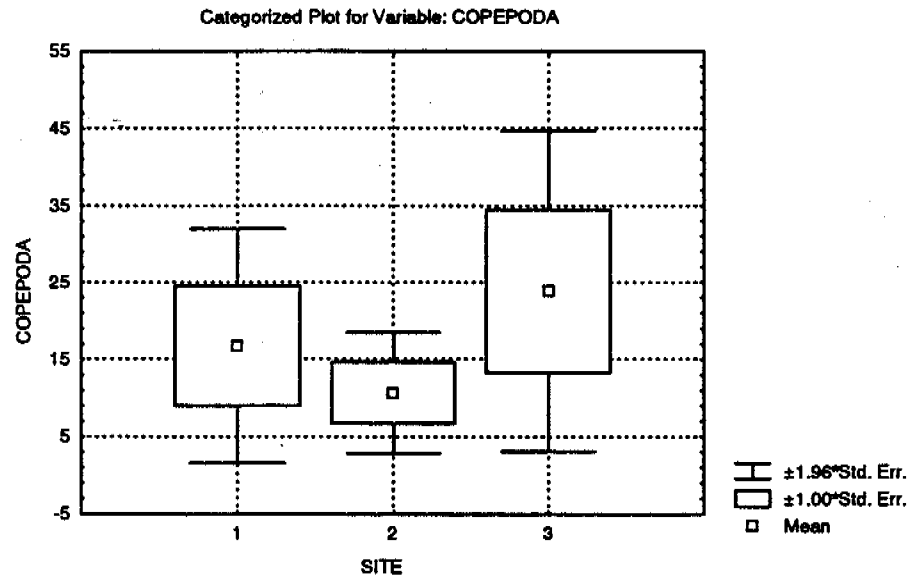


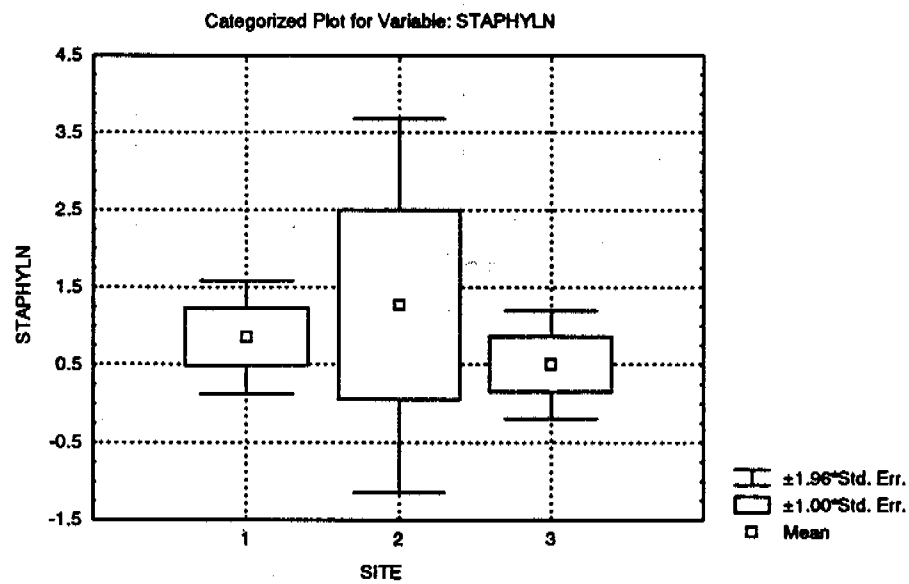

Categorized Plot for Variable: LEPTOPHIL
LEPTOPHIL
55
45
35
25
15
5
-5
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: GASTROPO
GASTROPO
24
20
16
12
8
4
0
-4
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

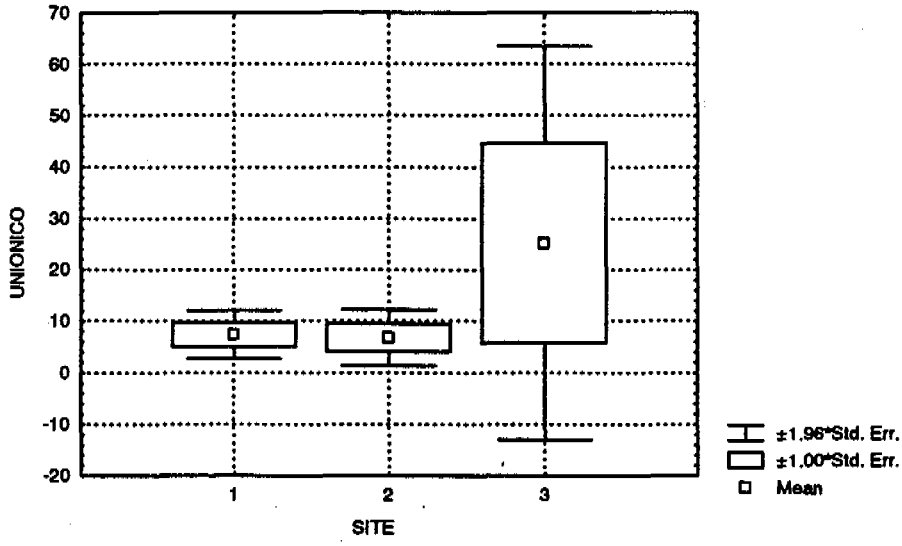

Categorized Plot for Variable: CORIXIDA
CORIXIDA
10
8
6
4
2
0
-2
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: APHROTEN
APHROTEN
5
4
3
2
1
0
-1
-2
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

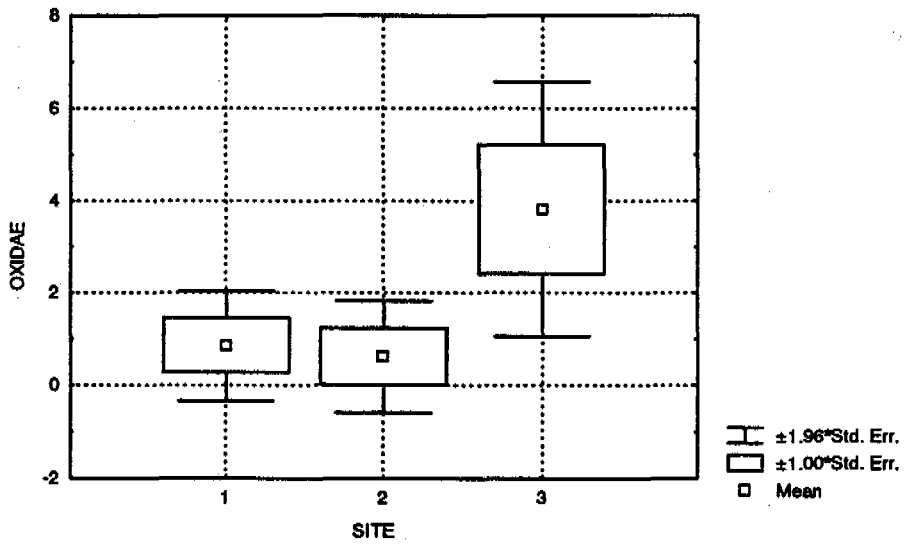

Categorized Plot for Variable: COPEPODA
COPEPODA
55
45
35
25
15
5
-5
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: STAPHYLN
STAPHYLN
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

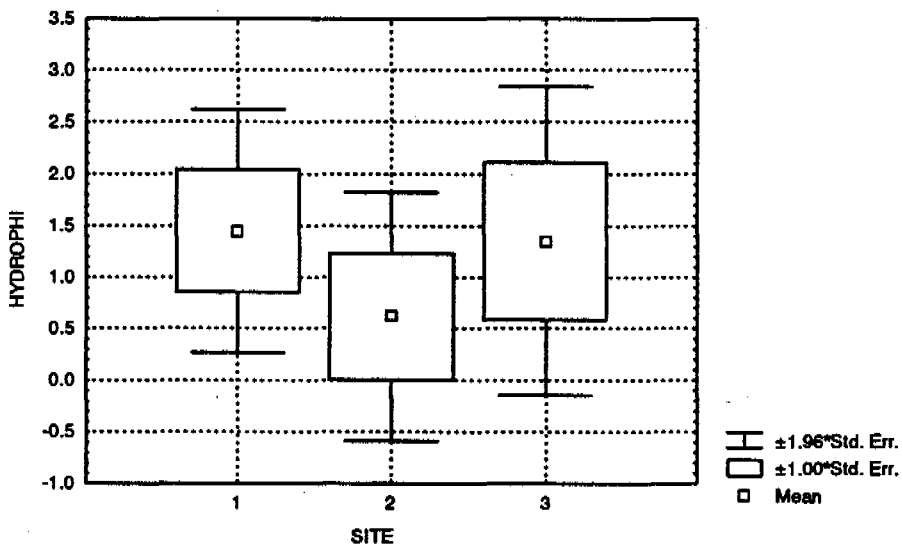
Categorized Plot for Variable: UNIONICO



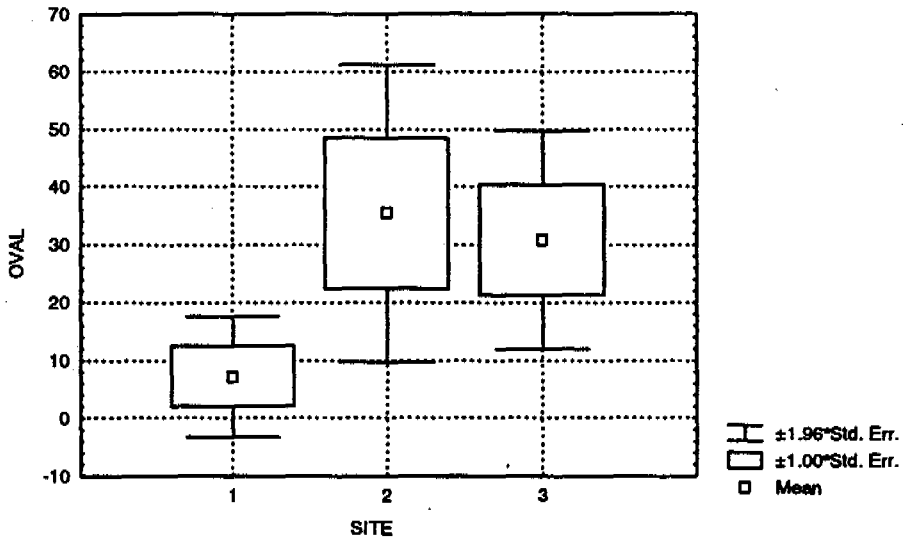
Categorized Plot for Variable: OXIDAE



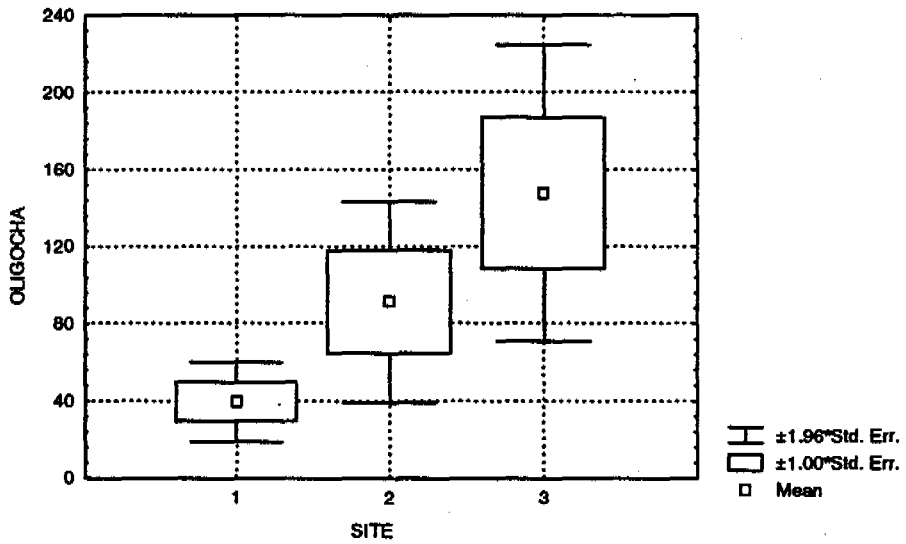
Categorized Plot for Variable: HYDROPHI



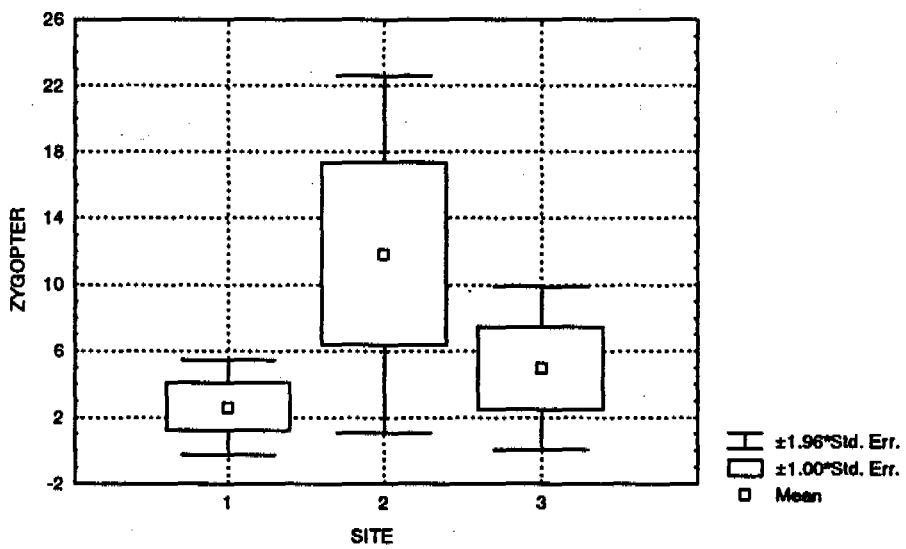
Categorized Plot for Variable: OVAL

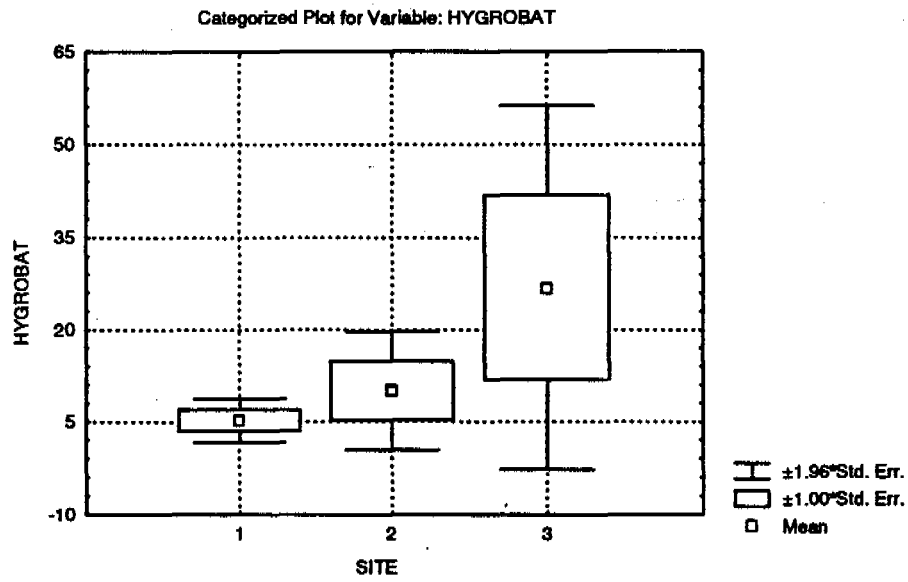


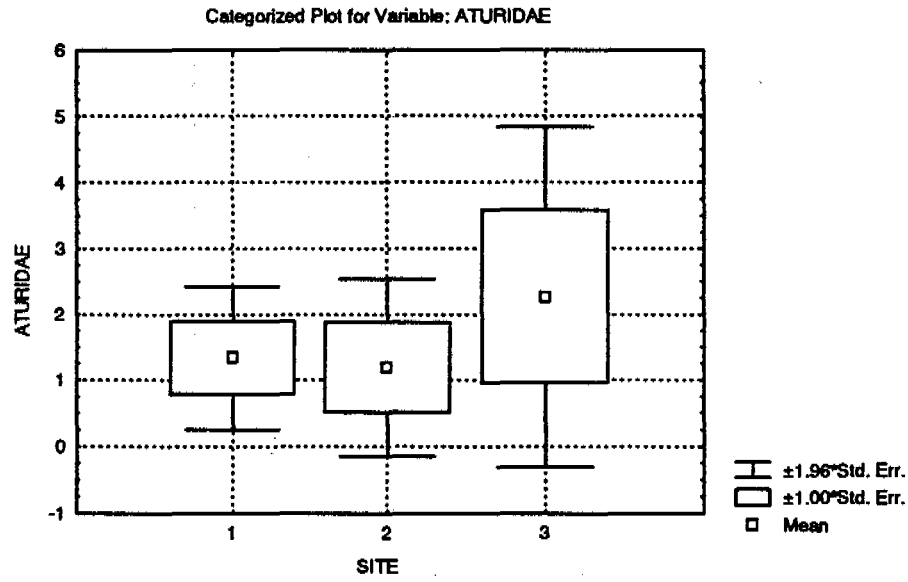
Categorized Plot for Variable: OLIGOCHA

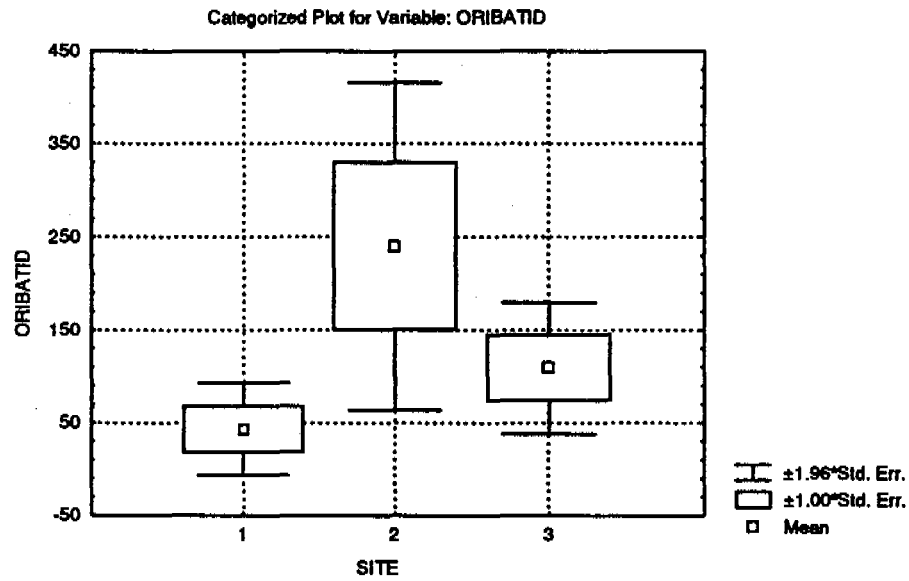


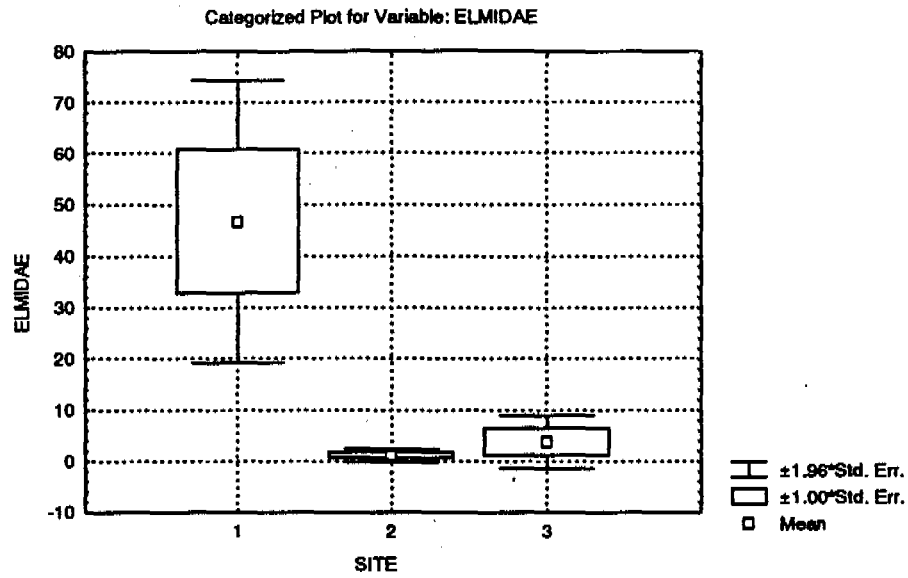
Categorized Plot for Variable: ZYGOPTER

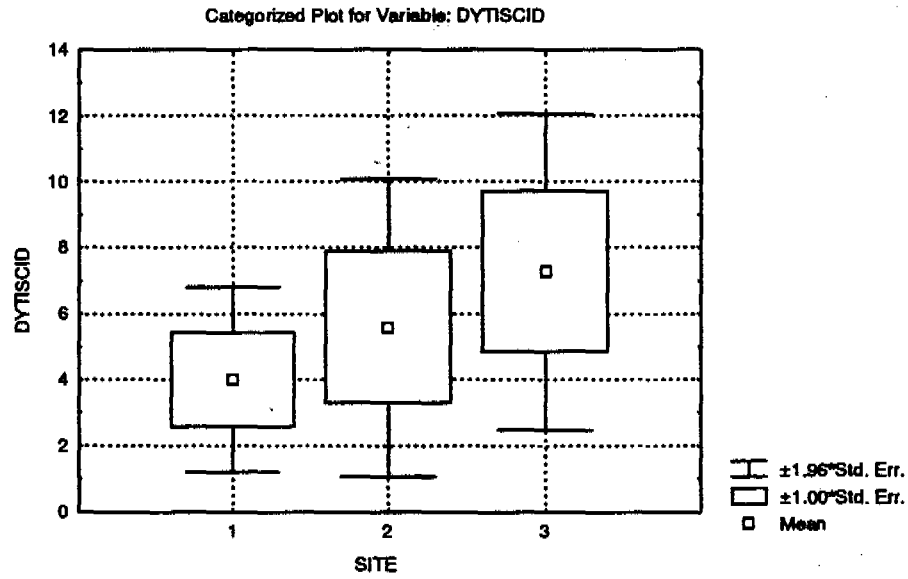


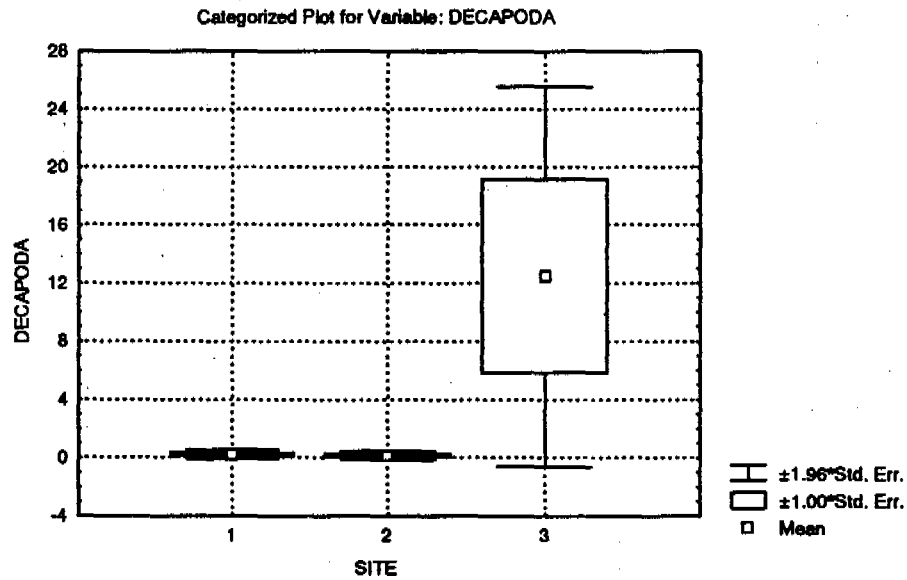

Categorized Plot for Variable: HYGROBAT
HYGROBAT
65
50
35
20
5
-10
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

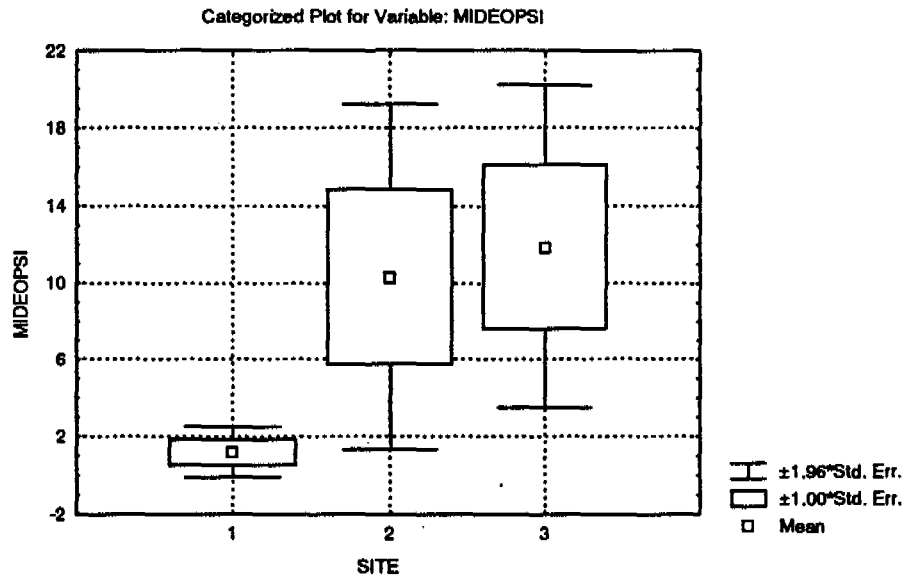

Categorized Plot for Variable: ATURIDAE
ATURIDAE
6
5
4
3
2
1
0
-1
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

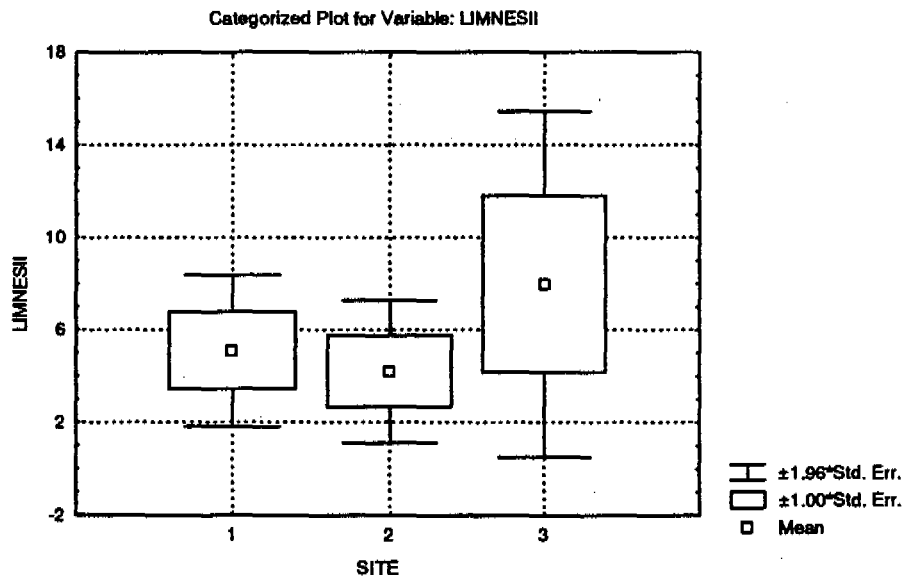

Categorized Plot for Variable: ORIBATID
ORIBATID
450
350
250
150
50
-50
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean

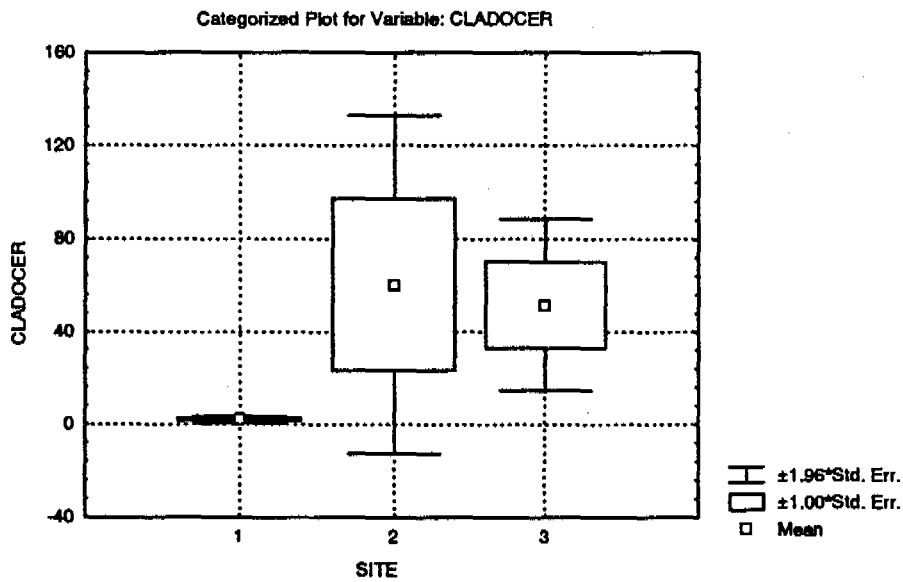

Categorized Plot for Variable: ELMIDAE
ELMIDAE
80
70
60
50
40
30
20
10
0
-10
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: DYTISCID
DYTISCID
14
12
10
8
6
4
2
0
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: DECAPODA
DECAPODA
28
24
20
16
12
8
4
0
-4
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: MIDEOPSI
MIDEOPSI
22
18
14
10
6
2
-2
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: LIMNESII
LIMNESII
18
14
10
6
2
-2
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean


Categorized Plot for Variable: CLADOCER
CLADOCER
160
120
80
40
0
-40
1
2
3
SITE
±1.96*Std. Err.
±1.00*Std. Err.
Mean