Australian Government

Department of Agriculture

AUSTRALIAN AQUATIC VETERINARY EMERGENCY PLAN

AQUAVETPLAN
Enterprise Manual
Version 2.0, 2015

AQUAVETPLAN is a series of manuals that outline Australia's approach to national disease preparedness and proposes the technical response and control strategies to be activated in a national aquatic animal disease emergency.

National Biosecurity Committee

This manual forms part of:

AQUAVETPLAN

This strategy will be reviewed regularly. Suggestions and recommendations for amendments should be forwarded to:

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It is the responsibility of the users of this publication to identify and ensure they have complied with all legislative or regulatory requirements of the relevant Australian state or territory and the Commonwealth prior to undertaking any of the response options set out within this publication.

Being a guide only, outbreaks or suspected outbreaks must be assessed on a case-by-case basis and expert advice should be obtained to determine the most appropriate management plan in response to the risk.

IMPORTANT NOTE: Important regulatory information is contained in the World Organisation for Animal Health (OIE) *Aquatic animal health code* 2014, which is updated annually and is available at the OIE website: www.oie.int/international-standard-setting/aquatic-code/access-online.

DISEASE WATCH HOTLINE

1800 675 888

The Disease Watch Hotline is a toll-free telephone number that connects callers to the relevant state or territory officer to report concerns about any potential emergency disease situation. Anyone suspecting an emergency disease outbreak should use this number to get immediate advice and assistance.

Preface

This Enterprise Manual for aquatic animal diseases is an integral part of the Australian Aquatic Veterinary Emergency Plan, or AQUAVETPLAN.

The manual aims to assist disease control operations in the field. It contains information that will be useful in all phases of a disease outbreak incident or emergency. The manual can be used in a variety of aquatic animal disease emergencies, including an exotic disease incursion or an outbreak associated with a previously unknown endemic agent.

The Enterprise Manual was the first of the series of AQUAVETPLAN manuals to be commissioned, in November 2000. The current version of the manual has been revised and updated to complement the other AQUAVETPLAN documents, which give further information on disease epidemiology, disinfection and disposal techniques, command structures, and response policies for selected diseases of aquatic animals. For information relating to diseases of terrestrial animals, refer to the series of AUSVETPLAN manuals (www.animalhealthaustralia.com.au/programs/emergency-animal-disease-preparedness/ausvetplan).

This Enterprise Manual is aimed at both government and industry personnel who may be involved in emergency aquatic animal disease preparedness and response. The manual is designed to enable decision-makers to access information on industry practices and environments so that they can create applicable control strategies at short notice. The manual is also designed to inform industry personnel of the necessary steps and factors involved in decision-making under emergency conditions. As well, the manual should be used as a training and emergency briefing resource for officers working on an aquatic animal disease control programme who are not familiar with aquatic animals.

The Enterprise Manual is designed to complement, rather than replace, state or territory, industry, or farm operational emergency plans. The manual uses a generic approach to reflect the diverse nature of aquatic animal industries, and the wide diversity of disease agents and hosts that may be involved in an emergency situation. In many cases, little will be known of the disease agent, and so a control strategy may need to be developed very quickly using first principles and available knowledge. This Enterprise Manual will help to provide that knowledge.

The Enterprise Manual is a concise source of information on industry practices and structures. It outlines approaches that should be considered in the face of an aquatic animal disease emergency. The manual covers the entire range of aquatic animal industries and has been split into the following ‘systems’:

- **open systems:** systems in which there is no control of either host movement or water flow (e.g. wild-caught fisheries)
- **semi-open systems:** systems in which there is control of host movement but no control of water flow (e.g. net-pen culture)
- **semi-closed systems:** systems in which there is control of host movement and some control of water flow (e.g. pond culture, race culture)
- **closed systems:** systems in which there is good control of both host movement and water flow (e.g. recirculation aquaculture, aquaria).

The husbandry practices of a single industry may incorporate more than one of the above systems in different phases of production—for example, prawn culture, where wild broodstock is collected from an open system, hatcheries use a closed and/or a semi-closed system, and grow-out uses a semi-closed system. Section B provides further information on systems.

The Enterprise Manual has three sections:

- **Section A** provides definitions and general response structures. It also includes a summary of the likely links and lines of communication during investigation of an outbreak or planning of a response.
- **Section B** addresses industry-specific information needed for disease control or eradication.
- **Section C** provides possible responses in the various systems to an aquatic animal disease emergency.

The Enterprise Manual has been designed to provide sufficient industry-specific information to enable timely and considered decisions to be made in response to an identified or unidentified aquatic animal disease emergency in any system. It does not address the actions to take if a particular disease occurs in a particular species. For these instances, relevant details may be contained in the disease strategies, operational manuals and management manuals. The full list of available AQUAVETPLAN manuals is as follows:

Disease strategies	**Operational manuals**
Abalone viral ganglioneuritis Crayfish plague Furunculosis Ostreid herpes-virus-1 microvariant	Disposal Destruction Decontamination
Piscirickettsiosis Infectious salmon anaemia	**Management manual**
Viral encephalopathy and retinopathy	Control centres management
Viral haemorrhagic septicaemia	
Whirling disease	**Enterprise Manual**
White spot disease Withering syndrome of abalone	Includes sections on open systems, semi-open systems, semi-closed systems, closed systems

The format of this manual was adapted from similar manuals in AUSVETPLAN. The format and content have been kept as similar as possible to AUSVETPLAN documents, to enable animal health professionals trained in AUSVETPLAN procedures to work efficiently with this document in the event of an aquatic veterinary emergency. The work of the AUSVETPLAN writing teams and the permission to use the original AUSVETPLAN documents are gratefully acknowledged.

The revised manual has been reviewed and approved by the following representatives of government and industry:

Government

- CSIRO Australian Animal Health Laboratory
- Department of Primary Industries, New South Wales
- Department of Primary Industry and Fisheries, Northern Territory
- Department of Agriculture, Fisheries and Forestry, Queensland
- Department of Primary Industries, Parks, Water and Environment, Tasmania
- Department of Fisheries, Western Australia
- Department of Environment and Primary Industries, Victoria
- Department of Primary Industries and Regions, South Australia
- Biosecurity Animal Division, Australian Government Department of Agriculture
- Australian Government Department of the Environment

Industry

- Manual sent to the National Aquatic Animal Health Industry Reference Group for comment

The complete series of AQUAVETPLAN documents is available on the internet (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan).

How to use this manual

Don't panic! This manual is not meant to be read from cover to cover.

The manual is divided into three user-friendly sections.

Section A provides general information on emergency responses.

Section B provides information on industry practices relevant to disease control.

Section C provides information on response options.

Appendixes provide information on Australian, state and territory legislation; seafood-borne disease in humans; diseases of concern; animal species currently used for aquaculture in Australia; use of drugs and other chemicals in aquaculture; and useful contact numbers.

1. Read Section A when you receive the manual.

2. Select the production system that relates to the current problem.

To determine which system you are considering, ask:

Is movement of the host controlled?

Is movement of the water controlled?

- Open systems: systems in which there is no control of either host movement or water flow (e.g. wild-caught fisheries).
- Semi-open systems: systems in which there is control of host movement but no control of water flow (e.g. net-pen culture).
- Semi-closed systems: systems in which there is control of host movement and some control of water flow (e.g. pond culture, race culture).

- Closed systems: systems in which there is good control of both host movement and water flow (e.g. recirculation aquaculture, aquaria).

Then select the appropriate section of the manual.

3. In the event of a disease outbreak, do the following.

Review Section A.

Read the part of Section B relevant to your industry.

Read Section C1 (general principles) and the section relevant to your industry and/or production system.

Check for relevant Disease Strategy manuals and other AQUAVETPLAN documents, when required.

Abbreviations

4WD	four-wheel drive
AFMA	Australian Fisheries Management Authority
AqCCEAD	Aquatic Consultative Committee on Emergency Animal Diseases
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CVO	chief veterinary officer
DF	director of fisheries
DMA	disease management area
DPIPWE	Tasmanian Department of Primary Industries, Parks, Water and Environment
EDTA	ethylenediaminetetraacetic acid
HOGG	head on, gilled and gutted
NSW DPI	New South Wales Department of Primary Industries
OIE	World Organisation for Animal Health
ppt	parts per thousand
PVC	polyvinyl chloride
QAP	Quarantine Approved Premises
RAS	recirculating aquaculture system
SBT	southern bluefin tuna
UV	ultraviolet

Glossary

Anoxic	Lacking oxygen
Benthic	Bottom dwelling
Biota	The living organisms present in a specific region or area.
Commensals	Organisms living in close association but not harming each other.
Demersal species	Organisms that live on or near the sea bottom.
Fomite	Any inanimate object via which pathogenic organisms may be transferred.
Hiab winch	Integrated hydraulic winch and crane unit for lifting.
Movement control	Restrictions placed on the movement of fish, people and fomites to prevent the spread of disease.
Motile	Moving, mobile
Pelagic species	Organisms that occur in the upper layers of the water column.
Pre-smolts	Young salmon that have not fully smoltified.
Ranching	A system in which intervention in the natural system is used to improve harvests—for example, stocking artificially produced or raised stock into open systems for grow-out to harvestable size, attracting fish to artificial structures, or feeding to aggregate fish for ease of harvesting.
Rotifers	Small, multicellular invertebrates of the phylum Rotifera, commonly used as first-feeding organisms in the culture of marine fishes.
Sessile	Not moving, immobile
Vector	Any organism that transmits a pathogen.

Contents

Section A—Overview

A1 Definitions

A1.1 General terms

Fish—in this manual, 'fish' refers to all fish, crustaceans or molluscs produced in a system. It does not include amphibians, mammals or reptiles.

Disease outbreak emergency—version 1 of the Enterprise Manual states that a disease outbreak emergency is indicated when:

> A population of aquatic animals is recognised as having undergone severe mortality events or significantly decreased productivity **and** the responsible authority within that State or Territory is of the opinion that the cause may be an infectious agent. The responsible authority **may also** consider latent events, such as the presence of an infectious agent but not the disease, as emergencies.

Under this deliberately broad definition, the term 'disease' usually refers to an infectious disease—in particular, an exotic infectious disease. However, in practice, this is not necessarily the case: significant emergencies have been associated with new or emerging diseases, and with toxins or environmental factors.

The term 'emergency' may have a specific meaning within certain legislation, which may have ramifications for issues such as funding. As this is an operational manual, such a legal meaning is not implied.

Actions by the state's or territory's responsible authorities and the managers of the enterprise are initiated in the alert phase of the emergency. The alert phase is invoked when an aquatic animal disease incident is recognised and reported. The incident is investigated, and interim management strategies are developed until the emergency disease is confirmed. These strategies, and any means of control, will depend on the extent of the likely threat to the ecosystem or industry.

A1.2 Terms used to define an emergency operation

The nature of the aquatic environment and aquatic animal diseases means that 'disease management areas' (DMAs) relevant to disease control operations may be difficult to define. Areas may need to be revised as further information is received on the nature of the disease agent and the extent of its spread. The AQUAVETPLAN Control Centres Management Manual (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan/control-centres) expands on these definitions and how they are interpreted in setting up a response to a disease outbreak.

Outside area—an area known to be free from the disease agent.

Declared area—an area that has been subjected to a legal declaration. There are two types of declared area: restricted area and control area.

Restricted area—the area around an infected premises (or area) that is likely to be subject to intense surveillance and movement controls. It is likely to be relatively small. It may include some dangerous contact premises (or areas) and suspect premises (or areas), as well as enterprises that are not infected or under suspicion. Movement of potential disease vectors out of the area will, in general, be prohibited. Movement into the restricted area will only be by permit. Multiple restricted areas may exist within one control area.

Control area—a buffer between the restricted area and areas free from disease. Restrictions on this area will reduce the likelihood of the disease agent spreading further afield. As the extent of the outbreak is confirmed, the control area may change in size. The shape of the area may be modified according to circumstances (e.g. water flows, catchment limits). In most cases, permits will be required to move animals and specified product out of the control area into the free area.

Premises or areas—production sites, which may range from an aquarium to an aquaculture lease in the open ocean. The following definitions can apply to premises or areas:

- An **infected premises or area** is the area in which the disease has been confirmed. The term 'infected area' (rather than 'infected premises') is more likely to apply to an open system such as an oceanic lease.
- A **suspect premises or area** is where the disease is suspected but not yet confirmed. The reason for the suspicion varies with the agent; it may involve observation of clinical signs or increased mortality.
- A **dangerous contact premises or area** has had a direct, and possibly infectious, contact with an infected premises or area. The type of contact will depend on the enterprise and disease agent involved—for example, it may involve fish movements between net lease areas, or movements of nets and equipment.

A1.3 Zoning and compartmentalisation

Zoning

For purposes of facilitating trade (e.g. after a disease has established in a particular area) zoning is the process of defining disease-free and infected zones. For purposes of disease management, zoning can be defined as the process of defining disease-free and infected zones to allow effective management of disease by reducing the risk of spread of disease by human activity. The concept of zoning is based on the fact that diseases do not recognise national (or state) boundaries; they are more likely to be restricted by hydraulic geography. The AQUAPLAN *Zoning policy guidelines* (www.agriculture.gov.au/animal-plant-health/aquatic/guidelines-and-resources) have been developed based on the World Organisation for Animal Health (OIE) guidelines.(www.oie.int/en/international-standard-setting/aquatic-code/access-online). They highlight the issues that need to be considered when developing zoning policies.

In essence, zoning could allow Australia to designate areas as disease-free, which would enable trade to continue from these regions during a disease outbreak. For example, if a disease is detected near Perth, Australia could use the concept of zoning to mount a case that trading partners could continue to trade with farms located on the opposite side of the country, such as in Townsville.

Zoning is not an easy or quick system to set up. If Australia elected to employ zoning as a trading tool, the OIE *Aquatic animal health code* requires that freedom is proven (through rigorous testing) rather than inferred. The requirements for testing for freedom and for recognising zones vary according to the biology of the disease agent. Currently, Australia does not have any zones established to report to the OIE.

A more complete explanation of the principles and requirements of zoning can be found in the AQUAPLAN *Zoning policy guidelines*, Subasinghe et al. (2004) and the OIE *Aquatic animal health code*, Chapter 4.1.

Compartmentalisation—a compartment is one or more aquaculture establishments operating under a common biosecurity management system. The compartment contains an aquatic animal population with a distinct health status with respect to a specific disease (or diseases), for which required surveillance and control measures are applied, and basic biosecurity conditions are met, for the purpose of trade. Such compartments must be clearly documented by the competent authority (i.e. the veterinary authority of the jurisdiction).

A compartment does not have to be contiguous facilities—it can apply to a series of farms over a large area, including over several jurisdictions. The key is that it must have in place a biosecurity management system that meets the guidelines in Chapters 4.1 and 4.2 of the OIE *Aquatic animal health code*, and that these systems have been documented by the competent authority.

A1.4 Key operational terms

Tracing—the process of locating animals, people or objects that may be implicated in the spread of disease.

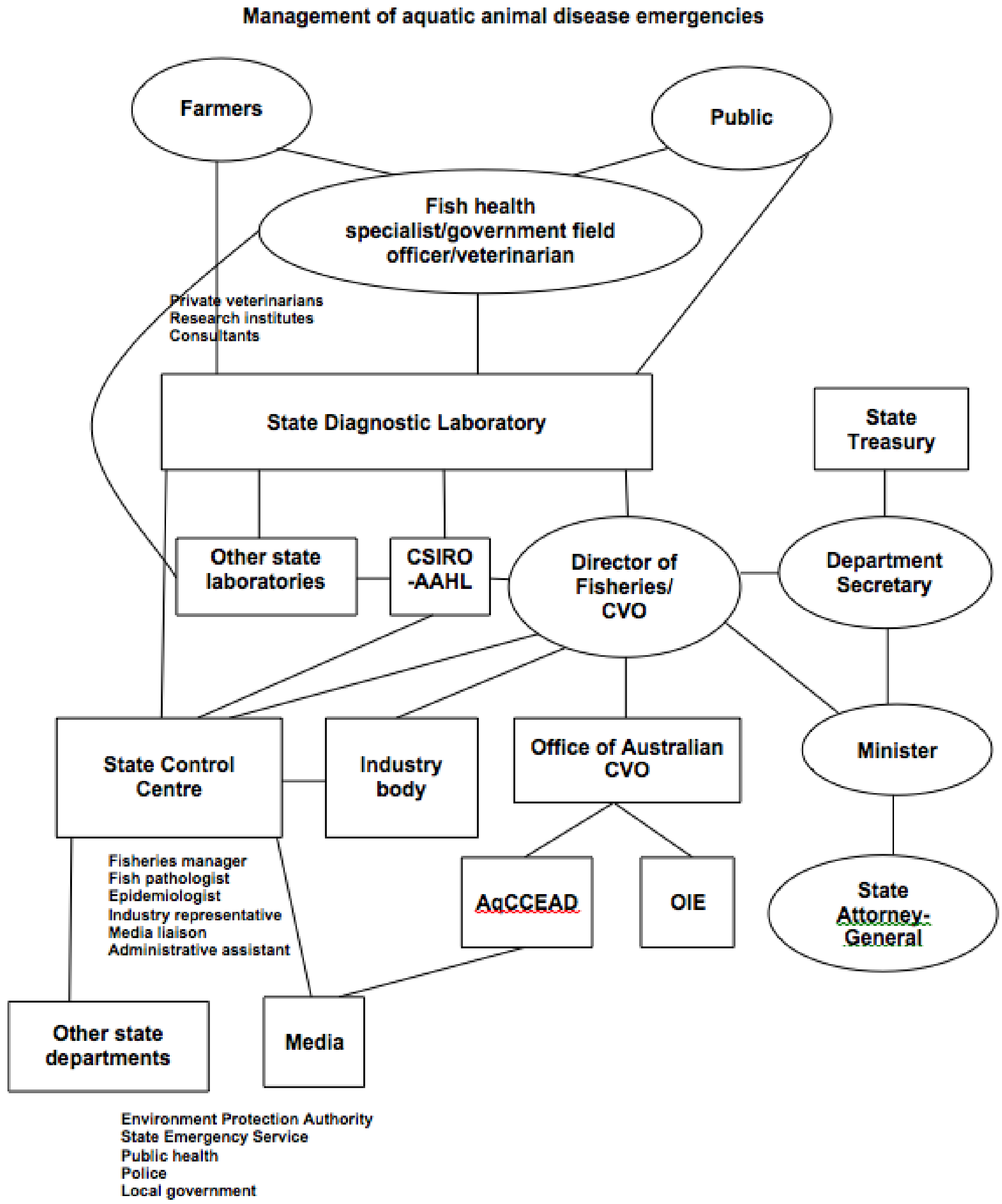
Surveillance—a systematic examination and testing to determine the presence or absence of a disease agent.

A **Local Disease Control Centre (LDCC)—**an operational unit that manages the disease control operation within a declared area. The LDCC manages the operations (e.g. eradication and decontamination) in infected premises, and coordinates surveillance and disease investigations (e.g. sample collection) at a local level. There may be one or several LDCCs, depending on the size of the operation. The operational guidelines of an LDCC are set out in the AQUAVETPLAN Control Centres Management Manual (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan/control-centres).

A2 Management of aquatic animal disease emergencies

The links and lines of communication that may be used during the management of an aquatic animal disease emergency are summarised in Figure 1.

Figure 1 Links and lines of communication during an aquatic animal disease emergency



Aq CCEAD = Aquatic Consultative Committee on Emergency Animal Diseases; CSIRO-AAHL = Commonwealth Scientific and Industrial Research Organisation Australian Animal Health Laboratory; CVO = chief veterinary officer; OIE = World Organisation for Animal Health

A2.1 Reporting

In most states and territories, fish kills are most likely to be reported initially by either farmers or members of the general public. These people will inform research institutes, private consultants, private veterinarians, fisheries officers, field officers or the state veterinary diagnostic laboratory directly.

Regardless of the avenue of reporting, it is imperative that the state or territory veterinary laboratory, or equivalent, is informed as soon as possible so that appropriate action is initiated; the state or territory government will be responsible for coordinating the response. However, in some states, investigation of fish kills may initially be the responsibility of a department other than the one that will coordinate the response—for example, the environment department. In these cases, prompt and transparent communication between the relevant government departments is necessary to determine whether a fish kill is due to a contagious disease or other causes, such as adverse environmental conditions or pesticide contamination.

A2.2 Coordination of the incident

Management of the incident is coordinated by the state or territory authority (agriculture or fisheries department)—usually through a single state or territory veterinary diagnostic laboratory (or equivalent), led by the jurisdiction's chief veterinary officer (CVO) and/or director of fisheries (DF). The state authority has links to other emergency agencies that may be mobilised in an emergency disease outbreak.

A2.3 Lines of communication during the incident

The state CVO, DF or delegates are the conduit for information within the state or territory to other jurisdictions and with Australian Government agencies. If the disease is of national importance, the CVO or DF will activate the Aquatic Consultative Committee on Emergency Animal Diseases (AqCCEAD). This committee is a communication network comprising the representatives from the Australian Government Department of Agriculture, CVOs or DFs, and the CSIRO Australian Animal Health Laboratory (CSIRO-AAHL). The AqCCEAD is chaired by the Australian CVO.

In an outbreak of a disease of national or international significance, the AqCCEAD is the central authority for communications both within Australia and to international agencies. The Australian CVO, on behalf of Australia, will carry out international communication. The Office of the Australian CVO is responsible for international reporting to the OIE. Reportable diseases are only reported after confirmation by the AqCCEAD, after the committee has considered the available evidence.

A2.4 A team approach

A taskforce or disease emergency management team may be formed. This team would include personnel with expertise relevant to the specific outbreak; therefore, the composition of the team will depend on the nature of the emergency. Industry representatives should play a key role in the taskforce.

The assistance of other agencies may be required to cope with issues such as public health, environmental protection and field operations. Such agencies could include the state emergency services, police, the environmental protection agency and the health department. Liaison with these services will be largely at the taskforce level, although links at a higher level will often be forged by the AqCCEAD to secure cooperation.

Teamwork between state or territory departments, national agencies and industry representatives is essential to effectively use the limited resources available for management of aquatic animal disease emergencies.

A2.5 Information management

Control of information and communication is important. Timely release of accurate information is the key to good information management. The aim is to keep relevant parties informed, reduce the spread of inaccurate information by rumour, and protect any appropriate trade position (domestic or international).

A2.6 Disease management in aquatic environments

Establishment of DMA boundaries during an aquatic animal disease emergency presents difficulties that normally do not arise in terrestrial animal disease control. Water movement through and around farms, within streams or rivers, and in the marine environment leads to a substantial risk of disease spread through transfer of infectious pathogens in the water column, movement of infected material (particularly on suspended organic and inorganic matter) and movement of infected wild organisms.

For example, although an infected area may be established around an individual land-based hatchery or farm, water bodies adjacent to the infected area and in the same catchment should be considered for monitoring and control measures. DMA boundaries around marine farms or wild fisheries may encompass large areas that must take into consideration local currents, natural barriers and the normal range of susceptible wild species.

Establishment of DMA boundaries must take into account dispersal of water discharged from any infected semi-closed aquaculture systems (e.g. hatcheries) or potentially infected processing facilities, and how this enters adjacent water. Outbreaks in semi-open systems (marine farms) require consideration of all oceanographically connected areas and distribution of wild host or vector populations. Spread of infected material through scavenging by other species also needs to be considered.

Thus, rather than property boundaries, the geography, water flow, distance between farming areas and range of susceptible species will define where DMA boundaries are placed.

In some cases (e.g. pelagic fisheries), establishment of infected areas and dangerous contact areas may not be practical or possible, and the disease response may rely primarily on measures applied to activities within the fishery. The Australian outbreak of pilchard herpesvirus during 1998–99 is an example of aquatic disease affecting wide-ranging wild fisheries. In this case, it was not possible to establish an effective restricted area, and control measures relied primarily on restrictions applied to commercial fishing activities in control areas.

Establishment of DMA boundaries and their classification must also take into account potential mechanisms by which a pathogen may move beyond these boundaries. In most circumstances, it is advisable to overestimate the size of DMAs and reduce their area as the response takes effect. In the initial response, DMA boundaries will usually need to include the whole of a catchment area in freshwater systems, and complete bays or regions in marine environments.

Section B Industry sector information

System definitions

Systems are defined by the degree of control over movement of water and animals. They vary from open systems (e.g. wild fisheries), in which there is no control over movement of water or animals, to closed systems (e.g. closed recirculation systems), in which there is complete control over movement of water and animals. Characteristics of these systems are summarised in Table 1.

Table 1 Characteristics of aquatic animal industry systems

System	Water movement containment	Animal movement containment	Examples
Open	No	No	Wild fisheries; ranching
Semi-open	No	Yes	Net-pens, cages
Semi-closed	Partial	Yes	Ponds, raceways
Closed	Yes	Yes	Recirculating systems; aquaria

B1 Open systems

B1.1 Introduction

Aquatic animal disease emergencies occurring in open waterways will be very difficult to manage because of the variety of animals present in these systems, uncontrolled movements of aquatic animals and the waters in which they live, and interactions with people who use the waterways. If diseases and pests become established in an open system, control options are very limited. Eradication from the environment may not be an option.

This section provides information on fishing industry practices, which will be useful in deciding:

- whether control measures are warranted in open systems
- which control measures could be used
- how to implement the control measures.

This section does not describe individual fisheries in detail. Individual Australian fisheries are described elsewhere (e.g. in FRDC 2003).

Information is provided on the types or species of animals in fisheries based on open systems (i.e. pelagic or demersal finfish, or crustaceans) and the types of technology involved in their capture (e.g. longline, trawl, pots). Information is also provided that will be useful in designing a disease control program. Section C details possible management strategies in open systems.

B1.1.1 Overview of open systems

Open systems are waterways in which there is little, if any, control over movement of animals and water. For control purposes, water and animals cannot be contained.

Open systems cover a diverse range of environments in fresh, brackish and salt water, and provide habitat for a vast array of animal species. Within these systems, a broad range of human activities take place, including commercial and recreational fishing, and other commercial and recreational pursuits.

Because of their complex nature, open systems have been separated into three broad categories:

catchment includes lakes, impoundments and river systems

marine refers to the oceanic environment

estuarine refers to the transitional zones between catchment and marine.

Open-water commercial fishing industries comprise:

- those managed by the state and territory governments (through their fisheries departments): coral reef, coastal marine and estuarine fisheries for finfish, shellfish (crustaceans, molluscs) and ornamental fishes
- those managed by the Commonwealth through the Australian Fisheries Management Authority (AFMA): marine deepwater trawl, scalefish, billfish, tuna, shark and scallop fisheries.

Open-water non-commercially fished waterways include:

- many freshwater lakes and estuarine fisheries in the mainland states and Tasmania
- some large lakes of the scale of Lakes Awoonga, Eucumbene and Jindabyne.

Although these areas can theoretically be closed off, their size means that they are more appropriately regarded as open systems. Stocked farm dams and the smaller commercial impoundments, where the discharge water could be contained, are considered semi-closed systems (see Section B.3).

Open-water aquaculture operations include:

- restocking and reseeding of molluscs (scallops, clams, trochus, oysters and abalone)
- ranching, which may involve aggregating fish (e.g. snapper) around feeders and artificial structures. Fish may have been stocked into the environment or may be attracted to the area. Some ranching may involve private ownership of stock (where the stock has been produced in aquaculture and released into a defined area). Ranching is not yet a preferred farming method in Australian waters but could grow in popularity.

Within these open systems, there are four main groups of animals:

- animals that form the basis of commercial and recreational fishing industries
- animals that have been restocked for fisheries or conservation/restoration purposes
- animals that comprise the remaining ecosystem fauna of the open waters of Australia
- animals that are farmed (in semi-open systems—see Section B.2), are within an open system, and include both native and introduced species.

B1.1.2 Controlling diseases and pests in open systems

Diseases and pests are difficult, if not impossible, to detect, manage or eradicate in open-water systems. Complex interactions of novel (including exotic) disease agents and hosts in open systems may result in disease, which may be transmissible to native species or new hosts, with potentially devastating results. However, this complexity means that not all exotic disease agents can be expected to manifest the same disease outcomes under Australian conditions as they display in other countries.

Catchment, estuary and marine ecosystems are quite different, with different populations of important pelagic, demersal and benthic species. In developing a framework for management of disease outbreaks in this environment, it is important to consider impacts at all levels of the ecosystem, as well as on commercial and recreational species. Losses at one level may have significant impacts on the stability of food chains across the ecology of an aquatic environment.

Table 2 provides an outline of the major groups of animals that, at a minimum, should be considered in the development of a disease control plan for an open system. Other animals (e.g. seabirds, wading birds) may also need to be considered if they interact in a significant way with aquatic species.

Table 2 Major aquatic species groups in open systems that should be considered in disease control plans

Life cycle behaviour	Habitat type		
	Catchment	Estuarine	Marine
Mobile migratory	Finfish	Finfish, crustaceans	Finfish, crustaceans, cephalopod molluscs
Mobile territorial	Finfish, crustaceans	Finfish, crustaceans	Finfish, crustaceans, cephalopod molluscs
Semi-mobile	Finfish, crustaceans	Finfish, crustaceans, echinoderms	Finfish, crustaceans, echinoderms
Sedentary	Crustaceans, molluscs	Crustaceans, molluscs, echinoderms	Crustaceans, molluscs, echinoderms, corals, live rock

B1.1.3 Interactions between open systems, farmed systems and aquaculture species

Semi-open and semi-closed farming systems interact with open systems and could contribute significantly to the potential for a disease outbreak. Farmed species may also act as indicators of a problem originating from the open system. Sections B2, B3 and B4 provide further information on farming practices in semi-open, semi-closed and closed systems, respectively.

Diseases found in farmed systems have the potential to affect wild animals, and any proposed controls on semi-open systems should include consideration of the potential impact and management on open-water species.

Farmed species with direct (or indirect) contact with open systems include:

- farmed marine or estuarine finfish—barramundi, bream, cobia, estuary cod, kingfish, mulloway, salmon, coral trout, ocean trout, tuna and snapper
- crustaceans— lobsters, prawns and mud crabs
- molluscs—Sydney rock oysters, Pacific oysters, pearl oysters, other edible oysters, abalone and mussels
- other invertebrates—sea cucumbers, sea urchins, corals and live rock.

Most farming activity takes place in the intertidal or coastal zone in semi-open systems; although farmed in open waters, stocked animals are contained and managed within the farm environment. Although farming in semi-open systems does not often take place in freshwater impoundments or rivers in Australia, semi-closed systems often use water from these sources, and the effluent then flows back into the waterways. This water exchange means that this type of farming has the potential to transmit disease to or from the farming enterprise. Escaped, released or translocated stock may also be carriers of disease that could be harmful to native aquatic animals.

B1.2 Catchment

Inland catchments have a range of native species, including finfish, crustaceans and molluscs. Many also have introduced species. Some systems are stocked periodically with introduced species such as salmonids, and native species such as Murray cod, trout cod, silver perch, barramundi, Australian bass and golden perch.

The interaction of closed, semi-closed and semi-open aquaculture systems with open systems as a result of restocking activities requires an understanding of the husbandry practices of hatchery operation. Once released, however, the stocked fish are considered as 'wild stock' in terms of open system management.

The main potential for disease introduction and transmission in catchments includes:

- deliberate or accidental introduction of exotic aquatic species such as sportfish and ornamental fish
- introduction of organisms transported in ballast water or attached to vessels
- release of effluent water from aquaculture sites
- stock escape from aquaculture
- use and translocation of domestic and imported live fish or fish products as bait
- movement of migratory birds and wildlife
- aquaculture feeds
- movement of contaminated fishing (commercial and recreational) or aquaculture equipment
- international human traffic and associated fomite vectors (e.g. fishing gear such as waders).

B1.2.1 Practices

General use of waterways

The freshwater environment in Australia is used by the general public for utilities, agriculture, industrial uses, some commercial fishing and a variety of recreational activities. Under state and territory legislation, not all freshwater and catchment systems are open to the public. Catchment areas may be closed to the public to conserve the quality of the water for human consumption, and for environmental purposes to preserve endangered stocks of native fish and other aquatic animals.

Recreational fishing

Recreational fishers target both native and introduced species using a variety of hook-and-line fishing methods for finfish, and traps and nets for freshwater crustaceans. Many recreational fishers have boats, and move around and between a number of catchments. Their equipment, which is generally not disinfected, moves with them—in some cases, into international waters.

Recreational fishing includes three main types of hook-and-line fishing activity:

- **Flyfishing**, predominantly a shore-based activity, involves the use of a long rod to cast artificial flies (lures), made from plastic, animal hair, fur and/or feathers, onto the surface of lakes and rivers. There are two different flyfishing techniques: wet and dry. The main difference is that dry flies are used on the water surface, whereas wet flies sink through the water column.
- **Trolling, spinning and lure fishing** all involve the use of a rod and reel of line to cast an artificial lure into the water, to entice a strike from a fish. A variety of lures are used; most are made from plastics (either hard or soft), wood or fibreglass. Trolling is where the lures are trailed behind the moving boat to catch fish.

- **Bait fishing** involves casting a baited hook at the end of a line. Bait fishers may also throw berley (e.g. pollard, squashed shellfish, minced fish, blood and offal) into the water to attract fish to the area, to increase the chance of a catch. Bait comes in a variety of forms—including worms, insects, grubs, cheese and sweet corn—depending on the species being targeted. Local or translocated native or aquarium fish are sometimes used as live bait; and imported or local fish and crustaceans (prawns) may be used as dead bait. Bait may also be used in traps set for freshwater crustaceans such as yabbies, redclaw and giant prawns (*Macrobrachium* spp.).

Commercial fishing
Commercial fishing activity in inland Australia centres on fishing for carp in the Murray–Darling system, eels in impoundments, and golden cobbler in Lake Argyle in Western Australia. Most other impoundments are open only to recreational fishers or are closed to protect fish stocks. Commercial fishers generally use nets, traps and line fishing methods. For example, eels are trapped in impoundments for export markets. Electrofishing is used in a number of waterways for carp—this involves stunning the fish, which are then scooped from the water using nets.

B1.2.2 Premises and equipment

The equipment used by recreational fishers is described above. Other premises and facilities used by recreational fishers and other users of the inland aquatic environment include camping sites, camping grounds, caravan parks, cabins and boat launching facilities. Fishing boats in inland waters are generally small (less than 6 m), of aluminium or fibreglass construction, and powered by petrol or electric motors, oars or paddles. Craft of this kind are used by both the recreational and commercial sectors. Canoes, kayaks and houseboats may also be used by recreational anglers.

Most fish catches are cleaned either on the boat or on riverbanks, with the offal cast back into the water. The fish are then washed and stored on ice, or frozen in portable cooler boxes. Freshwater prawns and crayfish may be transported live.

In the commercial industry, there are few processing facilities for freshwater fish. In most cases, processing of fish takes place either on the boat or at a shore-based facility. Carp are normally taken whole to be processed in an industrial feed or fertiliser processing facility. Fish that are processed for the domestic market for human consumption must be processed in facilities approved by the state or territory department of health.

B1.2.3 System inputs

Aquatic animals

Natural recruitment of species occurs in most systems, with the exception of some impoundments. In addition, salmonids and native fish are restocked for recreational angling, and for conservation and supplementation of native species. Fish and crustaceans may occasionally escape from semi-open and even semi-closed systems, particularly during flood events or cyclonic conditions.

The native populations of crustaceans, molluscs and eels are self-recruiting. The main possible mechanisms for disease transfer are migration of vectors or secondary hosts (e.g. eels, barramundi), translocation by people of species within their natural range, and introduction of new native or exotic species into a waterway. Translocation may occur for stocking purposes, through the use of live fish or crustaceans as bait, or through release of aquarium fish that are no longer wanted. Migrating eels, which can cover vast distances from the Pacific Ocean to inland waterways, may be carriers of infectious disease agents.

The introduction of fish from different systems can introduce disease if the fish are infected, either overtly (i.e. showing clinical signs) or covertly (i.e. as carriers with no clinical signs). Introduction of a new disease can devastate native fish populations because the fish may be naive, with no natural or acquired resistance to the disease. However, the pathogen will not necessarily establish because local conditions may not be conducive.

Water

The water in catchment systems comes from rainfall or springs. Rainfall water usually runs over land into the tributaries of rivers, or into the lakes or impoundments. As the water passes over the landmass, it picks up bacteria, viruses, chemicals, nutrients and minerals from the surrounding environment. These inputs to the water system may or may not have a significant effect on the ecosystem.

Other inputs to waterways include:

- water from stormwater drains and municipal sewage outfalls
- runoff from agricultural and pastoral areas
- organic carbon runoff from dead pasture after flood events
- waste from domestic livestock
- chemicals (pesticides, herbicides and fungicides), fertiliser, runoff from acid sulfate soils, runoff from landfill leaching and aquaculture
- chemicals such as hydrocarbons from motor fuel and oil, anti-fouling chemicals, and wastes from boats
- sunscreen cream, which has been identified overseas as a pollutant of water in holiday areas
- untreated sewage from houseboats
- untreated sewage runoff from recreational and camping areas, and from septic systems.

Such runoff may affect the health of the inhabitant fish (e.g. epizootic ulcerative syndrome in native freshwater and estuarine fish can be triggered by runoff from acid sulfate soils) or affect human food safety (e.g. via contamination by untreated sewage or generation of algal blooms). Pesticide, fungicide and herbicide use can result in spray drift or runoff into water bodies; these chemicals can lead to a wide suite of acute lethal and insidious sublethal effects on aquatic animal health.

Toxic algal blooms in the Murray–Darling river system have been linked to elevated nutrient levels. Sources of nutrients include municipal sewage outfalls, surface runoff from agricultural land where excess fertilisers are used, and runoff from livestock farming areas. Runoff has also been linked to deoxygenation events in the eastern drainage rivers during flood events.

Feed and bait

Bait and berley for both commercial and recreational activity include live and dead fish, worms, insects, insect larvae, frogs, tadpoles, meat, offal and blood from a variety of animals and birds. For some species, they may also include vegetable and cereal products such as sweet corn, tomatoes, pollard and bran.

Other influences (including personnel, equipment, vehicles and stores)

Personnel in freshwater areas include recreational boaters and fishers, and commercial fishers. Fishers and their equipment can act as fomites for pathogen transfer between waterways.

Commercial and recreational fishers, and the general public need to be educated about the need to advise authorities if fish kills and diseases are observed. This could be through schools, fishing clubs, fishers' co-ops and local media outlets. Contact points need to be established for information exchange. Nowak et al. (2005) provide an excellent template for fish kill investigation and sampling approaches.

B1.2.4 System outputs

Aquatic animals

Take of fish, freshwater mussels and crustaceans from inland rivers and lakes is limited by both the recreational and commercial sectors. Some, usually small, fish and shellfish may be taken for use as dead or live bait in the same locality or nearby.

Most fish taken are processed for human or pet consumption. A small number of brood fish are taken live for breeding schemes. These are generally taken under licence issued by the state or territory fisheries authority.

Water

The flow-through water in open catchment systems is often used for drinking water. Local public health authorities, or state or territory environmental protection agencies usually monitor water quality. Other monitoring may be done by farmers who use the water for domestic livestock or irrigation, or by local aquaculturists.

Waste materials

Best-practice use of the aquatic environment requires that people remove their rubbish from the area; however, food scraps are often left for birds and other scavengers to consume or spread. Other wastes in effluent water, septic overflows and sewage outflows enter the system from holiday facilities such as camping sites, caravan parks and cabins

B1.2.5 Groups involved in catchment management

Groups involved in catchment management vary between jurisdictions. They include water resources commissions or water boards, catchment management authorities, state or territory departments of primary industries and fisheries, environmental protection agencies, local governments, lands departments, health departments, acclimatisation societies, other recreational groups, farmers and conservation groups.

The Murray–Darling Basin Authority is the multijurisdictional body responsible for water management in the rivers and lakes of the Murray–Darling system.

Snowy Hydro and the New South Wales National Parks and Wildlife Service are involved in catchment management in the Snowy Mountains. In other states where dams have been constructed to generate hydroelectricity, the electricity authorities would be involved.

B1.2.6 Legislation and codes of practice

Legislation relating to the management of catchment fisheries is generally managed by state and territory fisheries managers. The exceptions are fisheries that are managed under the *Environment Protection and Biodiversity Conservation Act 1999* by the the Australian Government Department of the Environment, and waterways within national parks that are managed under national parks legislation. The Recfish *National Code of Practice for Recreational and Sport Fishing* (recfishingresearch.org/national-code-of-practice) applies in all environments.

See Appendix 1 for information on relevant legislation.

B1.2.7 Occupational health

Human health issues may be associated with chemical spills, algal blooms (especially blue–green algae), and infectious organisms such as *Cryptosporidium* and *Giardia*. Sewage contamination can lead to infectious diseases such as hepatitis A and enteric viral, bacterial and parasitic infections.

See Appendix 2 for information on seafood-borne disease in humans.

B1.3 Estuarine

Estuaries often have a tidal influence. They are subject to fluctuations in salinity, temperature and other environmental parameters linked to the tides and rates of freshwater flow. Estuaries are often the sites of ports and built-up areas, and may be used for many recreational activities. They are important breeding and nursery areas for many marine and diadromous fish and invertebrates, as well as wetland birds.

B1.3.1 Uses

The most common fishing practices in estuaries are prawning, crabbing, recreational line fishing, shellfish collection and commercial fishing. Aquaculture activities such as shellfish farming, prawn farming and finfish grow-out also occur. Other recreational activities in estuaries include swimming and boating. Estuaries are often ports or anchorages for marine fishing fleets, international cargo vessels and recreational craft, including international cruising and sailing craft.

B1.3.2 Premises and equipment

Both commercial and recreational fishers fish estuarine areas. Coastal fishing fleets, depending on the size of the craft, often travel significant distances offshore to fish and then return to their home ports. Commercial fishers in these areas use a variety of lines, traps, dredges, nets and trawls, depending on the target species (e.g. crabs, prawns, finfish, scallops). Scallop fisheries use dredges to extract scallops from the sediment.

Recreational fishers use a rod and line to target most species, but can also use hoop nets and traps to target crabs, and hand-dip nets and haul nets to capture prawns. Recreational fishers also use boats and dinghies, which often have outboard motors. Estuarine areas have boat ramps where fish captured by recreational fishers from estuaries and offshore locations are often cleaned.

The aquaculture sector has a number of different structures in estuarine areas, depending on the farmed species. Shellfish farms have sheds, racks, trays, punts, sticks and wharf facilities. Fish processing facilities can be large and generate significant quantities of waste. Restaurants and eating areas, which can be located on the water's edge, can generate processing and leftover wastes.

Camping facilities may be present—for example, council facilities for tents and permanent caravan-type structures, which also may have communal fish cleaning areas.

Also using the harbour and bunkering facilities of coastal ports and estuaries are an increasing number of pleasure and ocean-going boats from other areas of Australia or overseas.

B1.3.3 System inputs

Animals

Animals in estuarine environments include cultured or wild fish, molluscs, crustaceans, annelids, polychaetes, and myriad other benthic invertebrates and migratory birds. Fish and shellfish may occasionally escape from semi-open and even semi-closed systems, particularly during flood events, or equipment and plumbing failure. Some states and territories stock species in estuaries, including barramundi, mulloway, whiting and prawns, to enhance recreational fishing.

Water

Water inputs to estuarine areas include natural river and tidal flows, as well as anthropogenic sources, such as ballast water, stormwater, sewage (treated or overflow) and agricultural runoff.

Other

Other influences on inputs to estuarine areas include:

- aquaculture feeds, fish products, bait and berley
- rubbish dumping
- recreational boating inputs (e.g. weeds, water and mud brought in on trailers)
- processing waste from fish
- people.

Large numbers of people, from a wide variety of backgrounds, work in and enjoy estuarine areas.

B1.3.4 System outputs

Animals

Estuarine animals include fish, molluscs, crustaceans, echinoderms and birds.

Water

Water includes tidal flows and river flows.

Other

Other influences on outputs from estuarine areas include:

- ballast water uptake
- recreational boating (residual water in boats)
- dredging, and associated spoil and sediment

- people
- movement of boats from estuaries, either by water or over land, by commercial and recreational users.

B1.3.5 Groups involved

The groups involved in management of estuaries vary by jurisdiction. They are likely to include local authorities, port authorities, local government agencies, and state or territory departments (such as lands, national parks, fisheries and environmental protection agencies).

B1.3.6 Legislation and codes of practice

Legislation relating to the management of estuary fisheries is generally managed by state and territory fisheries managers. The exceptions are fisheries that are managed under the *Environment Protection and Biodiversity Conservation Act 1999* by the Australian Government Department of the Environment, and marine parks with estuarine components that are managed under national parks legislation. The Recfish *National Code of Practice for Recreational and Sport Fishing* (recfishingresearch.org/national-code-of-practice) applies in all environments.

Marine aquaculture legislation may need to be considered. This generally falls under state and territory fisheries departments.

Many ports operate under Commonwealth legislation rather than state or territory legislation. Some estuaries are administered by the Australian Government Department of Defence or have significant input from Aboriginal lands councils.

See Appendix 1 for information on relevant legislation.

B1.3.7 Occupational health

Immunocompromised people may be vulnerable to bacterial (e.g. *Vibrio vulnificus*) infections in estuarine areas. Some highly toxic dinoflagellates are also associated with estuarine environments. See Section B1.2.7 and Appendix 2 for information on seafood-borne disease in humans.

B1.4 Marine

Fisheries in open ocean waters include both motile and sessile wild-catch industries, fish and shellfish ranching sectors, net-pen aquaculture industries, and fisheries based on restocking and reseeding of finfish and molluscs. Within these sectors, there are large variations in the degree of mobility of species. As a result, development of effective emergency management plans requires specific information on each species and industry.

Motile species in coastal and open oceanic systems include a variety of commercially important wild-catch finfish (e.g. tuna, mackerel, reef fish, whiting, bream, mulloway, snapper), wild-catch prawns (*Haliporoides*, *Penaeus* and *Metapenaeus* species), other crustaceans (e.g. rock lobsters, crabs, bugs) and cephalopods (e.g. cuttlefish, squid, octopus), as well as a large number of non-commercially or recreationally important fish and crustaceans.

Sedentary species, or those of limited mobility, include abalone, marine snails, scallops, edible bivalves and pearl oyster species.

B1.4.1 Practices

Enterprises in marine and coastal areas are fishing commercially and recreationally for molluscs, crustaceans, cephalopods and finfish. The types of equipment and techniques used to target these species vary.

Aquaculture husbandry practices and the management of stock, broodstock selection, hatchery management and biodiversity may be issues to consider when restocking, ranching and reseeding practices occur in open waters. However, the occasional escape of stock from grow-out aquaculture enterprises can raise concerns over management of genetics, because inbred fish may be weaker and more susceptible to diseases. Once the stock is released into the environment, this section of the manual is relevant, and the principles for managing disease in wild stocks should be applied.

Aquaculture industries often source broodstock, and sometimes larvae, from the wild marine fisheries to support enterprises producing finfish, crustaceans and molluscs.

In wild-catch fisheries, the criteria used for selecting stocks for harvest should be considered. For the most mobile species, stocks selected for harvest will usually be the significant stocks. In the abalone industry, for example, quotas are allocated to larger areas, but the specific microenvironments harvested tend to be those with the best (or most accessible) populations. Populations in areas of low recruitment tend to be under-represented and underused because of the extra fishing effort required. Therefore, pressure is applied to the higher-density populations. This can affect a disease control exercise, as it can result in skewed data if commercial catches are used for surveillance purposes.

In the pearling industry, there has been a shift, since the 1950s, away from wild harvest of pearl oysters towards their culturing. Quotas are now set on the number of pearl oysters that can be taken from the wild and transported to farms for culture. In addition, pearl oyster spat are now also produced in hatcheries.

B1.4.2 Premises and equipment

In general terms, wild-catch harvesting of pelagic and demersal species of marine and estuarine finfish occurs by trawl, seine, longline, diving, set net, trap, and rod and line. This gear is mainly constructed of nylon, hemp, and galvanised or stainless steel. Divers taking pearl oysters generally dive by hookah and wear drysuits composed of neoprene, or nylon and urethane. They place the oysters into netting bags and send these up on lines to the boat on the surface.

If gear is used to catch diseased fish from one area, consideration must be given to the likelihood of transmission of the disease agent if the gear is then used in another area. Transmissibility of the disease agent depends on its properties. The fishing gear can be heavily contaminated with biological material (e.g. fish scales and mucus on nets, and mud on otter/trawl boards, which help keep the mouth of a net open), so consideration should be given to cleaning and disinfection routines before the gear is used in another, disease-free area. For example, abalone herpesvirus can be transmitted on contaminated abalone diver equipment such as boat surfaces, nets and wetsuits. In the United Kingdom, used oyster culture equipment was implicated in the introduction of oyster herpesvirus from infected areas of mainland Europe. Protocols have been developed for cleaning and disinfecting such equipment before it is used in other areas.

Trawl, seine or set net, trap or line gear is used by trawlers and other purpose-built fishing vessels in the oceanic environment. Ocean-going fishing vessels tend to be larger than recreational craft (ranging from 5 m for inshore vessels to 100 m for the larger international vessels), are generally designed to be very seaworthy, and provide a good work platform.

Recreational fishers tend to be highly mobile, and the same gear or boats may be used in several areas within a relatively short time. Boats, lines, pots, nets, bait and berley are all part of the recreational fisher's kit and can be sources of disease transmission between areas.

B1.4.3 System inputs

Animals

In the marine environment, the main input of live animals is migratory fish, escape of fish from semi-open aquaculture systems, migratory birds, marine mammals and humans. Some fish from stocking programmes in estuarine environments may travel into marine environments, and some species have been directly restocked into marine environments—for example, under the New South Wales Department of Primary Industry's (NSW DPI's) mulloway stocking programme in Botany Bay. Abalone and scallops have also been part of reseeding operations in marine areas in New South Wales and Queensland, respectively.

Water

Some potential sources of introduction of exotic pathogens into the marine environment are:

- effluent from aquaculture activities
- catchment and estuarine drainage
- ballast water discharge
- oceanic currents
- bait.

Natural and artificial baits are used in the marine environment and can vary depending on the species targeted. They can be locally sourced or imported. Records documenting the source of any bait or feed used would be useful to determine whether such products could carry disease agents. Particular attention should be paid to imported products that could potentially carry exotic disease agents.

Personnel

Personnel in marine environments include:

- recreational fishers
- commercial fishers
- divers
- other users who may not come into direct contact with fish stocks, such as recreational boaters.

Equipment

Equipment used in the marine environment may include:

- boats and other recreational watercraft (e.g. canoes, surf skis, jet skis)
- nets
- diving equipment, including wetsuits, drysuits and hookah apparatus
- fishing equipment used by commercial and recreational fishers.

Other influences

Other influences on inputs to the marine environment include:

- trawler movement and activities, such as dumping of catch or bycatch
- processing plants at shore margins.

B1.4.4 System outputs

Animals—primary product

AFMA and state or territory fisheries departments maintain databases of fishing effort and catch records for their jurisdictions. Commercial fishing cooperatives may also maintain records of fishing effort and catch data.

The primary products are dead fish and invertebrates for processing on shore or at shore margins, and live animals for processing or sale as live animals (including to export markets). In future, there may be an increasing output of wild-caught live animals for grow-out in aquaculture and value-adding situations; these animals could potentially be grown out at a distance from the original site of harvest.

Water

There is no control over water distribution in the marine environment. Pathogen spread can be affected by tides and currents.

Vehicles and equipment

Machinery and vehicles are likely to be moved into and out of the area. Such movement needs to be considered if the vehicles are likely to contact other stock, potentially acting as a fomite for disease transmission.

Other

Controls are needed on the following waste products:

- processing plant wastes
- shipping operation wastes
- ballast water.

In addition, education is needed on disposal of fishers' refuse.

B1.4.5 Groups involved

Government groups vary between jurisdictions. They include primary industries departments (agriculture and/or fisheries), environmental protection agencies, marine parks authorities and water authorities. Other groups include commercial fishers, recreational fishers, aquaculture grow-out operators and conservationists. International regulations, international fisheries efforts in Australian waters and bycatch issues also need to be considered.

When considering industry groups for consultation in a marine and coastal open-water environment, all groups that depend on the environment, and those with a strong interest, should be identified—this includes groups representing fishing, aquaculture, tourism, local coastal residents, recreational groups, and health and environmental interests.

The fishing industry organisations for commercial species are grouped under the Management Advisory Committees, which report to the state and territory fisheries departments on those fisheries that are in state waters, or have been ceded to the states under the Off-shore Constitutional Settlement Agreement. The Management Advisory Committees for Commonwealth-managed fisheries report through AFMA. The fishing industry is represented at the state and national levels by industry associations (e.g. Tasmanian Fishing Industry Council). The key national agency is Seafood Services Australia. This body has an elected industry board, and its membership includes the major sectors of the commercial industry.

The Australian aquaculture industry is represented by the National Aquaculture Council and industry groups such as the Tasmanian Salmonid Growers Association, the Australian Prawn Farmers Association, the Tuna Boat Owners Association, the South Australian Oyster Growers Association and the Australian Barramundi Farmers Association. These are key groups to consult with if disease occurs in, or can affect, their farming sector.

B1.4.6 Legislation and codes of practice

Each state and territory has its own legislation consistent with its constitutional responsibility for managing animal health within its borders. National guidelines cover a number of areas of aquatic animal health management, and provide a national framework and guidance for development of jurisdiction-specific policies.

See Appendix 1 for information on relevant legislation for each jurisdiction and the Commonwealth, as well as some codes of practice.

B1.4.7 Occupational health

In general, the risks to consumers from open ocean environments are low. Inshore areas may have higher risks due to interaction with human waste systems, which can result in high levels of human pathogens in filter-feeding molluscs, and high metal or dioxin levels in both molluscs and finfish. Finfish generally show low retention of human enteric bacteria, except for transient loading after recent exposure. Filter feeders may accumulate algal toxins, causing conditions such as paralytic shellfish poisoning. This is usually rare in other species; however, ciguatoxin accumulates in some reef fish that are higher in the food chain. Scombrotoxicosis from inappropriately handled tuna and mackerel is another uncommon human health problem.

See Appendix 2 for information on seafood-borne disease in humans.

The working environment

The ocean can be an extremely hostile environment, especially to inexperienced or poorly equipped workers. Death by drowning is one risk. Pearl and abalone divers are also exposed to the risk of shark attacks and decompression illness.

B2 Semi-open systems

B2.1 Overview of semi-open systems

Semi-open systems, generally used for culture of finfish and molluscs, are typified by net-pen systems in which the stock is contained or controlled in a relatively uncontrolled environment. Movement and control of stock is possible, but there is no control over the movement of water in, through and around the culture system.

B2.1.1 Finfish industries

In Australia, the main finfish industries using semi-open systems are:

- the southern bluefin tuna industry in South Australia (see Section B2.2)
- the salmonid industry that grows Atlantic salmon and rainbow trout in Tasmania (see Section B2.3)
- barramundi farming in the tropics and other regions where warm water is available (see Section B2.4)
- the yellowtail kingfish industry in South Australia (see Section B2.5).

Other finfish species such as snapper, cobia and mulloway are also being introduced to semi-open systems, and it is possible that these species will become commercially important in future.

The aquatic environment of semi-open systems is not modified for culture purposes; instead, the aquatic environment is chosen for its suitability for the culture system. The fish are reared in net-pens moored in marine, estuarine or freshwater environments, usually in sheltered situations. Because of the stocking density in semi-open systems, adequate circulation of water through the net-pens is essential for the wellbeing of the fish. There is virtually no control over the water in which the net-pens are located. Impermeable liners can be placed around net-pens, and are used to apply immersion treatments. They prevent movement of water, but also prevent oxygen-rich water reaching the fish and waste products (e.g. ammonia) being diluted.

In a semi-open system, excess feed falls through the net-pen to the bottom of the sea or estuary. Good management minimises such losses, to reduce waste and pollution. Some excess feed is eaten by cohabiting fish species or the benthic community that gather under the net-pens. Faecal material, depending on water movement, is either carried away from the site or deposited on the sea floor nearby. Good management incorporates seasonal fallowing of used net-pen sites within a farm lease to minimise the accumulation of fish waste on the substrate below, and to allow recovery of the sea floor and benthic biodiversity.

Premises in semi-open systems are usually land based, but much equipment needs to be suitable for use in open water, and able to withstand the harsh conditions of an open-water site. Important features of premises and equipment in semi-open systems are as follows:

- Boats are the main form of transport.
- Equipment used to house and contain the stock needs to be robust and, in many cases, transportable by towing or in boats.

- Premises can range from substantial buildings that contain machinery and feed, to sheds, offices, mess rooms, laboratories and simple sheds designed to protect workers from the weather.
- Large, open, on-land work areas are often available for maintenance and storage of nets and other equipment.
- Designated areas on land are usually available for disposal of dead stock, and other wet waste from harvesting and processing.

Transport of fish is usually tailored to the fish species and the particular culture techniques used for that species. Wild-caught tuna are caught in a purse-seine net and then transferred to a tow-cage that is towed by boat to the aquaculture site. Salmonids and kingfish are usually transported by road from the hatchery to the grow-out site. Once at the grow-out site, they may be transferred directly to the net-pens or transported to the site by well boats, helicopter drop or fish pumps. The barramundi industry is more widespread than other aquaculture industries, and the larger distances between hatcheries and grow-out sites often require barramundi fry to be transported by air, then road and boat in foam boxes or aerated bulk bins. Once at the grow-out site, the fry can be released directly into net-pens. Empty or stocked net-pens can be towed between different culture sites.

B2.1.2 Mollusc industries

Semi-open farming systems for molluscs usually have the shellfish suspended from longlines, held in baskets from lines or housed in racks. Young shellfish may be harvested from wild 'spat-fall' or cultured in tanks in sophisticated hatcheries from wild-caught or domesticated broodstock. Shellfish hatcheries supplying farms are usually semi-closed or closed systems, but some sectors rely on natural spat settlement—for example, mussel farming in some states and some Sydney rock oyster production.

Algae and diatom cultures are used to feed larvae during the hatchery and nursery phases. The molluscs are not actively fed during the grow-out period but rely on natural food floating through the lease area.

In northern and north-western Australia, pearl oysters are the basis of a large semi-open mollusc farming industry. The pearl industry is based on a sustainable wild-harvest pearl oyster fishery, using unique seeding and husbandry processes to cultivate pearls. The industry has also developed the capacity for pearl oyster production in hatcheries to ensure a secondary source of pearl oyster supply (see Section B2.6). Spasmodic mortality episodes from oyster oedema disease in hatchery spat have resulted in a dedicated research programme to determine the cause. No causative agent has yet been identified. Industry is managing operations to minimise the impacts of oyster oedema disease.

The commercial production of molluscs for human consumption is based on oysters (mainly Pacific oysters, Sydney rock oysters and flat oysters), mussels, abalone and scallops (see Section B2.7).

B2.1.3 Husbandry practices and disease control

In semi-open systems, the issues that are most important for disease control include:

- location of the culture site

- location of the stock source
- transport and movement of stock
- housing and husbandry of stock
- net cleaning schedule
- type, origin and method of application of stock feed
- handling during the semi-open production phase
- protection of stock from predation and disease (e.g. vaccination)
- fish health monitoring of stock feeding behaviour, mortality and disease status
- application of treatments
- harvesting method
- method and schedule for removing dead stock from culture facilities.

B2.1.4 Interactions between semi-open systems and the environment

There is a two-way interaction between the animals farmed in semi-open systems and the environment. There are no barriers between the farm area and the environment, and waterborne agents can move freely into and out of the net-pens. Animals in these systems interact directly with outside populations, as wild animals are attracted to the food source on, under and within the net-pens or other structures. Large structures, such as racks and nets, quickly become substrates for complex biofouling communities of sea plants and animals. Interaction can also occur if animals from semi-open systems escape into the wild.

B2.2 Southern bluefin tuna net-pen culture

Table 3 summarises the main features of the southern bluefin tuna (SBT) industry sector.

Table 3 Features of the southern bluefin tuna sector

Species	Southern bluefin tuna (*Thunnus maccoyii*)
Location	Port Lincoln, South Australia
Length of production cycle	2–9 months
Product	Fresh (head on, gilled and gutted) and deep frozen (–60 °C)
Annual production (2011–12) (ABARES 2013)	7087 t
Value (2011–12) (ABARES 2013)	$150 million
System	Net-pen culture
Feed used	Fresh and frozen whole fish (can be supplemented with moist manufactured feed and vitamin premix powder)

B2.2.1 Husbandry practices and disease control

Sea ranching of SBT involves catching wild stock by purse-seine net from the tuna fishing grounds in the Great Australian Bight, transferring the fish to a tow-cage, and then towing the fish up to 500 km back from the fishing grounds to the grow-out site near Port Lincoln. The fish are then on-grown in net-pens to the fatness or condition index required by the market. Most fish are held in cages at a depth of 20–25 m, while a smaller number are in deeper sites of more than 50 m.

Additional tuna are held for tourism (swim with and/or feed the fish) operations or breeding programmes. These stock are held in a sheltered bay close to Port Lincoln.

Access to wild tuna stocks is restricted by a quota system and the seasonal presence of tuna in South Australian waters (between November and May). At the grow-out site, the tuna are transferred from the tow-cage into 3–5 grow-out net-pens, which may be located on several lease sites. Licence conditions restrict stocking density to a net-pen biomass of less than 4 kg/m^3 at the time of stocking, and a lease biomass of less than 6 t/ha. All processes of capture and transfers are documented by swimming the fish past an underwater video camera—this process is known as stereo video monitoring. The tuna are not graded during the grow-out cycle and are not handled until they are harvested. Regular diving in net-pens is undertaken to remove any mortalities and repair damaged nets.

During grow-out, the tuna are fed fresh, frozen or defrosted whole baitfish that is either sourced domestically or imported by wholesalers registered by the Australian Government Department of Agriculture. Feed is delivered to freezer stores and then to the wharf by refrigerated truck. The feed is then transported to marine sites by boat and fed to the tuna once or twice per day, or continuously throughout the day.

Stocked net-pens are monitored daily for health status. Any dead fish are removed by divers and are either buried in a designated area on land or included in locally manufactured byproducts, such as fertiliser and meals for pigs and poultry. Water quality is monitored regularly, including by the identification and quantification of phytoplankton species.

Fish are harvested when they reach the appropriate condition (fatness), rather than a particular size. Section B2.2.4 provides details on harvesting and processing practices.

Net-pens are emptied within 2–9 months of the initial stocking. All nets are removed from the water, cleaned and air-dried before the next season's stocking. Some farms clean nets while the net-pen is stocked. Within a lease, a new net-pen site is used for each production cycle. Lease sites are large enough to allow a fallow period of at least five years for each net-pen site.

B2.2.2 Premises and equipment

Fish are held in double-collar polyethylene Polar Cirkel net-pens, custom-made single-collar net-pens or (very rarely) rubber Bridgestone ocean net-pens. The net-pens are 32–50 m in diameter (i.e. 100–157 m in circumference). The most common type is the 40 m diameter (126 m circumference) single-collar (450 mm) net-pen.

Containment nets are 100–160 m in circumference and 9–15 m deep (to the lead line), with a mesh size of 75–200 mm, and are made from polypropylene or nylon. Predator nets are usually 150–300-mm mesh size and either hang outside the containment net from the net-pen collar to the sea floor or take the form of a contained bag with a floor beneath the containment net floor. Nets are washed in situ, but this may not be necessary while fish are stocked. Hiab-type hydraulic winches are mounted on most boats for activities such as changing nets, lifting weights, installing mooring lines and feeding. Purse-seine vessels also have hydraulic power blocks that are used during the setting and hauling of nets.

Service vessels used for feeding, harvesting and towing vary between companies and range from 12 m to more than 30 m in length. The same boats and trucks are used for multiple tasks. Forklifts are ubiquitous throughout the industry.

Custom-made feeding devices are widely used; they consist of small floating mesh nets positioned in net-pens. The mesh net contains blocks of frozen feed, which defrost and trickle-feed the tuna over a 2–4-hour period.

All harvesting occurs on-site, so harvesting equipment is portable and is loaded onto boats before harvesting and removed afterwards. Harvest bins and processing factories are disinfected with export-certified detergents and sanitisers after every use. Most farms are able to fully equip a dive team with diving gear; however, not all farms have a dive team on staff, and contracting is common. The amount of gear available on a farm depends on whether contract divers are used.

All farms have fully equipped workshops at their land-based service facilities. Some farms have a laboratory equipped with microscopes, dissection equipment and equipment for testing water quality. The tuna industry maintains a central research office with laboratory facilities and scientific staff at the marina in Port Lincoln. Specialist pathology facilities are available in Adelaide, which is a 45-minute flight or overnight bus trip from Port Lincoln. The industry also uses the expertise and facilities of the Port Lincoln Marine Science Centre.

Stores

All imported feed is stored at Department of Agriculture–approved and registered freezer store areas, located mainly in the industrial area of Port Lincoln. Locally caught baitfish can be stored at the same Department of Agriculture–approved premises or at freezer stores owned by pilchard quota holders or processors; these are mainly located in the Port Lincoln industrial area.

Seven factories with export-approved facilities, also mostly in Port Lincoln, are used for processing the tuna as fresh or deep-frozen product. Other equipment, such as nets, trucks, feed bins, and feeding and harvesting equipment, is stored in sheds. Each company owns or leases shed facilities in the industrial parts of the town, which are used for storage or as workshops for activities such as net and net-pen repairs.

Some companies maintain export processing facilities, frozen feed storage facilities, canneries, storage sheds and large work areas at single sites.

Vehicles

All workers live in Port Lincoln or the surrounding districts, and drive between factories, workshops, wharves, shipyards and marinas. Trucks are used to transport feed from feed stores to boats. Forklifts are common at the shed and workshop areas, at feed storage freezer sites and at the processing factories. Refrigerated trucks are used to transport export product, destined for Japan, from the processing factories in Port Lincoln to the Sydney and Melbourne international airports. Containers of shore-frozen tuna are transported by road to a shipping port for sea freight to Japan.

B2.2.3 System inputs

Aquatic animals

SBT are captured in the Southern Ocean, transferred into a tow-cage and towed to the grow-out site. One tow-cage can supply tuna to many lease sites, but each lease site has only one company operating on it. The juvenile tuna captured are usually 2–3 years old and weigh between 12 kg and 20 kg. In some years, 2–5-year-old stock weighing 5–50 kg are caught. Adult SBT can grow to more than 200 cm in length and more than 200 kg in weight, and can live for up to 45 years. The tuna first spawn at around 8 years of age, when they are about 150 cm long. Tuna are highly migratory; the SBT has a circumpolar distribution between latitudes 30°S and 50°S.

Temperate tunas (i.e. southern and northern bluefin) have a system of cutaneous arteries and veins supplying blood to the muscle and retia mirabilia (heat exchangers that minimise loss of the heat produced by the fish's metabolism and activity). This enables the fish to maintain a body temperature up to 15 °C higher than the ambient water temperature.

However, in the farm situation, basal body temperatures are mostly only 2–4 °C above ambient water temperature. Unlike most fish, SBT are 'ram ventilators'; to breathe, they must constantly swim up to one body length per second. They are very active and powerful fish, and can attain swimming speeds of 20 body lengths per second (up to 80 km per hour). The gill surface area is large (approaching the surface area of a mammalian lung), and has an extensive array of cross-linkages and fused lamellae to allow the tuna to remove proportionally more dissolved oxygen from the water than any other fish. These features make tuna gills particularly vulnerable to obstruction by particulate matter and fine air or oxygen bubbles, which can lead to hypoxia. SBT are also vulnerable to parasites.

Many other species of wild fish and shellfish are seasonally or permanently resident near or in open-water net-pens, including baitfish (such as yellowtail, anchovies, pilchards, slimy or blue mackerel, tommy ruffs or Australian herring), Australian salmon, snapper, small blennies, seahorses, octopuses, squid, scallops, razorfish, sea cucumbers/holothurians, mussels, sea urchins and various types of jellyfish. Little is known about the movement patterns of many of these species, but some are known to be migratory and others sedentary. These fish can be a food source for the tuna but could also be important vectors of disease agents. It is likely that some species harbour potential pathogens, but the extent of this is unknown and the subject of ongoing research.

Aquatic animal and plant communities develop on the nets. Such fouling communities include green and brown algae, polychaetes, blue mussels, juvenile rock lobsters, multitudes of small crustaceans, other invertebrates and finfish. Some of these may be intermediate hosts for parasites considered important in tuna production.

Other animals

Seals and sharks are common predatory pests, harassing the tuna. At times they need to be removed from the nets, when they gain access to the fish.

Mussel farming operations are situated downstream (in the prevailing current) from the tuna farms. Mussels are filter feeders and may take up products used in the tuna farms. This should be considered in any management programme for the tuna in these areas.

A range of fish-eating birds regularly feed on waste feed distributed in the net-pens. These birds may fly between net-pens and between farms during the course of a day.

Water

Within a lease site, net-pens can be located close to each other (within 50 m). Neighbouring lease sites can be as close as 300 m. Water temperature ranges from a daily minimum of 12–14 °C in winter to a daily maximum of 22–27 °C in summer, varying from year to year. Temperatures above 24 °C sometimes stress the fish; when this occurs, the fish are not usually fed. Weather conditions can make the water rough in exposed sites, making work difficult.

Current flow varies between sites, but all sites have some daily variation in current; therefore, particular management practices (such as setting harvest nets) are more difficult at certain times of the day. Periods of low water current occur during neap tides.

Feed

During grow-out, the tuna are fed with a mixture of frozen and defrosted whole anchovies, pilchards, herrings, mackerel and squid from a variety of sources, including Australian and overseas fisheries. Fresh (never frozen), locally caught baitfish are fed to the tuna when available and comprise a minority of their diet.

Imported feed is supplied by, and stored frozen at, one of a number of Department of Agriculture–registered premises, most of which are in Port Lincoln. Compliance agreements are in place for all sites and companies using imported baitfish as tuna feed or for other uses. The agreements include a list of quarantine practices that must be followed, and the premises are subject to inspection and audits. Some operators supplement the wet fish diet with a vitamin and mineral premix. A semi-moist manufactured diet has been developed but is not widely used because of its relatively high cost. Diet work continues to develop new formulations, with a view to feeding tuna, which may emerge from the hatchery programme.

Personnel

Workers do not live on-site, but travel to work each day. On most farms, the number of workers remains reasonably constant. Larger farms may employ up to 70 workers. Some staff of the bigger companies have qualifications in aquaculture or marine sciences. The level of training and the competency of workers is high in many areas, and cooperation within the industry in some skill areas (such as diving) has ensured that high standards and protocols are maintained.

Workers may be involved in more than one activity, but usually there are land-based staff (for fish processing, stores, engineering and other duties) and sea-based crew (for diving, feeding and harvesting). Each production company may own a number of marine leases; in such cases, personnel (including vessels and equipment) move between sites daily. Companies that own processing and export facilities employ teams of specialists to process the fish for market; specialist teams are relatively static and rarely perform tasks on the farms.

Some farms have contract divers, while others have their own teams trained in commercial diving practices. A contract dive team might undertake towing, daily underwater inspections, net cleaning and harvest diving operations for a full season. However, practices are similar across farms, so workers from one farm have little difficulty moving to another farm. Currently, divers do not disinfect themselves between dives, but could do so if necessary.

Contractors may be used to repair and maintain farm equipment.

Farm sites may have regular visitors, such as recreational fishers, researchers, fish health advisers and other members of the industry. Some farms operate tourist ventures to swim with the tuna.

Equipment

Most farms have equipment available to fully equip a dive team with diving gear, but the amount available depends on whether contract divers are used. Most farms have transportable harvesting equipment, which is loaded onto boats before harvesting. Typical harvesting equipment includes a small seine net, a floating platform that carries up to five people and attaches to the net-pen collar, tables with sides and collection sumps to retain blood and mucus, and knives and processing implements.

All farms use video monitoring to count fish from the tow-cages into the grow-out net-pens at the start of the season. If required, this equipment is available throughout the year from AFMA-approved contractors. Some farmers also use submersible video cameras to observe subsurface feeding activity. Some companies own a number of marine leases and regularly move equipment between sites.

Stores

Feed is delivered directly from Department of Agriculture–registered premises to a cold store or to the marine sites. Before the season, feed is stockpiled ready for the arrival of the tuna, and new shipments arrive throughout the season. Some types of feed for restricted use can be stored from one season to the next. All farms have a shed and paddock store where small boats, nets, weights, ropes, harvest equipment and bins, feeder cages, and so on are kept. The amount of gear stored at these sites varies between farms.

Vehicles

Workers live off-site and drive private vehicles to work. Trucks are used to transport feed to stores and boat departure points. Forklifts are used at sheds and freezers; cranes, and truck or vessel Hiab winches are used on land to load and unload vessels.

Boats are used to transport personnel, equipment and feed to and between marine sites. Recreational fishers are present every day in the waters between leases and around tuna farm net-pens. The industry has limited control over the presence, practices and movements of recreational fishers.

B2.2.4 System outputs

Aquatic animals

Harvesting occurs when fish reach a desired condition (fatness), rather than a particular size. Marketable fish can weigh as little as 15 kg or more than 60 kg, depending on the initial stocking size. Between 40 and 2000 fish are harvested at the net-pen site with hook and line, or by net-crowding the fish and using gaffs or divers to retrieve them. Fish are killed by a spike to the head (known as iki jime) and bled on the vessel on-site. Operators on the boat remove the gills and viscera. All blood and viscera are retained on the vessel for disposal on approved land premises.

Fish are placed in ice slurry bins and tanks on the boat. If destined for airfreight or fresh product, they are processed and packed that day or the following morning in export factory premises on land. Fish destined for ultra-low freezing are either transferred onto freezer vessels at sea or unloaded to export premises on land. All fresh and frozen product is exported as whole fish, with gills and viscera removed. Most product is exported to Japan, but small quantities are sold in the United States and domestically in Australia. Net-pens are completely emptied within 2–9 months of the initial stocking.

Water

Fish are confined in net-pens, so adequate circulation of water through the net-pens is essential for their wellbeing. There is virtually no control over water movements where the net-pens are located. An impermeable liner placed around net-pens can prevent any movement of water, but also prevents oxygen-rich water reaching the fish and the dilution of waste products, such as ammonia. If water conditions deteriorate, net-pens can be towed within an hour.

Waste materials

During the grow-out period, excess feed and fish faeces may accumulate on the substrate below, or down-current from the net-pens. However, net-pen sites are only used for 2–9 months of the year, allowing a remedial fallow period of 3–10 months. Moreover, in the following season, net-pens are not placed in exactly the same location as in the previous season. Each net-pen has its own set of moorings, which are removed from the water after the pen is destocked. Any dead fish are removed and either dumped in landfill or processed into protein supplements at a rendering plant.

Gills and viscera are disposed of as landfill, processed into protein supplements at a rendering plant, or frozen to be used as leatherjacket bait in the commercial fishery. Wastewater from the factories is discharged into Proper Bay after treatment at the municipal sewage treatment plant, or after treatment at on-site wastewater treatment plants.

Vehicles and equipment

Workers live off-site and drive private vehicles to work. Boats are used to move between the three loading areas of Port Lincoln, the marine lease sites, different lease sites of the same company and lease sites of other companies. After the initial transfer of fish from the tow-cage after capture, boats do not tow net-pens containing fish except in an emergency (e.g. algal blooms, oil spills, jellyfish). Each company has its own equipment and vessels; apart from processing facilities, there are few shared facilities.

B2.2.5 Groups involved

A large number of groups are involved or actively interested in the operation and regulation of tuna net-pen culture systems, including:

- national, state and local government bodies
- the Australian Southern Bluefin Tuna Industry Association
- the Tuna Boat Owners Association
- community groups, such as environmental and conservation groups
- recreational fishing groups
- yachting and boating groups
- commercial fishers
- universities and other institutions
- other water users.

B2.2.6 Legislation and codes of practice

In South Australia, fish and fish diseases are covered by the *Livestock Act 1997* and the *Fisheries Act 2007*. The capture fisheries in state waters are managed under the Fisheries Act. SBT are usually captured in Australian national waters and brought into state waters for aquaculture. Therefore, the allowable wild catch (quota) is set and managed under the Southern Bluefin Tuna Management Plan by AFMA, which has jurisdiction until the fish are transferred into net-pens for grow-out on the lease sites near Port Lincoln. Primary Industries and Regions South Australia subsequently manages the fishery under the *Aquaculture Act 2001*.

See Appendix 1 for information on relevant legislation.

The Tuna Boat Owners Association has developed a code of practice for diving and is currently finalising a code of practice encompassing other industry activities.

B2.2.7 Public and occupational health

Public health

Issues relevant to public health that should be considered are:

- the safety of the product if it is harvested during a disease outbreak, or when toxic algal blooms and chemical spills are present
- the potential for transmission of seafood-borne diseases (see Appendix 2) via the product
- the quality of product if it is emergency-harvested because of disease threats
- availability of laboratories to undertake specific testing for the range of potential disease agents
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed
- chemical residues in treated fish
- disposal of dead fish and waste products, where required.

Worker safety

Aspects of worker health and safety that should be considered are:

- the potential for the combination of a harsh, unpredictable environment (e.g. bad weather conditions) and operation of boats and heavy equipment to impede safe work practices
- the need for specialised training and qualifications for diving—it is illegal and extremely dangerous for untrained personnel to dive, or for divers to work beyond the recommended diving times
- weather conditions and current flows if liners (to isolate fish) or nets (to capture stock) are deployed
- hazards associated with handling ropes, nets and heavy equipment
- the need for specialised qualifications and experience to operate boats
- the need for safety equipment
- potential threats to workers' health from collecting, handling and disposing of dead, decomposing or diseased stock
- the safety of workers preparing and applying chemical treatments.

B2.3 Salmonid net-pen culture

Table 4 summarises the main features of the salmonid industry grow-out sector.

Table 4 Features of the salmonid industry grow-out sector

Species	Atlantic salmon (*Salmo salar*)	Rainbow trout (*Oncorhynchus mykiss*)
Location	Tasmania	New South Wales, Tasmania, Victoria, Western Australia
Length of production cycle	12–29 months	7–22 months
Product	Fresh, processed and smoked product	Fresh, processed and smoked product
Annual production (2011–12) (ABARES 2013)	43 989 t (salmon and trout)	
Value (2011–12)	$512.6 million	
System	Net-pen culture	Net-pen and pond culture
Feed used	Dry pelleted ration	Dry pelleted ration

No live salmonids have been imported into Australia since 1965. Fresh salmonid products that meet Australia's quarantine requirements have been permitted entry into Australia since 1999. A moratorium remains on imports of all fresh salmonid products into Tasmania.

Atlantic salmon require water temperatures of 4–16 °C for optimal growth and good health. Temperatures above 18 °C cause stress to the salmon, and affect their growth and health. Rainbow trout can tolerate similar water temperatures to Atlantic salmon in fresh water, but are slightly less tolerant of high water temperatures at higher salinities.

B2.3.1 Husbandry practices and disease control

Atlantic salmon net-pen culture

Atlantic salmon farming consists of a freshwater hatchery stage (see Section B3.6) and an estuarine or marine grow-out stage. Young salmon (smolt or pre-smolt) are usually introduced into the marine environment when they are 10–17 months old and weigh 45–100 g (in Tasmania, this is from May to October). Special trucks are used to transport young salmon from the inland hatchery to the marine site. Fish are then either transferred into net-pens at the marine site land base or shipped by barge to net-pens in remote marine sites. Most hatcheries retain their broodstock in fresh water to minimise risk of disease introduction from marine areas.

Floating net-pens, of either individual circle or square-grid system design, are used to house the salmon in the marine environment. A circular net-pen consists of a circular plastic support to which is attached a circular nylon net. Net-pens have a circumference of 40–240 m, and the nets have a depth of 8–15 m. Circular net-pens may be placed as close as 25 m to one another within a lease. A system net-pen consists of a grid of plastic pontoons and steel walkways that support a number of square nylon or brass nets in close proximity to one another (2–3 m between neighbouring net-pens). Each square net is 25 m wide and 8–15 m deep. All net-pens are moored within a grid comprising an elaborate system of ropes and structures anchored to the seabed, and can be towed between mooring systems. Additional predator nets to protect stock from large predators, such as birds and seals, are usually installed to surround individual net-pens or raft systems.

Most net-pens are located in areas moderately well protected from wind and wave action; however, industry expansion is now resulting in placement of net-pens in new, more exposed lease areas. Salmon are usually grown in net-pens for 12–18 months. There are usually 10 000–60 000 fish in each net-pen, depending on its size and the size of the fish. This results in a stocking density of 4–15 kg/m^3 of water. Salmon are graded during grow-out, ensuring that fish in the same pen are of similar size.

Fish are fed a commercial dry pelleted ration. Most of the larger-sized pellet grow-out diets are produced in Australia. However, some fish feed is imported. During the warmer months, fish may be fed up to 3 per cent of their bodyweight per day, while in winter the rate can be as low as 0.5 per cent. Feed is usually delivered to the farms by truck in 1-tonne bags. Feeding methods vary between farms. On some farms, the fish are fed by automatic feeders—either individual units on each net-pen or a central control unit that feeds a number of net-pens. On other farms, the fish are fed from boats, either by hand with feed scoops or using a manually operated cannon feeder, which blows the feed into the net-pens.

At water temperatures above 18 °C, salmon are more susceptible to disease agents, and farmers will often not feed fish under such conditions. Warm summers with high water temperatures are detrimental to the growth and general health of the fish. Farm personnel regularly sample a small number of fish from each of the grow-out pens to inspect them for growth and health status.

Freshwater bath treatments are used to control amoebic gill disease. These treatments require plastic liners, a source of fresh water and adequate oxygen supply. Where required to control disease, other treatments such as antibiotics may be coated onto the feed and used under veterinary supervision.

Net-pens are monitored for dead fish ('morts') on a regular basis (2–7 days per week). Morts are removed from the pens by various methods, including dip-net, mort retrieval devices and scheduled diving. The collected morts are buried in a designated area on land, or processed using ensilage or rendering. Considerations for the selection of disposal sites are covered in the AQUAVETPLAN **Disposal Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan).

Farmers regularly monitor water quality at all sites. Records may be kept of dissolved oxygen, temperature, turbidity, pH, salinity and identified phytoplankton. Some farms fallow net-pen sites within a lease area for a year or more.

Salmon are usually harvested when they weigh 2.5–4.5 kg head-on, gilled and gutted (HOGG). Some farms have a processing facility near the marine sites, and net-pens are towed to this site for harvesting. Other farms harvest 'on the water', using barges or boats. Until recently, a typical slaughter line incorporated an anaesthetising tank (using a carbon dioxide–ice slurry), followed by a bleeding table (where gills were cut to allow terminal bleeding). However, the Tasmanian industry now almost exclusively uses automated percussive stunning and gill-cutting equipment, which maintains high flesh quality as well as high fish welfare standards.

During harvesting, fish are crowded in the pen and drawn from the water (usually 20–30 at a time), most commonly using a fish pump but sometimes using a brail net, to be delivered into the automated percussion stunning and killing unit. Once stunned, the fish are cut, usually near the base of the gills, to allow bleeding. Alternatively, the fish are swum into a percussion stunning unit, to maintain high fish welfare standards. In either case, fish are placed into ice slurry within a few minutes of bleeding out. If processing is on-site, the fish are eviscerated and cleaned, and then either packaged or forwarded to a value-adding section (e.g. for smoking or preparation into portions). If the processing site is distant from the harvesting site, the fish are trucked in bins (in ice slurry) to the processing facility. Fish may be kept in the ice slurry for up to 24 hours before processing, but are usually kept for less than 12 hours.

Harvest bins and equipment are sanitised between uses, and processing facilities meet export standards approved by the Department of Agriculture. Approximately 15 per cent of fresh fish are airfreighted overseas to reach the market within 24 hours of harvesting. Most of the remainder is airfreighted to the mainland wholesale markets in Melbourne and Sydney; some goes directly to restaurants and retailers.

Rainbow trout net-pen culture

Net-pen culture of rainbow trout is largely the same as for Atlantic salmon, except that rainbow trout do not go through a smoltification stage in which the fish prepares for the transition from fresh water to salt water. When introduced to brackish or salt water, rainbow trout immediately go through an acclimatisation stage. Because rainbow trout do not perform well in full salt water (31–35 parts per thousand—ppt), they are usually only grown in sites with brackish water (15–21 ppt). Fish are usually transferred to such sites when they are approximately 12 months old and weigh 50–100 g.

B2.3.2 Premises and equipment

Boats are the main form of transport on salmon farms. They are used to deliver feed, to tow net-pens, to clean or change nets, as dive vessels, to transport personnel, for inspection of fish, and to help carry out day-to-day maintenance on net-pens and mooring systems. Most are made of aluminium, are 4.5–7 m long and have outboard motors. Larger boats and barges may be used for heavier work and are often fitted with Hiab cranes or electric winches.

Most farms have an on-land facility with offices and buildings to house staff, machinery, feed, nets and other equipment. Most also have open work areas on land for net maintenance or for disposal of dead fish. Some farms have a dedicated laboratory, with a light microscope and equipment for taking pathology samples; most have equipment for sampling live fish. Farms have equipment for grading fish, for transferring fish between net-pens and for freshwater bath treatments to control amoebic gill disease.

Forklifts are commonly used around the land-based facilities, and trucks are used to transport feed to the farm and harvested fish to processing plants. Harvesting equipment is heavy and not easily transportable, but some farms use a large vessel to move it or to harvest ‘on the water’. Most farms have sanitising treatments to clean equipment.

Most farms fully equip a dive team, but the amount of gear available depends on whether contract divers are used.

B2.3.3 System inputs

Salmonid culture systems have a wide range of inputs that may be relevant to disease control.

Aquatic animals

Atlantic salmon and rainbow trout to be used for culture are usually transported by land from freshwater hatcheries to marine sites between March and November. This may involve movement between geographical zones of different disease status. The Tasmanian Salmonid Growers Association and the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE) have agreed on translocation protocols and movement restrictions between different culture areas to minimise the risk of disease translocation. Fish are most stressed after they have been transferred from fresh water to salt water.

Smoltification usually takes place in spring, but photomanipulation allows out-of-season smolts to go to sea as early as March. Pre-smolts can be transferred to brackish water sites earlier than they could be transferred to fully fresh water—this can lead to better growth rates.

On some farms, fish are graded to ensure that the sizes of individual fish are similar within the population in any particular net-pen. However, handling, grading and moving fish to achieve this consistency while the fish are growing stresses the fish and can make them more susceptible to disease.

Each company may own a number of leases and may transfer fish between sites. In some areas, neighbouring leases owned by the same or different companies may be a kilometre apart.

Fish age

Younger fish are more susceptible to most diseases and other health problems than older fish. It is more practical to treat younger fish for disease because of reduced costs, ease of handling and lower risk of chemical residues persisting in the harvested product.

Wild aquatic animal populations

Wild aquatic animals can act as vectors for disease. Many wild fish occur near net-pens in semi-open systems and often inside the pens themselves. They include baitfish (such as yellowtail, anchovies, pilchards, garfish, and slimy, blue and jack mackerel), tommy ruffs, Australian salmon and small blennies. Little is known about the movement patterns of these fish, but some are definitely migratory while others are more permanently resident. Potential pathogens (e.g. reovirus, birnavirus) have been identified in some of these wild populations, but the extent and role of these species as vectors or reservoirs of disease is poorly understood.

Aquatic animal and plant communities develop on the nets, even though nets are cleaned and changed frequently. Such fouling communities include green and brown algae, blue mussels, juvenile rock lobsters, cnidarians, ascidians, small crustaceans and finfish.

Jellyfish—including moon jellyfish and, to a lesser extent, lion's mane jellyfish—have been associated with epidermal damage to live fish, and fish kills in marine net-pens. Epidermal damage may not directly cause mortality, but increases the susceptibility of fish to a range of opportunistic pathogens.

Predators

Predators, particularly seals and birds, have a large impact on the health of salmonids in marine farms, through stress, injury and mortality. Prevention of stock predation requires anti-predator devices, such as protective nets around net-pens. The salmonid industry has operated a trap and relocation programme to mitigate the short-term damage from seals. Seals are highly mobile and can move vast distances between sites. DPIPWE, under the direction of the Marine and Marine Industries Council, has developed *A seal/fishery interaction management strategy* (http://dpipwe.tas.gov.au/Documents/Final-Management-Strategy-(FM).pdf).

Water

Semi-open systems are located in estuaries and exposed marine areas, so there is no control over the flow of water around net-pens. In some estuarine sites, rivers can be a significant source of fresh water. In places such as Macquarie Harbour in Tasmania, the water column can be stratified under low wind conditions, with a freshwater lens of 1–3 m depth overlaying the higher-salinity water.

In Tasmania, water temperatures range from about 9–10 °C in winter to 15–23 °C in summer. Temperatures above 18 °C cause stress to the fish and have been associated with toxic algal blooms. Significant thermoclines may contribute to these effects. Fish are usually not fed during this warm weather.

Fresh water is used on some farms as a therapeutic bath to reduce the impact of amoebic gill disease.

Feed

All salmon are fed a commercial dry pelleted ration. The length of pellets varies from 3 mm to 12 mm, according to the size of the fish.

Imported fishmeal and fish oils are used in the manufacture of pellets; fishmeal can make up to 45 per cent of the ration. The fishmeal and fish oil go through a heating process during extrusion manufacturing, and must be certified free of known pathogens for importation.

Personnel

Practices are similar across farms, so workers from one farm have little difficulty moving between employers. All farms have mess rooms or similar amenities. Larger farms may have up to 50 workers, and 30–40 of these may be out on the water at any one time. On larger farms, teams often specialise in a particular task, such as net changing or feeding. Each company may own a number of marine leases, and some personnel may move between these sites regularly. In contrast, workers on smaller farms may be involved in more than one type of activity. Companies that own processing and export facilities have teams of specialists to process the fish for market. These teams are relatively static and do not perform tasks on the farms.

Some of the bigger companies employ research staff, fish health veterinarians and technicians. Contractors may repair and maintain farm equipment. Some farms have contract divers, while others have personnel trained in commercial diving practices. On-farm divers do not disinfect themselves between dives, but contract divers may disinfect and dry equipment between dives at different farm sites.

The level of training and competency of workers is high, and cooperation within the industry in some skill areas (such as diving) has ensured that high standards and protocols are maintained. Some farm sites have regular visitors, such as researchers, fish health advisers or other members of the industry.

Equipment

Most farms fully equip a dive team, but the amount of equipment available depends on whether contract divers are used. In some cases, divers personally own their dive equipment. This may affect equipment availability, and could potentially be a biosecurity risk if the equipment is used off the farm site.

The type of harvesting equipment varies between farms. Some farms have equipment permanently installed on land or on boats, some have transportable equipment that is loaded onto boats before harvesting, and others have no harvesting equipment but tow the net-pens elsewhere to be harvested. Equipment can include crowd nets, fish pumps, brail scoop nets, airlift pumps, anaesthetising baths, percussive stunning machinery, bleeding tables, harvest bins, bin liners and aeration/oxygen stones.

Most farms have equipment for sampling live fish from net-pens and inspecting them for weight and health status (specialised sampling nets, anaesthetic baths and recovery bins). Forklifts are ubiquitous throughout the industry. Hiab-type hydraulic cranes and winches are commonly mounted on boats to assist in changing nets, and to lift feed, weights, mooring lines and so on. Grading equipment may also be available.

Most farms have some form of washing device to clean nets, either on land or in the water. On raft-system farms, nylon nets are placed above the waterline and allowed to dry in the sun before reuse. Most farms also have a laboratory facility; some have microscopes and pathology sampling equipment, and all have equipment for dissecting fish. Many farms have plastic net-pen liners and other equipment for large-scale therapeutic freshwater bath treatments.

Some farms have a fully equipped workshop on-site. Service vessels for transporting farm supplies and harvesting range in length from 12 m to more than 30 m. On most salmon farms, different vehicles and boats are used for specific functions, but on smaller farms they may be multifunctional. Some companies own a number of marine leases, and regularly move equipment between these sites.

Stores

Feed is stored on-site at land-based facilities for up to two weeks. All farms have stores for gear, but the amount of gear stored varies between farms.

Vehicles

Workers live off-site and drive private vehicles to work. Trucks are used to transport feed, live fish and harvested fish. Forklifts are in common use.

Other

Farms routinely use anaesthetics and non-prescription disinfectants. Other therapeutic agents, including antibiotics, are used where indicated under veterinary prescription, and farms may store an assortment of these substances. Most farms also use fresh water as a fish therapeutic agent. Anti-foulants are used on nets and vessels.

B2.3.4 System outputs

Aquatic animals

Salmon are harvested when they weigh 2.5–4.5 kg. Where the necessary facilities are available, fish are harvested on-site; otherwise, the net-pens are towed to the harvesting site. Processing is usually done away from the farm site. Processed product may be fresh (e.g. HOGG, fillets, cutlets or portions), frozen or value-added (e.g. smoked). Processing byproducts may be on-sold (e.g. rendered offal for inclusion in fertiliser).

Water

The relatively high stocking densities used in the salmonid industry require an adequate circulation of water through the net-pens. All areas used for salmon farming have some tidal flow. The water in these areas is affected by weather (wind) and rainfall patterns (freshwater inflow). In Tasmania, many farms are in areas close to human habitation and therefore can be affected by sewage and stormwater runoff, pesticides and other toxic chemicals, and an increased organic component in the water. These are typically diluted in the water mass around the net-pens.

There is no control over the water in and near the net-pens, unless an impermeable liner is placed around the net-pen. Such a liner prevents movement of water in and out of the net-pen, which means that oxygen-rich water cannot reach the fish and waste products (e.g. ammonia) inside the net-pen cannot be diluted. Liners can only be used as a very short-term measure.

Waste materials

Waste materials from farms include excess feed, fish faeces, mortalities and treatment wastes. Some farms fallow used net-pen sites to minimise accumulation of wastes and allow recovery of the sea floor. Offal (another waste material) can amount to 20–50 per cent of live weight, depending on whether the final product is 'head-on' or fillets. The offal is either buried or used in fertiliser production. Dead fish are collected and buried on land in a designated area. Treatment of 'bloodwater' (the water in which the fish lie while bleeding) before discharge into the marine environment must meet local requirements; if this practice is permitted, these requirements may include full treatment (removal of organic waste and sterilisation).

Vehicles and equipment

Workers live off-site and drive private vehicles to work. Boats are used to move between farm sites of the same company and of different companies, if these are reasonably close and weather conditions permit. Boats are also used to tow net-pens up to 40–50 km between sites.

Most equipment on a farm site is usually dedicated to that site. Among nearby sites, there may be some pooling of more expensive equipment, such as fish pumps, graders, percussive stunners and boats.

B2.3.5 Groups involved

A large number of groups are involved or actively interested in the operation and regulation of salmon net-pen culture systems in semi-open and semi-closed waters, including:

- national, state and local government bodies
- the Tasmanian Salmonid Growers Association

- community groups, such as environmental and conservation groups
- recreational fishing groups
- yachting and boating groups
- commercial fishers
- universities and other institutions
- other water users.

B2.3.6 Legislation and codes of practice

An area management agreement for salmon farming (including fish health issues) in Macquarie Harbour has been jointly developed by industry and DPIPWE. A Tasmania-wide biosecurity plan is also being developed by these two organisations.

See Appendix 1 for information on relevant legislation.

B2.3.7 Public and occupational health

Public health

Public health issues that should be considered are:

- the safety of the product if it is harvested when toxic algal blooms are present
- the potential of the product to transmit seafood-borne diseases (see Appendix 2)
- the quality of the product if it is emergency-harvested because of disease outbreaks or threats
- the availability of laboratories to undertake specific testing for the range of potential disease agents
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed
- chemical residues in treated fish.

Worker safety

Aspects of worker health and safety that should be considered are:

- daily variation in current flow, which can make some management practices (e.g. changing nets) unsafe at certain times of the day
- the potential for the combination of a harsh, unpredictable environment (e.g. bad weather conditions) and operation of boats and heavy equipment to impede safe work practices
- the need for specialised training and qualifications for diving—it is illegal and extremely dangerous for untrained personnel to dive, or for divers to work beyond the recommended diving times
- hazards associated with handling ropes, nets and heavy equipment
- the need for specialised qualifications and experience to operate boats
- the need for safety equipment
- potential threats to workers' health from collecting dead and decomposing fish
- disposal techniques for contaminated water
- the safety of workers preparing and applying chemical treatments
- potential exposure of divers to toxic algal blooms and jellyfish swarms.

B2.4 Barramundi grow-out

Table 5 summarises the main features of the barramundi industry grow-out sector.

Table 5 Features of the barramundi industry grow-out sector

Species	Barramundi (*Lates calcarifer*)
Location	New South Wales, Northern Territory, Queensland, South Australia, Victoria, Western Australia
Length of production cycle	6 months – 2.5 years
Product	Fresh or live
Annual production (2011–12) (ABARES 2013)	4498 t
Value (2011–12)	$41 million
System	Net-pens, ponds, raceways, intensive indoor tanks
Feed used	Dry pelleted ration

The culture of barramundi is economically viable in semi-open systems when water temperatures exceed 24–25 °C for much of the year. The optimal temperature for production is 28 °C. Barramundi can survive at water temperatures as low as 12 °C, but, at temperatures of 16 °C and below, growth ceases and the immune system is depressed, compromising fish health.

B2.4.1 Husbandry practices and disease control

Barramundi aquaculture involves three distinct phases: hatchery, nursery rearing and grow-out. Salt water is essential for the hatchery phase (which involves broodstock maintenance and larval rearing), while salt, brackish or fresh water can be used for the nursery and grow-out phases. All three phases may take place at a single site, such as in an estuary, although the majority of hatchery and nursery facilities are geographically separate from grow-out operations. The hatchery and nursery phases are described in Section B3.

Broodstock may be wild-caught or farm-reared stock.

Grow-out phase

Four different methods are currently used for growing barramundi fingerlings to market size:

- net-pen culture in semi-open fresh or marine waters (e.g. at Cone Bay, Western Australia)
- culture in semi-closed, purpose-built freshwater, brackish or seawater ponds (e.g. in northern Queensland, Northern Territory, northern Western Australia) (see Section B3 for further details)
- production in semi-closed, pump-ashore, seawater raceway systems. After flowing through the raceways, effluent water is passed through a series of settlement ponds before entering an estuarine environment.
- intensive production indoors, in controlled-environment buildings, using pathogen-free groundwater or surface water with a high level of recirculation, and mechanical

and biological filtration (see Section B4 for further details). This method may include polyculture with edible plants or other marketable varieties of plants

Grow-out of barramundi occurs in semi-open marine or estuarine systems (e.g. net-pens at Cone Bay, Western Australia); semi-closed fresh, brackish or seawater ponds or raceways (e.g. in northern Queensland, Northern Territory, northern Western Australia); or closed land-based systems with mechanical and biological filters, and high levels of water recirculation. Although the ponds and recirculation systems are semi-closed and closed systems, respectively, they are discussed in this section because grow-out practices are similar in the different types of systems.

Fingerlings are transferred to net-pens for grow-out from nursery facilities when they are 25–100 mm long, at 2–3 months old. In some cases, fingerlings are transported to remote grow-out sites in special trucks and transferred directly to net-pens or ponds. Smaller fingerlings may be airfreighted in bags within foam boxes, or in bulk aerated bins to all mainland Australian states. The net-pens may then be towed by boat to a mooring system.

Net-pens used for barramundi grow-out are usually deployed in a floating square-grid system design, although circular net-pens (e.g. Polar Cirkels) are increasingly being used. Systems consist of a grid of plastic pontoons and steel or wooden walkways that support a number of square nets close to one another. The distance between net-pens varies from 1 m to 3 m, depending on pen size. Net-pen design varies between sites. One site uses 25 m × 25 m steel-mesh nets with a depth of 8–15 m. At other marine and estuarine sites, nets may be made from nylon or polyethylene. Net-pens can be as small as 2 m × 2 m and 1.5 m deep for fingerlings after transfer, increasing to 6 m × 5 m and larger, circular net-pens. In all cases, the net-pens are moored to the substrate by an elaborate system of ropes and anchoring structures. The net-pens can be towed between mooring systems. Additional predator nets are usually installed to protect stock in individual net-pens from large predators such as birds, sharks and crocodiles.

Small floating net-pens are also used in ponds as small production units. These 2–5-m square net-pens consist of plastic frames and nets made from knotless nylon mesh, and are attached to a floating walkway.

Aeration may be supplied directly into the net-pens from a blower and airstones while the fingerlings are still young. As the fish biomass increases, paddlewheel and impeller aerators in the ponds maintain dissolved oxygen levels and increase water circulation.

The netting must be changed and cleaned regularly because biofouling can reduce the size of the mesh openings, restricting water flow through the pens and leading to poor water quality.

Ponds generally range in size from 0.2 ha to 0.6 ha and average 1.5–2.0 m water depth. Fish may be contained in cages within the pond or free-ranging. Stocking densities in net-pens or ponds are usually 10–25 kg/m^3, although higher densities are used on some farms. Most ponds can be drained and dried, if required. Aeration is typically delivered by paddlewheel aerators. Effluent water is typically treated through sedimentation ponds before discharge under strict environmental protection agency guidelines. Some pond farms reuse pond water after recycling it through wetlands.

Raceway farms use concrete or high-density polyethylene (HDPE)–lined raceways that hold around 1 ML of water. Large daily water exchange is used to remove wastes, and significant supplemental aeration is provided by paddlewheels and sometimes liquid oxygen injection. This allows very high stocking densities—up to 60 kg/m^3. Effluent passes through sedimentation ponds before discharge under strict environmental protection agency guidelines.

Recirculating aquaculture systems (RAS) use high to very high stocking densities, in indoor temperature-controlled facilities. Some use liquid oxygen injection to maintain stocking densities of 100 kg/m^3, while maintaining maximum fish growth. They generate very high productivity for the footprint of the operation. Effluent streams are typically used for irrigation on-site or passed through wetlands.

Barramundi are fed a commercial dry pelleted ration that may be produced domestically or imported. A semi-floating pellet is widely used because it is available to the fish for longer, and satiation is more easily observed. When first weaned, the fish are fed up to six times per day. Feeding frequency is reduced progressively to once or twice per day when the fish are heavier than about 100 g.

On most farms, fish are fed by hand or using blower tractor–driven feeders. Automated feeding systems are not in common use. Some RAS farms use a combination of autofeeders and handfeeding.

Feed is delivered to the farm site by truck; some remote grow-out sites may receive feed deliveries once a month. Where possible, feed is stored in air-conditioned cool rooms to lengthen its shelf life.

At many farms, water quality—including dissolved oxygen, pH, ammonia, temperature and turbidity—is monitored frequently. Aerators are used to maintain dissolved oxygen levels at more than 5 mg/L. In pond culture, water exchange rates vary with intensity of production.

Fish are graded (sorted according to size) throughout the grow-out cycle. Farm personnel regularly inspect the fish to determine health status and performance. Under veterinary prescription, in-feed antibiotic treatments may be used, if required. Immersion parasiticides, or hypersaline or freshwater bath treatments may be used on-site to treat live fish.

Dead fish (‘morts’) are collected from net-pens by dip-net when they are seen on the water surface (in warm water, morts float soon after death). Collection of morts by scuba divers is rarely required, but it is important to collect them before they sink again. Morts are buried within a designated area at the farm’s land base or at another approved disposal site.

Marketable plate-size fish (approximately 350–600 g) can be grown in 6–8 months, and are sold into both chilled fresh fish and live fish markets. However, some operations focus on producing fish heavier than 2 kg for filleting. These fish take 14–24 months to grow. Fish of intermediate size are also sold for certain markets (e.g. 600–1000 g ‘banquet’ fish).

Harvesting of barramundi requires the use of a nylon ‘crowd’ net. Fish are dip-netted or pumped from a crowded group and then killed by immersion in ice slurry. Some operators practise the technique of rested harvest using anaesthetic, which improves fish welfare and product quality. In most cases, fish are sorted during or after harvest. Some farms process harvested fish on-site, but most fish are sold as ITR (‘in the round’—that is, not eviscerated) product (either fresh chilled or live). Further processing, which is often undertaken by wholesalers, processors or end users, involves evisceration, filleting and/or value-adding.

Product may be sold directly to local or niche customers, as well as to domestic wholesalers in major capital cities. Smaller producers tend to trade via the auction floor. A small amount of fresh product is exported. There is a small live fish trade, and some farms export live barramundi fingerlings to Asia and the United States.

Contract divers may be used to maintain net-pens and mooring systems. Some farms may have skilled divers to do this work. Ponds are drained and dried (weather permitting) between production cycles.

B2.4.2 Premises and equipment

Boats are used to transport feed and sometimes deliver it around the farm to tow pens, as dive vessels, to change nets, to transport personnel to farm sites, for inspection of fish, and during day-to-day maintenance on net-pens and mooring systems. Net-pens are moored to the substrate by ropes and anchoring structures. The most common method of moving large fish around and between farms is by towing the net-pens. The majority of production, however, comes from ponds and raceways, without use of nets; transport tanks on trailers may be used to move fish between production ponds.

Predator nets are deployed around individual net-pens, net-pen systems or ponds.

Most farms have an on-land facility with offices and buildings to house staff, machinery and nets. Most farms have a cool store for feed and to hold chilled fish. On-land farm sites also have designated areas for net maintenance and for mort disposal. Some farms have a dedicated laboratory.

Harvesting equipment is heavy and not easily transportable, but some farms have their harvesting equipment on board a large vessel. Most farms have equipment for grading fish, and for sampling live fish from net-pens to inspect health and growth. The amount of dive equipment available on farm sites varies, depending on whether contract divers are used. Pond-based and land-based raceway farms typically tow equipment to the side of the area to be harvested.

Trucks are used to transport feed to the farm and harvested fish to processing facilities. Special trucks are used to transport young fish from the hatchery to the grow-out site. Forklifts are commonly used around land-based facilities. Earthmoving equipment may be available on sites with earthen ponds.

B2.4.3 System inputs

Aquatic animals

Broodstock is either wild caught or farm reared. On some farms, broodstock is maintained on the same site as the grow-out facilities. Larvae are transferred from the hatchery to nursery facilities to grow to fingerling size and then transported to the grow-out sites until harvest. Wild fish, zooplankton and benthic organisms are present in and around farms. Some farms may have multiple fish species growing out simultaneously, including jade perch, silver perch, cobia, flowery cod and estuary cod.

Crocodiles may move in and out of earthen ponds and have contact with net-pen operations in areas within their natural range.

Water

Barramundi farm sites are usually widely separated but, on any site, the distance between net-pens or ponds may be very small (2–3 m). Some companies may own a number of farm sites. Most net-pen sites are in sheltered areas with strong tidal currents. Net-pen sites experience the full environmental water flows occurring at the site, which can include sediment-laden freshwater river flows in the wet season and tidal brackish or marine water.

Water quality is directly affected by the local environment and tidal flows. Pond-based farms use adjacent surface-water sources and groundwater, where available. Indoor tank-based systems often rely on groundwater sources, recycling the water after filtration or use in wetlands. Raceway farms may use unfiltered marine water supplies that are pumped ashore.

Important water quality parameters include:

- temperature
- dissolved oxygen
- pH
- ammonia, nitrates and nitrites
- salinity
- toxicants
- algae.

Freshwater ponds may be subject to daily water exchange when stocking densities and feed rates are high.

Feed

Pelleted feeds are produced commercially by a number of companies in Australia and overseas; these feeds are milled and heat pelleted by extrusion. Fresh and frozen local fish species, pilchards, other baitfish, squid and prawns are used to maintain broodstock. Multivitamin and mineral supplements are regularly added to the fresh food. Some hatcheries also use imported, specialist feeds for marine finfish broodstock and larval diets.

Feed trucks may make multiple deliveries to different farm sites in a day. Feed is usually carried from the mills by commercial freight trucking companies and/or rail.

Personnel

With the exception of two or three larger companies, most barramundi farms are small, family-based operations with fewer than five full-time employees. Personnel are usually multiskilled and may work in a number of areas on the farm. Farm workers may live off-site. Contractors are used for maintenance of farm equipment. All farms have a mess room or similar amenity.

Visitors to farms may include fish health advisers and others. Recreational fishers and boat users may use the waters around marine and estuarine farm sites.

Equipment

Equipment used in association with system inputs includes:

- fish pumps and seine nets for harvesting
- hand nets
- fish bins with lids

- net-pens, walkways and floats
- tanks
- backup generators
- feed bins, scoops and tractors
- clothing, including boots
- pond aerators, oxygen bottles, blowers, liquid oxygen tanks and oxygen stones
- vehicles, trucks, forklifts and earthmoving equipment
- manual grading grids and mechanical graders
- harvesting equipment and bins
- boats
- cold-room store
- water-quality testing apparatus
- dive equipment
- maintenance machinery
- treatments for parasitic and bacterial diseases, including vaccines
- sanitising treatments for harvest bins and other equipment.

Stores

Feed is stored in a cold room, on-site at the land-based facility, for up to two months. All farms have stores for gear, but the amount stored on-site varies between farms.

Vehicles

Vehicles on barramundi farms include trucks, tractors, forklifts, six-wheelers, boats and punts, private cars, 4WD vehicles and utilities. Excavators and earthmoving equipment may also be available. Feed trucks may make multiple deliveries to different farm sites in a day, without disinfection or washdown.

B2.4.4 System outputs

Animals

Product may be sold by the producer directly to customers, or to outlets such as restaurants. Some product may be sold wholesale to fish markets. Most fish are sold dead; however, some are sold live to restaurants (shipped in tanker trucks), and some farms export live fish. A few farms process fish (fillets, value-added products) for retail sale.

Water

The quality of effluent water from the net-pens depends on:

- feeding rates—for example, overfeeding increases waste below net-pens
- water exchange, which is influenced by water flow past the net-pens and biofouling on the nets.

Waste materials

Waste materials include excess feed and fish faeces on the sea floor or the bottom of the grow-out tank or pond, metabolic (nitrogenous) byproducts, dead fish and processing waste. Ponds and tanks are cleaned and dried out between production cycles. Waste is usually disposed of on-site; occasionally, RAS facilities will use council-approved waste disposal sites. Any dead fish are buried in a designated area on land, mostly on the farm site.

Settlement ponds are used in pond culture systems to remove suspended solids from effluent water before any discharge or reuse through a wetland to remove nutrients. RAS effluent is typically irrigated onto adjacent pasture or recycled through a wetland before re-entering the farm.

The quantity of processing waste depends on the size of the farm; it can be up to 50 t per year. Processing waste may be disposed of at approved sites or onsold as byproduct.

Equipment

Equipment used in association with system outputs includes:

- harvest bins
- storage tanks
- transport tanks
- cold-room store
- pond building and maintenance machinery
- live fish trucks
- private vehicles
- transport vehicles for product sales
- service punts and boats.

B2.4.5 Groups involved

A large number of groups are involved or actively interested in the operation and regulation of barramundi net-pen, pond, raceway and RAS culture systems in semi-open and semi-closed waters, including:

- the Australian Barramundi Farmers Association (ABFA)
- the Aquaculture Council of Western Australia
- the National Aquaculture Council
- national, state and local government bodies
- community groups, such as environmental and conservation groups
- recreational fishing groups
- yachting and boating groups
- commercial fishers
- universities and other institutions
- other water users.

B2.4.6 Legislation and codes of practice

Codes of practice that apply to barramundi grow-out are:

- the ABFA *Post Harvest Handling Code of Practice* (www.abfa.org.au/quality.html)
- the *Industry environmental code of best practice for freshwater finfish aquaculture*, produced by the Aquaculture Association of Queensland (www.daff.qld.gov.au/__data/assets/pdf_file/0004/65227/7-NFHITF-Fresh-Water-Finfish-Code-of-practice.pdf).

Relevant legislation is listed in Appendix 1.

B2.4.7 Public and occupational health

Public health

Public health issues that should be considered are:

- the safety of the product if it is harvested when toxic algal blooms are present
- the potential of the product to transmit zoonotic diseases (see Appendix 2)
- the quality of product if it is emergency harvested because of disease outbreaks
- the availability of laboratories to undertake specific testing for the range of potential disease agents
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed
- chemical residues in treated fish.

Worker safety

Worker safety issues that should be considered are:

- harsh weather conditions during net-pen operations, which can make work dangerous and impede safe work practices
- daily variation in current flow, which can make some management practices (e.g. changing nets) unsafe at certain times of the day
- the need for specialised training and qualifications for diving—it is illegal and extremely dangerous for untrained personnel to dive
- hazards associated with handling ropes, nets and heavy equipment
- the need for specialised qualifications and experience to operate boats
- the need for safety equipment
- potential threats to workers' health from collecting dead and decomposing fish
- disposal techniques for contaminated water
- the safety of workers preparing and applying chemical treatments
- potential exposure of divers to toxic algal blooms, jellyfish swarms and large predators (sharks and crocodiles).

B2.5 Yellowtail kingfish net-pen culture

Table 6 summarises the main features of the yellowtail kingfish industry sector.

Table 6 Features of the yellowtail kingfish industry sector

Species	Yellowtail kingfish (*Seriola lalandi*)
Location	South Australia
Length of production cycle	18 months – 2.5 years
Product	Fresh or frozen
Annual production (2011–12) (Econsearch 2013)	1504 t
Value	$16.1 million
System	Net-pens
Feed used	Dry pelleted ration

Yellowtail kingfish is a temperate fish with a water temperature tolerance of 10.5–29 °C. However, optimal growth and health is achieved in a water temperature range of 18–28 °C. Yellowtail kingfish farming consists of a marine hatchery stage (see Section B3.7) and an estuarine or marine net-pen culture stage. In Australia, commercial hatchery culture started in 1998, and commercial net-pen culture began in 2000. Yellowtail kingfish hatchery facilities and net-pen culture facilities used for grow-out may be located on the same estuarine or marine farm sites. The majority of yellowtail kingfish grow-out in Australia takes place in South Australia in various net-pen grow-out facilities in Spencer Gulf.

B2.5.1 Husbandry practices and disease control

Fingerlings are transferred to net-pens 50–60 days after hatching, at a weight of 5–10 g. Purpose-built tanks are used to transport fingerlings by truck, then boat, from the hatchery to the marine site, where they are transferred to a nursery lease and placed into small net-pens, well protected from bird predation. Plastic Polar Cirkel net-pens are used for commercial-scale yellowtail kingfish grow-out. A Polar Cirkel consists of a circular plastic support to which a circular nylon net is attached (steel netting is being trialled). The net-pens have circumferences of 80–120 m, and the nets are 8–14 m deep. Net-pens may be placed close to one another (up to 50 m) within a lease. Interconnected net-pens are not being used by the industry because they make it hard to control parasitic fluke infections.

All net-pens are moored to the sea bottom by an elaborate system of ropes and anchoring structures. The net-pens can be towed between mooring systems. At some times of the year, additional predator nets may be installed around individual net-pens to protect stock from large predators, such as seals and sharks. Kingfish are usually on-grown in net-pens for 18–30 months. Usually 8000–25 000 fish are in each net-pen, depending on the size of the pen and the size of the fish. This results in a maximum stocking density of 10 kg/m^3 of water. The kingfish are graded during grow-out, ensuring that fish in the same pen are of similar size.

Grow-out fish are fed a commercial dry pelleted ration that is produced in Australia. Larval and fingerling feeds are mostly imported. Feed is usually delivered by sea and road freight to the on-land farm site, where it is stored for up to two weeks. The fish are fed by hand until they are heavier than 200 g, after which a manually operated cannon feeder is used to blow the feed into the net-pens.

Kingfish are usually harvested when they weigh 3–6 kg. The smaller fish supply the restaurant sector, while the larger fish are destined for the premium sashimi sector. Depending on the market, the fish are sold as whole, HOGG or fillet (pin-bone in, collar on, skin on). No farms have processing facilities adjacent to their marine operations, so harvesting is by barges or boats. During harvesting, fish are crowded in the pen and either drawn from the water using a fish pump, or collected 20–30 at a time with a brail net. Fish are either lifted into an anaesthetic tank or stunned with a pneumatic hammer.

During harvesting, carbon dioxide may be used to anaesthetise the fish. The carbon dioxide is bubbled through a bath containing the fish, which are moved onto a bleeding table when sufficiently anaesthetised. The fish are cut near the base of the gills to allow bleeding and then, within a few minutes, placed in an ice slurry for trucking in bins to the processing facility. Fish are usually kept in the ice slurry for less than 12 hours. Harvest bins and equipment are sanitised with certified treatments between uses, and processing facilities meet export standards. Fresh fish are transported by road and airfreight to domestic wholesale markets; some are sold directly to restaurants and other customers.

At water temperatures below 14 °C, yellowtail kingfish are more susceptible to disease agents, and farmers will often reduce feeding rates significantly. Particularly cold winters with low water temperatures are detrimental to the growth and general health of the fish. Farm personnel regularly sample a small number of live fish from each grow-out net-pen to inspect their growth and health.

Therapeutic bath treatments of hydrogen peroxide are used to control skin and gill fluke infestations. These treatments require plastic liners and adequate oxygen supply. Net-pens are monitored for dead fish ('morts') every 1–3 days. Monitoring varies with the season, being most frequent in the warmer months and less frequent in winter. Morts are removed from net-pens by various methods, including dip-nets and scheduled diving. The collected morts are transferred to a waste processing factory.

Antibiotics are used under veterinary prescription and strict environmental monitoring to control bacterial diseases. Experimental trials of medicated feeds, designed to remove skin and gill flukes, are also being conducted. Praziquantel may be used to combat fluke infestations. Husbandry practices have improved in recent years, with a farm-based health management programme assisting with disease management.

Farmers regularly monitor water quality, including nutrient levels and the presence of phytoplankton species, at all their marine sites. Daily records of dissolved oxygen, temperature, turbidity and salinity are kept by most farms.

B2.5.2 Premises and equipment

Boats are the main form of transport on marine farms. They are used to transport and deliver feed around the farm, to tow net-pens, to change nets, as dive vessels, to transport personnel out to farm sites, for inspection of fish, and during day-to-day maintenance on net-pens and mooring systems. Large boats and barges may be used for heavier work and are often fitted with Hiab cranes or electric winches.

Most farms have on-land facilities with offices and buildings to house staff, machinery, feed, nets and other equipment. In addition, most farms have open work areas on land for net maintenance and for disposal of dead fish. Some farms have dedicated laboratories, equipped with light microscopes. Most have equipment for sampling live fish. Farms have equipment for grading fish, for transferring fish between net-pens and for therapeutic bath treatments to control fluke infestations.

Forklifts are commonly used around land-based facilities; trucks are used to transport feed to the farm and harvested fish to processing plants. Harvesting equipment is heavy and not easily transportable. Some farms use large vessels to transport harvesting equipment and/or to harvest 'on the water'. Others use a dumb barge, which is moored in a favourable location, and tow the stock to be harvested to the barge.

Most farms have sanitising treatments to clean equipment. Most farms fully equip a dive team, but the amount of equipment available depends on whether contract divers are used.

B2.5.3 System inputs

Aquatic animals

Yellowtail kingfish fingerlings used for net-pen culture are usually transported from the hatchery to the marine sites during September–January. On some farms, fish are graded. However, handling, grading and moving fish stresses them and can make them more susceptible to disease. Younger fish are more susceptible to disease and other health problems than older fish, but are more practical to treat because of reduced costs, ease of handling and lower risk of residues.

Many wild fish occur near net-pens in semi-open systems, and often venture inside the net-pens. Wild fish populations can potentially act as vectors for disease, but the extent to which they harbour pathogens is not fully known. Aquatic animal and plant communities develop on the nets, even though the nets are changed frequently.

Predators (particularly birds, sharks and seals) have a large impact on the health of fish through stress, injury and mortality. Prevention of stock predation requires anti-predator devices, such as protective nets around net-pens.

Water

Semi-open systems are located in bays and exposed marine areas, so there is no control of the flow of water around net-pens, which is determined by coastal currents and weather conditions. Water temperatures usually range from about 12 °C in winter to 25 °C in summer. Temperatures may rise above 27 °C in summer; although this does not seem to cause stress to the fish, they are usually not fed during such warm weather. Research in Japan has shown that temperatures above 29 °C depress feeding and growth rates significantly.

Each company may own a number of leases and transfer fish between sites. In some geographical areas, neighbouring leases owned by the same or different companies are required to be at least 1 km apart.

Feed

Kingfish are fed a commercial dry pelleted ration. The pellets are 3–11 mm long, with the size depending on the size of the fish. Imported fishmeal and fish oils are used in the manufacture of the pellets, and fishmeal can make up to 45 per cent of the ration. The fishmeal and fish oil must be pasteurised before importation to ensure that they are free from potential pathogens. Smaller-sized feeds are typically fully imported from European sources.

Personnel

Practices are similar across farms, so workers from one farm have little difficulty moving to another. All farms have a mess room or similar amenity. Farm size varies significantly; personnel numbers at the grow-out site range from around 5 to 30. Each company may own a number of marine leases, and some personnel regularly move between sites. Workers are multiskilled and may be involved in more than one type of activity.

Companies that have some ownership in a processing and export facility have teams of specialists to process the fish for market. These teams are relatively static and do not perform tasks on the farms. Some of the larger companies employ fish health workers, veterinarians and technicians. Contractors are used for maintenance of farm equipment.

Some farms use contract divers, while others have personnel who are trained in commercial diving practices. Divers generally do not disinfect themselves between dives. Some farm sites have visits from researchers, fish health advisers or other members of the industry.

Equipment

Most farms fully equip a dive team, but the amount of equipment available depends on whether contract divers are used. The type of harvesting equipment varies between farms. Some have equipment permanently installed on barges or boats, whereas others use transportable equipment, which is loaded onto boats before harvesting.

Most farms have equipment for sampling live fish from net-pens, and inspecting their weight and health. Forklifts are used throughout the industry. Hiab-type hydraulic cranes and winches are commonly mounted on boats to assist with changing nets, and to lift weights and mooring lines, and so on. Grading equipment may also be available.

The larger farms have some form of washing device to clean nets. Most farms have a laboratory facility; some of these have microscopes, and all have equipment for dissecting fish.

Most farms have plastic net-pen liners and other equipment required for large-scale therapeutic bath treatments. Some farms have a fully equipped workshop on-site.

Service vessels for feeding and harvesting range from 10 m to more than 30 m in length. On most kingfish farms, vehicles and boats are multifunctional.

Some companies may own a number of marine leases and regularly move equipment between sites.

Stores

Feed is stored on-site at the land-based facility for up to two weeks. All farms have a store for gear, but the amount of gear stored on-site varies between farms.

Vehicles

Workers live off-site and drive private vehicles to work. Trucks are used to transport feed, live fish and harvested fish. Forklifts are used to load trucks and boats.

Other

Anaesthetics and antibiotics are used to a limited extent, where indicated. All farms regularly use hydrogen peroxide for fluke infestations, and trials of feeds medicated with anthelmintics are being undertaken. Anti-foulants are used on vessels, but not on nets.

B2.5.4 System outputs

Aquatic animals

Yellowtail kingfish are harvested when they weigh 3–6 kg. Harvesting is done on-site if harvesting facilities are available; otherwise, the net-pens are towed to a harvesting barge. Processing is usually done away from the farm site. Processed product may be fresh or frozen, and whole, HOGG or fillet. Processing waste may be onsold for byproducts (e.g. for inclusion in fertiliser).

Water

Adequate circulation of water through the net-pens is important, but there is no control over water movement. All areas used for kingfish farming have considerable tidal movement of water. The water in these areas is also affected by the wind. Because the areas where kingfish are cultured have low rainfall and few significant streams, rainfall has little effect. Nets are changed regularly to prevent biofouling and optimise water flow through the net-pens.

Waste materials

Waste material from the farms includes excess feed, fish faeces and treatment wastes. Some farms fallow used net-pen sites, to minimise accumulation of wastes and allow recovery of the sea floor. Offal, another waste product from processing, is either buried or used in fertiliser production. Morts are collected and buried in a designated area on land or sent to a waste-processing facility.

Treatment of ‘bloodwater’ (the water in which the fish lie while bleeding) ranges from full treatment through municipal wastewater to discharge back into the marine environment through purpose-built settlement ponds. Outflow is measured regularly to ensure minimal environmental impact.

Vehicles and equipment

Workers live off-site and drive private vehicles to work. Boats are used to move between farm sites of the same company and of different companies, if the sites are reasonably close and weather conditions permit. Boats are used to tow net-pens between sites. Such tows are rarely more than 10 km.

Usually, most equipment on a farm is dedicated to that location (which may include multiple licence sites). There may be some pooling of more expensive equipment, such as harvesting or bathing equipment, among farms that are near each other. Feed trucks may make multiple deliveries to different farm sites in a week.

B2.5.5 Groups involved

A large number of groups are involved or actively interested in the operation and regulation of yellowtail kingfish net-pen culture systems, including:

- national, state and local government bodies
- the South Australian Marine Finfish Farmers Association
- community groups, such as environmental and conservation groups
- recreational fishing groups
- yachting and boating groups
- commercial fishers
- universities and other institutions
- other water users.

B2.5.6 Legislation and codes of practice

A draft code of practice has been completed for the industry in South Australia.

See Appendix 1 for information on relevant legislation.

B2.5.7 Public and occupational health

Public health

Public health issues that should be considered are:

- the potential for seafood product to transmit pathogens (see Appendix 2—no pathogens are specific to yellowtail kingfish)
- the quality of product if it is emergency harvested because of disease outbreaks; quality can be managed if harvesting is properly organised
- the availability of laboratories to undertake specific testing for the range of potential disease agents
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed
- chemical residues in treated fish.

Worker safety

Worker safety issues that should be considered are:

- the variable and, at times, harsh weather conditions, which can make work dangerous and impede safe work practices
- daily variation in current flow, which can make some management practices (e.g. changing nets) unsafe at certain times of the day
- the need for specialised training and qualifications for diving—it is illegal and extremely dangerous for untrained personnel to dive
- hazards associated with handling ropes, nets and heavy equipment
- the need for specialised qualifications and experience to operate boats
- the need for safety equipment
- potential threats to workers' health from collecting and disposing of dead and decomposing fish ('morts'), and fish effluent
- the need for appropriate protective clothing, training and safety awareness for preparation and application of chemical treatments
- potential exposure of divers to jellyfish swarms and large marine predators (e.g. sharks).

B2.6 Pearl oyster culture

Table 7 summarises the main features of the pearl oyster marine farm industry sector.

Table 7 Features of the pearl oyster marine farm industry sector

Species	Pearl oyster (various species)
Location	New South Wales, Northern Territory, Queensland, Western Australia,
Length of production cycle	8 months – 2 years (grow-out only)
Product	Pearls, pearl shell, oyster meat (fresh or frozen)
Value (2011–12) (ABARES 2013)	$120.3 million
System	Suspended or benthic panels
Feed used	None (filter feeders)

Pearls are produced by aquaculture techniques using pearl oysters, gathered from wild stocks or produced in a hatchery. In 2011–12, the pearl industry was Australia's fourth-highest value aquaculture industry. The industry is predominantly (98 per cent of value) based on the silver-lipped pearl oyster *Pinctada maxima*, located in the north and north-west of Australia. It centres on the northern waters of Western Australia, with some production in the Northern Territory and Queensland; water temperatures average 22–32 °C in these regions.

Interest in the production of half pearls and smaller round pearls from other pearl oyster species, such as *Pinctada margaritifera, Pinctada albina* and *Pteria penguin*, is also increasing. In mid-west Western Australia, Queensland and New South Wales, there has also been research into, and early commercial trials of, pearls from the Akoya oyster (*Pinctada imbricata*).

The industry uses two different culture techniques:

- collection of wild adult pearl oysters that are transferred to marine farms for use in pearl production
- production in marine hatcheries of pearl oysters that are transferred to marine farms for further growth and later used for pearl production.

This section describes marine farm grow-out operations and pearl production. See Section B3 ('Semi-closed systems') for details of pearl oyster hatcheries.

B2.6.1 Husbandry practices and disease control

Adult oysters are collected under licence from sustainably managed wild stocks in the north and north-west of Australia. After collection, the oysters are held in steel-framed mesh panels, which are placed on the seabed near the fishing grounds. After 2–4 months, they are retrieved and seeded by specialist technicians. The seeding operation involves implanting a nucleus made from imported freshwater mussel shell and a small piece of mantle tissue from another oyster into the gonad of the oyster to be seeded. The oysters are returned to the panels on the sea floor after seeding, and the panels are turned over intermittently for two months, while the pearl sack forms around the nucleus in each seeded oyster. The oysters are then transported by sea to farms in coastal bays in the Kimberley and the Northern Territory, hundreds of kilometres from the fishing grounds.

An increasing number of larval oysters are being produced in hatcheries for grow-out and seeding. In some cases, the hatchery may be located at an onshore facility associated with pearl farm sites. In other cases, the hatchery is distant from the final pearl farm site but spat may be on-grown near the hatchery until large enough to transport by sea to the pearl farm site. Young hatchery-reared oysters are transferred to marine grow-out sites at three months, when they reach a shell length of 6 mm. They are on-grown for two years, until they reach around 110 mm and are ready to be seeded.

At the farm site, the oysters (either wild caught or hatchery reared) are suspended vertically in the water, in mesh panels that hang from a horizontal longline between anchored buoys. The suspended panels are regularly retrieved and cleaned of biofouling using specialised cleaning vessels with high-powered seawater hoses. No chemicals are used. The oysters are not removed from the panels, to minimise biofouling, maximise food access and maximise water flow to the oysters. Some farms are trialling antifouling barriers on the exterior of oyster shells and on submerged equipment.

During the cleaning process, any sick or dead oysters ('morts') are collected. Each shell is accounted for, and health checks are carried out.

Water quality is monitored regularly on farm sites, and some farms identify marine algae.

Oysters are X-rayed six months after seeding to check that the pearl seed has not been rejected. Oysters producing round pearls are left in the water for two years. Then they are retrieved from the water, the pearl is removed and, if the oyster is in good condition and the pearl is of good quality, a new pearl seed is inserted. An oyster may produce up to three pearls over six years before it is regarded as less than productive and removed from the system—the shell is sold as mother of pearl, and the adductor muscle is sold for human consumption as pearl meat. The balance of the animal is disposed of into the sea.

Pearl operations and harvesting take place on work vessels or at shore facilities.

Harvested pearls are initially graded on-site and then sent to shore bases for polishing and specialist grading, before being sold as loose pearls or as part of jewellery sets to wholesalers and retailers.

Pearls and pearl shell are sold on domestic and export markets, including in the United States, China, Japan, South-East Asia, Europe and the Middle East. Oyster meat is sold in Australia and Hong Kong.

The industry, working with state and territory government laboratories in Western Australia and the Northern Territory, funds a surveillance and translocation health certification management programme for movement of all pearl oysters between farming areas, between Australian jurisdictions, and from hatcheries to farm sites.

B2.6.2 Premises and equipment

Most pearling companies operate a number of farm lease sites. Most farms are only accessible by sea or float plane; some have shore facilities. Ship and shore facilities may consist of engineering facilities, storage and personnel accommodation. Most farms have dive equipment, the amount of which depends on whether contract divers are used.

Pearling ships are open-water vessels longer than 20 m; smaller barges with handling and cleaning equipment may be used closer to shore on the farms. Work vessels move to, from and between different farm lease sites. Guidelines are available for disease management protocols for translocating infrastructure and equipment, including seeding technicians' tools.

Tractors or forklifts are available on some shore bases for moving heavy equipment. Some farms have limited processing facilities at shore stations. Contract workers, including pearl seeders and divers, are often used. Because of the remoteness of many farm sites, there are relatively few site visitors or recreational fishers.

B2.6.3 System inputs

Animals

Spat are sourced from hatcheries or collected from natural spat-fall. Adult oysters are harvested by divers from wild stock fishing grounds.

Many species of wild fish, crustaceans and molluscs occur around pearl oyster farm sites. Aquatic animal and plant communities develop on the longlines and the oysters, even though they are cleaned regularly.

Water

There is no control over water on open leases. Since many farmers hold leases in several areas, they can move the oysters to different sites to select different water conditions.

Shellfish farmers have an intense interest in the quality of the water on their leases, and many take regular readings of water quality. Some areas have shellfish monitoring systems, and monitor phytoplankton species and densities on marine sites.

Water temperatures on most sites farming *P. maxima* range from approximately 22 °C to 32 °C during the year. Temperatures tend to be lower on sites in Queensland and New South Wales farming *Pinctada imbricata,* with a range of 16–26 °C.

Feed

Pearl oysters are filter feeders and feed on the plankton naturally present in the water column. Initially, hatchery-reared stock may be fed from a range of cultured algae, until they are large enough to move out into the open-water environment.

Personnel

The workforce on leases varies between companies and with the production cycle or season. The majority of operations are ship based rather than shore based. The work on leases is usually timed to occur with slack tides, and this should be considered when trying to contact personnel. Personnel may live on-site, and some personnel may work and travel between a number of sites.

Contract workers, including pearl technicians and divers, are often used. There are few visitors and recreational fishers in the vicinity of remote marine leases.

Vehicles

Personnel use privately owned vehicles to travel to shore stations. Boats are used to transport personnel and equipment to marine farm sites, as well as to conduct maintenance work. Vessels move between different farm sites.

Tractors and forklifts are used at onshore facilities to move heavy equipment. Trucks may occasionally be used to make equipment deliveries to farm sites. Float planes are used for access to remote sites.

B2.6.4 System outputs

Animals

The main products are pearls, pearl shell and pearl meat (adductor muscle) for human consumption. Stock may be moved between sites.

Waste

Pearl oysters are filter feeders and are not fed by farmers; therefore, pearl oyster farming produces no feed waste. The flesh (excluding adductor muscle) of processed oysters is usually disposed of into the sea. All pearl shell is collected, accounted for and sold.

Equipment

Equipment is usually shared between several sites.

Vehicles

Personnel use privately owned vehicles to travel from shore stations and farm sites every day. Boats are used to transport personnel and equipment from marine farm sites. Vessels move between different farm sites. Product may be transported from farm sites by sea.

B2.6.5 Groups involved

Groups involved in pearl production include:

- licensed pearling operators
- national, state/territory and local government bodies
- state and territory government laboratories
- aquatic animal health advisers
- Aboriginal land councils
- environmental and community groups
- the Aquaculture Council of Western Australia
- the Pearl Producers Association
- the Western Australian Fishing Industry Council
- recreational fishing groups
- yachting and boating groups
- commercial fishers
- universities and other institutions
- other water users.

B2.6.6 Legislation and codes of practice

A policy guideline is in place for pearl oyster aquaculture in Western Australia.

Relevant legislation is listed in Appendix 1. It includes legislation on licensing and quota management for pearl oyster aquaculture in the Northern Territory. In Western Australia, the legislation for the *P. maxima* pearling industry is the *Pearling Act 1990*.

Other pearl oyster species are considered aquaculture species, and the relevant legislation is the *Fish Resources Management Act 1994*.

B2.6.7 Public and occupational health

Public health

Public health issues concerning pearl oyster meat are:

- the safety of the product if it is harvested when toxic algal blooms are present
- the safety of the product if it is harvested when sewage or heavy metals are present (due to development, runoff, etc.)
- the potential of the product to transmit seafood-borne diseases such as vibriosis (see Appendix 2)
- the quality of the product if it is emergency harvested because of disease outbreaks
- the availability of laboratories to undertake specific testing for the range of potential disease agents, including algal toxins
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed.

Worker safety

Aspects of worker health and safety that should be considered are:

- hazards associated with pearl oyster fishing, which is carried out on the open ocean in isolated areas but outside the cyclone season
- onerous tropical weather conditions, which require companies to ensure safe work practices
- daily variation in tidal flow, requiring that operational activities are carefully managed
- the need for specialised training and qualifications for diving in the pearling industry
- hazards associated with handling ropes, nets and heavy equipment
- the need for specialised qualifications and experience to operate boats
- the requirement for safety equipment under workplace and marine safety regulations
- the potential for lacerations to the skin from handling stock and shells
- potential threats to workers' health from collecting decomposing stock
- the need for appropriate disposal techniques for contaminated water
- hazards associated with handling chemicals, which should follow guidelines provided by authorities
- potential exposure of divers to toxic algal blooms, jellyfish swarms and large marine predators (e.g. sharks).

B2.7 Edible shellfish grow-out

Aquaculture of shellfish for human consumption has a long history in Australia. The industry, based on Sydney rock oysters (*Saccostrea glomerata*), has operated for more than 100 years. More recently, there has been increasing interest and success in the culture of other species of shellfish. The main species now are Pacific oysters (*Crassostrea gigas*), rock oysters (*S. glomerata*) and blue mussels (*Mytilus* *galloprovincialis*). Flat (or mud) oysters (*Ostrea angasi*) have been successfully cultured in southern states, although production volumes are low.

Intertidal species can be removed from the water for some time (from days to weeks, depending on species and temperature). This allows translocation for grow-out purposes and transport of live stock to distant markets. Oysters and mussels may be sold live and whole in markets across the country.

Table 8 gives a brief summary of the edible shellfish industry sector (grow-out only).

Table 8 Features of the edible shellfish industry sector (grow-out)

Species	Rock oyster	Pacific oyster	Mussel[a]	Flat oyster	Scallop	Abalone[a]
Location	NSW, Qld, WA	NSW, SA, Tas.	NSW, SA, Tas., Vic., WA	NSW, SA	Qld, Tas., WA	NSW, Qld, SA, Tas., Vic., WA
Length of production cycle	2–3 years	1–2 years	7–15 months	1–2 years	18 months	3–4 years
Product	Live, fresh	Live, fresh, frozen	Live, fresh, frozen, pickled	Live, fresh	Fresh, frozen	Live, fresh, frozen, canned
Annual production (t, 2006–07) (O'Sullivan & Savage 2009)	4745	11 286	3404	31	10	604
Value ($)[a]	35.1 million	51.1 million	9.3 million	0.28 million	0.05 million	19.2 million
System	Rack, tray and stick	Racks, longline	Longline	Racks, longline	Longline	Tanks, floating barrels or ships, submerged net-pens
Feed used	None (filter feeders)	None (filter feeders)	None (filter feeders)	None (filter feeders)	None (filter feeders)	Formulated pelleted feed

a Figures from ABARES (2013) for 2011–12

Experimental aquaculture of the saucer scallop (*Amusium balloti*) was previously attempted in Western Australia and Queensland, with varying degrees of success. Commercial scallop (*Pecten fumatus*) is cultured in Tasmania.

Sources of stock for the aquaculture of these species vary. The rock oyster, mussel and scallop industries are based on larvae acquired from natural spat-fall in estuaries, or larvae in hatcheries from wild-sourced and selectively bred domesticated broodstock. Abalone are produced exclusively in hatcheries from wild-sourced and domesticated broodstock. Pacific oysters are produced in hatcheries from broodstock collected from commercial oyster leases. Shellfish hatcheries are semi-closed systems (for more information on hatchery operations, see Section B3). The current section describes grow-out conditions and operations.

B2.7.1 Husbandry practices and disease control

The techniques used for grow-out of shellfish vary between species, but some practices are common. Both species-specific techniques and common practices are described below.

Rock oysters

Rock oysters are farmed in New South Wales, south-eastern Queensland and Western Australia. They are grown on sticks, on trays on racks, and in bags or baskets on longlines in the intertidal zone of estuaries, in areas with depths to 3 m. Grow-out can occur in either estuarine or marine waters, as rock oysters can tolerate a large range in water salinity (11–48 ppt). Rock oysters prefer water temperatures of 14–30 °C.

The rock oyster industry is based on larvae acquired from natural spat-fall in estuaries, and on larvae produced in hatcheries from wild-sourced broodstock. The latter may have been selectively bred for faster growth and resistance to certain diseases.

Natural spat-fall collection

Spat (young oysters) settle on sticks or polyvinyl chloride (PVC) slats that are racked in estuaries, where spat-fall is most reliable. To encourage spat-fall, the sticks are often coated with concrete slurry.

Once covered in spat (after 6–9 months), the sticks have traditionally been removed to racks in a low spat-fall area of the estuary, where they are allowed to grow for a further 18–30 months. More convenient methods using trays or plastic mesh cylinders have also been developed. Young oysters (3–8 mm) are removed from the sticks or slats soon after settlement and placed into the trays or cylinders for growth. Spat treated in this way are referred to as ‘single seed’—that is, the oysters are not attached to each other, as are oysters left to grow out on sticks.

Transfer of hatchery-produced spat

Spat produced at hatcheries are transferred to tanks at nursery facilities soon after settlement. Nursery facilities may be located on the same site as either hatchery facilities or grow-out facilities. The spat are fed a range of artificially cultured algae until they reach a size of 3–8 mm and then transferred to grow-out facilities. The young oysters may be transported overland by truck to the grow-out site, where they are placed into mesh bags or cylinders on racks for grow-out.

Farmers grade their single-seed oysters at intervals of 3–5 months during grow-out, to maintain size consistency. The mesh size of grow-out bags or cylinders increases with animal size to optimise water flow to the animals. Growth to market size takes 2–3 years. During this time, oysters may be moved both within an estuary and between approved estuaries—this is known as ‘highway farming’. Oysters may be relayed to an approved grow-out site and subjected to natural depuration (purification)—that is, held in very clean, natural water that is regularly tested for microbiological parameters to ensure safety—before harvest, .

Rock oysters are harvested at a shell length of 5–8 cm, which equates to a weight of 30–60 g in-shell, or around 14 g of edible flesh. Harvested oysters can survive up to two weeks out of water, and are often held for prescribed periods and at prescribed temperatures on land before they are shipped for sale. Where the state’s shellfish quality assurance programme stipulates, a depuration process is carried out for 36 hours before sale. The depuration tanks use filtered and ultraviolet (UV)-treated water. These facilities may be single-company or cooperative operations, and may be located on-site or distant from farm operations. Product is usually sold in-shell to fish markets or, less frequently, directly from the farm gate as bottled, half-shell or in-shell product.

Most farm operations take place from flat-bottomed barges.

Production levels have declined in the past 20 years because of water quality problems, disease and institutional arrangements for the management of estuaries.

Mussels

The aquaculture industry based on blue mussels (*Mytilus galloprovincialis*) was established in 1976. It started in New South Wales and has since spread to South Australia, Tasmania, Victoria and Western Australia. Mussels are grown in marine intertidal waters, at depths of 5–20 m, and prefer water temperatures of 8–20 °C. They are grown on ropes or in bags, on long horizontal or vertical ropes that are suspended from rafts. The industry is based on larvae acquired from natural spat-fall in estuaries, or produced in hatcheries from wild-sourced broodstock. Spat collection sites and growing sites are usually different.

Natural spat-fall collection

In late winter, vertical collector ropes are suspended in the water from longlines between anchored buoys to catch natural spat-fall. The young mussels are stripped from the ropes in summer and put into 'socks' (netting bags), which are then rehung from ropes on the longlines.

Transfer of hatchery-produced spat

In addition to collection of wild spat, there is some hatchery production in Tasmania and Victoria.

In hatcheries, vertical collector ropes are placed in tanks, and young mussels are allowed to settle on the ropes. The mussels are grown to a size of less than 2 mm and then transported to grow-out sites by truck and boat.

Mussels are graded once or twice during grow-out. They can be moved between sites during production to maximise growth and survival at different life stages (e.g. spat and final grow-out).

The crop grows for 7–15 months and is usually harvested between July and February, after reaching a minimum shell length of 60 mm. Mussels are sold based on size, but the market usually requires a 25 per cent meat to shell ratio.

Harvested mussels can survive up to seven days out of water and are often held on land before shipment for sale. They are usually sold live in-shell to fish markets. Some farms have processing facilities and produce value-added product (e.g. pickled mussels). Processing facilities may be on-site or distant from onshore facilities. Some farms sell product at the farm gate or directly to local customers, such as retail outlets.

Pacific oysters

Pacific oysters (*Crassostrea gigas*) were first introduced to Tasmania and are now cultured in Tasmania, South Australia and selected estuaries in New South Wales. Spat are mainly produced under controlled hatchery conditions in New South Wales, South Australia and Tasmania. Translocation of Pacific oysters into Western Australia is not permitted.

Spat are produced in hatcheries and supplied to farmers as single-seed spat (i.e. not attached to sticks). Spat are transferred to grow-out facilities at a size of 3–10 mm (sieve grade size). Transfer of spat to farms may involve interstate movement of stock by truck or airfreight. Hatcheries undertake selective breeding for faster growth rate, shell symmetry and higher meat content. They may provide triploid stock—this is essential in New South Wales, where Pacific oysters are considered invasive.

Rearing in protected marine sites or estuarine leases can involve several methods. Young oysters may be placed in flat plastic trays, placed in plastic or wire mesh bags on intertidal racks, suspended in mesh bags from vertical ropes below anchored rafts, or clipped to horizontal steel-tensioned plastic wires that can be adjusted for depth between buoys or posts. Use of longlines provides a full subtidal existence, without the usual daily air exposure. Pond culture is rarely used.

Pacific oysters can grow at depths of 2–20 m and prefer water temperatures of 8–30 °C. They may be regularly taken from the water for removal of excess shell margin and for grading. Pacific oysters are harvested at a shell length of 60–100 mm (in-shell weight of 60–100 g; meat weight of 10–14 g), at 18 months to three years of age.

Harvested Pacific oysters can survive around one week out of water, and are often held on land before they are shipped for sale. Where the state's shellfish quality assurance programme stipulates, a depuration process is carried out for 36 hours before sale. The depuration tanks use filtered and UV-treated water. These facilities may be single-company or cooperative operations, located on-site or distant from farm operations.

Harvested product is usually sold live in-shell to fish markets or other local customers, such as restaurants. Less frequently, oysters are sold directly from the farm gate as bottled, half-shell or in-shell product. Product may be transported to processing facilities or wholesale markets by truck or airfreight. Product for export is frozen.

Flat oysters

Native mud or flat oysters (*Ostrea angasi*) are cultured experimentally in New South Wales, South Australia and Victoria, often at the same facilities that produce Pacific oysters and rock oysters. Hatchery protocols differ from those used for cupped oysters, because flat oysters incubate broods of larvae before spawning. Grow-out methods are similar to those used for Pacific and rock oysters. Flat oysters are harvested at a shell length of 60–100 mm (in-shell weight of 60–100 g; meat weight of 10–14 g), at 18 months to three years of age.

Harvested product is usually sold live in-shell to fish markets or other local customers, such as restaurants. Less frequently, oysters are sold directly from the farm gate as bottled, half-shell or in-shell product. Product may be transported to processing facilities or wholesale markets by truck or airfreight.

Abalone

Aquaculture of abalone occurs across southern Australia. The native greenlip abalone (*Haliotis laevigata*), blacklip abalone (*H. rubra*) and hybrids of the two species are farmed. Hybrids have favourable growth characteristics.

Abalone spat are produced in marine hatcheries from wild-sourced or domesticated broodstock. Up to one year after hatching, they are large enough to transfer to grow-out tanks or grow-out facilities in the sea.

Abalone are mainly grown in onshore tanks and raceways. Offshore grow-out is a smaller sector of production. Abalone in offshore situations feed mainly on naturally occurring algae. Some experimental offshore farming is occurring in South Australia (in submerged net-pens) and Western Australia (on artificial reefs). Proposals for 'ranching' of hatchery-reared stock on reefs have been made, but this is still under development.

Harvested product is sent live in-shell or as shucked meat (shell removed) directly to processing facilities or wholesale markets, by truck and airfreight. Movement of wild-caught abalone to processing plants (where they may be held for several days to purge) may stress the animals, which can allow subclinical infections to emerge.

Scallops

The scallop aquaculture industry in Tasmania is based on the commercial scallop (*Pecten fumatus*). Larvae are acquired from natural spat-fall in estuaries, or are produced in hatcheries from wild-sourced broodstock. The saucer scallop (*Amusium balloti*) is also being produced in hatcheries in Queensland and Western Australia, where reseeding of wild populations is being trialled.

P. fumatus spat are grown in subtidal marine waters at depths of 1–20 m, either on ropes or in bags, attached to a long horizontal rope. Commercial scallops prefer water temperatures of 8–20 °C, while southern saucer scallops can tolerate warmer temperatures up to 26 °C, with optimal temperatures for juveniles of this species being 18–20 °C. Spat collection sites and growing sites are usually different.

Natural spat-fall collection

In September–October, vertical collector ropes or collector trays are suspended in the water from longlines, between anchored buoys, to catch natural spat-fall. The young scallops are stripped from the ropes or trays in February and transferred to netting bags, which are rehung from ropes on the longlines. In addition to collection of wild spat, Queensland, Tasmania and Western Australia have some hatchery production (see Section B3 for more information on scallop hatchery operations).

Transfer of hatchery-produced spat

Young scallops are transferred to grow-out sites from nursery facilities at a size of 10–15 mm. They are transported by truck in polyboxes, or by boat in lantern cages covered with wet hessian.

Scallops are graded every 4–6 months, and harvested after 18 months or more at a size of 90– 100 mm. Although scallops are harvested in response to size, mature gonads add weight and, subsequently, a higher value to the product.

Harvested scallops can survive less than one day out of water, and are often held on land before shipment to the processing plant.

Scallops are generally sold as a half-shell or flesh-only product, fresh or frozen. Processing facilities may be on-site or distant from onshore farm facilities. Product is transported to wholesale fish markets or retail outlets by truck and airfreight.

Culture of the saucer scallop (*A. balotti*) in Queensland and Western Australia involves the hatchery production of spat from wild-caught broodstock. The spat are then reseeded into the wild, in what is essentially a sea ranching operation. This species of scallop prefers warmer water temperatures of 18–25 °C and grows quickly, with a projected grow-out period of six months.

Common practices

With the exception of abalone, shellfish are not fed processed or formulated feed during grow-out. The bivalves are filter feeders and rely on the natural plankton in the surrounding water. No chemicals or medical treatments are used during the grow-out part of the production cycle.

Water quality is closely monitored on farm sites. Shellfish monitoring systems are used in commercial production areas to detect toxic algae, disease and bacterial levels. Old shell or dead animals may be collected from farm sites and dumped in a designated onshore area.

Limited processing of harvested animals may take place on some farm sites. Alternatively, harvested animals may be transported live in-shell to distant processing facilities or wholesale markets, by truck and airfreight. Processing may involve the shucking (removal) of shells and packaging of flesh. Processing sometimes includes freezing, canning or value-adding (e.g. pickling of mussel flesh or removal of abalone viscera). Shells and viscera removed from animals are disposed of in a designated area at shore facilities, or transported from processing facilities to an approved disposal site.

Some farms may sell product at the farm gate or directly to local customers, such as restaurants.

B2.7.2 Premises and equipment

There are many similarities among the industries in the equipment used to collect spat. Sticks or slats are traditionally hardwood, 1.8 m long and 25 mm square, and often tarred or coated with a slurry of cement. Some sticks are now made of plastic, with a cement slurry coating for spat collection only. Oyster racks used to be predominantly tarred hardwood or treated pine; however, plastics are more durable, making them today's preferred material. Trays may be dark-coloured plastic or galvanised wire. Bags, baskets or 'socks' may be wire mesh, dark-coloured plastic mesh or synthetic netting. Ropes are usually synthetic, and buoys are painted galvanised metal or plastic.

Most production practices on marine leases take place from a barge or punt, but the operations also have a shore facility for storage, equipment servicing and some processing. Shore facilities usually consist of sheds and, in some cases, cool stores by the waterfront. Some shore bases may have a dedicated laboratory space equipped with a microscope. There may be a designated area on-site for disposal of processing wastes (shucked shell) and old shell. In other cases, processing facilities are distant from farm facilities.

Many leases are distant from the shore base and can only be reached by boat. Each company may own a number of leases, and many leases in various areas may be serviced from one shore base. Service vessels (usually aluminium punts or barges with outboard motors) are used to transport stock, personnel and equipment between leases. The boats may have hydraulic or winch-powered lifting equipment and can often carry high-pressure cleaning equipment.

Trucks or utility vehicles are used to transport stock overland from hatcheries to shore facilities, between grow-out sites and to market following harvest. Tractors and forklifts may be available at shore facilities for moving heavy equipment and conducting work at low tide.

Most operations are reasonably small, employing 2–10 multiskilled personnel who are involved in a number of activities throughout the production process. Contract workers may be used for equipment maintenance or diving, where required.

B2.7.3 System inputs

Animals

Young shellfish can be sourced from natural, local spat-fall or from onshore marine hatcheries. Spat may be sourced far from production sites.

Wild aquatic animals live in, on and around estuarine and marine leases, and adjacent to outfalls from some land-based facilities. Aquatic animal and plant communities develop on submerged equipment.

Water

There is no control over water on open leases. However, many farmers hold several leases in different areas, and so can optimise growth by moving the animals to different sites to access different water conditions.

Many shellfish farmers have an intense interest in the quality of the water on their leases and take regular readings. Land-based abalone farms may use some level of water recirculation, which requires appropriate biofiltration and regular water quality monitoring.

Feed

Bivalve shellfish are not fed processed or formulated feeds. They are filter feeders and rely on the plankton in the surrounding water. Hatcheries and nursery facilities may use specific types of algal cultures for feeding young oysters.

Abalone in land-based farms are fed a formulated pelleted ration, which is based on plant products. It is primarily produced in Australia, based on imported ingredients. Abalone in offshore net-pens feed mainly on algae, which recruit naturally on the pen mesh.

Personnel

The workforce on leases varies, but most operations are relatively small and employ fewer than 10 people. The work on leases is usually conducted in time with tides, and this should be considered when trying to contact personnel.

Personnel are multiskilled and are involved in a number of activities throughout the production process. They move between different areas on farm leases and shore facilities. Contract workers may be used for equipment maintenance or diving, where required.

There may be visitors to shellfish farm facilities, including researchers and aquatic animal health advisers.

Farmers have minimal control over the presence or practices of recreational fishers in the vicinity of marine and estuarine leases.

Vehicles

Personnel use privately owned vehicles to travel to work each day.

Most farms have a truck or utility vehicle for transporting stock, equipment and personnel overland to various shore facilities. Tractors are used on some leases at low tide.

Many operations on water take place from punts or barges. Service vessels transport stock, equipment and personnel to estuarine and marine farm sites.

B2.7.4 System outputs

Animals

Harvested molluscs are usually sent to fish markets or processing facilities, but a proportion may be processed and sold on-site.

Waste

Because bivalve shellfish are filter feeders and are not fed by farmers, grow-out facilities produce no feed waste. However, abalone often require feeding in intensive culture, especially in land-based farms, and excess abalone feed may contribute to wastes produced by abalone grow-out.

Limited processing of harvested animals may occur on some farm sites; otherwise, the shellfish are processed at distant facilities. Processing usually involves the shucking (removal) of shells. For abalone, it also usually involves the removal of viscera.

Shells and viscera removed from animals are either disposed of in a designated area at shore facilities or transported from processing facilities to an approved disposal site. Old shell and dead animals may be collected and dumped in a designated area on-site.

Equipment

Equipment is usually shared between several sites. Old sticks and broken equipment are usually disposed of in landfill or burned.

Vehicles

Personnel use privately owned vehicles to travel to work each day.

Service vessels transport stock, equipment and personnel from estuarine and marine farm sites to onshore facilities. Most farms have a truck, 4WD vehicle or utility vehicle for transporting stock, equipment and personnel overland from various shore facilities. Tractors and forklifts usually remain at onshore facilities.

B2.7.5 Groups involved

Groups involved in shellfish grow-out include:

- the Queensland Oyster Growers Association
- the New South Wales Farmers Association (Oyster Section)
- the Oyster Farmers Association of NSW
- the South Australian Oyster Growers Association
- the South Australian Oyster Research Council
- the Tasmanian Oyster Research Council
- the Tasmanian Shellfish Executive Council
- the Australian Abalone Growers Association
- the Victorian Abalone Growers Association
- the Western Australian Abalone Aquaculture Association
- the Abalone Industry Association of South Australia

- the Victorian Mussel Growers Association
- the South Australian Mussel Growers Association
- the Western Australian Mussel Producers Association
- the Aquaculture Council of Western Australia
- national, state and local government bodies (including agriculture and fisheries agencies, and health departments)
- environmental agencies and associations
- Aboriginal land councils
- recreational fishing groups
- yachting and boating groups
- other community groups and water users
- commercial fishers
- universities and other institutions.

B2.7.6 Legislation and codes of practice

Shellfish quality assurance programmes are operated by the governments of New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia. These programmes monitor biotoxins (e.g. toxic algae and bacterial levels) in shellfish grow-out areas, and provide contingency plans for the management of shellfish product quality. In South Australia, the programme is legislated under the *Fisheries Act 1982*. In Queensland, the programme is incorporated into the conditional terms of shellfish farm licences. In addition, a national quality assurance program (http://www.agriculture.gov.au/export/food/fish/shellfish-qa) applies to bivalve molluscs and is complementary to the programmes operated at the state level.

Shellfish sanitation schemes and codes of practice exist for shellfish culture in New South Wales, including the *NSW shellfish industry manual* (www.foodauthority.nsw.gov.au/_Documents/industry_pdf/NSW_Shellfish_Industry_Manual.pdf). South Australia and Western Australia both have shellfish quality assurance programmes. The South Australian Oyster Growers Association has launched an industry-owned, non-regulatory food safety certification programme that is supported by the state government’s audit arrangements; registration is conducted by Primary Industries and Regions South Australia (PIRSA). The Western Australian Department of Fisheries has developed a policy for abalone aquaculture in Western Australia. (www.fish.wa.gov.au/Documents/Aquaculture/abalone-aquaculture-in-western-australia.pdf). An Australian shellfish quality assurance programme operations manual is available through various state government departments (www.pir.sa.gov.au/__data/assets/pdf_file/0006/120948/ASQAP_Manual_2009-01_091102.pdf).

See Appendix 1 for information on relevant legislation.

PIRSA has developed a disease response plan for response to Pacific oyster mortality syndrome if the disease is detected in the Pacific oyster industry in South Australia.

B2.7.7 Public and occupational health

Public health

Public health issues that should be considered are:

- the safety of product if it is harvested when toxic algal blooms are present (this is covered by legislation and under each state's biotoxin monitoring and contingency program)
- the safety of wild-harvested product, which in some cases may not be regulated by food safety schemes
- the potential for product to transmit zoonotic diseases (see Appendix 2)
- the quality of product if it is emergency harvested because of disease outbreaks
- the availability of laboratories to undertake specific testing for the range of potential disease agents and algal toxins
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed.

Worker safety

Worker safety issues that should be considered are:

- the harsh environmental and weather conditions, which can make the work dangerous and impede safe work practices
- daily variation in current flow, which can make some management practices unsafe at certain times of the day
- the need for specialised training and qualifications for diving—it is illegal and extremely dangerous for untrained personnel to dive
- hazards associated with handling ropes and heavy racks
- the need for specialised qualifications and experience to operate boats
- the need for safety equipment
- the potential for lacerations to the skin from handling stock and shells
- potential threats to workers' health from collecting decomposing stock
- the need for appropriate disposal techniques for contaminated water
- potential exposure of divers to toxic algal blooms, jellyfish swarms and large marine predators (e.g. sharks).

B3 Semi-closed systems

B3.1 Overview of semi-closed systems

Semi-closed aquaculture systems are those in which finfish, crustaceans or molluscs are contained so that the animals, water and associated materials are not in direct contact with natural waterways. Water is usually taken from an adjacent natural or groundwater source, and discharge water or effluent from the enterprise is released back into the same waterway.

This water may be released as a continuous or intermittent flow, directly or indirectly into the waterway. It may be possible to completely contain the animals and water in the system, if necessary, but the level of containment possible will vary between systems. However, these systems are not designed to be self-contained, and switching off incoming or outgoing water may have adverse affects on the stock after only short periods. For culture of some species (such as race culture of salmonids), this period may be only a few hours; for others (such as pond culture of freshwater crayfish), water control could be extended to several months.

Examples of semi-closed systems are crustacean, finfish and oyster hatcheries; prawn, freshwater finfish and crayfish grow-out ponds; and pump-ashore abalone culture. Species farmed in semi-closed systems for at least part of their life cycle are listed in Appendix 3.

This section addresses the major industry sectors that use semi-closed systems, and illustrates several important common threads. In semi-closed systems, there is some control over both stock movements and water flows. Many of the animals used in these systems are introduced from another site—a hatchery or nursery—and therefore are often disseminated from a single point. The animals are fed, usually with artificially prepared feeds. Animals are generally harvested by partially draining the ponds (or similar system), followed by netting. In many cases, the holding ponds, dams or races can be dried out or cleaned, usually between stockings.

B3.1.1 Interactions between semi-closed systems and the environment

Under normal operations, most semi-closed systems have significant flow through of water from rivers, estuaries, dams, groundwater or bores. They all have some degree of direct connection to the outside aquatic environment, so it is necessary to consider animals (and potentially disease agents) in the supply water, and contamination of downstream environments with disease agents in the effluent.

B3.2 Native freshwater finfish

Species used in this industry are silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*), Australian bass (*M. novemaculeata*), the threatened Macquarie perch (*M. australasica*), Murray cod (*Maccullochella peelii*) and three endangered cod species—eastern freshwater cod (*M. ikei)*, Mary River cod (*M. mariensis*) and trout cod (*M. macquariensis*). A number of other species are produced in small quantities for restocking or experimental farming, or as ornamental fish, including sleepy cod

(*Oxyeleotris lineolatus*), Barcoo grunter or jade perch (*Scortum barcoo*), and eel-tailed catfish (*Tandanus tandanus*).

The silver perch, golden perch and Murray cod sectors involve both hatchery and grow-out facilities, whereas catfish, bass, and the threatened and endangered species are only produced at hatcheries, for restocking as fingerlings for conservation and recreational fishing purposes. Silver perch historically dominated the industry; however, production of Murray cod has increased in recent years.

Murray cod fingerlings are produced from spawnings in semi-closed systems (earthen ponds), but are reared predominantly in indoor recirculating aquaculture system (RAS; see Section B4). However, some fingerlings are also now grown out in raceways within outdoor earthen ponds and in standard earthen ponds.

Government hatcheries and research facilities in New South Wales and Victoria, and private commercial enterprises in all mainland states are involved in this industry. Hatcheries and farms are located in New South Wales, Queensland, South Australia and Victoria. Western Australia also has silver perch farms.

Silver perch are grown to market size (450 g – 1 kg) in earthen ponds and predominantly sold live. In 2011–12, New South Wales produced 260 t of product, valued at $3.1 million (NSW DPI 2013). Queensland produced 75 t of product, valued at $0.87 million (DAFF 2013). Australian production for 2011–12 was 349 t, valued at $4.2 million (ABARES 2013).

Murray cod are grown to market size of around 800 g – 1 kg. Fish are sold both live and chilled fresh on ice. Production is increasing slowly, with the majority coming from indoor recirculation systems in south-east Queensland and Victoria.

B3.2.1 Practices

Broodfish are collected from the wild, selectively bred farmed stock or farm dams, and held in small (approximately 0.1 ha) earthen ponds. They are recaptured annually by draining the ponds in the breeding season—winter for bass, and early spring through summer for the other species. Some operators use individual personal identification tags on their broodstock fish to assist stock management.

Murray cod, catfish and Mary River cod may spawn naturally in ponds, and the eggs are collected and taken to the hatchery. All species can be induced to spawn using exogenous hormones. Male and female silver perch, golden perch and bass spawn in tanks. Some cod species, and sometimes bass, are hand-stripped several days after injection. Fertilised eggs are incubated in fibreglass tanks or troughs, usually in flow-through systems. Murray cod lay eggs in a spawning drum, which is put in the dam during the breeding season. Eggs are collected and moved to the hatchery immediately after spawning.

First-feeding larvae are stocked into earthen ponds (0.1–0.4 ha) that have been fertilised with inorganic fertilisers (nitrogen, phosphorus, potassium) and/or organic fertilisers (lucerne hay or poultry manure) to promote the production of phytoplankton and zooplankton. Larvae of all species initially feed on small zooplankton, then, after a few weeks, on larger zooplankton and insects. Bass larvae are reared intensively using rotifers and *Artemia* (brine shrimp) at some hatcheries.

The larvae of all species metamorphose and, by 5–7 weeks, become fry, which measure 25–40 mm in length. Silver perch are weaned onto artificial feed in the ponds. During this rearing period, larvae and fry are regularly monitored for ectoparasites, which can be treated using formalin (25–30 mg/L). Fry are usually harvested by seine net, by draining the pond into a concrete sump, or via pipe to a central drainage sump. Harvested fry are taken to tanks and quarantined for several days before being transported to grow-out facilities, stocking sites and farm dams. The larval-rearing ponds are usually left dry from late autumn to early spring. Regular checking of fry and fingerlings for disease, using light microscopes, is common. Many hatcheries give prophylactic salt baths to fingerlings during this period.

Silver perch are cultured in three phases: hatchery, fingerling and grow-out. This strategy is usually combined with a single-batch system, where each pond has only fish of the same age, which are harvested completely before the pond is restocked. Some farms are dedicated to rearing fish only to the fingerling phase. However, most farmers either:

- run their own hatchery and then rear fingerlings and market-size fish, or
- purchase fingerlings only and grow these to market size (more than 450 g).

Silver perch are cultured in static, aerated earthen ponds (0.1–0.5 ha). Recommended stocking rates are 20 000–100 000 fish/ha in the fingerling phase and 5000–21 000 fish/ha in the grow-out phase. Dissolved oxygen levels should be maintained above 4 mg/L to optimise growth and survival. Approximate lengths of the phases are 6–10 weeks for hatchery, 3–4 months for fingerlings and 10–15 months for grow-out. Annual production rates of up to 10 t/ha are achieved in the grow-out phase, with good management. Fish are fed a formulated diet (35–50 per cent crude protein) at rates of up to 10 per cent bodyweight daily for fry, 5 per cent for fingerlings and 1–2 per cent for fish heavier than 50 g.

B3.2.2 Premises and equipment

Native fish hatcheries and farms are usually located near permanent rivers and creeks. Other types of water supplies are underground water and runoff. Water is pumped directly to ponds or a reservoir, from where it is gravity-fed to ponds and buildings. Earthen ponds are the main production units used for broodfish, larvae, fingerlings and market-size fish. The ponds are constructed from impervious soils such as clay or clay-loams. Each pond has a separate inlet, a screened outlet, and an internal or external harvest sump, and can be fully drained. Most silver perch ponds are aerated using electrically powered surface aerators, such as paddlewheels.

Feeding most often uses a tractor or bike and trailer blower feeder, which distributes pelleted feed evenly around the pond.

Spawning, incubation, quarantine and purging tanks are generally fibreglass or polyethylene circular tanks of 500–20 000 L, depending on the purpose. A range of mechanical filtrations methods are used. Tanks are aerated using small compressors or high-volume, low-pressure air blowers.

B3.2.2 System inputs

Animals

Broodfish are caught in the wild (rivers, creeks, lagoons, etc.) and taken to hatcheries. Broodfish for aquaculture breeding programmes are generally selected from high-performance grow-out fish. Fry and fingerlings are moved from hatcheries to farms. Market-size fish come from grow-out farms.

Forage fish and crustaceans that are naturally produced in ponds may be used to feed broodfish. During conditioning periods, additional food for broodfish, including forage fish and crustaceans, is often moved from the wild and farm dams. Occasionally, additional supplementary foods, in the form of purchased seafood or bait, may be used to condition broodfish.

Birds come from natural waters or other farms and include cormorants, egrets, darters, herons and ducks.

Water

The quality of the water entering the facility influences fish health. Surface waters from rivers, creeks, runoff and irrigation canals may carry pathogens from wild fish or other farms located upstream. Small wild fish may enter via the water supply and are a potential source of pathogens.

Reservoir and effluent or settlement dams may contain small fish or escapees from ponds; these are also potential hosts of pathogens. Good management strategies will minimise risks—they may include appropriate screens, efficient harvesting and annual drying of the reservoir. Reuse of water from a 'clean' effluent or settlement dam will reduce the number of pathogens entering from the wild.

Underground water usually contains few or no pathogens, virtually eliminating the risk of introduction of obligate fish parasites with the source water.

Feed

Silver perch are fed artificial feed from weaning (at 4–8 weeks of age) to market size. The feed is extruded, and the main ingredients are imported fishmeal, domestic meatmeal, soybean meal and wheat. The feed is usually 35–50 per cent crude protein. The feed is trucked directly from feed mill to farm using commercial freight companies.

The feed conversion ratio is between 1.6:1 and 2:1—that is, 1.6–2 t of dry feed is used to produce each tonne of fish. Using recommended feed and feeding strategies, nutritional diseases are unlikely, although problems can occur with excessive or incorrect storage of feed in moist, hot conditions.

Personnel

Many farms are owner operated with assistants. Larger farms work seven days per week, and may have 2–10 employees, including managers, biologists and assistants. Casual workers are used for harvesting, breeding, construction and maintenance.

Other visitors to farms can include hatchery staff delivering fry and fingerlings, transportation contractors, government extension officers, scientists, aquatic animal health advisers, general visitors from other farms and interested members of the public.

Equipment

Earthen hatchery ponds may have concrete monks with wood or concrete boards; however, most grow-out ponds are drained through a standpipe. Metal mesh screens, and wire or plastic bird netting are used at some farms on outlets to prevent fish escaping. Almost all ponds have aerators. Each pond is about 0.3 ha in area and about 1 m deep.

Building equipment includes quarantine/purging tanks (fibreglass or polyethylene), PVC plumbing, pumps, filters and blowers. Laboratory equipment includes microscopes, balances, glassware and other equipment. Shed equipment includes machinery, workshops, vehicles, equipment for feed storage and other general equipment. It can also include water quality meters and a secchi disc. Nets used are seine nets (for fingerlings and larger fish), hand nets and plankton nets.

Transport tanks are fibreglass, range from 500 to 10 000 L in volume, and are transported on a truck or trailer. Most farms have backup power generators, if mains power fails.

Stores

Stores are used to house feed, spare paddlewheels, hormones for broodstock, and other chemicals (formalin, salt, anaesthetics, disinfectants, fertilisers). Antibiotics are rarely, if ever, indicated or used for silver perch.

Vehicles

Vehicles may include utilities, 4WD vehicles, tractors and four-wheel motorbikes. Earth-moving equipment may also be used.

B3.2.4 System outputs

Animals

Fry and fingerlings are moved from hatcheries to farms, usually annually in spring–summer. Fry are first moved to quarantine tanks, where they are usually treated with a daily salt bath, then stocked in ponds after several days. On many farms, fry are received into quarantine tanks, salt bathed and kept in quarantine for 1–2 weeks before being stocked in ponds. Restocking programmes will typically introduce the fish directly from the hatchery transport tanks into the wild, with prophylactic salt baths occurring at the hatchery before transport. Fish may be transported in brackish water (2–5 ppt).

Market-size fish are harvested live, and transported either live or chilled and whole to wholesalers, restaurants and fish markets. Fish are harvested using a seine net for complete or partial harvest, or the pond is drained for a complete harvest. Yields can be up to 250 000 fry from a rearing pond of 0.4 ha. Market-size fish yields may be 1 t from a 0.1-ha pond, or 5 t from a 0.5-ha pond. Market-size fish are harvested to brackish water purging tanks (to remove off flavours) for up to two weeks before being sold live, fresh, chilled or processed.

The chain of handling is as follows:

- Fry are harvested.
- Fry are transported in aerated fibreglass transport tanks or plastic bags, with approximately 10 kg of water and an oxygen atmosphere, to the stocking site (fish farm, public waterway or farm dam).
- Fry are weaned from natural live foods onto pelleted feed.

- The grow-out period (approximately 20 months) takes place.
- Live fish are harvested to purging tanks.
- Either live product is transported via tanker transporter to wholesalers' tanks or restaurants, or the fish are killed, chilled and packed on ice, then transported (usually by road) to wholesalers, fish markets, restaurants or retail fish shops.
- Some farms undertake limited processing in approved premises to distribute fillets.

Water

Grow-out ponds are static, with no or very limited water exchange. All effluent water is discharged into an effluent or settlement dam. No effluent water directly enters natural waterways. Most farms irrigate their settlement dam water onto adjacent pasture.

Some effluent water may leave hatcheries or farms with live fish, under monitoring by the environmental protection agency.

Parasitic diseases in ponds are usually treated in situ (with formalin, copper sulfate, potassium permanganate or trichlorfon). Diseases are readily contained on farms, when diagnosed.

Waste materials

There are very few waste materials, and these are generally buried on-site.

Vehicles and equipment

Hatchery and farm vehicles regularly move on-farm and off-farm. Nets may be shared between the smaller farms. Larger farms are self-contained in terms of equipment.

B3.2.5 Groups involved

Groups involved in the native freshwater finfish industry include:

- the Victorian Warmwater Aquaculture Association
- the Silver Perch Growers Association
- the NSW Aquaculture Association
- the South Australian Aquaculture Council
- the Aquaculture Association of Queensland
- the Queensland Aquaculture Industries Federation
- the National Aquaculture Council
- state and territory departments of agriculture and fisheries
- water authorities
- environmental protection agencies, and other environmental groups and agencies.

B3.2.6 Legislation and codes of practice

NSW DPI has a Silver Perch Aquaculture Policy, which sets essential and desirable criteria for the location, design and operation of farms in New South Wales. NSW DPI has recently implemented the Hatchery Quality Assurance Program across the state.[1] The NSW Silver Perch Growers Association is formulating a code of practice. The Aquaculture Association of Queensland has implemented an environmental code of practice.

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1 www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/223534/Hatchery-Quality-Assurance-Program.pdf

Legislation relevant to aquatic animals and health is listed in Appendix 1.

B3.2.7 Occupational health

There are several health and safety issues for staff, including the following:

- Pond mud is rich in bacteria and should be treated with caution, especially if the operator has skin abrasions. See Appendix 2 for information on seafood-borne disease in humans.
- Significant amounts of heavy lifting can be involved in harvesting and handling fish. Caution should be taken to prevent back injuries.
- Earthmoving equipment, tractors and forklifts should be operated with care after appropriate safety training.
- Electrical problems are common, and qualified electricians should be used, as required.

B3.3 Prawns for grow-out

The prawn culture industry in Australia is mainly based on the black tiger prawn (*Penaeus monodon*), with contributions from the banana prawn (*Fenneropenaeus merguiensis*), brown tiger prawn (*P. esculentus*) and kuruma prawn (*P. japonicus*). The cycle of production involves relatively few wild-caught or domesticated broodstock, which are used to produce post-larvae in a hatchery. These post-larvae are then transferred into earthen grow-out ponds linked by supply channels to a pump house and neighbouring estuaries, or directly to the sea. The ponds are about 1 ha in area and 1.5 m deep.

A large proportion of black tiger prawn, brown tiger prawn and banana prawn product is sold domestically, whereas most kuruma prawn product is sold for export. The prawn aquaculture industry in Australia produced almost 4000 t of product, valued at more than $59 million in 2011–12, with the bulk produced in Queensland (ABARES 2013).

B3.3.1 Practices

The grow-out season for a crop of prawns in Australia ranges from around 150–170 days for *P. monodon* and *F. merguiensis* to a maximum of 190 days for the slower-growing *P. japonicus*. Post-larvae are stocked into ponds when water temperatures are above 20 °C, at 15–50 prawns per square metre. At stocking, ideal water quality parameters are salinity of 25 ppt, pH of 7.5–8.5, secchi depth of 0.7–1.0 m and temperature above 25 °C. Ponds are filled (to 1.5 m depth) two weeks before stocking of post-larvae, to ensure optimum water quality and to attempt to establish a plankton bloom. At 1–6 weeks after stocking, post-larvae are fairly hard to see because of their small size and their distribution throughout the pond. If the pond has been well prepared before stocking, no water inflow or outflow is required at this early stage in the cycle. It is standard practice to operate aerators at night. Manufactured post-larvae feed is hand fed to the pond in very small quantities during the first month, as post-larvae mostly feed on natural benthic organisms.

After six weeks, feed trays (1 m square, mesh) are placed in the feeding strip on the pond bottom to judge feed consumption and to visually check prawns. Prawns will start to look for pelleted feed after a month and will be visible on the feed trays. Daily calculations of feeding rate are made, based on size and survival of prawns in a pond, the previous day's feed consumption and general observation of the prawns. Feed is delivered to the ponds via blowers on the back of four-wheel motorbikes or small feed trucks.

Feedings (usually four or five in total) are spread through a 12–16-hour workday. As a general rule, 1–6 g prawns are fed 5 per cent of biomass per day, 6–15 g prawns are fed 4 per cent of biomass and 15–25 g prawns are fed 3 per cent of biomass. If water conditions deteriorate (usually as a result of excess rainfall or overfeeding), feeding is reduced, and water exchanges may be used to allow pond water to stabilise. As prawns increase in size, they can be visually inspected more carefully, by observing the feed trays and cast netting in the ponds. A sample of prawns is individually weighed each week.

Daily water quality readings are taken, including pH, dissolved oxygen, visibility and ammonia. Water exchange (inflow from, and outflow to, the estuary) takes place according to water quality readings and the availability of good-quality water from the estuary during high tides. As biomass increases in the pond, aeration is increased; four horsepower per tonne of biomass is a general rule. Aeration is left on all night and, depending on the weather, may be turned on for periods during the day. After 18–20 weeks, prawns are harvested either by netting in the pond or by draining the pond. Production from a 1-ha pond is 2–10 t, depending on the species and geographic location. Domesticated tiger prawn production rates can be significantly higher (average 17.5 t/ha).

After harvest is complete, the pond is drained and left to dry out. The pond bottom is tilled and relevelled, agricultural lime is applied and, if the previous crop has been affected by mortalities, chlorine may be applied. Good practice allows complete farm dry-out—that is, all ponds, and inlet and outlet channels remain empty for at least 4–6 weeks.

B3.3.2 Premises and equipment

Prawn farms consist of 4–100 earthen ponds, each of which is generally 1 ha in area and 1.5–1.8 m deep. The volume of water in each is about 15 000 m^3. Pond walls are generally a 1:3 slope, with a top width of at least 2 m to allow vehicle access around the pond. Inlet and outlet channels can be made of earth or concrete culverts, plastic pipes or a combination of these. Generally, inlet channels run down the centre between ponds, and outlet channels run around the outside perimeter of the ponds. Each pond has an inlet pipe, which can be closed off from the inlet channel, an outlet pipe and/or a monk, which has an automatic overflow when the pond water level reaches a maximum height. If lower levels of water are required, the outlet pipe or monk can be adjusted right down to completely empty the pond.

Around the ponds are three-phase electricity points for aeration equipment. Water is pumped up from the estuary by electric or diesel pumps into inlet channels. Pump size varies according to the number of ponds on a farm: a minimum of a 250-mm diameter pump is required for 4 ha of ponds.

Buildings associated with a farm generally include a feed storage shed or workshop, a processing shed (for cooking and packing prawns) and a residence for a farm manager. Vehicles generally include a tractor with earth-tilling equipment, excavator or scraper; four-wheel motorbikes with feed blower attachment; and a utility or 4WD vehicle.

Equipment used includes aerators, cast nets, feed trays, sprayers, water quality meters, a microscope, harvest nets, prawn cookers, insulated bins, prawn washers, cooling tanks, brine tanks, cool rooms, a brine freezer, a grading machine and a sorting table. Backup generators and spare paddlewheels are common.

B3.3.3 System inputs

Animals

Post-larval prawns from hatcheries are usually size PL15 and weigh less than 0.1 g when transferred to the farm. Although the incoming water is coarsely filtered when the ponds are filled, incidental animals at very early larval stages cannot be filtered out of the water. Incidental animals that may be introduced with water inflow from the estuary include native prawn and fish larvae, jellyfish, eels and crabs. Crocodiles may enter ponds in some areas.

Water

Salinity of estuary water is greater than 10 ppt, with the ideal being 20–25 ppt. In an estuary, water is best pumped from an incoming tide to ensure that the best quality water is obtained (i.e. water that is high in trace elements, with low levels of suspended solids and nutrients).

Once the ponds are filled, usually no water exchange takes place during the first 60 days of the crop. However, around 5 per cent of pond volume per day can be exchanged, if required, to improve pond conditions.

To encourage growth of algae blooms in ponds, fertilisers can be added to incoming waters. Many farmers find that, after a few crops, the need for fertilisers is reduced and the pond will bloom of its own accord if weather conditions are suitable. Algicides can be used to reduce unwanted blooms such as blue–green algae, and approved blue dye may be used to avoid excessive benthic algal growth in ponds that fail to rapidly establish blooms. Biocides can be used to reduce bacterial blooms.

Feed

Pelleted extruded feeds obtained from local or overseas feed mills are used. All prawn feeds contain imported ingredients. Large farms directly import feed. Smaller farms buy from imported feed distributors or local mills in multiples of 1 t pallet loads that are delivered to the farm by freight company trucks. The average feed conversion ratio is 2:1—therefore a
1-ha pond requires 10 t of feed to produce 5 t of prawns.

Personnel

A general rule is one farm hand per 4 ha of pond. Farms tend to have strict control over entry of personnel other than workers and state officials; casual visitors are discouraged.

Stores

Feed is kept in a cool store during the growing season. Generally, feed for at least four weeks is kept on hand. Fertilisers and other chemicals may be stored in small quantities, as they are usually brought in for immediate use.

B3.3.4 System outputs

Animals—primary product

The primary product is prawns of at least 20 g, cooked or green, chilled or frozen. The most common method of harvest is complete pond harvest through netting or drain harvesting. An average harvest of a 1-ha pond is 3–5 t. The harvested product is moved within the farm from the pond to the processing shed, where prawns are graded, sorted, washed, cooked, chilled, brined and packed into styrofoam boxes for shipment to market as fresh chilled or cooked product. Frozen (green or cooked) prawns are processed on-farm and stored for up to six months after harvest. Most prawn farmers make sales direct to wholesalers who, in turn, supply retail outlets and restaurants.

Secondary product and other animals

Sometimes extra products (crabs or fish) are incidentally produced, but these are usually consumed by workers on-site or close by. Birds can carry prawns from a pond and then drop them into other ponds or surrounding waters. Migratory birds could potentially be significant in disease transmission, either through mechanical means or after ingesting infected material. Crabs and crocodiles can walk out of farm areas into surrounding waters.

Water

To allow water exchange, pond water is discharged as new water comes into the pond. Typically, a pond outlet cannot be made completely secure, and some flow of water generally occurs at all times. Some farms do not use a holding pond before discharge into the waterway because land height is not sufficient—farms are typically located on a floodplain. Newer farms incorporate sedimentation and effluent treatment ponds, to remediate water before it is discharged into the waterway.

Ponds are emptied completely at the end of the crop. During this drain harvesting, animals can potentially escape in discharge waters into outlet waters.

Waste material

Dead crustaceans are collected from the pond bottom after it is emptied and then buried in landfill. Organic and inorganic fine silt, which is removed from the centre of the pond after draining, becomes landfill or is used on-site to repair roads and pond walls.

Equipment

Nets and aeration devices taken from one pond and used in another are generally dried and cleaned thoroughly between uses (i.e. all marine organisms are removed from the equipment).

B3.3.5 Groups involved

Groups involved in prawn grow-out include:

- the NSW Prawn Farmers Association
- the Australian Prawn Farmers Association
- the Mackay Mariculture Association
- the Mackay Prawn Farmers Association
- the Commercial Mariculture Council of Queensland
- the Queensland Aquaculture Industries Federation
- the National Aquaculture Council

- state departments of agriculture and fisheries
- water authorities
- environmental protection agencies, and other environmental groups and agencies.

B3.3.6 Legislation and codes of practice

The Australian Prawn Farmers Association has published an *Environmental Code of Practice for Australian Prawn Farmers* (www.nretas.nt.gov.au/__data/assets/pdf_file/0020/20369/appendix3.pdf). Each hatchery normally establishes its own protocols and manual of standard operating procedures, which include hatching techniques, sanitation, grow-out and standard methodology. Several farms have also embraced environmental management systems implemented through ISO 14001 standards.

Relevant legislation is listed in Appendix 1.

B3.3.7 Occupational health

The following occupational health issues should be considered:

- Farm machinery can be dangerous if used without due care.
- Pond mud is rich in bacteria and should be treated with caution, especially if the operator has skin abrasions.
- Potential threats to workers' health should be considered before the collection, handling and disposal of dead, decomposing or diseased stock.
- The safety of workers preparing and applying chemical treatments should be considered.

Information on seafood-borne disease in humans can be found in Appendix 2.

B3.4 Prawn hatcheries

Production of post-larval prawns for stocking into grow-out ponds requires collection of broodstock from the wild. Research is in progress to domesticate prawns so that the full life cycle can be grown in captivity, and this represents the trend for the future. *P. monodon*, *P. japonicus*, *P. esculentus* and *F. merguiensis* have been successfully domesticated in Australia, and other species of prawn have been bred domestically overseas. Some problems with fecundity of domesticated stock still need to be overcome before it can fully replace the wild-caught alternative.

B3.4.1 Practices

Broodstock caught from the wild or grown in farm ponds is moved to maturation tanks in the hatchery. Since the animals can only mate during moult when the female's shell is soft, most hatchery operators prefer to receive gravid or berried broodstock from the wild, where fertilisation has already taken place.

The broodstock, if ripe and ready to spawn, is placed in a spawning tank, and her eggs are collected after she spawns. If the broodstock is not fully gravid, she is ablated (one eyestalk is removed), thus accelerating the spawning process. Eggs are collected, rinsed and washed, sometimes in a weak solution of formalin or iodine to clean the eggs and reduce the potential for vertical transmission of disease. The eggs are usually counted, and then placed in hatching tanks.

When the eggs hatch, they go through six stages of nauplius development and metamorphosis. Before the sixth stage, they are usually moved to larger tanks of sea water. In these tanks, the animals progress through three zoea stages and three mysis stages before metamorphosing to post-larval prawns.

The young prawns are usually kept in the hatchery until they reach 15 days of age and are then sold to grow-out farms for culture. The entire process from egg to post-larvae (15 days of age) takes normally about 25 days, but can be longer in the cooler winter months.

B3.4.2 Premises and equipment

Facilities differ but have similar basic needs, both in Australia and overseas. Hatcheries come in various sizes; the volume of tanks in the hatchery depends on the number of post-larval animals that the owner or operator plans to produce. Large commercial hatcheries may produce 60–100 million post-larval prawns per year, whereas others produce 20 million or fewer.

Generally, hatcheries include a building to house the various tanks required for maturation, spawning, hatching, larval rearing, grow-out and algae production. Ancillary support equipment includes pumps to take water from the sea or estuary, settlement ponds, reservoir tanks, heating equipment such as boilers to maintain water temperature, filtration devices, ozone disinfection units, UV flow-through devices to eliminate bacteria in the water column, a food storage area, and a small laboratory and office.

B3.4.3 System inputs

Broodstock

Animals are usually purchased from prawn trawlers and placed in maturation tanks. Some are produced in maturation ponds and are second or third generation. Wild broodstock carry covert viral infections that can become problematic in an intensive farm situation because they can be vertically transmitted to larvae.

Water

Water is the most important input in the hatchery. Pristine, high-salinity (32–35 ppt) water is required. Since water is one of the most important sources of disease, it is treated very carefully before either broodstock or larval prawns are introduced.

Incoming water is filtered intensively and usually passed through UV light to minimise the intake of unwanted bacteria and other pathogens. The water is treated with EDTA to chelate heavy metals, and may be chlorinated in the tanks before living animals are introduced. Chlorine has to be allowed to dissipate before the tanks are seeded; this is done with sunlight and vigorous bubbling with air stones. Sodium thiosulfate may be used to neutralise the chlorine in the tank.

Feed

Feed for broodstock is usually fresh or frozen, and consists of squid, liver, mussels, polychaete worms and artificial high-protein pellets. It is supplied by local bait feed suppliers. Pelleted feed is supplied by an importer or distributor.

Larval feed consists of imported microencapsulated feed, supplemented with algae of many species—for example, *Chaetoceros calcitrans, C. muelleri, Tetraselmis* spp. and

Skeletonema costatum. Algal starter cultures are usually purchased from CSIRO and grown up on-site. Another live feed used is imported brine shrimp (*Artemia* spp.), which come in cyst form in tins, and are rehydrated and hatched on-site.

Personnel

Most hatcheries are operated by their owners. Some are solely a family operation, but most employ two or three qualified technicians with hatchery experience.

Equipment

Equipment is fairly specialised and consists of fibreglass tanks of various sizes, from 1 t to 25 t or more. Some hatcheries use concrete tanks.

Air blowers, usually Roots blowers, are used to maintain a constant supply of air to the tanks. Most hatcheries have a stand-by generator in case of public power failure. Some hatcheries have well-equipped laboratories for water quality analysis and disease monitoring, whereas others have very little support equipment.

Stores

An adequate supply of feed is necessary to complete a hatchery run. Chemicals used for cleaning and disinfecting tanks, air lines and air stones are also kept on-site. Filter material, screens, dip-nets, weighing scales, freezers for feed storage, maintenance tools and spare parts are all kept in an adjacent storeroom.

Vehicles

Workers live off-site and drive private vehicles to work. Usually, a hatchery that is associated with a farm, or comes under the same ownership, will have 4WD or utility vehicles. Most hatcheries have transporter tanks that are hitched to trucks to make routine larval animal deliveries to farmers on completion of sales. When the hatchery has ponds on the property, four-wheeled all-terrain vehicles are commonly used.

B3.4.4 System outputs

Animals

Post-larvae are the only product. They are harvested from the grow-out tanks by concentrating them in small containers of a given volume so that a volumetric count can be made. They are then poured into a transporter and taken to the farm, or packed into plastic bags containing salt water and packed into foam boxes for shipping to farms via air transport. Excess feed, including algae, may be flushed out at the end of a production cycle.

Water

During the culture period, water is usually not discharged. Generally, hatcheries are required to have a settlement or holding pond for water outflow, as part of the conditions of their aquaculture permit. Treatments such as chlorination can be undertaken in these holding ponds. Tank discharge at harvest is high in organic matter through accumulation of faeces, uneaten feed, and some dead larval animals and moult material.

Waste

Dead post-larvae are washed out with wastewaters into holding or settlement ponds. Spent broodstock is generally cooked and eaten.

Equipment

Movement of disease from one tank to another in the hatchery situation is a real risk. All equipment is thoroughly cleaned and disinfected between hatchery runs. Regular dry out of all tanks, pipes and holding ponds is advisable between runs. Each tank has its own individual accessories. Cross-contamination should be avoided because any importation of disease (viral, bacterial or another infectious cause) can trigger a mass mortality event.

B3.4.5 Groups involved

Groups involved in production of post-larval prawns include:

- the NSW Prawn Farmers Association
- the Australian Prawn Farmers Association
- the Mackay Mariculture Association
- the Mackay Prawn Farmers Association
- the Queensland Aquaculture Industries Federation
- the National Aquaculture Council
- state departments of agriculture and fisheries
- water authorities
- environmental protection agencies, and other environmental groups and agencies.

B3.4.6 Legislation and codes of practice

The Australian Prawn Farmers Association has published an *Environmental code of practice for Australian prawn farmers* (www.nretas.nt.gov.au/__data/assets/pdf_file/0020/20369/appendix3.pdf). Each hatchery normally establishes its own protocols and manual of standard operating procedures, which include hatching techniques, sanitation, grow-out and standard methodology. Several farms have also embraced environmental management systems implemented through ISO 14001 standards.

Relevant legislation is listed in Appendix 1.

B3.4.7 Occupational health

Chemicals (e.g. disinfectants, antifungals, antibiotics) that may pose a health risk are commonly used in hatchery operations.

Information about seafood-borne disease in humans can be found in Appendix 2.

B3.5 Trout in fresh water

Approximately 2000 t of trout are produced annually in Australia (O'Sullivan & Savage 2009), mostly in Tasmania in marine net-pens (semi-open systems). The bulk of freshwater production comes from north-eastern Victoria and southern New South Wales, but trout are also produced in South Australia, Tasmania and Western Australia. Stocking densities vary both across and within farms. Before grow-out, juvenile fish are often held at very high densities (up to 60 kg/m^3) to check growth. Trout that are growing out may be held at 15–30 kg/m^3.

B3.5.1 Practices

Trout eggs are stripped from adult females in winter and incubated in hatcheries. After several months in tanks, the young fish are transferred to raceways that have large volumes of water running through them. Some hatcheries in Tasmania use highly controlled recirculation systems for early fingerling growth and high levels of sanitation. Victorian and New South Wales hatcheries tend to use unfiltered flow-through water.

Fish are graded and moved around the farm at various stages of their lives. This involves seine nets congesting the fish at a particular point. The fish are then moved with either hand-nets or fish pumps. Regular mechanical grading takes place, and fish are relocated by fish pump hoses or transport tank trailers.

Fish are harvested using seine nets to crowd the fish, and then either dip-nets or fish pumps to move them into harvesting bins with ice slurry. Percussive stunners are used on some farms before the fish are bled. Some farms use automated bleeding and processing machinery.

Fish may be sold whole or HOGG, as fresh or frozen fillets, or as smoked whole fish and fillets.

B3.5.2 Premises and equipment

In Australia, trout are produced commercially in a variety of systems, including flow-through earthen ponds, flow-through concrete raceways and RAS facilities. Although every farm has a different set-up, ponds are generally about 20–30 m long, 10–15 m wide and 1–2 m deep.

Most farms pass water through the system once only; however, the same water may flow through a number of different ponds (i.e. ponds are set up in series). Other farms have raceways set up in parallel, being fed with fresh source water from a manifold. Effluent is typically directed through a settlement area before discharge.

Most farms have their own broodstock and hatchery. Upwelling incubators are the industry standard for holding fertilised eggs. Hatching down is done through Californian egg trays. Fry are generally grown in aluminium or fibreglass troughs. For slightly larger fry, circular tanks or small concrete tanks are used.

Intake water is typically pumped using large electrical pumps. Backup generators are available in case of mains power failure. Most farms have mechanical grading machines, and some have automated processing and value-adding facilities (e.g. smokers) on-site.

B3.5.3 System inputs

Animals

The most commonly farmed species is the rainbow trout (*Oncorhynchus mykiss*), which may be from an on-site hatchery, or introduced from other hatcheries or farms. Some stock is introduced to the mainland from Tasmanian hatcheries.

Water

Rainbow trout require a high standard of water quality to maintain growth and health. The water supply is a route for entry of pathogens (mainly bacteria) and parasites (mainly protozoa) shed from wild fishes inhabiting the watercourse, or discharged from upstream aquaculture enterprises. There can be multiple farm sites on one river, as well as runoff from agriculture, and point sources for introduction of stormwater or municipal wastewater. As a result, a range of factors in addition to entry of pathogens can cause stress to the fish and precipitate disease—they include chemical contamination, biological oxygen demand and chemical oxygen demand of inlet water, temperature (usually high), turbidity (which can cause gill irritation) and low oxygen concentration.

Feed used

Specifically formulated trout rations (either steam pelleted or extruded) are available from several suppliers. Ingredients in the diet include domestic and imported products, such as fishmeal and fish oil. Depending on the ration, the availability of natural food (e.g. insects) and the expertise of the farmer, feed conversion ratios can range from 1.1:1 to 1.6:1.

The industry is moving towards higher-energy rations to combat environmental concerns about nutrient levels in the waste streams. This change has reduced feed conversion ratios.

Personnel

Personnel on these farms include employees, visitors, tourists (some farms are run as tourist and/or fish-out operations) and fish health advisers.

Equipment

Equipment is frequently shared between sites run by the same operator and occasionally between operators. Equipment includes fishing tackle and waders in trout fish-out operations, grading sheds, nets and harvesting equipment (e.g. harvesting race), fish boxes, and equipment used for mixing medications.

The farm may also have a hatchery with tanks, and ozone and UV water treatment. Processing equipment may be on-site.

Vehicles

Vehicles include feed trucks that visit other farms and sites, tanker trucks and trailers that move young stock, and transport for industry service personnel who visit several farms. Most farms have access to 4WD vehicles, utilities and tractors, and may have light earthmoving equipment.

Other inputs

Other inputs include chemicals such as salt, formalin and drugs (e.g. antibiotics, anaesthetics).

B3.5.4 System outputs

Animals

Most trout farms have some level of direct sale to the public. Farms sell through a variety of wholesale and retail seafood outlets, including supermarkets. Markets range from sale of live fish at local markets to sale of smoked products to Hong Kong.

Water

Effluent water quality is monitored by environmental protection agencies, and settlement ponds and wetlands are used to clean water before discharge. Since many trout farms are in the same catchments and some are even on the same rivers, the effluent water from one farm has the potential to be the intake water for a downstream farm.

B3.5.5 Groups involved

Groups involved in freshwater trout farming include:

- the Australian Trout and Salmon Farmers' Association
- the Tasmanian Salmonid Growers Association
- the Victorian Trout Association
- the Aquaculture Council of Western Australia
- the National Aquaculture Council
- recreational fishing groups in New South Wales, Tasmania and Victoria
- state departments of agriculture and fisheries
- water authorities and electricity authorities (e.g. Snowy Hydro)
- environmental protection agencies, and other environmental groups and agencies.

B3.5.6 Legislation and codes of practice

Information on relevant legislation can be found in Appendix 1.

B3.5.7 Occupational health

Occupational health issues to be aware of include:

- periodic use of chemicals and drugs, which requires appropriate awareness and use of safety equipment
- use of heavy equipment
- potential threats to workers' health associated with collection, handling and disposal of dead, decomposing or diseased stock
- hazards associated with the location of farms on fast-running rivers with cold water; these rivers are potentially dangerous for workers if they are required to enter them.

See Appendix 2 for information on seafood-borne disease in humans.

B3.6 Salmon hatcheries and raceways

Although salmon can be produced in fresh water, most salmon spend only the first part of their life cycle in fresh water before being moved to net-pens. Production of fish fully in fresh water occurs in Victoria, where Atlantic salmon (*Salmo salar*) is farmed. Chinook salmon (*Oncorhynchus tshawytscha*) is produced in a hatchery in Victoria for stocking purposes.

The freshwater/seawater production style is common in Tasmania. For further information on the adult phase of salmon kept in fresh water, see the description under Section B3.5 for trout. For further information on salmon (or trout) kept in net-pens, see Section B2.3.

B3.6.1 Practices

The salmon farming industry can be subdivided into the separate stages of the production process, progressing from broodstock to the hatchery production of fry and smolts, to marine grow-out, to the distribution of the final product in domestic and export markets. The broodstock may be maintained at either freshwater or seawater farm sites, where they start to mature during late summer and early autumn (February–March). At freshwater sites, the broodstock is typically held in flow-through raceways or tanks. Broodstock is exposed to wild aquatic animals that may harbour potential pathogens (e.g. birnaviruses in marine finfish and invertebrates, reovirus). Some hatcheries are now avoiding the use of broodstock that may have been exposed to marine pathogens. The broodstock become fully mature and ripen in late autumn (May), when the milt (sperm) and ova (eggs) may be stripped and mixed to facilitate fertilisation and the generation of a new year-class of stock.

Fertilised ova (6–8 mm in diameter) are maintained at the hatchery facility. The embryos progress through the green and eyed stages until they hatch as alevins (yolk-sac fry) and develop into first-feeding fry (approximately 0.2 g), ready to commence exogenous feeding. When the fry have established a feeding pattern, they continue to be maintained in the hatchery facility until they develop into parr (1–2 g fish with characteristic colouration)—this process takes a further 2–3 months (October–November). Subsequently, parr are transferred to smolt-rearing facilities, where they are maintained until smoltification: the physiological metamorphosis that facilitates the fish's survival in the marine environment. Typically, smoltification takes place in September–October (approximately 15–16 months after fertilisation) and occurs in response to the increase in day length associated with the onset of spring. In some cases, the development of fish to the smolt stage can be advanced by up to 5–6 months (in March–May) by manipulating the photoperiod.

Smolts (60–100 g fish that resemble adults and are capable of surviving in the marine environment) are transferred to marine farms for grow-out. They are maintained in floating net-pens as they develop into salmon (adult fish) ready for harvest. This process takes a further 12–20 months.

At all stages, salmonids require cool water, ideally 10–15 °C, with high levels of dissolved oxygen (generally greater than 80 per cent saturation or 5 mg/L).

During the freshwater stages of production, the majority of husbandry activities are associated with spawning, feeding and grading fry and parr, and transporting smolts.

B3.6.2 Premises and equipment

The majority of salmon hatcheries are located on the upper reaches of major river systems, where relatively consistent supplies of water can be extracted from areas with minimal industrial, agricultural and domestic sources of pollution. Separate areas are usually available for egg incubation, rearing of larvae and holding of broodstock.

Egg incubators and larval-rearing tanks are generally constructed from fibreglass and/or plastics. Their size is determined by life history stage and the scale of the operation. For example, first-feeding tanks may range in volume from approximately 1 to 10 m^3, while smolt production tanks can range from 4 to 60 m^3. Some hatcheries undertake smolt production in large, closed RAS facilities, with extremely high levels of ozone and UV sanitation, to produce pathogen-free smolt. Raceways for holding broodstock are constructed from concrete and may be placed in series or in parallel.

Broodstock may be sourced from net-pen sites, and thus may be exposed to pathogens that have been transferred with the broodstock fish to hatchery sites. For many pathogens (e.g. the exotic viral pathogens such as infectious pancreatic necrosis virus, viral haemorrhagic septicaemia virus and infectious haematopoietic necrosis virus), the young fry are the most susceptible to disease. Under these circumstances, it is important that broodstock is maintained in facilities that are completely separate from egg incubation and larval-rearing areas. In addition, it is advisable to maintain individual lines of eggs in separate areas, with individual clean water supplies.

B3.6.3 System inputs

Animals

Whether maintained entirely in fresh water or returned to freshwater sites for spawning after a period of seawater residence, broodstock is a possible vector for both vertical (primarily viruses) and horizontal (primarily bacteria and protozoa) transmission of pathogens to other stock held at hatchery sites. Similarly, at sites where year-classes of stock overlap, the older cohort is a potential source of infection for the younger cohort. Any transfers of new stock onto a site (e.g. the return of broodstock for spawning or the relocation of other life history stages) may introduce disease organisms. Depending on the level of pre-filtration of hatchery source water, small stages of wild fish and other aquatic organisms may be able to enter the hatchery site.

Water

Variable levels of pre-filtration are undertaken on intake water at hatcheries. Salmon require a high water quality to maintain growth and health. The water supply is a route for entry of pathogens (mainly bacteria) and parasites (mainly protozoa) shed from wild fishes inhabiting the watercourse or other fish farmed upstream. For conventional flow-through systems, this is the most significant source of infection for farmed stocks. There can be multiple farm sites on one river, in addition to runoff from agriculture, stormwater and municipal wastewater.

With the adoption of water recirculation technology, the volume of water extracted from the source can be lower, reducing the likelihood of disease introduction. The most sophisticated systems reduce the water requirement by 95 per cent and use systems that facilitate complete disinfection (e.g. using ozone and UV light) of any make-up water introduced into the farm.

Importantly, the quality of water supply is a significant risk factor. Reduced water quality (e.g. extremes of temperature, inadequate levels of dissolved oxygen, excessive organic loading) can be a major cause of stress, which may compromise immunocompetence and lead to infection, or a change in fish health status from carrier to clinically diseased.

Feed

Feed ingredients, particularly fishmeal and fish oil, are a potential source of infection, especially if the drying and reduction process involved in their preparation has been ineffective in pasteurising the feed stocks. Generally, the extrusion cooking processes used in manufacturing complete formulations results in adequate heat-treating of ingredients and provides protection against disease transmission via the feed.

Aquaculture feed may also be a source of nutritional disease. Some historical problems have been traced to contamination of feed, poor quality control of the final ration formulation and ingredients, and suboptimal feed storage, resulting in exposure to microbial toxins and rancid fats.

Nutritional status can influence immunocompetence. The majority of feed for early stages of fish is imported from European sources. Quality control at manufacture, combined with Australian Government Department of Agriculture limitations on the types and sources of both ingredients and complete formulations, limits the likelihood of microbial or nutritional disease. The majority of feed pellets larger than 2 mm is sourced directly from local manufacturers, whose production and quality control procedures minimise the likelihood of microbial or nutritional disease.

The quantities of feed used are highly variable. Intake averages approximately 2 per cent of site biomass per day.

Personnel

Activities of personnel are a disease risk factor. Husbandry activities that require fish to be handled directly may facilitate infection through damage to mucous and epithelial layers. Moreover, any procedure or omitted procedure that results in fish stress can precipitate disease. There is also some risk of disease transmission by personnel via direct contact with contaminated fish and fish products, water, equipment and surfaces. Generally, relatively simple disinfection measures such as handwashing, use of footbaths, and changing and disinfecting protective clothing are effective and should be routinely employed as part of normal operations.

Equipment

Equipment used includes egg incubators, tanks, aerators, pumps, UV sterilisers, ozone generators, airlines, biofilters, nets, bulk oxygen supplies and spare parts.

Vehicles

Vehicles are also a possible means of disease transmission. In particular, trucks and tanks used for live fish transport may transfer infected stock (especially apparently healthy carrier fish) and contaminated water between sites. Consequently, care should be taken when moving live fish during disease episodes, and simple disinfection measures should be applied.

Vehicles used for removal of large volumes of dead fish (especially those that have died as a result of a disease episode) represent a significant potential route for disease transfer. Disinfection is possible but difficult, especially for containers used to hold material for disposal, because of the decomposition of carcasses and the tendency of the resulting material to adhere to surfaces. Physical scrubbing before applying disinfectants will be required. See the AQUAVETPLAN **Decontamination Manual (**www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan) for specific instructions.

B3.6.4 System outputs

Animals

Smolts are the primary product. They are transferred directly to marine grow-out facilities using specially designed truck-mounted tank systems. On arrival, they are discharged into net-pens.

Water

Effluent water is a route for entry to the watercourse of pathogens and parasites shed by farmed stocks. For conventional flow-through systems, effluent treatment is generally limited to solids retrieval. Consequently, there is little likelihood of controlling the release of pathogens to the environment. Water recirculation technology can reduce effluent volumes to allow improved disinfection of effluent water.

Importantly, establishment of disease within a recirculation system is a significant threat because the system facilitates recycling of pathogens and continuous reinfection of stock. Furthermore, the microbial populations inhabiting the biological filters may be negatively affected by chemotherapeutic measures, with a negative impact on water quality. This can increase stress, compromise immune function and hinder any recovery process.

Waste materials

For effluent treatment, refer to 'Water' (above).

Solid waste from effluent treatment in both flow-through and recirculation systems can be disposed of in landfill sites, or composted and used as organic fertiliser. Fish carcasses resulting from routine, non-disease related mortality or culling of excess stock can also be disposed of in landfills or processed (e.g. acid ensiled) to yield material that can be used as an organic fertiliser.

B3.6.5 Groups involved

Groups involved in salmon production include:

- the Australian Trout and Salmon Farmers Association
- the Tasmanian Salmonid Growers Association
- the Victorian Trout Association
- the Aquaculture Council of Western Australia
- the National Aquaculture Council
- state departments of agriculture and fisheries
- water authorities
- environmental protection agencies, and other environmental groups and agencies.

B3.6.6 Legislation and codes of practice

Relevant legislation is listed in Appendix 1.

B3.6.7 Occupational health

Occupational health issues to be aware of include:

- periodic use of chemicals and drugs
- use of heavy equipment
- potential threats to workers' health associated with collection, handling and disposal of dead, decomposing or diseased stock
- hazards associated with the location of farms on cold, fast-running rivers; these rivers are potentially dangerous for workers if they are required to enter them.

See Appendix 2 for information on seafood-borne disease in humans.

B3.7 Marine finfish hatcheries

The marine finfish hatchery industry sector in Australia uses semi-closed systems. The number of facilities is low, because of their high cost of operation, technical difficulty in their management and the level of demand for fingerlings. They culture both tropical and temperate species. Only a few are commercial hatcheries; the remainder are government research facilities. Very few farms use semi-closed systems for grow-out of marine fish. An exception is inland saline aquaculture research, which uses methodologies similar to those used for grow-out of native freshwater finfish (see Section B3.2) and is trialling aquaculture of estuarine and marine species such as bream, snapper and mulloway, as well as trout.

This section focuses on hatchery production of marine finfish. Table 9 lists the main species being investigated and their present status.

Table 9 Status of marine finfish species being used in semi-closed systems—Commercially grown-out species

Commercially grown-out species	Status
Australian bass (*Macquaria novemaculeata*)	Produced commercially in NSW and Qld for restocking for recreational fishing
Barramundi (*Lates calcarifer*)	Produced commercially in NT, Qld, SA and WA for grow-out and restocking for recreational fishing
Barramundi cod (*Chromileptes altivelis*)	Produced commercially in Qld for grow-out and the ornamental industry
Black bream (*Acanthopagrus butcheri*)	Produced commercially in NSW and WA for small-scale grow-out and restocking for recreational fishing
Coral trout (*Plectropomus leopardus*)	Produced commercially in Qld for grow-out
Cobia (*Rachycentron canadum*)	Produced commercially in Qld for grow-out
Estuary cod (*Epinephelus coioides*)	Produced commercially in NT and Qld for grow-out
Mangrove jack (*Lutjanus argentimaculatus*)	Produced commercially in Qld for restocking for recreational fishing
Mulloway (*Argyrosomus japonicus*)	Produced commercially in SA for grow-out, and in NSW and WA for restocking for recreational fishing
Snapper (*Pagrus auratus*)	Produced commercially in NSW for grow-out
Yellowtail kingfish (*Seriola lalandi*)	Produced commercially in SA and WA for grow-out, and in NSW for research in government laboratory

Table 10 Table 9 Status of marine finfish species being used in semi-closed systems—Experimentally reared species

Experimentally reared species	Status
Dolphin fish (*Coryphaena hippurus*)	Experimental larval rearing and grow-out in government laboratory and private sector
Golden snapper (*Lutjanus johnii*)	Experimental larval rearing and grow-out in government laboratory
King George whiting (*Sillaginodes punctata*)	Experimental larval rearing and grow-out in government laboratory
Southern bluefin tuna (*Thunnus maccoyi*)	Fingerlings produced in commercial hatchery, but none grown out
Striped trumpeter (*Latris lineata*)	Experimental larval rearing and limited grow-out in government laboratory
Summer whiting (*Sillago ciliata*)	Experimental larval rearing and grow-out in government laboratory
West Australian dhufish (*Glaucosoma herbraicum*)	Experimental larval rearing in government laboratory

B3.7.1 Practices

Marine fish hatchery production is a technically complex process, involving the provision of a live food chain consisting of microalgae, rotifers and *Artemia*, or copepods, followed by weaning processes using inert microdiets. Broodstock is either wild-caught or selected domesticated fish. Hormones may or may not be used to induce ovulation, and eggs are obtained by either hand-stripping or natural spawning in the holding tanks. Broodstock temperatures and photoperiods are generally manipulated to provide year-round spawning.

Developing eggs are generally incubated in fibreglass or polyethylene tanks of around 100 L, with upwelling water flow and light aeration. Hatched larvae are moved to fibreglass or polyethylene larval rearing tanks of 500–10 000 L before feeding. The larvae are very small and poorly developed at hatch, and are unable to digest artificial diets, initially surviving off the yolk sac reserves. Feeding is generally with enriched rotifers, followed by enriched *Artemia*, although copepods can be used and microalgae may be added to the tanks for the first 10 days or so in greenwater culture systems. Generally, there is a weaning stage at around 30 days after hatching (metamorphosis), during which the newly metamorphosed juveniles are trained to eat an artificial diet. Juveniles are reared in an onshore nursery facility with pumped sea water before transfer into net-pens, at a weight of around 20–50 g.

Grow-out is in net-pens (see Sections B2.3 and B2.5) and ponds, raceways or RAS facilities (see Section B2.4). Market size is reached at 2–3 years of age, depending on the species.

B3.7.2 Premises and equipment

Marine fish hatchery buildings are generally constructed from insulated concrete or galvanised steel frames. Sea water is pumped directly from the local area into a header tank(s) and gravity-flowed into the rearing area through a set of fine filters, often to 1 micrometre filtration (see Section B2.7). Disinfection with ozone and UV is common practice to minimise pathogen entry from source water.

There are generally separate areas for algal culture, rotifer culture, *Artemia* culture, egg incubation, larval rearing, and holding of broodstock. Tanks are constructed of fibreglass or polyethylene, sometimes concrete. In tropical areas, the algal culture unit may be outside.

B3.7.3 System inputs

Animals

Broodstock is either wild caught or selected domesticated broodfish. Although both sources may be subject to strict quarantine measures, they may still be carriers of infectious agents, such as nodavirus. Live feed organisms may be imported or harvested from ponds on-site. Wild harvest of feed organisms is unusual (see below). Any animal introduced from the wild (open systems) may be carrying covert infections that could be problematic in farming situations (semi-open, semi-closed or closed systems).

Water

Good-quality marine water is pumped directly from the ocean and used either as flow-through or recirculated water. Filtration down to 0.2 micrometres is required for the algal culture facility, while 1 micrometre–filtered or coarse sand–filtered water is used elsewhere. Some heating or cooling of water may be required; this generally occurs in recirculating systems to conserve energy. Recirculation, in particular, is used for larval rearing, nursery culture and broodstock holding.

Feed
Algal concentrates for live food used in some hatcheries are imported under Department of Agriculture permits that are assessed on a case-by-case basis. Copepods are native to Australia. L-type rotifers have been in Australia for many years, and S-type rotifers are imported from Japan. Both L- and S-type rotifers move regularly around the country, generally in sealed containers by airfreight. *Artemia* is imported as cysts from overseas, mainly from the United States.

Artificial diets and enrichment formulae for live feeds, larvae and early juveniles are imported from Japan and Europe under Department of Agriculture import permits. Grow-out diets are generally produced in Australia.

Personnel
Between 5 and 15 people are required to operate a marine fish hatchery, depending on the level of output. Hatchery production is very labour intensive and involves a broodstock team, an algal production team, a live-feed production team and a larval-rearing team, as well as administrative and security personnel.

Labour is required during normal working hours; staff on stand-by outside normal hours and a skeleton staff for weekends are also required. Many staff are highly trained scientists or people with commercial experience obtained overseas. Levels of commercial experience are increasing in Australia.

There are frequent visits from overseas scientists, sometimes conducting experimental work on-site, and fish health advisers.

Equipment
Equipment used includes fibreglass or polyethylene tanks, pumps, filters (including a 0.2-micrometre filtration system), nets, outlet screens, juvenile graders, microscopes, balances, and blood and ovarian sampling equipment. Most research facilities also have chemistry, histology and analytical laboratories, or have access to such facilities through collaborative arrangements.

All equipment is normally sterilised using a sterilising agent, such as chlorine, between uses. Each culture area is generally equipped with an air-conditioner that maintains a set temperature, or a heater–chiller unit to control water temperature in a narrow range.

Equipment from each area is generally kept separately and not used in the other areas, but this is not always the case.

Stores
A store is used to house enrichment formulae, yeast and formulated feeds, hormones, heparin, antibiotics, algal nutrient mixes, and chemicals such as chlorine and formalin.

Vehicles
The main vehicles entering hatcheries are fish transport tankers collecting broodstock from fishing vessels. Workers live off-site and drive private vehicles to work.

B3.7.4 System outputs

Animals
Movement of juveniles out of the nursery facilities and onto marine grow-out sites varies in frequency, depending on the species. Movement of barramundi occurs year-

round, whereas kingfish are mainly moved in early spring, to take advantage of the conditions for fastest growth during the warmer months of the year. Some movement of rotifers occurs because of the expense of continuous year-round maintenance. Some farms are finding it economically viable to import rotifers from larger establishments during spawning periods.

Water

Water from larval tanks contains ammonia, solid waste, microalgae, rotifers and *Artemia*. Water from juvenile and broodstock tanks contains ammonia and solid waste.

Waste materials

Waste materials include chemicals such as chlorine and formalin. Dead fish are normally held in a mortality freezer before disposal by incineration or burial.

Vehicles and equipment

The main vehicles leaving hatcheries are fish transport tankers transporting juveniles to farms. Workers live off-site and drive private vehicles to work.

B3.7.5 Groups involved

Groups involved in marine finfish hatchery operations include:

- the Marine Finfish Farmers Association of Western Australia
- the Australian Barramundi Farmers Association
- the South Australian Marine Finfish Farmers Association
- the Aquaculture Council of Western Australia
- the National Aquaculture Council
- state departments of agriculture and fisheries
- water authorities
- environmental protection agencies, and other environmental groups and agencies.

B3.7.6 Legislation and codes of practice

Relevant legislation is listed in Appendix 1.

B3.7.7 Occupational health

An occupational health issue to be considered is the periodic use of chemicals and drugs.

See Appendix 2 for information on seafood-borne diseae in humans.

B3.8 Freshwater crayfish

Crayfish are adapted to freshwater or damp terrestrial environments. The term 'lobster' is more properly reserved for related, but distinct, animals found in marine environments. A variety of species of crayfish may be farmed; they can be divided into smooth crayfish, spiny crayfish and burrowing crayfish. Species showing the best commercial potential are the smooth crayfish species: yabby (*Cherax destructor* and *C. albidus*), redclaw (*C. quadricarinatus*) and marron (*C. tenuimanus* and *C. cainii*). The relative suitability of each depends on locality, climate and fishery laws in a given area.

Currently, production of marron under aquaculture is 62 t, valued at $1.8 million; marron is farmed in South Australia and Western Australia. Redclaw is only farmed in quantity in Queensland, with 41 t valued at $0.8 million. Yabbies produced from a number of states total 48 t and $0.74 million. (All figures are for 2011–12 [ABARES 2013].)

Some other species of smooth crayfish are sometimes used for culture, mainly in northern New South Wales, southern Queensland and southern Western Australia.

Spiny crayfish, including Murray crayfish (*Euastacus armatus*), are found on the eastern seaboard of mainland Australia and in Tasmania. Some spiny crayfish grow to a large size, but all are unsuited to farming because they grow slowly, are aggressive among themselves and usually require higher water quality than can be provided economically under farming conditions. Burrowing crayfish are generally small and not considered to offer any potential for farming.

Most crayfish farming is semi-intensive or extensive and takes place in shallow in-ground ponds with no, or limited, regular water exchange. Stock is usually fed formulated foods similar to chicken pellets, which are made in Australia. Aeration to circulate water and prevent development of a thermocline is standard practice. Stocking densities may be increased with artificial aeration and the provision of suitable material for habitat.

Farmed crayfish are mostly offered for sale whole as a gourmet food. They may be either live or already cooked. Occasionally, processed products such as yabby paté or frozen tail meat may also be sold. Markets may be anywhere in Australia or overseas.

B3.8.1 Practices

The most suitable method of disease control may be determined by the mode of husbandry employed. Farming practices vary from business to business and with the type of plant, location of the farm, phase of production, species farmed and product offered for sale.

Species-specific requirements

Smooth crayfish are best adapted to conditions commonly found on farms. Yabbies and redclaw, in particular, are resistant to poor water quality. Low levels of dissolved oxygen are rarely fatal, and the crayfish may leave the water if oxygen levels drop significantly. Yabbies are adapted to temperate conditions, but can withstand very high water temperatures. Redclaw are adapted to tropical conditions.

Marron are more particular in their temperature and water quality requirements, and usually require lower stocking levels, and greater levels of aeration and water exchange. They are best grown in areas with an environment matching that of southern Western Australia.

There may be legal limitations on where a given species may be grown.

Yabbies and redclaw will breed readily in captivity and spawn repeatedly during the warmer months. Marron spawn only once a year, during spring, and require specific conditions before they will breed.

Yabbies are primarily produced somewhat opportunistically in extensive systems (often in pre-existing farm dams), whereas marron and redclaw are generally grown in purpose-built semi-intensive ponds.

Phases of production

There are several phases of production, which involve differient husbandry practices. Most crayfish farms undertake all stages.

Hatchery

Seed stock can be produced by natural reproduction or in a specialist hatchery. Yabbies, marron and redclaw will breed naturally in grow-out ponds but can also be produced in a hatchery. The fertilised eggs adhere under the tails of females for some time before hatching, and it is common practice to seed ponds by placing gravid females in the ponds and waiting for juveniles to leave. Removing eggs from gravid females and hatching them in a secure and sterile incubator environment has recently been successful.

Wild-caught broodstock may be introduced into the hatchery to maintain genetic diversity due to inbreeding, particularly for yabbies and redclaw. Some operations will buy stock or broodstock from neighbouring farms. Both these practices increase the risk of disease introduction. Redclaw farmers are now producing disease-free stock through artificial rearing of stripped eggs.

Nursery

In semi-intensive farming systems used for redclaw and marron, it is common practice to have dedicated breeding and nursery ponds. In contrast, it is not common to use a separate nursery stage for extensive yabby production. However, in some instances, seeded ponds are steadily flooded, increasing in size as the crop grows. The extra water provides more room for growing stock and provides a source of feed from freshly inundated pasture.

Grow-out

Grow-out is generally undertaken in outdoor earthen ponds. Under extensive conditions, there is a focus on encouraging algal growth for natural feed production, which requires the addition of NPK fertiliser. Clay turbidity is managed with the addition of alum sulfate and agricultural lime for humic turbidity. As farming intensifies (i.e. stocking and feeding rates increase), water exchange and aeration become necessary. However, the majority of farms operate at low densities, only requiring minor airlift aeration to reduce thermal stratification.

The presence of three-dimensional habitat in a pond increases surface area and survival, and is therefore beneficial to production. These ‘habitats’ or ‘shelters’ may be plastic that has been moulded specifically for this purpose, or may consist of mesh bundles, lengths of PVC pipe or various other available materials, such as used prawn trawler netting.

Harvest

The most common form of harvest uses ‘opera house’–style baited traps to remove larger animals 4–6 weeks before the main harvest. Traps are also used throughout the grow-out period to help remove the fastest growing marron. It is also common to harvest marron by draining ponds and collecting the crop by hand. Some farms drain harvest to a harvest pond, using a seine net or sock to catch stock (similar to prawn harvest techniques). Redclaw are most commonly harvested using a flow trap, as they have a strong instinct to walk into a current of flowing water.

An alternative method, where extensive ponds are difficult to drain, is to maintain a smooth bottom on the ponds and to use a drag net. This is quick but produces product with a relatively large number of injured individuals and is not suited to market requirements.

Purging

Crayfish are sold, cooked and eaten with gut intact. The quality of the product is improved if the gastrointestinal tract is depurated ('purged') before sale. This process improves the presentation of the product and means that no 'gritty black line' appears in the cooked tail. Crayfish also travel better as a live shipment when purged.

For extensive yabby farms, purging is often conducted at a central facility. Semi-intensive marron and redclaw farms have their own dedicated purging facilities. Generally, purging facilities are in open, flow-through tanks that are aerated and shaded next to ponds; they are usually not purpose-built facilities.

Purging is most effective if stock is held in cages under water spray or drip systems, or in well-designed tanks. Purging is generally natural, with the addition of salt for removal of external parasites, commensals and fouling. No other chemical agents are added.

Product at farm gate

In temperate areas, the growing season is from spring to autumn, whereas, in tropical areas, the growing season may be year-round. Yabbies and redclaw can generally be harvested at 40–90 g after one season. Marron will take two or more seasons to reach the target size. The majority of production is sold live.

B3.8.2 Premises and equipment

The type of premises and equipment used depends on the degree of intensity of farming. Farming of freshwater crayfish is undertaken in shallow in-ground ponds, with no or limited water exchange. Ponds may be covered with netting to prevent bird predation—this is good practice but expensive. Small boats may be used for access to water distant from the banks.

In some circumstances, farmers attempt to grow freshwater crayfish in very intensive systems. These are generally not commercial. Higher stocking densities and feed input require a much greater level of attention to maintenance of water quality. A higher level of water turnover is generally employed, and this may lead to the need for disposal of larger quantities of wastewater. Filter systems can be employed, but require continual maintenance. Intensive farming operations are usually in lockable sheds.

Little machinery is used in the process of farming, although small boats may be used to set and check traps. These boats may be transferred from pond to pond. The farmer may use a truck to move between locations. Other equipment used includes aerators, in-pond shelters, harvest traps or pots, flow traps, drag nets, purging systems (which may use cages), four-wheel motorbikes and fencing.

B3.8.4 System inputs

Animals

Seed stock may come from remote hatcheries and be translocated over a considerable distance. Disease organisms may arrive with this stock or in the transport water. If ponds are stocked using gravid females, the mother crayfish may also carry pathogens or commensals. In extensive farms, biota other than crayfish may become established in the open farm ponds. In most cases, farmers attempt to increase production of natural food by promoting an infusion of zooplankton, by flooding pre-grown pasture or adding material such as hay or pea straw.

In uncovered ponds, waterbirds may be attracted to the area and may defecate into ponds. Water rats, foxes and eels may also develop an interest in the crop. To secure ponds against overland movement of crayfish and predators, many semi-intensive farms erect secure perimeter fences, which are sometimes electrified.

Water

It is common practice to dry out ponds between crops, or at least at regular periods. In many circumstances, rainwater is used to refill ponds. Water may also be pumped from a local watercourse, groundwater or irrigation; in a few cases, it may come from a town water supply.

Ponds need water at other times, as well. Evaporation (the level of which depends on the local climate) may require ponds to be topped up to maintain levels. Water discarded during removal of wastes may also need to be replaced. As stocking levels increase, it becomes more important to provide a means of aeration and destratification, and to attend to water quality issues. In some instances, a fraction of the water may need to be replaced with new water to maintain water quality.

Feed and bait

Generally, crayfish are fed formulated pellet diets from local manufacturers. Lupins, maize and other grains are also used when locally abundant. Bait may be used to encourage animals to enter traps. This may be the usual feed, but may sometimes consist of cattle offal or dog food pellets.

Vehicles and equipment

Boats may be used for access to parts of the ponds remote from the bank. Four-wheel motorbikes, utility vehicles, 4WD vehicles, trucks and so on may be used by farmers to transport stock and gear around. Pots and traps from other locations may be introduced to the water for harvest.

Some operators will catch wild stock from farm dams to supplement their farm-grown supplies. This involves widespread movement of all harvesting and holding equipment.

B3.8.4 System outputs

Animals

Freshwater crayfish are generally kept alive after harvest, and generally the whole animal is presented for sale. They may be marketed live, either purged or unpurged, or processed on-site.

When water quality falls below an acceptable standard, freshwater crayfish are capable of walking away overland. This can happen at night and may not be readily visible. Some farmers use metal fences about 30 cm high.

In inadequately protected ponds, predators such as waterbirds, water rats and foxes may eat some of the crop and move away from the ponds for cover. Survival of individual crayfish is unlikely, but organic material may be transferred via the predator's gut.

Water

Most freshwater crayfish farms use ponds without regular water exchange. For more intensive levels of production, some water exchange may be desirable. Appropriate disposal of this water is necessary.

In overstocked or poorly managed ponds, there can be a water quality collapse. In this case, a large water exchange may be used to improve pond conditions.

Wastewater may be used to irrigate pasture or may be recycled back to the production ponds, after passing through a settlement pond. Very rarely is pond water discharged directly into waterways. Environmental protection legislation usually provides added incentive to irrigate or recycle. Effluent ponds are used on some of the larger farms for settling and reuse.

Waste materials

After several years' use, soil on the bed of ponds can become highly fertile and anoxic. It is generally good practice to dry out ponds and aerate the soil. In some cases, the soil may be removed and placed in other areas, where its high nutrient load may be considered beneficial. It is common practice, when drying ponds, to apply lime to the bottom. Some farms apply rotenone when refilling and before restocking with crayfish, to prevent predatory fish species from establishing in the pond.

Purging facilities may reuse or discard water. Solid wastes may accumulate in poorly designed or maintained facilities. Purging tanks are commonly cleaned and sterilised using sodium hypochlorite.

Personnel

Commonly, crayfish farmers walk into ponds or through damp mud at the margins. Materials may become attached to bare feet or footwear, and be transported in this way.

Vehicles and equipment

Crayfish are often harvested using a pot or trap, which may be removed from the water and stored in other locations.

If ponds are drain-harvested, shelter material that was in the water may be stored away from the pond. Old netting, traps or in-water shelter material may be discarded when it is no longer in use.

Boats may be transferred from pond to pond. Utility vehicles, 4WD vehicles, trucks or other motor vehicles may be used by the farmer to move between locations.

Water may be pumped, and pumps and hoses may retain water or mud.

B3.8.5 Groups involved

Groups involved in farming freshwater crayfish include:

- the Australian Freshwater Crayfish Growers Association (South Australia)
- the Australian Freshwater Crayfish Growers Association (Victoria)
- the Yabby Growers Association
- the Marron Growers Association of Western Australia
- the Yabby Producers Association of Western Australia

- the Queensland Aquaculture Industries Federation
- the Queensland Crayfish Farmers Association
- the Aquaculture Council of Western Australia
- the National Aquaculture Council
- the NSW Aquaculture Association
- state departments of agriculture and fisheries
- water authorities
- environmental protection agencies, and other environmental groups and agencies.

B3.8.6 Legislation and codes of practice

South Australian crayfish growers have a code of practice relevant to the sourcing of stock and pond construction, but not to disease issues. Yabby farmers in Western Australia have a code of practice for farming and handling yabbies, developed by the Yabby Producers Association of Western Australia and endorsed through the Aquaculture Council of Western Australia (frdc.com.au/research/Documents/Final_reports/1995-077-DLD.pdf).

Relevant legislation is listed in Appendix 1.

B3.8.7 Occupational health

The following occupational health issues need to be considered:

- The animals have powerful pincers and can inflict small, painful bites.
- Chemicals are not generally used for freshwater crayfish. External parasites and unsightly commensals are commonly found attached to crayfish.
- Copper-based compounds are highly toxic to crayfish and unlikely to be used.
- Pond mud is high in bacteria, so skin abrasions may become infected (see Appendix 2).
- Blue–green algae blooms may occur in crayfish ponds.
- Hydrated lime can irritate skin and eyes.
- Use of rotenone entails risks from inhalation, absorption through skin and swallowing.

B3.9 Abalone

Aquaculture of greenlip abalone (*Haliotis laevigata*) occurs in South Australia, Tasmania, Victoria and Western Australia. Blacklip abalone (*H. rubra*) are produced in Tasmania and Victoria. Greenlip and blacklip species can hybridise, and the hybrid, known as ‘tiger abalone’, is cultured in Tasmania and Victoria. Greenlip and brownlip (*H. conicopora*) abalone can also be successfully hybridised, and the hybrid is being produced in Western Australia. In warmer regions, Roe’s abalone (*H. roei*), ass’s ear abalone *(H. asinina*) and staircase abalone (*H. scalaris*) have been grown experimentally.

The cycle of production involves relatively few wild-caught or selected aquacultured broodstock, which produce larvae in a hatchery. The larvae are grown in special nursery areas, and then transferred to large, shallow concrete ponds with large volumes of flow-through sea water. The whole area is covered to reduce light and heat penetration.

The abalone aquaculture industry in Australia produced product valued at more than $19 million in 2011–12, with the bulk produced in South Australia, Tasmania and Victoria (ABARES 2013).

B3.9.1 Practices

Larvae produced in the hatchery are transferred to settlement tanks, where they settle onto surfaces covered with suitable food organisms (diatoms, some green algae). The nursery tanks are held in an area where sunlight intensity is controlled to allow some algal growth. The settled spat grow in these conditions for about 8–12 months to a size of 6–15 mm, when they are transferred to grow-out tanks. Spat may be transported overland by truck from hatcheries to grow-out sites.

Abalone are mainly grown in onshore tanks and raceways. Grow-out tanks are large, usually shallow tanks with a large surface area. Structures may be placed in tanks to provide shelter, but open-space systems with low light intensity permit easy cleaning, laminar water flow and ease of management, and are increasingly being used. The ponds are covered with shade cloth to limit sunlight exposure and prevent access by birds. Large volumes of sea water (in some facilities, more than 50 ML/day) are pumped ashore, usually after some filtration, passed through the abalone tanks and discharged. Grow-out of spat takes about two years; during this time, they may be sorted, graded and moved several times. Density in tanks depends on the size of the abalone.

Abalone in these systems are fed pellet diets sourced from Australian manufacturers or, more rarely, imported. Feeding rate is monitored by direct observation and adjusted regularly. Temperature and dissolved oxygen are monitored daily. Water exchange (inflow from, and outflow to, the ocean) is continuous.

Abalone are harvested by hand for further processing, usually at an off-site processing facility. Many abalone are shipped live to the Australian restaurant trade and overseas markets.

After harvest is complete, the pond is drained, cleaned and dried out.

B3.9.2 Premises and equipment

Abalone farms consist of 20 or more concrete, or high-density polyethylene (HDPE)-lined concrete, ponds. Each pond is 20–100 m^2 in area and 0.3–0.5 m deep. Inlet and outlet channels can be made of concrete culverts, plastic pipes or a combination of these. Generally, inlet channels run down the centre between rows of ponds, and outlet channels run around the outside perimeter of the ponds. Each pond has an inlet pipe, which can be closed off from the inlet channel, and an outlet pipe, which has an automatic overflow when the pond water level reaches a maximum height. Inlets are designed to ensure laminar flow of water through the entire pond. If lower levels of water are required, the outlet pipe can be adjusted right down to completely empty the pond.

Water is pumped up from the ocean by electric pumps into inlet channels. Continuous water flow is essential in most facilities because abalone are sensitive to high temperatures (>23 °C) and low oxygen levels. If water flow is interrupted, abalone may start dying within several hours. Pump size varies according to the number of ponds on a farm.

Buildings associated with a farm generally include a feed storage shed or workshop, a processing shed and a residence for a farm manager. Vehicles generally include four-wheel motorbikes, and a utility or 4WD vehicle.

Equipment

Equipment used includes nets, water quality meters, a microscope, harvest bags, insulated bins, cool rooms and a sorting table. Backup generators are essential.

B3.9.3 System inputs

Animals

Abalone spat may be reared on-site in a dedicated, segregated area. Larvae may be produced in a hatchery, which may be located near the grow-out facility or some distance from it. Since abalone larvae do not feed for a short time after hatching, they can be readily transported.

Broodstock may be wild caught or selected from the cultured stock. Broodstock is usually held in a separate facility, which may be contained within or adjacent to the grow-out facility.

Water

Water must be oceanic-quality sea water. Because of the large volumes of water required, only coarse filtration is possible. Sterilisation is only practical where smaller volumes of water are used, such as in the hatchery.

The preferred water temperature and depth vary among abalone species. Greenlip abalone prefer water temperatures of 12–24 °C; blacklip abalone prefer temperatures of 10–20 °C, although blacklip from areas such as Port Phillip Bay have a much greater temperature tolerance (8–26 °C). Both species can be found at depths of up to 40 m, below which food is limiting. Roe’s abalone prefer water temperatures of 14–26 °C and depths up to 4 m.

Feed

Cultured diatoms are used as food for newly settled larvae and spat. Diatoms are cultured on-site in sterilised sea water. Artificial feeds obtained from Australian feed mills are used for larger spat and grow-out. All abalone feeds contain some imported ingredients. Feeds for smaller abalone may be relatively high in protein (up to 35 per cent). The feed conversion ratio is variable, depending on feed and conditions, but may vary from 0.6 to more than 1.5.

Small quantities of feed are brought in to grow-out areas and stored close to where the feed is used. Some fresh algae may be used as a supplement in specific circumstances (e.g. conditioning). Abalone are fed daily.

Personnel

Farms tend to have strict control over entry of personnel other than workers and government officials. Casual visitors are discouraged.

Stores

Bulk feed is kept in a cool store. Generally, feed for several days is kept on hand. Fertilisers and other chemicals may be stored in small quantities, as they are usually brought in for immediate use.

B3.9.4 System outputs

Animals—primary product

The primary product is live or fresh frozen abalone. Sizes depend on the market and price—abalone from 30 to 150 g may be sold.

Abalone are harvested by hand direct from the pond, which allows on-site grading. An average harvest is 3–5 t/ha. Harvested abalone can survive up to 1.5 days out of water. The harvested product is moved within the farm from the pond to the processing shed, where the abalone are graded, sorted and packed into boxes for shipment.

Most Australian product is snap frozen or canned and exported to Asia, although increasing amounts are shipped live. Animals to be shipped live are normally not fed for up to three days, and are cooled to 8–12 °C to increase survival during transport. Frozen abalone are processed in a processing plant, and may be either sold in-shell or shucked and gutted before preparation for freezing or canning.

Live in-shell or shucked product may be sold directly to processing facilities, wholesale markets or, where local food regulations permit, local customers such as restaurants. It may be flown or trucked to its destination.

Secondary product and other animals

In the past, abalone gut was used as bait for fishing. This is now prohibited in most jurisdictions. Small amounts of shell may be sold for craft and decoration.

Water

Water is exchanged continuously through overflow along one side of the pond. Flow is designed to enhance self-cleaning of ponds to remove faeces and uneaten food. All facilities are potentially able to close off outflow of water, although this would result in death of stock, depending on how long the flow is stopped.

Water may be held in a settlement pond for a short time before discharge, or discharged directly into the sea. Discharges are sited to minimise contamination of pumped inflow water and may be some distance offshore. Farms must comply with state environmental legislation relating to water discharge. As abalone are quite mobile, some may escape into outlet drains, where mesh and other obstacles prevent their escape into the wild.

Waste material

Dead abalone are collected from the pond bottom every day by staff, and buried on-site or disposed of in municipal waste systems. Uneaten food, faeces and other wastes from the abalone may be captured in sediment ponds or discharged back to the ocean under permit from environmental agencies, as part of the farm's aquaculture permit.

Equipment

Each pond usually has its own brooms, nets and other equipment, although some equipment may be shared between ponds. Sanitation baths for sterilising equipment are spread throughout the facility.

B3.9.5 Groups involved

Groups involved in abalone aquaculture include:

- the Australian Abalone Growers Association
- the Tasmanian Abalone Growers Association

- the South Australian Abalone Growers Association
- the Victorian Abalone Growers Association
- the National Aquaculture Council
- state departments of agriculture and fisheries
- environmental protection agencies, and other environmental groups and agencies.

B3.9.6 Legislation and codes of practice

Each hatchery normally establishes its own protocols and manual of standard operating procedures, which include hatching techniques, sanitation, grow-out and standard methodology. Farms comply with state or territory legislation relating to aquaculture and specific conditions for abalone, which include specifications regarding translocation of stock, quality of discharge water, and operating procedures.

B3.9.7 Occupational health

The following occupational health issues should be considered:

- Farm machinery can be dangerous if used without due care.
- Pond surfaces may be slippery.
- Collection, handling and disposal of dead, decomposing or diseased stock may pose threats to workers' health.
- Working in enclosed spaces may be required and needs special training.
- Workers may need to prepare and apply chemical treatments, which could pose threats to their safety.

Information on seafood-borne disease in humans can be found in Appendix 2.

B4 Closed systems

B4.1 Overview of closed systems

A closed system is characterised by the following:

- Premises are easily quarantined from the wider environment.
- Premises are usually relatively small and contained in a shed or under cover.
- Stock is easily confined and accessed.
- Minimal water exchange occur; most systems use mechanical and biological filter systems.

Closed systems provide the opportunity to closely control environmental variables. Hence they can be operated virtually anywhere in the country. The capital and operating costs of these facilities may be greater than for equivalent production in semi-open and semi-closed systems, depending on location. However, this is partly offset by the ability to locate such facilities in peri-urban areas, defraying some transport costs, and allowing supply to the high-value live fish market sector.

The industry sectors that use this husbandry system can be divided into three main groups: ornamental aquatic animals, the live animal trade (excluding ornamental animals), and food fish hatcheries and grow-out facilities.

B4.1.1 Ornamental aquatic animals

Breeding and supply of ornamental animals to wholesale and retail outlets, and direct sales to the public are a large and diverse industry. Transport for ornamental fish is via standard plastic bag (1/3 water and 2/3 oxygen). Transport is mainly via air according to International Air Transport Association standards.

The operators involved are:

- breeders (commercial and hobbyists); there is also a growing level of trade between hobby breeders via internet forums
- collectors (wild harvest)
- importers
- wholesalers
- zoos and parks.

B4.1.2 Live animal trade (excluding ornamental animals)

Collection, holding and shipping of live animals, principally for the restaurant trade, is a significant industry. Animals can be wild caught or from aquaculture farms. The operators involved are:

- collectors (wild harvest)
- producers (aquaculturists), including producers of barramundi, silver perch, Murray cod and jade perch
- transporters (using oxygenated tanks on trucks or trailers)
- restaurants or markets (with display aquariums on the premises).

B4.1.3 Food fish hatcheries and grow-out facilities

Larvae or fingerlings are produced to supply commercial grow-out ventures, farm dams and government restocking programs. The operators involved are:

- commercial hatcheries
- intensive grow-out facilities.

B4.1.4 Interactions between closed systems and the environment

Relatively little interaction occurs between closed systems and the environment, because much of the water is recycled with the use of mechanical and biological filtration. Health and survival of the stock within the closed system are highly dependent on water quality, which is controlled mainly by the filtration system, rather than water exchange. In considering the operation of a closed system, it is important to consider the operation and interlinkages of the filtration system(s).

In some ways, the filter itself can be regarded as a living organism. Biological filters use microbial populations to convert toxic nitrogenous wastes into non-toxic compounds. To provide a sufficient area of substrate for the microbial community, the filter is made up of a matrix with a large surface area (such as shells, plastic or ceramic media), through which there is a constant flow of water.

In many facilities, the wastewater produced is either diverted to a settlement pond or emptied into urban sewerage systems. The potential for farmed animals to escape from this type of system is minimal. Many farms are contained entirely within an enclosed building, thereby reducing the role of predators in spreading disease.

B4.2 Ornamental aquatic animals

A large range of native and exotic finfish species are cultured for the ornamental industry. The majority of ornamental species are imported freshwater fishes, although an increasing number of enterprises are culturing marine species such as clown fish.

Enterprises include small backyard operations in domestic residences, large commercial farms operating intensively in large buildings, extensive pond systems on properties in rural or semi-rural locations, and large wholesalers or importers operating in warehouses in urban and industrial areas.

B4.2.1 Practices

Outdoor pond culture

Goldfish and livebearers are generally produced in earthen ponds (100–500 m^2) or in above-ground tanks (usually around 5000 L). Water is generally sourced from bores, dams or creeks, and is recycled via settlement ponds back into the systems or used for crop irrigation (see Section B3.2). In the case of outdoor pond culture, the fish spawn in the ponds, and the eggs are usually removed to other ponds to hatch and on-grow for sale.

Indoor culture

Most other species are kept and cultured indoors. Indoor culture ranges from the hobbyist with 10–100 aquaria in a shed or room of their house to the commercial breeder with a custom-built, temperature-controlled facility. Water is generally sourced from domestic mains or, in the case of larger enterprises, bores or springs. Initial and replacement stocks are obtained from either the wild, other breeders, aquatic animal wholesalers or retail outlets. For indoor culture, spawning takes place in small tanks. At a suitable time (depending on the species), the offspring are transferred into grow-out tanks, where they are held until sold.

Quarantine facilities

Several medium and large-scale importers of ornamental fishes operate quarantine facilities that meet the Australian Government's Quarantine Approved Premises (QAP) criteria 7.1 (Fresh Water and Marine Ornamental Fin Fish)(www.agriculture.gov.au/import/general-info/qap/class7/class-71-ornamental-fin-fish). QAP criteria 7.1 outline the requirements for premises that are used to hold imported live fish while under quarantine. The criteria cover requirements for location of premises, identification and construction of the quarantine area, operational guidelines, work practices, disinfection, disposal of wastewater and solids, reporting of disease to the Department of Agriculture, testing, treatment of fish, disposal of fish, maintenance of offices and records, and other administrative requirements.

B4.2.2 Premises and equipment

Stock is usually held in glass or acrylic aquaria, but fibreglass, moulded plastic and concrete tanks are also common. Sizes vary depending on the species farmed; 60–80 L is a common volume for a glass aquarium.

The premises normally comprise a single shed with office, laboratory, packaging and store areas. Many premises have a small, equipped workshop, often associated with the owner's house. A covered outside area may be used for culture at ambient water temperatures. Retail premises are similar to wholesale operations in many details of design and operation (except for scale), but also have public access.

Power, water and sewerage connections are standard, and hot water is often available. If marine species are cultured, the sea water is pumped from the sea nearby, or carted by truck or trailer in 1–10-tonne tanks. Air supply to tanks is usually from a central air blower with backup. Air and water plumbing is usually constructed from PVC and/or polypropylene.

Biological filters, sand, cartridge and carbon filters, and protein skimmers are normally required. This equipment may be central to the whole facility, connected to only part of the facility or confined to individual tanks. The connection plan of the filters is a very important factor in potential pathogen spread and control responses. Backyard operators often have a poor understanding of the correct plumbing assembly.

Buckets, hand nets, and screens of various pore sizes and materials (nylon and cotton) are routinely used. Larger businesses often have a small laboratory or clean area with microscopes, weighing balances, glassware and so on for maintaining algal cultures. Pumps often include large water pumps (and associated plumbing) to extract water from the sea or a bore, and reticulate it through the facility, and numerous small water pumps for water flow in recirculating tanks.

Details for construction and operation of QAP are contained in QAP criteria 7.1.

B4.2.3 System inputs

Animals

Introduction of animals onto the site will depend on the species farmed. Initial breeding and replacement stock can be obtained from other breeders, imported or wild caught. Many ornamental fish producers breed most stock on-site. Some farmers endeavour to maintain closed stocks to minimise disease introductions, whereas others regularly bring in new broodstock to acquire desired characteristics and keep up with changing trends.

Feed

The majority of hobbyists use prepacked and imported dry foods. Commercial producers usually use dry pelleted or flaked feed obtained from local feed mills.

Juvenile and adult fish are fed either dry flakes or pellets, and/or a mixture of beef heart, vegetables, mineral/vitamin premix, rolled oats and other ingredients. For marine animals, a mixture of fresh and frozen baitfish, prawns, molluscs and vegetables is common. This type of feed may be obtained from the local bait supplier.

For some species, algae are grown and fed to zooplankton (rotifers, daphnia, copepods), which are then fed to the larval stages of the species farmed. *Artemia* (brine shrimp) is a common zooplankton used; it is often imported as cysts.

The amount of dry food fed per day is approximately 5 per cent of the bodyweight of the animal. Feed is stored on-site in storerooms (temperature controlled in the tropics), freezers and fridges, usually only in small quantities.

Chemicals are stored on-site in small quantities; they include chlorine, sodium thiosulfate, formalin, antibiotics, malachite green, methylene blue, and salts and fertilisers for algal production. Chemical use in quarantine facilities is highly regulated—sensitivity testing is required before use of antibiotics and disinfectants, which must be approved by the Australian Pesticides and Veterinary Medicines Authority or used under veterinary guidance.

Water

Water quantity and quality, including temperature and salinity, are normally well controlled. In many premises, water, particularly sea water, is filtered through sand filters or similar. Potable water (town supply) is often filtered through carbon filters and/or aerated to remove excess chlorine. Bore, stream, dam or spring water may also be used. Some marine businesses reconstitute their sea water using salts and town water.

Disposal of wastewater in quarantine facilities must meet conditions specified in QAP criteria 7.1.

Personnel

The industry has many part-time one-person operators. Most enterprises are a small family business employing fewer than four people. Staff are usually skilled and are normally involved in all aspects of production.

Vehicles

Most staff have a vehicle. Larger businesses may have utilities, 4WD vehicles or vans to transport stock or stores. Marine businesses may have a trailer with a tank for carting sea water.

B4.2.4 System outputs

Animals

Juveniles or adults are sold depending on the market requirements (size, colour, sex) for that species.

B4.2.5 Groups involved

Groups involved in farming of ornamental aquatic animals include:

- the Pet Industry Association of Australia (PIAA)
- the Australian Government Department of Agriculture
- the National Aquaculture Council
- state and territory departments of agriculture and fisheries
- water authorities
- environmental protection agencies, and other environmental groups and agencies.

B4.2.6 Legislation and codes of practice

Relevant codes of practice include the PIAA *Code of Practice for Aquarium Operations* and the PIAA *National Code of Practice.* Both codes of practice are available to members at the PIAA website: piaa.net.au.

Information on relevant legislation can be found in Appendix 1.

B4.2.7 Occupational health

The following occupational health issues need to be considered:

- Periodic use of chemicals and drugs requires safety precautions.
- Some species of ornamental fish have venomous spines, which require extra care during handling.
- Particular care should be taken handling sick or dead fish, as they can transmit some zoonotic pathogens.

See Appendix 2 for information on seafood-borne disease in humans.

B4.3 Native freshwater finfish

Several enterprises use closed water systems for intensive grow-out of native freshwater finfish such as barramundi, Murray cod, eels and jade perch. The scale of these operations varies from small backyard operations located on domestic properties to large commercial farms operating intensively in large buildings.

B4.3.1 Practices

Most enterprises undertaking intensive grow-out of native finfish do so in purpose-built indoor facilities. Water is generally sourced from domestic mains or, in the case of larger enterprises, bores or springs. Fingerlings may be produced on-site in a separate hatchery in vertically integrated establishments, but are more commonly sourced from commercial fingerling suppliers. The fingerlings are grown out for various periods until they reach market size, when they are sold.

Some farms use hydroponic systems to reduce nutrient loading of the water and provide an additional source of income. Other farms use wetlands to strip nutrients and recycle water back to the fish.

B4.3.2 Premises and equipment

Stock is held under cover in fibreglass, moulded polyethylene or concrete tanks. Tank volumes vary between 500 and 10 000 L, or even larger, depending on the size and design of the facility and the species farmed. The premises normally comprise one or more sheds with office, laboratory, packaging area, pump house, workshop, store areas and sometimes hydroponic systems.

Power, water and sewerage connections are scaled to meet the flow requirements of each facility. Air supply to tanks is usually from a central air blower with backup; alternatively, bulk oxygen sources may be used, with a variety of injection techniques. Air and water plumbing is usually constructed from PVC and/or polypropylene. Where liquid oxygen is used, copper or stainless-steel lines may be used in high-pressure and/or low-temperature areas.

Biological filters, drum filters for removal of suspended solids, foam fractionators and protein skimmers are normally required. They may be central to the whole facility, connected to only part of the facility or confined to individual tanks. The connection plan of the filters is a very important factor in potential pathogen spread and control responses.

Grading and harvesting is usually undertaken by draining tanks, anaesthetising fish, and using hand nets or fish pumps. Fish may be graded by hand or using mechanical grading equipment.

Trucks are used to transport feed to the farm and harvested fish to processing facilities. Special trucks are used to transport fingerlings to the site and live product to customers. Forklifts are commonly used to transport feed and fish tanks, and perform other routine lifting tasks.

Backup diesel electricity generators are often wired into alarm systems that activate when mains power fades or fails. Complex alarm systems are common in larger farms to alert the farmer to low oxygen levels, reduced water flows, low tank levels and other equipment failure.

B4.3.3 System inputs

Animals and plants

Introduction of animals onto the site will depend on the species farmed. Broodstock may be held on-site, and fingerlings may be produced in an on-site hatchery. The majority of grow-out systems fly in fingerlings from commercial hatcheries under strict guidelines from state authorities.

Farms using hydroponic systems to reduce nutrient loading of the water may also introduce plant seedlings from on-site nurseries or off-site commercial suppliers.

Feed
The majority of farmers use dry extruded pellet feed obtained from Australian feed mills, which use local and imported ingredients, such as fishmeal and fish oil. Feed is delivered by commercial freight companies. Juvenile fish may be fed exclusively on imported feeds. Larger farms commonly use a range of autofeeder technologies to optimise feed delivery to the fish.

Water
Water quality and quantity are normally maintained within certain limits. Variables under control include temperature, dissolved oxygen, hardness, alkalinity, pH, ammonia, nitrite, nitrate and salinity. Nutrient levels in the water are controlled using periodic water changes or hydroponic systems. In many premises, water, particularly sea water, is filtered through sand filters or similar. Potable water (town supply) is often filtered through carbon filters to remove excess chlorine. Bore, stream, dam or spring water may also be used. Some farms use ozone and liquid oxygen, which are both highly flammable and potentially toxic.

Personnel
Most of these enterprises are small businesses, employing fewer than 10 people. Staff are usually skilled and normally involved in all aspects of production.

Vehicles
Most staff have a vehicle. Larger businesses have a utility, 4WD vehicle, truck or van to transport stock or stores. Live transport vehicles may be shared between operations.

Stores
Feed is stored on-site in store rooms (temperature controlled in the tropics), freezers and fridges. Chemicals, such as chlorine, sodium thiosulfate, formalin and salts, may be stored on-site. Bottled backup oxygen and oxygen diffuser stones may also be stored on-site.

B4.3.4 System outputs

Animals and plants
Finfish product is sold live to markets or directly to restaurants. It may be sold whole iced or head on, gilled and gutted (HOGG), depending on the demand for the particular species. Some smaller enterprises may sell product to the public at the farm gate. Some larger recirculating aquaculture system enterprises undertake on-farm processing to manufacture smoked products.

Plant products are sold into markets or directly to retail outlets.

B4.3.5 Groups involved

Groups involved include:

- the Australian Barramundi Farmers Association
- the Victorian Warmwater Aquaculture Association
- the South Australian Aquaculture Council
- the Aquaculture Association of Queensland
- the Queensland Aquaculture Industries Federation
- the National Aquaculture Council

- state and territory departments of agriculture and fisheries
- water authorities
- environmental protection agencies.

B4.3.6 Legislation and codes of practice

Relevant codes of practice are:

- the Australian Barramundi Farmers Association *Post harvest handling code of practice.* Available to members at www.abfa.org.au/quality.html.
- the Aquaculture Association of Queensland's *Industry environmental code of best practice for freshwater finfish aquaculture* (www.daff.qld.gov.au/__data/assets/pdf_file/0004/65227/7-NFHITF-Fresh-Water-Finfish-Code-of-practice.pdf).

Information on relevant legislation can be found in Appendix 1.

B4.3.7 Occupational health

The following occupational health issues need to be considered:

- Periodic preparation and administration of chemicals and drugs requires safety precautions.
- Frequent exposure to high nutrient loads can result in high bacterial counts in water, increasing the risk of infection of cuts and other open wounds.
- The combination of water and electricity requires a thorough understanding of risks. Approved electricians should be involved during build installations and maintenance.
- Some farms use ozone and liquid oxygen, which are both highly flammable and potentially toxic. Adequate safety precautions should be taken.

See Appendix 2 for information on seafood-borne disease in humans.

Section C Response options

C1 General principles

C1.1 Introduction

This section of the Enterprise Manual deals with the responses involved in managing a disease emergency. It presents the general factors to consider in assessing response options, and a summary of available response options. It also includes information specific to the four systems covered by this manual.

Responses may range from simply monitoring the situation while further information is being collected to quite drastic measures if the presence of a significant exotic pathogen is confirmed.

A number of factors should be considered in assessing the situation and deciding on the most appropriate response option—many apply to any aquatic animal disease emergency, whereas others apply only to specific situations. For any aquatic animal disease emergency, it is likely that an emergency management taskforce will be established. The taskforce will make decisions based on available information and will liaise with the local disease control centre. See the AQUAVETPLAN **Control Centres Management Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan) for further details.

Each of the options discussed in these manuals could be used to varying degrees and in any combination, depending on the:

- aim of operations (control or eradication)
- nature of the disease
- aquaculture systems involved
- location of the outbreak
- economic impact on industry
- impact on the local environment.

The strategy adopted to control a disease outbreak is often dynamic, changing as more information is received on the disease agent, its likely spread and the types of facilities affected. An outbreak that starts as a disease within a closed system can easily become a disease within an open system, and vice versa. Industry, state and territory, and national groups will also need to consider:

- the cost of action or inaction
- lost production time and disruption to industry
- possible environmental impacts
- possible occupational health and safety impacts
- impact on public access and activities
- potential for, and consequences of, failure to control the outbreak.

General benefits of effective management of an emergency disease outbreak include:

- maintenance of consumer confidence
- minimisation of trade disruption
- maintenance of long-term productivity (through decreased mortality and morbidity, and maintenance of trade access)
- minimisation of ecological and environmental impacts of disease spread.

Containment (requiring prompt action) may have an advantage over more extensive control or eradication programs, in terms of the cost of control and lost productivity.

In addition to management of the disease outbreak, management of public risk should be considered—for example, through announcements that rotten fish can constitute a public health risk. See Appendix 2 for information on seafood-borne diseases in humans.

The following sections summarise the factors to consider in assessing the response options, and the response options available during an aquatic animal disease emergency.

Following the incident (after stand-down of the emergency response), the review process may indicate or recommend modification of practices, to assist in avoiding or controlling similar outbreaks in the future.

C1.2 Factors to consider in assessing the response options

C1.2.1 Stage of the disease outbreak

- How long has the outbreak been active?
- Has the agent already spread?
- Are wild populations involved?

This information will help to determine whether control is warranted and, if so, how it should be approached. The level of containment will be system specific. If the outbreak has been occurring for some time without any containment, attempts at control are unlikely to be successful, especially in non-closed systems.

An epidemiologist should be engaged at an early stage in the assessment process.

C1.2.2 Disease agent epidemiology, biology and stability

- Has an infectious agent been identified?
- How much is known about the epidemiology and biology of the agent? For example, what is the host range?
- Which species are susceptible to disease?
- Are vectors a concern?
- How well does the agent survive in the environment?
- To which disinfectants is the agent susceptible?

Appendix 4 provides further information on reportable disease agents.

C1.2.3 Site-specific features

- What is upstream and downstream of the affected site?
- What are the construction materials of the holding structures?
- Is there a facility to hold effluent water?
- Is there a facility to harvest or treat animals on-site?
- Can water input and/or output be controlled?

These factors will influence the choice of methods for control and indicate the likelihood of spread. A further source of infection may be identified if other facilities share the same water. The construction materials of the structures on the site will determine the type of disinfection procedures that are possible.

C1.2.4 System management practices

- What hygiene practices are already in place?
- What emergency procedures are possible within existing procedures?
- Are there legislative requirements, or requirements of the Department of Agriculture?

The site may have a contingency plan already, which will assist management of the disease. Information on hygiene practices should be obtained from the site manager. A supply of disinfectant may be available on-site for early response. The staff may already have training in skills useful in a control programme (e.g. drug treatment, fish bathing). Records of water quality, and inputs and outputs from the facility may be available on request. Some sampling equipment (e.g. boats, nets) may already be available on-site.

Legislative or Department of Agriculture requirements may need to be considered when working in Quarantine Approved Premises (QAP).

C1.2.5 Proximity to other establishments or natural environments with vulnerable species

- If the disease agent has not been contained, what other aquatic animal populations are at risk?
- How can the outbreak be contained?
- What are the implications of the presence of other aquatic animal populations for the likelihood of success of a control program?
- What monitoring could be undertaken in potentially exposed populations?
- Are divers required to sample fish at the site or in the outside environment?

Much of this information is likely to be available from local or regional state/territory fisheries or agriculture officers (see Appendix 5 for contact numbers). Sampling equipment and reagents (e.g. fixatives, transport media, bacteriological plates, dissection equipment, nets) are likely to be available at state or territory central veterinary and fisheries laboratories.

C1.2.6 Stage of development of affected stock

- How much investment is at risk?
- What is the value of the stock?
- Can the animals be emergency harvested?
- Can diseased and unaffected fish be separated to allow grow-out of healthy animals?
- Can an emergency-harvested product be processed on-site to a safe form, or will transportation protocols be required to carry it to processing plants?
- Can healthy or exposed product be sold for human consumption on domestic or international markets?
- Where several shipments of ornamental fish exist in a QAP facility, what happens to a shipment that is not affected? Is there a mechanism to move these animals out to prevent their contamination?

Information on suitability for human consumption of emergency-harvested animals may require input from health agencies (contact the chief medical officer of the relevant state or territory) and seafood quality assurance programs (contact the central office of the state or territory fisheries agency). Permission to transport affected stock and equipment off-site should be sought from the state or territory chief veterinary officer.

C1.2.7 Effectiveness of treatment, vaccination and control measures

- Are any treatments available?
- What is the likelihood of 'carrier' animals remaining in the population?
- What are the withdrawal periods for any drugs used?
- Does treatment have any environmental implications?

The local environmental protection agency may need to be consulted if disinfectant and drug treatments are used. Most viral diseases cannot be treated effectively. The state or territory chief veterinary officer and the Australian Pesticides and Veterinary Medicines Authority should be consulted about emergency use of antibiotics or parasiticides. Refer to Appendix 6 for further information on treatments for reportable diseases.

C1.2.8 Implications of the disease and control measures for industry and trade relations

What are the implications of either control or eradication strategies:

- – to the industry?
- – to other industries?
- – to the environment?

Since trade occurs both nationally (interstate) and internationally, both state/territory government and Australian Government officers will need to be involved in discussions concerning trade issues. These issues are most likely to be addressed at the state/territory and national level, rather than at a field officer level; however, communication between all levels is necessary to ensure coordination.

C1.2.9 Cost of control

What is the cost–benefit ratio:

- – in the short term?
- – in the long term?

- How long can a control programme stay in place before it becomes untenable?

These issues are likely to be decided at a high level (e.g. director of fisheries or chief veterinary officer), but advice may be sought from field operatives, aquatic animal health advisers and industry representatives. Communication between levels is necessary to ensure coordination.

C1.3 Response options

C1.3.1 Responses requiring no disruption to regular operations

When very little information is available (e.g. it is unclear whether the emergency is due to an infectious agent or some environmental factor), regular farm practices should be continued. This includes maintaining a health monitoring programme and other activities, such as harvesting and grading. As more information becomes available, a more active option may present itself.

C1.3.2 Responses requiring some disruption to regular operations

The following responses may require extra resources—such as equipment, materials, personnel and time—both for the state or territory authorities and for the producer.

Increased vigilance

Increased vigilance is required to ensure that optimal environmental conditions are maintained at the facility. If an infectious agent is present, minimising stress on the affected aquatic animals by optimising environmental conditions can reduce the impact of the infection and even prevent the occurrence of disease (clinical signs and mortality).

Stress on the animals can be minimised by decreasing stocking density, reducing handling to the minimum level practical to the situation and ensuring good water quality. Special attention should be given to suspended solids, dissolved oxygen, temperature, pH, and ammonia and nitrite levels. Past records of these parameters may be available from the farm manager or owner.

Movement control

To control spread of the disease agent, movement to and from affected sites should be controlled—that is, quarantine should be imposed. Quarantine is a method of restricting access of people and materials into a dangerous site, and restricting movement of dangerous items to the outside environment. Control does not necessarily mean prohibiting movement; it may involve movement by permit, or following drug treatment and/or disinfection. Each of the following should be considered for control:

- primary aquatic animals (e.g. farmed stock)
- vectors
- secondary aquatic animals (animals other than the farmed stock)
- birds and other wildlife (e.g. water rats)
- personnel
- equipment
- water (incoming and effluent).

Treatment

Treatment may be available for some diseases (e.g. diseases caused by parasites and bacteria). The current state of chemical registration should be checked to ensure that any chemicals are used according to current regulations. The cost of treatment also needs to be considered.

Refer to Appendix 6 for information on available drug therapies and protocols for obtaining temporary permits for emergency use of drugs. For many diseases (e.g. most viral diseases), treatment of infected stock is not an option.

Disinfection of farm equipment and other fomites may be appropriate when items are to be moved onto or off the affected site. Disinfection of personnel moving onto or off the affected site and during final clean-up at the conclusion of the emergency situation should be considered. Disinfection protocols are available in the AQUAVETPLAN **Decontamination Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan).

Information on the following categories of treatment should be collected:

- chemical therapeutics (e.g. immunostimulants, antimicrobials, parasiticides)
- vaccines
- disinfection.

C1.3.3 Responses requiring major disruption to regular operations

In some instances (e.g. exotic disease incursion), it may be possible to undertake a stringent control or eradication programme to protect unaffected premises, the industry sector and the environment.

Isolation of premises

For some systems, it may be possible to isolate the affected premises to protect other operations and/or wild populations. Isolation of QAP is relatively straightforward. Isolation of other types of affected premises can be achieved using:

- voluntary and legislative means (see Appendix 1)
- disinfection of incoming and effluent water
- prohibition of stock movements onto and off affected premises
- controls on movement of equipment and personnel onto and off affected premises; disinfection may be required.

Extra personnel are required to oversee movement restrictions. The state or territory chief veterinary officer or director of fisheries would be consulted on these matters.

Relocation of stock

Facilities may be available to enable either isolation of the infected stock from unaffected populations or isolation of unaffected stock from the infected animals. Permission for this action should be sought from the chief veterinary officer or director of fisheries.

Laboratory testing based on valid epidemiological sampling may be required to prove freedom from disease in stock to be relocated. The potential for false negative or false positive results should be considered.

Destruction of stock

The most serious response option, destruction of stock, has to be considered in some circumstances—for example, a serious disease outbreak involving nationally listed or OIE-listed diseases. In this approach, diseased and untreatable animals would be destroyed; ‘in-contact’ animals may also need to be destroyed. See the AQUAVETPLAN

Destruction Manual (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan) for more details.

Exposed, clinically affected and subclinically infected animals may be used (emergency harvested) to recoup some investment, depending on public health and trade issues. In some systems, animals other than the primary product may also be exposed and/or infected and need to be considered. Options are:

- for primary aquatic animals (farmed stock)
  - emergency harvest and sale
  - emergency harvest, evisceration or other risk reduction measures (e.g. cook on-site and sale), as appropriate,
  - destruction, removal and disposal (or burial or ensilage on-site)
- for secondary aquatic animals (cohabiting non-farmed animals)
  - destruction, removal and disposal (or burial or ensilage on-site); see the AQUAVETPLAN Disposal Manual (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan) for more details.

For stock in QAP, fish must be disposed of according to the requirements of QAP criteria 7.1 (www.agriculture.gov.au/import/general-info/qap/class7/class-71-ornamental-fin-fish).

Reopening the affected facility

Another aspect to be considered is the mechanism for reactivating the affected farm or quarantine facility. How soon after decontamination can it start operating? How can this be facilitated to ensure minimal economic loss?

C2 Open systems

C2.1 Introduction

Read Section C1 before reading this section.

The response options available in open water systems may be limited, especially in ocean and estuarine waters. Oceanic and estuarine systems are the least controllable, with respect to both water and animal movement. Responses may be restricted to damage control of market impact or reduction of spread through human activity. Other options may include wild stock reduction or segregation, which could be warranted in specific circumstances—its feasibility is strongly influenced by the level of mobility of susceptible species.

C2.2 Factors to consider in assessing the response options

C2.2.1 Stage of the disease outbreak

In open systems, where it is unlikely that active surveillance is operating, detection of a disease outbreak relies on reports of dead or dying fish from the public or fisheries officers. If there is a latent or lag period before visible sickness, the disease agent will have had time to spread and infect new hosts, or spread to other areas before measures can be implemented to manage its spread. It is likely that significant numbers of fish would be involved (e.g. pilchard mortalities in 1995 and 1998, oyster mortalities after the emergence of Pacific oyster mortality syndrome) and that the infectious agent will be at relatively high levels within the aquatic environment when there are large numbers of infected and dying animals.

C2.2.2 Disease agent epidemiology, biology and stability

The success of possible response options will depend largely on the natural rate of spread of the agent. This will be determined by the:

- course of the infection
- transmissibility and persistence of the agent
- mobility of the host or hosts, including vectors.

To assess response options, identification of the agent, and its natural hosts and vectors is needed. Experience has shown that, even in confined stocks, a readily transmitted agent such as infectious haematopoietic necrosis virus is likely to spread (as a clinical infection) to all net-pens on a farmed site within 2–4 weeks. It may spread at least 10 km in open, unrestricted water flow, but is less likely to spread to areas outside the water flow. Spread may be facilitated via infection of other non-salmonid fish species, although scientific data are lacking on such spread, and on susceptible and potential carrier species.

C2.2.3 Site-specific features

Natural physical or behavioural barriers may inhibit the spread of waterborne infection and stock migration. For more mobile species, or infections readily spread through water transmission, zones for monitoring and movement control will need to reflect natural barriers to water flow, such as headlands, water movement channels, and migratory limits of the infected stocks and possible carrier species.

C2.2.4 System management practices

Possible response options may depend on the structure and operation of an industry. Information on these factors is presented in Section B (Industry sector information). The feasibility of limiting recreational activities may affect the likelihood of success of response activities.

C2.2.5 Proximity to other establishments or natural environments with vulnerable species

It is important to maintain communication with other management authorities and industries (such as aquaculture industries), especially if vulnerable species are located in the path of spread. This will allow industry and management authorities to prepare for a possible incursion of an infectious agent.

C2.2.6 Stage of development of affected stock

The age of the affected stock may have implications for catch rates and stock recovery. It may also influence future catch limits or temporary fishery closures imposed on industry or recreational fisheries.

C2.2.7 Effectiveness of treatment, vaccination and control measures

It is unlikely that any treatment or vaccination would be applicable in open systems. Other control measures, such as limiting water flow in rivers, may not be effective and would have consequences for other users of the river system.

C2.2.8 Implications of the disease and control measures for industry and trade relations

The effect of the disease on industries and trade relations may determine the type of response required. Clearly, if little impact on the environment, industry or trade is expected, extensive control measures may not be warranted. However, close attention would be warranted for an exotic incursion that could have widespread implications for industries and trade relations.

C2.2.9 Cost of control

An important consideration is the cost–benefit ratio of a control measure.

C2.3 Response options

An essential factor in minimising impact on fishing industries is coordinated and balanced information flow to the public and trading partners. Lack of information and communication can cause unwarranted trade and financial impacts, with loss of market confidence. Any public health risks must be addressed fully.

For a disease outbreak of local significance only, state or territory authorities will establish a protocol for information management and dissemination. For diseases of national or international importance, the Office of the Australian Chief Veterinary Officer will establish a protocol for information dissemination. All agencies involved in the management of the disease outbreak must adhere to the agreed protocol. This will ensure that information released is consistent and that requests for information are directed to the appropriate source, and will allow other personnel to undertake their tasks unhindered by such requests.

Response options will depend on each emergency situation but could include one or more of the following.

C2.3.1 Responses requiring no disruption to regular operations

In the first instance, especially when little information is available, it may be most appropriate not to enforce any control measures but to simply monitor the situation. This may be the most realistic option for diseases of little current international concern. The decision to monitor only (no active intervention) should not be taken lightly, because failure to obtain data on the distribution of the disease agent may limit domestic or export market opportunities for a wider sector of the industry and may affect other industries within the region. This lack of data may also allow inadvertent spread of the disease through human activity.

Active rather than passive surveillance will ensure that there are sufficient data to enable inadvertent spread to be minimised. It provides knowledge of the species affected, and the spatial and temporal distribution of the infection for market reassurance. Further information on surveillance and monitoring is provided below.

C2.3.2 Responses requiring some disruption to regular operations

Increased vigilance

Surveillance for distribution of the disease agent may be necessary both to manage attempts to prevent spread through human activity and to protect markets of uninfected areas, especially open waters. Surveillance needs to collect data on:

- distribution of the agent in the affected species and movement patterns of the species
- other species, including predators in the areas and whether they are infected carriers or vectors.

For many diseases, few data are available on the range of potential carrier species, and virtually no data on the potential of local endemic species to carry or become clinically affected by exotic disease agents.

Note that there may be a need to consider shellfish as vectors or reservoirs of finfish infections. For example, birnaviruses of the infectious pancreatic necrosis type have been isolated from filter-feeding molluscs. Depending on the agent, this may be a true infection or transient retention of virus concentrated through filter-feeding activity. Ectoparasites, including crustaceans (copepods, isopods), may transmit bacterial and viral disease agents between fish.

Surveillance techniques include:

- traceback to the geographical source if the disease agent is detected at harvest inspection (the ability to do so will require improved record keeping in many industries)
- increased monitoring of fish for lesions at harvest or processing in all areas (infected, uninfected and threatened) where gross lesions are evident
- taking more specific samples for laboratory testing from animals at processing
- specific catch surveys
- enlisting the recreational and/or commercial fishing sectors in monitoring by increasing publicity of the lesions expected—this may be very effective in detecting new outbreaks, but may provide an unmanageable level of irrelevant submissions and will not normally provide good negative surveillance data
- stock assessment—the value of this as an indicator of the effect of a disease incident will depend on the availability of comparable historical data.

Movement control

Prevention of movement of the disease agent through human activity may be a high priority. The following activities could be considered:

- Wash down boats and equipment moving out of an infected area.
- Stop movement of at-risk product out of the area for processing.
- Suspend all catch activities if the agent is likely to be spread through normal product sales.
- Stop movement of fish from the area as bait for the commercial industry sector and recreational fisheries.
- Stop or discourage recreational fisheries in the area.
- Prevent movement of captured live animals to other areas.
- Inform trading partners, to reduce the presence of foreign fishing vessels in infected areas.
- Cooperate with public health authorities to rapidly inform the public of the risks of disease transfer, because readily caught dying fish are likely to be collected for use as bait or food, possibly in other locations.

Treatment

In open systems, it is unlikely that treatment of a disease outbreak would be feasible.

C2.3.3 Responses requiring major disruption to regular operations

Zoning

Zoning is the process of defining disease-free and infected zones to allow effective management of disease by reducing the risk of spread of disease by human activity. A more complete explanation of the principles and requirements of zoning can be found in the AQUAPLAN *Zoning policy guidelines* (www.agriculture.gov.au/animal-plant-health/aquatic/guidelines-and-resources).

It may be necessary to establish geographical zones where fishing activities of various types can or cannot occur. This process should be based on knowledge of the current distribution of the agent and its likely pattern of spread. The zoning may need to be reassessed as further knowledge is gained through surveillance.

In the case of open water, managed fisheries are already split into zones by their managing authorities, according to hydrographic and stock distribution criteria. These zones may be used in a control program—for example, the fishery affected by the outbreak may be closed, and the fishing fleet may be able to transfer its activity to a zone adjacent to an infected area. This would allow the fleet to continue production, as well as decreasing the number of potential hosts adjacent to the infected zone.

Relocation of stock

Removal of uninfected animals from a threatened area to a secure environment can be considered to preserve important genetic stocks. This could be important in the case of a severe disease that may threaten the survival of a species, or to ensure a source of disease-free stock for later scientific study of the disease. When considering this course of action, the likelihood of freedom of the relocated animals from the disease agent and the security of the new environment should be considered to prevent the acceleration of spread of the disease to a new area.

Infected animals may be removed from an infected area to a secure environment for study of new or poorly understood diseases. This may enable continued study of the disease after destruction of known infected stocks. The security of the holding facility against escape of the agent is paramount.

Emergency harvest

Risks associated with removal of infected animals for processing or destruction must be taken into account when considering emergency harvest, or deliberate reduction or elimination of infected stocks. It is likely that the fishery will be closed because harvesting of diseased fish has legal implications, and it would be difficult, or impossible, to sort healthy from diseased fish in a net from an infected zone.

If infected stock is harvested, the product should be processed to a non-infective product if it could come into contact with susceptible hosts. This usually involves evisceration as a minimum, but other processes such as freezing or cooking may be necessary. Initial processing on-site or at non-marine sites with effective water containment may be necessary.

Emergency installation of water treatment capability at processing plants may be needed because many processing plants have evolved from handling facilities at home port–based catch fisheries, and so have little effluent water treatment. Similarly, it is essential to link boat and equipment hygiene to any emergency harvesting activity.

Destruction of stock—Eradication through wild stock reduction

For a disease of international concern that could have an impact on the market access of other industry sectors, it may be necessary to reduce or even eradicate infected wild stock with limited mobility, such as shellfish. Culling of infected stock may be necessary to maintain a healthy population, as fishers will selectively harvest healthy stock. The feasibility of stock reduction must be considered—it may be practical only where the stock is sedentary, the infected area is small and the stock is well defined. It is unlikely to be feasible or effective where disease spread is rapid, animals are cryptic (e.g. abalone) or mobile populations are affected.

Ideally, diseased or potentially diseased stock should be removed rather than killed in situ. The stock may be removed manually, or heavily harvested with dredges or other harvest equipment. The impact on the ecosystem of operations such as heavy dredging must be considered, and these operations must be undertaken in consultation with environmental authorities.

Following stock removal, consideration should be given to monitoring stock recovery. The option of re-seeding the infected area is associated with a range of genetic, disease and ecological risks that should be considered carefully.

For some diseases, such as bonamiasis, it is suspected that survivors of an epizootic are likely to be a selected population of individuals that are best adapted to the disease. However, very limited data are generally available on the degree of natural resistance likely in a population.

Creation of a depopulated buffer zone

For sedentary stock, depopulation techniques, such as manual removal or dredging of stock, can be used to create a ‘fire break’ around the infected areas. This strategy can be effective with parasites that have a high infective dose, for which dilution significantly reduces the likelihood of infection. It can delay the rate of spread to allow time for infected stock to be removed. This method has been used to limit the spread of *Bonamia* introduced to the United Kingdom; breaks of about 100 m have provided short-term protection. The strategy is unsuitable for mobile hosts or diseases that have highly mobile vectors.

C3 Semi-open systems

C3.1 Introduction

Read Section C1 before reading this section.

Semi-open systems are typically aquaculture systems in which animal movement is controlled but water flow is not there is control of animal movement but no control of water flow. Examples are net-pen culture of finfish and rack culture of shellfish. The majority of farms using semi-open systems are situated on clumped leases within bays or estuaries, and thus are highly regionalised. This means that, in the event of a disease outbreak, the property of several farmers may be affected, although other farming zones will probably be unaffected.

The clumping of leases means that the environmental conditions at a set of sites are likely to be similar within a single region, whereas the conditions may be significantly different in another region or estuary. This may be important in the expression of either infectious or environmental causes of disease.

In situations where little is known about the incident, the initial response may be to do nothing more than monitor the situation until further information becomes available. Other options include:

- treatment of the affected population (using chemotherapy, freshwater or saltwater baths, or vaccination)
- emergency harvest
- complete quarantine with restrictions on movement of animals, all materials (including waste), personnel, vehicles and equipment.

C3.2 Factors to consider in assessing the response options

C3.2.1 Stage of the disease outbreak

If there is no ongoing surveillance for known diseases, or a new disease occurs, it is likely that the infection will be well advanced by the time overt clinical signs become apparent. Early or rapid definitive diagnosis will increase the chances of controlling spread beyond the primary focus of infection.

If the disease has been present for some time, the value of strong control measures, such as quarantine and disinfection, is lower because the disease agent may have already spread into natural waterways. The likely time of the incursion will indicate the extent to which tracing of stock or product will be necessary.

C3.2.2 Disease agent epidemiology, biology and stability

For a known disease, factors such as the likely primary host(s), intermediate host(s) and carrier species, and their presence in the local environment may be quickly ascertained. For a newly emerging or exotic disease, lack of knowledge of the susceptibility of native Australian aquatic animals may make these predictions more difficult. Consideration should be given to the likely source of infection of the stock, as this will indicate likely contacts on the farm or in the region. Knowledge about the stability of the agent in the environment will assist in determining appropriate disinfection or treatment techniques, and the likelihood of spread of the agent via waste, on equipment, in product and in effluent water.

C3.2.3 Site-specific features

The systems in place at the aquaculture site are very important in determining the likely spread of the agent and the ability to control such spread. An understanding of the flow of water is paramount. Other site-specific questions include the following:

- Is the area tidal?
- What is upstream and downstream?
- What are the directions of the prevailing winds?
- What are the movement patterns of fish-eating birds?

C3.2.4 System management practices

The available response options may be limited by the structure and operations of the affected site—that is, the systems used, the species farmed, the size and locality of the facility, and current management practices (e.g. movement of stock within the site). Section B provides further information on these aspects.

Some farms are better prepared than others for managing a disease emergency. Access to records (e.g. records of stock movement, water monitoring results, occurrence of clinical signs, mortalities), contingency plans and maps of the facility layout can be useful in managing the disease outbreak.

C3.2.5 Proximity to other establishments or natural environments with vulnerable species

It is important to identify the location of other aquaculture facilities or natural environments with susceptible species. These could constitute either the source of infection or other populations at risk.

C3.2.6 Stage of development of affected stock

The stage of development of the affected stock can be important in the diagnosis and management of the disease. The stage of development may:

- provide an indication of the likely time of introduction of the disease to the system
- indicate likely further movements and other contacts—for example, if infected young have recently arrived from a central hatchery, further investigation of the hatchery is necessary
- indicate whether emergency harvesting (with at least some return to the farmer) can be considered to remove stock that are infected or likely to become infected.

C3.2.7 Effectiveness of treatment, vaccination and control measures

For known diseases, recommended treatments, vaccinations and/or control measures may be available (see Appendix 6).

C3.2.8 Implications of the disease or control measures for industry and trade relations

The risk to other facilities and regions, to sustainability of the industry, and to interstate and international trade will affect the selection of control measures. For outbreaks of local concern that may affect more than one site but are unlikely to spread beyond state or territory borders, the state or territory chief veterinary officer or director of fisheries may establish a local disease control centre and disease control taskforce. This decision will depend on information gathered from local state or territory authorities and laboratories.

For outbreaks of national or international concern, the Australian Chief Veterinary Officer should be informed by the state or territory chief veterinary officer, and a meeting of the Aquatic Consultative Committee on Emergency Animal Diseases (AqCCEAD) may be convened.

C3.2.9 Cost of control

An important consideration for any control measure is the cost–benefit ratio of the proposed control measure, compared with the cost–benefit ratio of passive surveillance only (i.e. not implementing any control measures).

C3.3 Response options

Response to a disease emergency in a semi-open system may include one or more of the following.

C3.3.1 Responses requiring no disruption to regular operations

In the initial stages of a disease emergency, it may be inappropriate to enforce any control measures. The most appropriate option may be to monitor the situation (passive surveillance) while essential information is being collected.

Passive surveillance should be undertaken until further information is available (on the history of the incident and the nature of the disease) to enable a decision on the next most appropriate action. Although this is a potentially low cost option (as it has minimal disruption to farm operations as well as state operations) there is an increased risk of further spread of the disease.

In the early stage of any campaign, monitoring and diagnosis should be used to help define the problem. For a disease that is not easily transmitted, monitoring may be used to define zones of infection or, alternatively, free zones to enable the continuation of trade. For a disease that spreads quickly, taking the ‘monitor only’ option for a long period can be costly. Delays in implementing appropriate control measures can lead to further spread of the disease. Subsequently, disease eradication may require a larger effort with less likelihood of success.

Monitoring is an important part of ascertaining and documenting progress in active campaigns.

C3.3.2 Responses requiring some disruption to regular operations

Increased vigilance

To gain further information on the host and geographic range of the infectious agent, samples must be collected from the affected farm or region and adjacent farms or regions (active surveillance). Increased resources are required at the:

- operational level (including the farm site), for collection of samples
- diagnostic laboratory, for testing of the samples
- policy level, for establishment of a disease emergency taskforce to liaise with the local disease control centre (see the AQUAVETPLAN **Control Centres Management Manual—**www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan).

If the agent can be carried in dead tissues, on birds, in intermediate hosts or in other susceptible species, control of fishing, birds and animals should be considered.

Movement control

Movement control can be achieved by controlling inputs and outputs (see Section B). Semi-open systems lack control over water input and output, and so are relatively difficult to quarantine. Although movement of stock, personnel and equipment can be restricted, other control measures may be more effective. It may be appropriate to disinfect personnel and equipment before they leave the infected premises. Recommended protocols for disinfection are available in the AQUAVETPLAN **Decontamination Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan)**.**

To restrict spread of the disease, it may be preferable to destroy diseased animals, emergency-harvest healthy but exposed animals, and/or place exposed and at-risk animals into quarantine, if facilities are available, to allow grow-out to market size (see Section C3.3.3, 'Relocation of stock' and 'Emergency harvest'). Following such procedures, decontamination of premises and equipment is essential.

Treatment

Some pathogens, especially parasites and bacteria, are susceptible to chemotherapy. This should be considered if the therapy is likely to be effective, because it can be relatively cheap and animals are preserved for later sale.

If considering chemotherapy, factors to consider are:

- the possibility of an incomplete response to treatment
- the possibility of carrier animals (which carry the agent but show no clinical signs) remaining
- the use of registered or unregistered chemicals, and the required withholding period if the animals are for human consumption. If stock is treated, its subsequent harvest may be restricted because of the presence of chemical residues.

C3.3.3 Responses requiring major disruption to regular operations

Isolation of premises

All movement of stock on and off the premises can be prohibited. In semi-open systems, the lack of control over the water supply and effluent means that this may not be very effective in reducing spread. It will also be difficult or impossible to restrict the movement of wild animals around or within the aquaculture site. These wild animals may be vectors of the disease agent and thus provide a source of continued infection of the farmed stock. Removal of the stock (through emergency harvest or destruction) may be more appropriate.

Considerations when isolating a farm include:

- the need to set up checkpoints, which will cause some inconvenience to the operator, the public and transport industries
- the need for access for essential and emergency services
- impacts on recreational activities
- disposal of wastes—wastes need to be treated or kept on-site
- the extensive resources required to enforce quarantine
- use of suitable disease control legislation and the issuing of a quarantine order
- generation of significant media interest, because placing premises under quarantine tends to be an emotive issue and therefore makes good press.

Advantages of isolating a farm include:

- the potential for quarantine to be an effective method of containing a pathogen
- preservation of trade by surveillance and zoning on a regional or national scale.

Relocation of stock

Relocation of unaffected stock should only be considered when there is a very high probability that the stock in question is not carrying the infectious agent. It may be considered if the stock in question is not susceptible to infection with the agent; however, facilities holding other susceptible species in the region may need to be destocked and disinfected. If the stock in question is susceptible to the disease, a reliable history of separation from the disease agent and a reliable detection test applied to a statistically significant number of animals, based on an epidemiological understanding of the disease, are needed. This information can be used to prevent movement of the disease agent with the stock.

If this course of action is to be contemplated, clean transport water and monitoring of destination sites are required.

Since relocation of stock could result in the accidental relocation of the disease agent with the stock, the potential consequences of relocation should be carefully assessed to avoid worsening the overall problem.

Emergency harvest

Selective harvest to recover some value of the stock may be considered if there are clinically unaffected animals that are close to harvest age on infected premises. This action will preserve some value of the crop for the owner while removing potentially infected animals from the environment.

Destruction of stock

Destruction of stock is the most severe measure. Since it will cause major disruption to farm income, it should not be considered lightly. Notwithstanding, the quick removal of infected animals will markedly decrease the amount of infectious agent released to the environment and therefore the likelihood of spread of the disease. Refer to the AQUAVETPLAN **Destruction Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan) for more details.

C4 Semi-closed systems

C4.1 Introduction

Read Section C1 before reading this section.

Semi-closed systems are characterised by the capacity for good control over farmed stock and some control, if only for a limited time, over water flow to and from the aquaculture facility. Thus, several options are available in semi-closed systems for control of disease. All response measures can be considered as types of containment. Control is possible at the level of:

- production unit (e.g. single pond)
- farm or enterprise
- catchment or coastal area
- zone
- country.

C4.2 Factors to consider in assessing the response options

The following factors need to be considered in assessing the response options for a disease outbreak in a semi-closed system.

C4.2.1 Stage of the disease outbreak

The speed of disease diagnosis is paramount. If the disease agent is detected quickly, it is possible that there will be little, or no, spread beyond the primary focus of infection. However, if the disease has been present for some time, strong control measures, such as quarantine and disinfection, are less useful because the agent may have already spread into natural waterways. The time of likely incursion will give an indication of the required amount of tracing of stock or product.

C4.2.2 Disease agent epidemiology, biology and stability

Factors such as the likely primary host(s), carrier(s) and intermediate host(s), and their presence in the local environment can often be quickly ascertained. For an exotic disease, lack of knowledge about the susceptibility of native Australian aquatic animals may make these predictions more uncertain.

The likely stability of the agent in the environment will define the type of disinfection techniques required, and the likelihood of spread of the agent via waste, on equipment, in product and in effluent water.

C4.2.3 Site-specific features

The systems of water supply and output on the site will affect the likely spread of the agent and the ability to control it. These systems vary between farms.

It should be noted whether:

- water comes from single or multiple sources

- water is piped directly to a single pond or flows through several ponds; if water is reused, the chance of restricting the disease to one production unit is reduced, depending on the treatment regime used between systems
- effluent treatment ponds are available
- production ponds could be used to treat effluent before its release.

C4.2.4 System management practices

Some farms will be better prepared than others for managing a disease emergency. Normal farming practices may increase the spread of the agent within the premises. Knowledge of the husbandry practices used on the premises may indicate the probable time of introduction of infection and the likelihood of spread of disease to the external environment.

Recent operations of the farm must be ascertained, and access should be requested to any documents that could be useful in managing the disease outbreak—for example, records of stock movements, water monitoring results, and occurrence of clinical signs and mortalities; contingency plans; and maps of the facility layout.

Further movement of live fish to a new pond for grading purposes must be reconsidered. These movements should be examined to predict likely disease spread around the enterprise and to limit further spread. The effect of stress on host susceptibility to disease agents should also be taken into account.

Section B provides further information on this aspect.

C4.2.5 Proximity to other establishments or natural environments with vulnerable species

Water discharge practices and facilities may significantly affect possible control measures. Some farming systems only periodically take in or discharge water, into either settlement ponds or directly into natural watercourses. Some farms may be prone to flooding, with the potential for escape of stock or disease agents.

C4.2.6 Stage of development of affected stock

The stage of development of affected stock can be important because it may:

- assist in the diagnosis of disease
- indicate the likely time of introduction of the disease to the system
- indicate likely further movements and other contacts—for example, detection of infected young recently arrived from a central hatchery will require further investigation of the hatchery
- indicate whether emergency harvesting should be considered to remove stock that is likely to become infected.

C4.2.7 Effectiveness of treatment, vaccination and control measures

For known diseases, recommended treatments, vaccinations and/or control measures may be available (see Appendix 6).

C4.2.8 Implications of the disease and control measures for industry and trade relations

Selection of control measures will depend on the risk to other facilities and regions, to sustainability of the industry, and to interstate and international trade. For outbreaks of local concern that are unlikely to spread beyond state or territory borders, the state or territory chief veterinary officer or director of fisheries may establish a local disease control centre and disease control taskforce. This decision will depend on information gathered from local state or territory authorities and laboratories.

For outbreaks of national or international concern, the Australian Chief Veterinary Officer should be informed by the state or territory chief veterinary officer, and an AqCCEAD meeting may be convened.

C4.2.9 Cost of control

An important consideration for any control measure is the cost–benefit ratio of the proposed control measure, compared with the cost–benefit ratio of passive surveillance only (i.e. not implementing any control measures).

C4.3 Response options

Response to a disease emergency involving a semi-closed system may include one or more of the following.

C4.3.1 Responses requiring no disruption to regular operations

In the initial stages of a disease emergency, it may be inappropriate to enforce any control measures. The most appropriate option may be to monitor the situation (passive surveillance) while essential information is being collected.

In the early stage of any campaign, monitoring and diagnosis should be used to help define the problem. For a disease that is not easily transmitted, monitoring may be used to define zones of infection or, alternatively, free zones to enable the continuation of trade. For a disease that spreads quickly, taking the ‘monitor only’ option for a long period can be costly. Delays in implementing appropriate control measures can lead to further spread of the disease. Subsequently, disease eradication may require a larger effort with less likelihood of success.

For some diseases that do not spread easily, monitoring may be used to define zones of infection, or alternatively free zones to enable continuation of trade. Monitoring is an important part of ascertaining and documenting progress in active campaigns.

C4.3.2 Responses requiring some disruption to regular operations

Increased vigilance

To gain further information on the host and geographic range of the infectious agent, samples must be collected from the affected farm or region and adjacent farms or regions (active surveillance). Increased resources are required at the:

- operational level (the farm site), for collection of samples
- diagnostic laboratory, for testing of the samples
- policy level, for establishment of a disease emergency taskforce to liaise with the local disease control centre (see the AQUAVETPLAN **Control Centres Management Manual**—www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan).

If the agent can be carried in dead tissues, on birds, in intermediate hosts or in other susceptible species, control of fishing, birds and animals should be considered.

Movement control

Semi-closed systems can potentially be placed under quarantine because some control is possible over water input and output. Movement of stock, personnel and equipment can also be restricted. Disinfection of personnel and equipment before they move off the infected premises may be appropriate. Ponds may be available for treatment of effluent water. Recommended protocols for disinfection are available in the AQUAVETPLAN **Decontamination Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan)**.**

To restrict spread of the disease, it may be preferable to destroy diseased animals, emergency harvest apparently healthy but exposed animals, and/or place exposed and at-risk animals into quarantine to allow grow-out to market size (see Section C4.3.3, 'Relocation of stock' and 'Emergency harvest'). Following such procedures, decontamination of premises and equipment is essential.

Treatment

Some pathogens, especially parasites and bacteria, are susceptible to drug therapies. This should be considered if the therapy is likely to be effective, because it can be relatively cheap and animals are preserved for later sale.

If considering drug therapy, factors to consider are:

- the possibility of an incomplete response to treatment
- the likelihood of carrier animals (which carry the agent but show no clinical signs) remaining
- the use of registered or unregistered drugs, and the required withholding period if the animals are for human consumption. If stock is treated, its subsequent harvest may be restricted because of the presence of chemical residues.

C4.3.3 Responses requiring major disruption to regular operations

Isolation of premises

Semi-closed systems are land based and therefore can be quarantined simply by controlling access via the main gate to the farm. Consideration should also be given to controlling access via water. Security of both stock and water may include installing meshes or other appropriate escape prevention measures on outlets and water supplies.

In semi-closed systems, inputs of water can be easily controlled by turning off pumps or closing weir gates, but the effect on water quality should be considered carefully. In some systems, ponds can be cut off from water supply and drainage for relatively long periods with little effect. However, other systems that rely on regular supply of water—

such as race culture of salmonids or abalone—will have a very short period before the stock will suffer or die as a result of the decrease in water quality.

Considerations when isolating a farm include:

- the need to set up checkpoints, which will cause some inconvenience to the operator, the public and transport industries
- the need for access for essential and emergency services
- impacts on recreational activities
- disposal of wastes—wastes need to be treated or kept on-site
- the extensive resources required to enforce quarantine
- use of suitable disease control legislation and the issuing of a quarantine order
- generation of significant media interest, because placing premises under quarantine tends to be an emotive issue and therefore makes good press.

Advantages of isolating a farm include:

- the likelihood that quarantine in this system will be a very effective method of containing a pathogen
- preservation of trade by surveillance and zoning on a regional or national scale.

Relocation of stock

Relocation of unaffected stock should only be considered when there is a very high probability that the stock in question is not carrying the infectious agent. It may be considered if the stock in question is not susceptible to infection with the agent; however, facilities holding other susceptible species in the region may need to be destocked and disinfected. If the stock in question is susceptible to the disease, a reliable history of separation from the disease agent and a reliable detection test applied to a statistically significant number of animals, based on an epidemiological understanding of the disease, are needed. This information can be used to prevent movement of the disease agent with the stock.

If this course of action is to be contemplated, clean transport water and monitoring of destination sites are required.

Since relocation of stock could result in the accidental relocation of the disease agent with the stock, the potential consequences of relocation should be carefully assessed to avoid worsening the overall problem.

Emergency harvest

Selective harvest may be considered if there are clinically unaffected animals that are close to harvest age on infected premises. This action will preserve some value of the crop for the owner while removing potentially infected animals from the environment.

The mode of harvest should be considered. Many systems rely on reduced water levels to enable netting of the stock. This may entail release of infective material into waterways unless an effluent collection facility is available where wastewater can be treated by chlorination or another means before it is released.

Destruction of stock

Destruction of stock is the most severe measure. Since it will cause major disruption to farm income, it should not be considered lightly. However, the quick removal of infected animals will markedly decrease the level of infectious agent released to the environment and therefore the likelihood of spread of the disease. Refer to the

AQUAVETPLAN **Destruction Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan) for further details.

Disinfection is used in concert with quarantine or destocking. Methods of disinfection will depend on the infective agent; they may include drying out of ponds, chemical treatment of water, and chemical treatment of tanks and equipment. Disinfection of premises can be labour intensive. Recommended protocols for disinfection are available in the AQUAVETPLAN **Decontamination Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan).

C5 Closed systems

C5.1 Introduction

Read Section C1 before reading this section.

In closed systems, movement of stock and water are highly controlled. The self-contained nature of closed systems means that there is a good chance of controlling an infectious disease within the affected facility. However, the nature of the system brings other major difficulties and implications, such as treatment of biofilters, the fate of animals while the biofilter is out of action, and the high throughput and dissemination of animals from these facilities either into grow-out facilities or to retailers and home aquaria. Further considerations may also be necessary if the premises is a QAP containing one or more consignments of animals in quarantine.

C5.2 Factors to consider in assessing the response options

C5.2.1 Stage of disease outbreak

In closed systems, animals can be readily monitored for the presence of major infectious agents using eDNA or other screening techniques or, if an outbreak is suspected, for clinical signs. Maintaining good record-keeping practices will facilitate tracing in disease outbreaks.

C5.2.2 Disease agent epidemiology, biology and stability

Disease factors that need to be considered in a closed system include:

- origin of the host (imported, or native and domestically raised)
- identity of the disease agent
- species that can be clinically affected (primary host) or are able to carry the disease agent (secondary hosts and vectors)
- ease of transmission of disease by water or other means
- environmental persistence of the pathogen
- carrier species that may be involved and the likelihood of contact with them.

C5.2.3 Site-specific features

Possible response options in a closed system may depend on the structure and operation of the enterprise. Aspects of the design of the facility to be considered include:

- separation of the water supply from possible sources of infection
- separation of water filtration systems from tanks or sections within the premises
- ability to isolate sections within the facility
- Department of Agriculture or legislative requirements relating to QAP.

Section B provides information on these factors.

C5.2.4 System management practices

For closed systems, it should be possible to control spread of the disease to the outside environment, but it may be difficult to prevent spread within the system unless good system management practices are in place. Factors that may affect the ability to control spread within the system include:

- physical separation and water supply separation between production stock and breeding stock and/or between infected stock and other stock
- separation of sources of feed and equipment (especially nets) between tanks or sections
- species involved in the outbreak (compared with species contained in the facility).

Section B provides further information on these aspects of control of spread of disease.

Consideration should also be given to the likely source of infection of the stock, as this will indicate likely contacts throughout the farm or region.

C5.2.5 Proximity to other establishments or natural environments with vulnerable species

By the time the disease has become apparent, the disease agent may well have escaped from the affected facility. Factors to consider include:

- the ability to isolate the facility from the outside ecosystem
- the likelihood of widespread distribution of disease within the facility or the wider population.

C5.2.6 Stage of development of affected stock

The stage of development of affected stock can be important because it may:

- assist in the diagnosis of disease
- indicate the likely time of introduction of the disease to the system
- indicate likely further movements and other contacts—for example, detection of infected young recently arrived from a central hatchery will require further investigation of the hatchery
- indicate whether emergency harvesting should be considered to remove stock that is likely to become infected
- determine the location of the disease in the aquaculture facility—this may determine the method of control of spread within the facility and the approach to containment.

Uninfected stock may be able to be separated or relocated to an unaffected site or, if appropriate, to grow-out facilities. If the stock cannot be moved, some sort of treatment may be possible. Alternatively, destruction of stock should be considered (see Section C5.3.3).

C5.2.7 Effectiveness of treatment, vaccination and control measures

In a closed system, treatment or vaccination of animals should be relatively easy.

For known diseases, recommended treatments, vaccinations and/or control measures may be available (see Appendix 6).

C5.2.8 Implications of the disease and control measures for industry and trade

Selection of response options will be influenced by the potential consequences for the affected and potentially affected industry sectors if the disease were to spread and become enzootic. In addition, the control measures required to eradicate or limit the spread of the disease may be impractical or too expensive to enforce.

Factors to consider include:

- the likely importance of the disease to the industry or the environment
- the status of the disease—that is, whether it is notifiable in the state or territory, nationally or internationally.

C5.2.9 Cost of control

An important consideration for any control measure is the likely cost of the uncontrolled disease compared with the cost of the control measures. This must also be balanced with the likelihood of success. The financial or ecological impact on the environment, industry and operator should be considered when deciding on measures to be used.

C5.3 Response options

Response to a disease emergency involving a closed system may include one or more of the following.

C5.3.1 Responses requiring no disruption to regular operations

In the initial stages of a disease emergency, it may be inappropriate to enforce any control measures. The most appropriate option may be to monitor the situation (passive surveillance) while essential information is being collected.

Passive surveillance should be undertaken until further information is available (on the history of the incident and the nature of the disease) to enable a decision on the next most appropriate action. Although this is a potentially low cost option (as it has minimal disruption to farm operations as well as state operations) there is an increased risk of further spread of the disease.

In the early stage of any campaign, monitoring and diagnosis should be used to help define the problem. For a disease that is not easily transmitted, monitoring may be used to define zones of infection or, alternatively, free zones to enable the continuation of trade. For a disease that spreads quickly, taking the ‘monitor only’ option for a long period can be costly. Delays in implementing appropriate control measures can lead to further spread of the disease. Subsequently, disease eradication may require a larger effort with less likelihood of success.

Monitoring is an important part of ascertaining and documenting progress in active campaigns.

In a closed system, monitoring must include monitoring of the external environment to detect spread of the infection beyond the facility.

C5.3.2 Responses requiring some disruption to regular operations

Increased vigilance

To gain further information on the host and geographic range of the infectious agent, samples must be collected from the affected farm or region and adjacent farms or regions (active surveillance). Increased resources are required at the:

- operational level (the farm site), for collection of samples
- diagnostic laboratory, for testing of the samples
- policy level, for establishment of a disease emergency taskforce to liaise with the local disease control centre (see the AQUAVETPLAN **Control Centres Management Manual**—www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan).

Movement control

It may be possible to separate infected stock from uninfected stock, and control movement of personnel, equipment, water and stock between the separated populations.

Stopping all water flow in and out of the facility or section should be considered to contain the infection within the facility or, at least, to prevent further spread of the infection from the facility. By definition, this strategy is relatively easy with closed systems. It may involve the facility as a whole or prevention of water exchange between parts of the same premises. The feasibility of the latter will depend on the type of facility and the degree to which it, and especially the filtration system, is compartmentalised. Although these systems are referred to as 'closed', in practice there is usually some periodic water exchange.

A second step is to stop the introduction of any new stock into the premises, to maximise the time that the existing stock can be maintained without water exchange. Many facilities have a water storage facility, temporary tanks or collapsible pools, which may be set up to hold overflow before treatment.

With no water exchange, water quality may decrease, depending on the biological demand of the system, the load on filters, the stocking density, the timeframe and the capacity of the system to function without water exchange. These factors may lead to compromised systems and increased stock mortality.

Since volumes of water used in closed systems may be relatively small, it may be possible to use water trucked in from a known uninfected source. Alternatively, water could be treated with UV, ozone or chlorine before use. Chlorine-treated water will need to be dechlorinated with sodium thiosulfate, or using carbon filters and/or aeration. The water may also need pH or temperature adjustment.

To decrease aerosol circulation and minimise spread between tanks and into the environment, air pumps can be switched off, circulation pumps can be used, or the tops of the tanks and filters can be covered with glass or plastic.

Switching off either air or water recirculation pumps will severely affect the filtration and oxygenation of water. Depending on the species and stocking densities, the aquatic animals may survive for a period ranging from hours to days. The decision to switch off air or water recirculation pumps should take into account the expected survival of the species in question. This information may be gained from the aquarist, as pump failures may have been experienced in the past.

Depending on the design of the facility, it may be possible to treat effluent water before release to inactivate infectious agents.

Treatment

Treatment or vaccination of some or all stock can be considered if aspects of the agent and the treatment make it practical and economical. When a treatment regime is considered as either the sole means of control or as part of a control scheme, issues to be addressed are:

- the potential for carrier animals to remain in the population
- contamination of water with either the disease agent or the treatment chemical
- environmental and worker health and safety
- development of resistance
- treatment costs
- withholding periods for product destined for human consumption.

Benefits of treatment include:

- preservation of stock
- preservation of cash flow
- possible low cost.

C5.3.3 Responses requiring major disruption to regular operations

Isolation of premises

Isolation of the premises (quarantine) can be achieved by controlling inputs and outputs (see Section B). Consideration should be given to the level of containment that is advisable both during a confirmed outbreak and before an incursion of a disease agent is confirmed.

Quarantine of an affected area and its water systems may involve either the whole facility or part of the facility. This will depend on an understanding of the facility affected and the traffic between it and other facilities, or within the facility. The information will be used to define which of the affected tanks, buildings and so on to isolate and what should be controlled.

Quarantine may involve stopping shipment of stock, controlling the flow of effluent, and controlling vehicular and personnel traffic. If the entire premises is to be quarantined, product and vehicles cannot be moved without suitable treatment and/or testing and certification.

Considerations when isolating a farm include:

- the need to set up checkpoints, which will cause some inconvenience to the operator, the public and transport industries
- the need for access for essential and emergency services
- impacts on recreational activities

- disposal of wastes—wastes need to be treated or kept on-site
- the extensive resources required to enforce quarantine
- use of suitable disease control legislation and the issuing of a quarantine order
- generation of significant media interest, because placing premises under quarantine tends to be an emotive issue and therefore makes good press.

Advantages of isolating a farm include:

- the likelihood that quarantine in this system will be a very effective method of containing a pathogen
- preservation of trade by surveillance and zoning on a regional or national scale.

Relocation of stock

Relocation of stock should only be considered when there is a very high probability the stock in question is not carrying the infectious agent. It may be considered if the stock in question is not susceptible to infection with the agent; however, facilities holding other susceptible species in the region may need to be destocked and disinfected.

If the stock is susceptible to the disease, a reliable history of separation from the disease agent and a reliable detection test performed on a statistically significant number of animals, based on an epidemiological understanding of the disease, are needed. This can prevent movement of the disease with the stock.

If this course of action is to be contemplated, clean transport water and monitoring of destination sites are required.

Since relocation of stock could result in the accidental relocation of the disease agent with the stock, the potential consequences of relocation should be carefully assessed to avoid worsening the overall problem.

Emergency harvest

In multiple-species farms, depending on the disease, it may be safe to continue trading in unaffected species if clean water and equipment are used for processing or transport. Product for human consumption may be emergency harvested if the animals are of suitable size, deemed safe and in good condition. This will allow the destocking of a farm with some recompense. However, food safety, processing waste and environmental safety are important considerations.

Risks associated with emergency harvesting include:

- an increased risk of contaminating the premises from having infected stock for longer
- the possibility that quarantine measures will be insufficient to restrict escape of the disease agent, particularly if conditions on dispersal and sale of stock are not rigorously adhered to.

Destruction of stock

Destruction of stock is an extreme measure that might be an option in particularly serious situations—for example, where the level of mortality is very high, there is evidence of rapid disease spread or the presence of a severe exotic pathogen is proven. Destruction of stock can be very effective in controlling a restricted outbreak of disease. Clearly, the consequences of undertaking this action, such as loss of saleable stock or valuable broodstock, and the cost of disposal, are also extreme. Refer to the

AQUAVETPLAN **Destruction Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan) for further details.

All materials, equipment (e.g. nets) and permanent structures (e.g. cement tanks) that are likely to have been exposed to the disease agent should be decontaminated following destruction of stock. Different materials and agents require different methods of cleaning and decontamination—for example, drying out of earthen ponds, and treatment of concrete using hot disinfectants.

A range of disinfectants are available, and not all are suitable for all situations or all disease agents. Recommended protocols for decontamination are available in the AQUAVETPLAN **Decontamination Manual** (www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan).

Section D Appendices

Appendix 1

Table A1 Summary of relevant legislation, programs and codes of practice

Jurisdiction or agency	Relevant legislation, code or program
Australian Capital Territory	*Stock Act 1993* *Animal Diseases Act 1993* *Nature Conservation Act 1980* *Fishing Act 1967*
New South Wales	*Exotic Diseases of Animals Act 1991* *Stock Diseases Act 1923* *Fisheries Management Act 1994* Fisheries Management Act (Aquaculture) Regulations 1995 New South Wales Shellfish Quality Assurance Program (in www.foodauthority.nsw.gov.au/_Documents/industry_pdf/NSW_Shellfish_Industry_Manual.pdf)
Northern Territory	*Livestock Act* Livestock Regulations *Fisheries Act* Fisheries Regulations *Agriculture and Veterinary Chemicals (Control of Use) Act* Agriculture and Veterinary Chemicals (Control of Use) Regulations Pearl Oyster Culture Industry Management Plan 1998 NT Fisheries Emergency Response Investigation Protocol for Aquatic Animal Pests and Diseases *Transboundary movements of living aquatic animals: a zoning strategy for disease control in the Northern Territory*
Queensland	*Fisheries Act 1994* Fisheries Regulations 1998 *Industry environmental code of best practice for freshwater finfish aquaculture* (www.aaq.com.au/images/pdf/Fresh%20Water%20Finfish_Code_of_practice.pdf) *Chemical Usage (Agricultural and Veterinary) Control Act 1988* Chemical Usage (Agricultural and Veterinary) Control Regulation 1999 *Environmental Protection Act 1994* *Sustainable Planning Act 2009*
South Australia	*Livestock Act 1997* *Fisheries Management Act 2007* *Aquaculture Act 2001* Aquaculture Regulations 2005 (specifically Regs 10–12: off-label chemical use, disease management) Exotic Fish, Fish Farming and Fish Disease Regulations 1984 *Code of Practice for the Environmental Management of the South Australian Oyster Farming Industry* 1997 (www.epa.sa.gov.au/xstd_files/Water/Code%20of%20practice/cop_saoyster.pdf)

Jurisdiction or agency	Relevant legislation, code or program
	South Australian Shellfish Quality Assurance Program (www.pir.sa.gov.au/__data/assets/pdf_file/0009/33876/NEW_pamphletfinal_110720.pdf) Food safety information (www.pir.sa.gov.au/biosecurity/food_safety/seafood)
Tasmania	*Animal Health Act 1995* *Inland Fisheries Act 1995* *Living Marine Resources Management Act 1995* *Marine Farm Planning Act 1995* *Agricultural and Veterinary Chemicals (Control of Use) Act 1995* Tasmanian Shellfish Quality Assurance Program (www.dhhs.tas.gov.au/peh/tsqap)
Victoria	*Livestock Disease Control Act 1994* Fisheries Regulations 1998 *Agricultural and Veterinary Chemicals (Victoria) Act 1994* Victorian Shellfish Quality Assurance Program (www.depi.vic.gov.au/fishing-and-hunting/aquaculture/publications/shellfish-quality-asurance)
Western Australia	*Exotic Diseases of Animals Act 1993* *Biosecurity and Agriculture Management Act 2007* Biosecurity and Agriculture Management Regulations 2013 *Fish Resources Management Act 1994* Fish Resources Management Regulations 1995 *Pearling Act 1990* *Abalone aquaculture in Western Australia: policy* (www.fish.wa.gov.au/Documents/Aquaculture/abalone-aquaculture-in-western-australia.pdf) Western Australia aquaculture management (www.fish.wa.gov.au/Fishing-and-Aquaculture/Aquaculture/Aquaculture-Management/Pages/default.aspx)
National	*Fisheries Management Act 1991* *Quarantine Act 1908* *Environment Protection and Biodiversity Conservation Act 1999* *Agricultural and Veterinary Chemicals Act 1994* Offshore petroleum and minerals exploration Acts Australian Ballast Water Management Requirements 2011 (www.agriculture.gov.au/biosecurity/avm/vessels/quarantine-concerns/ballast/australian-ballast-water-management-requirements) *A National Code of Practice for Recreational and Sport Fishing* (recfishaustralia.org.au/national-code-of-practice-2010) Australian Aquaculture Code of Conduct (www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/446765/Appendix-7-Australian-Aquaculture-Code-of-conduct.pdf) Australia New Zealand Food Standards Code (www.foodstandards.gov.au/code/Pages/default.aspx) *National policy for the translocation of live aquatic organisms: issues, principles and guidelines for implementation*

Jurisdiction or agency	Relevant legislation, code or program
	(data.daff.gov.au/brs/brsShop/data/12105_translocation.pdf) *National investigation and reporting protocol for fish kills* (www.agriculture.gov.au/SiteCollectionDocuments/animal-plant/aquatic/field-guide/4th-edition/amphibians/fish-kill-protocol.pdf) National surveillance guidelines (www.agriculture.gov.au/SiteCollectionDocuments/animal-plant/aquatic/field-guide/4th-edition/amphibians/surveillance.pdf) *AQUAPLAN: zoning policy guidelines* (www.agriculture.gov.au/SiteCollectionDocuments/animal-plant/aquatic/field-guide/4th-edition/amphibians/zoning-final-aug.pdf)
International	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (www.cites.org) International Convention for the Prevention of Pollution from Ships 1973/78 (MARPOL 73/78) (www.imo.org/about/conventions/listofconventions/pages/international-convention-for-the-prevention-of-pollution-from-ships-(marpol).aspx) United Nations Agreement on Straddling Fish Socks and Highly Migratory Fish Stocks, London Convention (www.un.org/Depts/los/fish_stocks_conference/fish_stocks_conference.htm) World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures (SPS agreement) (www.wto.org/English/tratop_e/sps_e/spsagr_e.htm) OIE—World Organisation for Animal Health (www.oie.int/international-standard-setting/overview)

Note: All websites were accessed in 2015.

Appendix 2

Table A2 Seafood-borne disease in humans

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Virus	Hepatitis A	Oysters Scallops	Worldwide Fresh water Estuarine Sea water	Consumption of raw or partially cooked fish and shellfish from sewage-contaminated waters	Incubation: 2–6 weeks Sudden onset of fever, malaise, nausea, anorexia, joint pain and abdominal discomfort, followed by jaundice	Moderate–serious Can lead to chronic liver damage and cirrhosis	Cook shellfish Ensure source water is uncontaminated	Fatality rate is 0.1–1% in healthy individuals but up to 20% in pregnant women
Virus	Hepatitis E	Fish Oysters Scallops	Worldwide Fresh water Estuarine Sea water	Consumption of raw or partially cooked fish and shellfish from sewage-contaminated waters	Incubation: 2–6 weeks Sudden onset of fever, malaise, nausea, anorexia, joint pain and abdominal discomfort, followed by jaundice	Moderate–serious Can lead to chronic liver damage and cirrhosis	Cook shellfish Ensure source water is uncontaminated	Fatality rate is 0.1–1% in healthy individuals but up to 20% in pregnant women

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Virus	Norwalk sp. (norovirus) Snow Mountain agent	Oysters Clams	Worldwide Estuarine Sea water	Consumption of raw or partially cooked shellfish from sewage-contaminated waters, or unhygienic handling by humans after product was cooked	Nausea, vomiting, diarrhoea, abdominal pain, headache, fever Mild illness with onset 24–48 hours following consumption and persisting for 24–60 hours	Mild	Cook shellfish Ensure source water is uncontaminated	N/A
Bacterium	*Clostridium botulinum*	All aquatic animals Fish can harbour *C. botulinum* in their intestinal tracts Shellfish and crustaceans may harbour it in their gills and viscera	Worldwide Fresh water Estuarine Sea water	Consumption of undercooked or uneviscerated seafood where neurotoxin is produced by *C. botulinum*. Also lack of human hygiene in processing	Lassitude; vertigo; double vision; difficulty speaking, swallowing and breathing; weak muscles; abdominal distension and constipation Onset: 18–36 hours following consumption	Serious Can be life-threatening)	Evisceration Cook for at least 5 minutes at 85 °CRefrigeration	Incidence worldwide is low, but mortalities are high if not treated immediately

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Vibrio parahaemolyticus*	Some fish (range unknown) Principally shellfish and crustaceans	Worldwide Estuarine Sea water	Consumption of raw or partially cooked, or cooked but recontaminated, fish and shellfish	Onset: 4–96 hours after consumption Median duration: 2.5 days Diarrhoea, abdominal cramps, nausea, vomiting, headache, fever and chills	Mild–moderate Sometimes requires hospitalisation	Evisceration Cook seafood for 2.5 minutes at 55 °C Refrigeration	Sensitive to refrigeration below 5 °C
Bacterium	*V. vulnificus*	Crabs, oysters, clams	Worldwide Estuarine Sea water	Consumption of raw or partially cooked, or cooked but recontaminated, shellfish and crustaceans, or via breaks in the skin during handling	Usually a mild case of gastroenteritis in otherwise healthy individuals (diarrhoea, abdominal cramps, nausea, vomiting, headache). In immunocompromised patients (leukaemia, cirrhosis, lung carcinomas, steroid-treated asthma, etc.), primary septicaemia can develop	Moderate–fatal Mortality following onset of septicaemia is >50%	Evisceration Cook oysters for 10 minutes at 50 °C Refrigeration	N/A

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*V. cholerae*	Host range unknown	Temperate Estuarine Sea water	Consumption of raw shellfish from polluted bays and estuaries *V. cholerae* is also present in low numbers in non-polluted waters	Onset: 6 hours to 5 days Duration: 6–7 days Characterised by watery (‘rice-water’) stools, abdominal cramps, nausea, vomiting, dehydration and shock. Death may occur following severe loss of fluid and electrolytes	Moderate–serious May require intravenous rehydration	Evisceration Cook seafood for 3 minutes at 60 °C Refrigeration	Causes 'cholera', often in local epidemics associated with breakdown of sewerage systems
Bacterium	*V. mimicus* *V. alginolyticus* *V. fluvialis* *V. damsel* *V. hollisae* *V. furnissii*	Species range unknown	Worldwide Estuarine Sea water	Consumption of raw or partially cooked, or cooked but recontaminated, fish and shellfish, or via breaks in the skin during handling	Mild gastroenteritis Wound and ear infections	Mild	Evisceration Cook seafood Refrigeration Wear gloves, and keep wounds clean and dressed when handling fish	N/A

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Aeromonas hydrophila* *A. caviae* *A. sobria*	All seafood are potential carriers	Fresh water Brackish water	Transmission is via breaks in the skin from water and flesh during handling, and through ingestion of contaminated water or seafood	Cholera-like ('rice water') diarrhoea, or a dysenteric illness with loose stools containing blood and mucus Usually a mild case of gastroenteritis in otherwise healthy individuals	Mild–moderate, but can be serious for the young, elderly and immunocompromised	Evisceration Cook seafood Refrigeration Wear gloves, and keep wounds clean and dressed when handling fish	Primary septicaemia can develop in immunocompromised patients (leukaemia, cirrhosis, lung carcinomas, steroid-treated asthma, etc.)
Bacterium	*Erysipelothrix rhusiopathiae*	All seafood are potential carriers	Worldwide Fresh water	Infection occurs via cuts and abrasions to the skin, or through mucous membranes	Swollen, slightly elevated patches appear on the skin of hands or fingers, associated with a burning, tingling sensation and intensely itchy. Mild arthritis of finger joints occurs Headache, fever, and heart or nervous system complications sometimes result Duration: 2–6 weeks. Relapses may occur. Although rare, symptoms can persist for a long time	Mild	Prompt washing and dressing of cuts or breaks to the skin. Regular disinfection of workbenches and equipment	More a problem for fish handlers and processors than consumers

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
	Leptospira interrogans, serovars Pomona and Canicola	All seafoods are potential carriers	world-wide freshwater	infection occurs via cuts and abrasions to the skin or through mucous membranes	Mild cases: symptoms can last from one to several days, with fever, headache, severe muscle pain, dehydration, nausea and photophobia. Several days following onset, a rash develops on skin and blood pressure decreases, with dysfunction of the kidney and liver, before a long convalescence. Duration 3–6 weeks before complete recovery Severe cases: symptoms can recur after an apparent 1–3 day recovery. with higher temperature; more severe headaches; rigors and chills; and excruciating pains in calf muscle, thigh and back. Jaundice, nosebleeds, haemorrhagia and protracted vomiting may develop. Patients surviving the renal and	Mild–fatal	Wear gloves, and keep wounds clean and dressed when handling seafood	Associated with water contaminated by urine of infected animals (e.g. rats, cattle)

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Mycobacterium marinum* *M. fortuitum* *M. chelonae*	All seafood are potential carriers			Onset: 2–9 weeks Slightly raised, scaly, warm and red bumps from hand to arm, with little to no pain, sometimes purulent. Infection via deep wounds can cause tendons and joints to swell and become stiff No fever, headache or abdominal pains	Mild	N/A	Commonly referred to as swimming pool disease in humans Often associated with tuberculosis and granulomas in infected fish
Bacterium	*Mycobacterium fortuitum* *M. chelonae*	All seafood are potential carriers	Worldwide Fresh water		Occasionally causes pulmonary or disseminated disease in humans and wound infections	Mild	Wear gloves and keep wounds clean and dressed when handling seafood	*M. fortuitum* was first isolated from frogs *M. chelonae* was first isolated from turtles
Bacterium	*Nocardia asteroides*	All seafood are potential carriers	Worldwide	Infection occurs via inhalation of the bacterium or through breaks in the skin	Cough with sputum, progressive difficulty breathing, malaise, weight loss, fever, night sweats, chest pain, joint pain, liver and spleen enlargement	Moderate	Wear gloves and keep wounds clean and dressed when handling fish	70% of patients treated are immunosuppressed through other medication or predisposing illness

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Plesimonas shigelloides*	All aquatic animals but particularly shellfish	Fresh water	Consumption of uncooked seafood	Onset: 20–24 hours Duration: 1–7 days but usually 1–2 days in healthy adults Fever, chills, stomach pain, nausea, non-bloody or mucoid diarrhoea, vomiting	Mild in healthy adults, moderate in children <15 years Serious in infants or immunocompromised people	Rinse seafood in clean or boiled water and cook for at least 30 minutes at 60 °C	N/A
Bacterium	*Edwardsiella tarda*	All aquatic animals but particularly shellfish	Freshwater Marine	Consumption of uncooked seafood	Similar to *P. shigelloides*	Similar to *P. shigelloides*	Similar to *P. shigelloides*	N/A
Bacterium	*Bacillus cereus*	All seafood are potential carriers	Worldwide	Contamination resulting from inadequate refrigeration and storage of fresh seafood, or reheating of previously cooked seafood (i.e. food must be rapidly cooled to, and kept below, 4 °C)	Diarrhoeic strain—onset: 6–15 hours; duration: 24 hours Watery diarrhoea, nausea, stomach cramps and pain, rarely vomiting Emetic strain—onset: 0.5–6 hours; duration: <24 hours Nausea, vomiting, sometimes diarrhoea and stomach cramps	Usually mild, with possible serious complications	Constant refrigeration of both fresh and cooked seafood	Reheating may kill the bacteria in cooked seafood that has been poorly stored, but not the heat-stable toxins produced by *B. cereus*

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Clostridium perfringens*	Species range unknown	Worldwide Fresh water Marine Soil	Some organisms can survive cooking, and multiply in the cooling-down process and inadequate storage temperatures	Onset: 8–22 hours. Duration: 24 hours (1–2 weeks in the infirm). Intense stomach cramps, diarrhoea Type C strain: enteritis necroticans or pig-bel disease	Mild (common strain)—fatal (Type C strain)	Refrigerate cooked foods quickly and maintain temperatures below 4 °C Reheat thoroughly to >60 °C for >10 minutes	Duration is protracted in the young and elderly The fatal Type C strain is very rare *C. perfringens* is also involved in transforming histidine to histamine in scombroid poisoning
Bacterium	*Listeria monocytogenes*	Raw and smoked fish	Fresh water	Prolonged exposure to temperatures either above 4 °C or below 60 °C (e.g. cooked foods allowed to cool, or refrigerated/frozen foods allowed to warm slowly at room temperature) Usually associated with contamination through unsanitary handling or facilities during food preparation	Onset of gastrointestinal symptoms: 12 hours. Onset of manifestations of listeriosis—septicaemia, meningitis (or meningoencephalitis), encephalitis, intrauterine infections leading to spontaneous abortion in pregnant women: a few days to 3 weeks	Mild–serious	Keep food at temperatures outside the danger zone (either below 4 °C or above 60 °C)	Most healthy people suffer no symptoms. The potentially fatal expressions of the disease are found in pregnant women (especially the fetus) and immunocompromised people

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Salmonella typhi*; *Salmonella arizonae*	All sea foods are potential carriers	Fresh water Marine	Ingestion of bacteria with undercooked seafood Septicaemia follows penetration of *Salmonella* organisms into small intestine	Onset: 6–48 hours Duration: 1–2 days. May be prolonged, depending on age, health and dose ingested Acute symptoms: nausea, vomiting, abdominal cramps, diarrhoea, fever, headache Chronic symptoms: arthritic symptoms may follow 3–4 weeks later	Moderate–serious	Keep food at temperatures outside the danger zone (either below 4 °C or above 60 °C)	Usually associated with faecal contamination of water
Bacterium	Other *Salmonella* spp.	All sea foods are potential carriers	Fresh water Marine	Ingestion of bacteria with undercooked seafood Septicaemia follows penetration of *Salmonella* organisms into small intestine	Infections typically manifest as a self-limited gastroenteritis similar to *S. typhi* but less severe In less than 5%, infection spreads through the bloodstream, causing focal infection or abscess in almost any organ	Moderate–fatal	Keep food at temperatures outside the danger zone (either below 4 °C or above 60 °C)	N/A

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Shigella* sp.	All sea foods are potential carriers	Associated with waters polluted with human effluent	Consumption of raw or partially cooked shellfish from sewage-contaminated waters, or unhygienic handling by humans after product was cooked	Onset: 12–50 hours Abdominal pain, cramps, diarrhoea; fever; vomiting; blood, pus or mucus in stools; tenesmus	Moderate–serious	Keep food at temperatures outside the danger zone (either below 4 °C or above 60 °C)	N/A
Bacterium	*Campylobacter* sp.	All sea foods are potential carriers	Associated with unsanitised water. Bacteria are present in intestinal tract of many animals, including humans	Ingestion of bacteria and associated enterotoxins occurring in seafood that has been insufficiently cooked, has cooled too slowly after cooking, or has been insufficiently heated during reheating, or cross-contamination from human handling	Onset: 2–5 days Duration: 7–10 days (relapses in <25% of cases) Diarrhoea with fever, abdominal pain, nausea, headache and muscle pain	Moderate–serious	Cooking **does not** destroy the toxin. Observing critical temperatures during handling and processing will minimise toxins produced by these bacteria before cooking	Complications can include meningitis, urinary tract infections, reactive arthritis and, rarely, Guillain-Barre syndrome

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Escherichia coli*	All seafoods are potential carriers	*E. coli* is present in all animal intestinal tracts and is largely beneficial. Some strains (such as O157:H7) are pathogenic to humans	Consumption of seafood that has been either insufficiently cooked or eaten raw	Onset: rapid Duration: up to 8 days Abdominal pain, diarrhoea (initially watery, becoming bloody), occasional vomiting, low fever	Mild–moderate	Cooking all seafood. Rinse seafood in sanitised or boiled water. Ensure sanitary preparation area. Fully cook all seafood. Observe critical storage temperatures (below 4 °C and above 60 °C)	Complications with some biotypes include haemolytic uraemic syndrome in the very young, resulting in renal failure and haemolytic anaemia

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Bacterium	*Staphylococcus aureus*	All seafoods are potential carriers	Present everywhere in the environment	Ingestion of bacteria and associated enterotoxins occurring in seafood that has been insufficiently cooked, has cooled too slowly after cooking, or has been insufficiently heated during reheating, or cross-contamination through human handling	Onset: rapid Duration: 2–3 days Nausea, vomiting, retching, abdominal pain, prostration	Mild–moderate	Cooking all seafood Rinse seafood in sanitised or boiled water. Ensure sanitary preparation area Fully cook all seafood Observe critical storage temperatures (below 4 °C and above 60 °C)	Complications include haemolytic uraemic syndrome in the very young, resulting in renal failure and haemolytic anaemia
Bacterium	*Francisella philomiragia*	Present on fish and other marine life, also in sea water	Worldwide	Appears to be from exposure to contaminated water or sea life	Onset may be rapid but detection is extremely difficult Duration: variable, but may be long term; can result in death via multiple organ failure Chronic granulomatous disease	N/A	Rare disease	Complications include antibiotic resistance; complementary infections, including pneumonia; splenomegaly; organ nodules; adenitis

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Nematodes-roundworms)	Anisakid spp. e.g. *Anisakis simplex*, *Psuedoterranova decipiens*, *Contracaecum* spp., *Hysterothylacium* spp.	Salmon, herring, flounder, squid, octopus, copepods	Worldwide Marine	Consumption of undercooked or raw seafood contaminated with nematode larvae	Onset: 1 hour – 2 weeks Duration: typically <3 weeks Severe cases result in acute abdominal pain similar to acute appendicitis. Typically self-limiting and asymptomatic until diagnosed, when an irritated throat brings up a nematode	Moderate–serious	Rapid evisceration and removal of belly flaps in fish Fully cook seafood before consumption If seafood is to be served semi-raw, it should be blast frozen to below –35 °C for at least 15 hours (or –20 °C for 7 days)	Nematodes move from viscera to the flesh if fish is not eviscerated promptly Dead nematodes remaining in seafood, while not causing anisakiasis in humans, may elicit an allergic response

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Nematodes-roundworms)	*Angiostrongylus cantonensis*	Marine species of crustaceans and molluscs	South-east Asia and Pacific	Consumption of raw, infected molluscs, vegetables contaminated with mollusc slime, or marine crustaceans such as crabs and prawns that have consumed infected molluscs	Onset: 2–30 days (average 3 weeks) Nausea, vomiting, abdominal discomfort may occur soon after ingestion, developing into severe headache and stiff neck with eosinophilic meningitis. Fever may be present in children and severely infected adults	Moderate–serious	Cook all seafood Rinse seafood in clean or boiled water	N/A

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Nematodes-roundworms)	*Gnathostoma* spp.	Freshwater fish	Ecuador, Mexico, eastern Africa, Asia (including Japan)	Consumption of undercooked fish or consumption of terrestrial animals (e.g. pigs, poultry) that have eaten undercooked infected fish	Onset: several weeks Duration: unknown Subcutaneous swellings, oedema and pruritus Can lead to eosinophilic myeloencephalitis, involving intense radicular pain, paralysis of the lower extremity, urinary retention, severe headache, coma and death	Mild–moderate	Evisceration Cook all fish thoroughly	These nematodes cannot mature in the human host, so the larvae migrate through the internal organs or under the skin

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Nematodes-roundworms)	*Capillaria philippinensis*	Freshwater and marine fish	Asia, Middle East	Consumption of uncooked or uneviscerated seafood	Onset: symptoms develop over several weeks Abdominal discomfort and pain, intermittent diarrhoea. Untreated, it will progress to 8–10 voluminous stools per day with significant weight loss, malabsorption, cardiac failure, low blood pressure, oedema and hypogammaglobulinemia	N/A	N/A	Diagnosed by finding characteristic peanut-shaped eggs in stool
Parasite (Nematodes-roundworms)	*Capillaria hepatica*	Freshwater and marine fish	Korea, Japan, South America	Consumption of uncooked or uneviscerated seafood	Fever, shortness of breath; neck, chest and abdominal pain	N/A	N/A	N/A

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Cestodes-tapeworms)	*Diphyllobothrium latum* *Diphyllobothrium pacificum*	Larvae in viscera of both freshwater and marine fish. Larvae only migrate to the flesh of freshwater or anadromous fishes	Worldwide *D. pacificum* is from Peru.	Consumption (or tasting) of raw or undercooked fish	Onset: 10 days Abdominal distension, flatulence, diarrhoea. Other minor clinical signs include nausea, headache, nervousness, diarrhoea, weakness and a 'sensation that something is moving inside' Visualisation of spent proglottid (tapeworm segment–bearing ovule) in stool is often the first confirmation of diagnosis	Mild–moderate but can be serious for immunocompromised people	Evisceration Cook all fish thoroughly	*D. latum* grows to 10m in intestine, *D. pacificum* is about half this size

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Cestodes-tapeworms)	*Diplogonoporus grandis,* *D. nihonkaiense* *D. balaenopterae*	Marine fish	Far east (esp. Japan and Korea)	Consumption (or tasting) of raw or undercooked fish	Onset: 10 days Abdominal distension, flatulence, diarrhoea. Other minor clinical signs include nausea, headache, nervousness, diarrhoea, weakness and a 'sensation that something is moving inside' Visualisation of spent proglottid (tapeworm segment–bearing ovule) in stool is often the first confirmation of diagnosis	Mild–moderate but can be serious for immunocompromised people. May result in elevated IgE level.	Evisceration Cook all fish thoroughly	*D. nihonkaiense* is common in Japan

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Trematodes-flukes)	*Clonorchis* and *Opisthorchis* spp.	Freshwater cyprinids	Asia and Pacific—*C. sinensis* and *O. viverrini* Europe—*O. felineus*	Consumption of undercooked (pickled or salted) fish	Onset: 1–4 weeks Largely asymptomatic, but acute illness can occur with fever, epigastric pain and eosinophilia Chronic infections can result in gall stones, inflammation and erosion of the bile duct and liver parenchyma. Blockages from extensive tissue fibrosis can result in liver enlargement and cirrhosis, with severe pain	Moderate–serious	Evisceration Cook all fish thoroughly	Average infection is ~2–3 dozen worms in the bile duct and liver Heavy infections can have up to 20 000 worms in the liver
Parasite (Trematodes-flukes)	*Metagonimus yokagawai*	Freshwater fish	Far East	Consumption of uncooked or uneviscerated seafood	Diarrhoea, abdominal pain. The parasite can break down the lining of the small intestine, allowing its eggs to enter the bloodstream and infect the liver, heart and brain	moderate to serious	ensure all fish is eviscerated and cooked thoroughly.	N/A

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Trematodes-flukes)	*Heterophyes* spp.	Diadromous fish	Africa, South-east Asia, Pacific	Consumption of uncooked or uneviscerated seafood	Similar symptoms to *Metagonimus yokagawai*	moderate to serious	ensure all fish is eviscerated and cooked thoroughly.	N/A
Parasite (Trematodes-flukes)	*Stellantchasmus falcatus*	Diadromous fish	Asia, Polynesia	Consumption of uncooked or uneviscerated seafood	Similar symptoms to *Metagonimus yokagawai*	Moderate–serious	Evisceration Cook all fish thoroughly	N/A
Parasite (Trematodes-flukes)	*Paragonimus* spp	Freshwater decapods, particularly crabs and crayfish	*P. westermani* dominates west Africa and east Asia *P. mexicanus*, *P kellicotti* and *P. caliensis* occur in south and central America	Consumption of raw or undercooked freshwater crabs or crayfish	Onset of symptoms: ~3 months Starting with a dry cough that develops into a rusty sputum that is pronounced on awakening; pleuritic chest pain Difficult to distinguish from pneumonia or tuberculosis based on clinical signs alone	Mild–serious	Cook until muscles turn white or immerse in water above 55 °C for 5 minutes	Typically a disease of the lungs. Juvenile worms may cause ectopic lesions in other organs, including the brain

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Parasite (Trematodes-flukes)	Echinostomatid trematodes	Freshwater fish clams	SE Asia and western Pacific	consumption of uncooked or uneviscerated seafood	generally asymptomatic heavy infections can result in diarrhoea and vague abdominal discomfort with eosinophilia	mild	ensure all fish is eviscerated and cooked thoroughly	N/A
Parasite (Trematodes-flukes)	*Nanophyetus salmincola*	anadromous fishes,(principally salmonids) some freshwater snails	Northern Pacific	consumption of uncooked or uneviscerated seafood	onset- 5 to 8 days diarrhoea, mild abdominal discomfort and nausea	mild	ensure all fish is eviscerated and cooked thoroughly	N/A
Parasite (Trematodes-flukes)	*Metorchis conjunctus*	freshwater fish	North America	consumption of uncooked or uneviscerated seafood	onset- 1 to 15 days low fever, continuous epigastric abdominal pain and anorexia	mild - moderate	ensure all fish is eviscerated and cooked thoroughly	N/A

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Biotoxins	**Diarrhoetic Shellfish Poisoning (DSP)** okadaic acid, dinophysis toxins, pectenotoxins and yessotoxin	all shellfish(esp. mussels, oysters, scallops, clams and cockles)	Japan and Europe (incl. Scandinavia and the Mediterranean) also reported from New Zealand and Tasmania	genera of dinoflagellate implicated: *Dinophysis* & *Prorocentrum*	onset-½ to 3.hoursduration- 2 to 3 days nausea, vomiting, diarrhoea and abdominal pain with headache chills and feve	mild gastro disorder	Avoid eating shellfish in areas where red tides are known to occur. •Cooking, and discarding the cooking fluids afterwards diminishes the amount of poison ingested.	N/A
Biotoxins	**Paralytic Shellfish Poisoning** saxitoxin derivatives	all shellfish(esp. mussels, oysters, scallops, clams and cockles)	world-wide	bioaccumulation of toxins produced in a number of dinoflagellate and other phytoplankton species consumed by shellfish. (including *Alexandrium,Gymnodinium &Pyrodinium)*	onset- ½ to 2 hours tingling, burning, numbness, drowsiness, incoherent speech and respiratory paralysis recovery is usually complete so long as respiratory support is applied within 12 hours of exposure	death may occur due to cardiovascular collapse	As for DSP	Affected shellfish cannot be identified visually.

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Biotoxins	**Amnesic Shellfish Poisoning** domoic acid	marine fin fish (eg. anchovies); all shellfish(esp. mussels, oysters, scallops, clams and cockles) ,crabs	North America, Europe and New Zealand	bioaccumulation of toxins produced in a number of dinoflagellate and other phytoplankton species consumed by shellfish and finfish. Diatom-*Nitzchia pungens*	onset- gastrointestinal, less than 24 hours - neurological, within 48 hours gastrointestinal symptoms- vomiting, diarrhoea, abdominal pain and neurological problems- confusion, memory loss, disorientation, seizure and coma	serious to fatal	As for DSP	all fatalities have involved the elderly where symptoms can resemble Alzheimer's Disease
Biotoxins	**Scombroid poisoning** (histamine)	Scomberoids and other pelagic fishes; abalone and scallops	Worldwide Marine	Consumption of seafood in which certain bacteria (e.g. *Clostridium* spp.) have been responsible for metabolising histidine to dangerously high levels of histamine if ingested by humans	Onset: immediate—0.5 hours Headaches, itching skin, nausea, vomiting and diarrhoea, tingling, burning sensation in mouth, rash on upper body, reduced blood pressure	Elderly or impaired patients sometimes require hospitalisation	Cold temperature is the only preventive to histamine production post-harvest. Keeping temperature below freezing will delay the metabolism of histidine to histamine by bacteria	N/A

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Biotoxins	**Ciguatera** (ciguatoxin)	sub-tropical and tropical reef fish (eg. coral trout, grouper, mackerel)	Tropical and subtropical waters	Bioaccumulation of toxins produced by the dinoflagellate *Gambierdiscus toxicus* as part of the reef fish community's diet	Onset: <6 hours Duration: usually several days from onset; however, severe cases can persist for weeks, months and even years with recurring neurological symptoms Perioral numbness and tingling (paraesthesia), spreading to extremities; nausea, vomiting and diarrhoea; joint and muscle pain; headache; temperature sensory reversal; vertigo; physical exhaustion; cardiovascular signs, including arrhythmia, bradycardia or tachycardia, and reduced blood pressure	Death is rare but can occur following respiratory and cardiovascular failure	Avoid consuming any reef fish, particularly reef-dwelling predatory fish and larger (i.e. older) fish of a given species	Susceptibility to the disease depends on concentration of toxin in fish, quantity of fish eaten, and fish-eating history of patient (i.e. cumulative effect over time) Not all fish of a given species from a given location will be toxic

Class of pathogen	Disease causing agent	Seafood susceptible to contamination	Distribution and habitat	Transmission risk and factors	Disease and symptoms	Seriousness	Prevention and control	Comments
Biotoxins	**Pufferfish poisoning** (tetrodotoxin)	puffer fish, parrotfish, angelfish , octopus, marine snails, crabs	Indo–Pacific	Consumption of organs (e.g. liver, gonads, intestines, skin) of the puffer fish and other animals (e.g. newts, starfish, frogs) Bacteria commonly present in aquatic environments are required in producing these toxins	Onset of stage 1: 20 minutes to 3 hours Slight numbness of lips and tongue, increasing paraesthesia in face and extremities, with sensation of floating and difficulty in walking. Headache, epigastric pain, nausea, diarrhoea and/or vomiting may also occur	Fatal	Avoid consuming any fish from the pufferfish family (Tetraodontiformes), or at least ensure that all Tetraodontiformes are well eviscerated Tetradotoxin is heat stable and cannot be made safe through cooking	Pufferfish ('Fugu') is commonly eaten in Japan after special preparation, but mortalities are not uncommon Mislabelling of this product as anglerfish resulted in three deaths in Italy in 1977

Sources: Brusle (1997); Hui et al. (2001a, 2001b, 2001c); Lawley & Gibbs (1998); Rieman & Cliver (2006); Stoskopf (1992); USFDA (1998); WHO (1989)

Appendix 3

Species of animals used for aquaculture in Australia

Table A3 Finfish—commercial operations

Common name	Scientific name	Product	Where produced	Destination	Systems involved
Atlantic salmon	*Salmo salar*	Whole, fresh fish; various smoked products; eggs	SA, Tas., Vic.	Domestic markets and export	Hatcheries, raceways, net-pens
Australian bass	*Macquaria novemaculeata*	Live	NSW, Qld	Domestic waterways	Hatcheries
Barramundi	*Lates calcarifer*	Live, fresh product	NSW, NT, Qld, SA, WA	Domestic waterways	Hatcheries
Barramundi cod	*Cromileptes altivelis*	Live, fresh product	Qld	Export markets	Hatcheries, tanks
Black bream	*Acanthopagrus butcheri*	Live	WA	Domestic waterways	Hatcheries
Brown trout	*Salmo trutta*	Live	Vic.	Domestic waterways	Hatcheries, ponds, raceways
Clownfish	*Amphiprion* spp.	Live	Qld, WA	Domestic aquaria	Hatcheries, tanks
Cobia	*Rachycentron canadum*	Whole, fresh product	Qld	Domestic markets and export	Hatcheries, tanks
Coral trout	*Plectropomus leopardus*	Live, fresh product	Qld	Export markets	Hatcheries, tanks
Eastern freshwater cod	*Maccullochella ikei*	Live	NSW	Domestic waterways	Hatcheries
Eels	*Anguilla australis*	Live chilled or, frozen product	NSW, Qld, Tas., Vic.	Export markets	Dams, ponds, tanks
Estuary cod	*Epinephelus coioides*	Whole, fresh product	Qld	Domestic markets and export	Hatcheries, tanks
Golden perch	*Macquaria ambigua*	Live	NSW, Qld	Domestic waterways	Hatcheries
Goldfish	*Carassius auratus*	Live	All states	Domestic aquaria	Hatcheries, ponds, tanks
Greenback flounder	*Rhombosolea tapirina*	Whole, fresh product	Tas.	Domestic markets and export	Hatcheries, tanks
Jade perch	*Scortum barcoo*	Live; whole, fresh product	Qld	Domestic markets	Hatcheries, ponds

Common name	Scientific name	Product	Where produced	Destination	Systems involved
Kingfish	*Seriola lalandi*	Whole, fresh product	SA	Domestic markets and export	Hatcheries, net-pens
Mangrove jack	*Lutjanus argentimaculatus*	Live	Qld	Domestic waterways	Hatcheries
Mary River cod	*Maccullochella mariensis*	Live	Qld	Domestic waterways	Hatcheries
Mulloway	*Argyrosomus japonicus*	Live; whole, fresh product	NSW, SA	Domestic markets and waterways	Hatcheries, net-pens
Murray cod	*Maccullochella peelii*	Live, whole product	NSW, Qld	Domestic markets and waterways	Hatcheries, ponds, tanks
Rainbow trout	*Oncorhynchus mykiss*	Eggs; chilled, frozen or smoked product	NSW, SA, Tas., Vic., WA	Domestic markets and export	Hatcheries, ponds, raceways, net-pens
Silver perch	*Bidyanus bidyanus*	Live; whole, fresh product	NSW, Qld, SA	Domestic markets	Hatcheries, ponds
Snapper	*Pagrus auratus*	Live; whole, fresh product	NSW, WA	Domestic markets	Hatcheries, net-pens
Trout cod	*Maccullochella macquariensis*	Live	NSW, Vic.	Domestic waterways	Hatcheries, ponds, tanks

Table A4 Finfish—research and development

Common name	Scientific name	Product	Where produced
Dolphin fish	*Coryphaena hippurus*	Research stage	Qld, WA
Golden snapper	*Lutjanus johnii*	Research stage	NT, Qld, WA
King George whiting	*Sillaginodes punctata*	Research stage	SA
Southern bluefin tuna	*Thunnus maccoyi*	Research stage	SA
Striped trumpeter	*Latris lineata*	Research stage	Tas
Summer whiting	*Sillago ciliata*	Research stage	Qld
West Australian dhufish	*Glaucosoma hebraicum*	Research stage	WA

Table A5 Crustaceans—commercial operations

Common name	Scientific name	Product	Where produced	Destination	Systems involved
Banana prawn	*Fenneropenaeus merguiensis*	Live; chilled product	NT, Qld	Domestic markets and export	Hatcheries, ponds
Black tiger	*Penaeus monodon*	Live; chilled	NSW, NT,	Domestic	Hatcheries,

prawn		product	Qld	markets	ponds
Blue crab	*Portunus pelagicus*	Dead, chilled, soft shelled	Qld	Domestic markets and export	Onshore holding systems
Brown tiger prawn	*Penaeus esculentus*	Live; chilled product	NSW, Qld	Domestic markets and export	Hatcheries, ponds
Kuruma prawn	*Penaeus japonicus*	Live; chilled product	NSW, Qld	Domestic markets and export	Hatcheries, ponds
Marron	*Cherax cainii*	Live	NSW, SA, WA	Local market and some export	Juveniles from wild, hatcheries, ponds
Moreton bay bug	*Thenus orientalis*	Live; cooked or frozen	NSW, Qld, WA	Domestic markets and export	Hatcheries, tanks
Mud crab	*Scylla serrata*	Live	NT, Qld	Domestic markets and export	Hatcheries, ponds
Redclaw	*Cherax quadricarinatus*	Live	NSW, Qld	Local market and some export	Hatcheries, ponds
Southern rock lobster	*Jasus edwardsii*	Live; cooked or frozen	Tas., SA	Research	Hatcheries, pueruli collectors, tanks
Tropical rock lobster	*Panulirus ornatus*	Research	Qld	Research	Hatcheries, tanks
Western rock lobster	*Panulirus cygnus*	Live; cooked or frozen	WA	Research	Pueruli collectors, tanks
Yabby	*Cherax destructor* (*C. albidus* only in WA)	Live	NSW, SA, Vic., WA	Local market and some export	Hatcheries, ponds, dams

Table A6 Molluscs—commercial operations

Common name	Scientific name	Product	Where produced	Destination	Systems involved
Akoya pearl oyster	*Pinctada imbricata*, *P. fucata*	Spat for grow-out; pearls from seeded oysters; adductor muscle meat	NSW, Qld	Marine sites	Hatcheries, grow-out on longlines or rafts
Blacklip abalone	*Haliotis rubra*	Spat for grow-out or reseeding; shucked and processed meat sold frozen or cooked; some live trade to Asia	SA, Tas., Vic., WA	Marine sites	Hatcheries, tanks, raceways, net-pens

Common name	Scientific name	Product	Where produced	Destination	Systems involved
Blacklip pearl oyster	*Pinctada margaritifera*	Spat for grow-out; pearls from seeded oysters; adductor muscle meat	WA	Marine sites	Hatcheries, grow-out on longlines or rafts
Blue mussel	*Mytilus edulis planulatus*	Spat for grow-out; market-size mussels sold live and in-shell to markets	NSW, SA, Tas., Vic., WA	Marine sites	Hatcheries, grow-out on longlines
Greenlip abalone	*Haliotis laevigata*	Spat for grow-out or reseeding; shucked and processed meat sold frozen or cooked; some live trade to Asia	SA, Tas., Vic., WA	Marine sites	Hatcheries, tanks, raceways, net-pens
Native flat oyster	*Ostrea angasi*	Spat for grow-out	NSW, Tas.	Marine sites	Hatcheries (experimental)
Pacific oyster	*Crassostrea gigas*	Spat for grow-out; market-size product sold frozen or live, in-shell	NSW, SA, Tas., Vic.	Marine sites	Hatcheries, grow-out on racks or longlines
Saucer scallop	*Amusium balloti*	Spat for grow-out; deshelled meat sold fresh, frozen or canned	Qld, WA	Marine sites	Hatcheries, grow-out in tanks and then reseeding onto sea floor
Shark Bay pearl oyster	*Pinctada albina*	Spat for grow-out; pearls from seeded oysters; adductor muscle meat	WA	Marine sites	Hatcheries, grow-out on longlines or rafts
Silver-lipped pearl oyster	*Pinctada maxima*	Spat for grow-out; pearls from seeded oysters; adductor muscle meat	NT, Qld, WA	Marine sites	Hatcheries, grow-out on longlines or rafts
Southern scallop	*Pecten fumatus*	Spat for grow-out; deshelled meat sold fresh, frozen or canned	Tas.	Marine sites	Hatcheries, harvest from wild-farmed product for grow-out in net-pens and then reseeding onto sea floor
Sydney rock oyster	*Saccostrea glomerata*	Bottled, half-shell or in-shell product	NSW, Qld	Estuaries and rivers	Hatcheries; grow-out using bags, stick and tray
Winged pearl oyster	*Pteria penguin*	Spat for grow-out; half pearls from seeded oysters	Qld, WA	Marine sites	Hatcheries, grow-out on longlines or rafts

Table A7 Molluscs—research and development

Common name	Scientific name	Product	Where produced	Destination	Systems involved
Blacklip oyster	*Saccostrea mytiloides*	Spat for grow-out	NT	Marine sites	Hatcheries, grow-out in open systems
Giant clam	*Tridacna squamosa*	Spat for grow-out	NT	Marine sites	Hatcheries, grow-out in open systems
Milky oyster	*Saccostrea mordax*	Spat for grow-out	NT	Marine sites	Hatcheries, grow-out in open systems

Table A8 Echinoids—research and development

Common name	Scientific name	Product	Where produced	Destination	Systems involved
Sandfish	*Holothuria scabra*	Production of juveniles for grow-out	NT, Qld	Marine sites	Hatcheries, grow-out in tanks and then reseeding onto sea floor or aquaculture ponds

Appendix 4

Australia's National List of Reportable Diseases of Aquatic Animals

The list is regularly updated. An electronic version of the list is available at www.agriculture.gov.au/animal-plant-health/aquatic/reporting/reportable-diseases.

Table A9 Finfish

Disease	Listed in the OIE *Aquatic animal health code* (2015)	Listed regionally (OIE/NACA) (2015)	Exotic to Australia
1. Epizootic haematopoietic necrosis—EHN virus	Yes	Yes	No
2. European catfish virus/European sheatfish virus	No	No	Yes
3. Infectious haematopoietic necrosis	Yes	Yes	Yes
4. Spring viraemia of carp	Yes	Yes	Yes
5. Viral haemorrhagic septicaemia	Yes	Yes	Yes
6. Channel catfish virus disease	No	No	Yes
7. Viral encephalopathy and retinopathy	No	Yes	No
8. Infectious pancreatic necrosis	No	No	Yes
9. Infection with HPR-deleted or HPR0 infectious salmon anaemia virus	Yes	No	Yes
10. Infection with *Aphanomyces invadans* (epizootic ulcerative syndrome)	Yes	Yes	No
11. Bacterial kidney disease (*Renibacterium salmoninarum*)	No	No	Yes
12. Enteric septicaemia of catfish (*Edwardsiella ictaluri*)	No	Yes	Yes
13. Piscirickettsiosis (*Piscirickettsia salmonis*)	No	No	Yes
14. Gyrodactylosis (*Gyrodactylus salaris*)	Yes	No	Yes
15. Red sea bream iridoviral disease	Yes	Yes	Yes
16. Furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*)	No	No	Yes
17. *Aeromonas salmonicida*—atypical strains	No	No	No
18. Whirling disease (*Myxobolus cerebralis*)	No	No	Yes
19. Enteric redmouth disease (*Yersinia ruckeri*—Hagerman strain)	No	No	Yes

Disease	Listed in the OIE *Aquatic animal health code* (2015)	Listed regionally (OIE/NACA) (2015)	Exotic to Australia
20. Koi herpesvirus disease	Yes	Yes	Yes
21. Grouper iridoviral disease	No	Yes	Yes
22. Infectious spleen and kidney necrosis virus–like (ISKNV-like) viruses[a]	No	No	Yes
23. Infection with salmonid alphavirus	Yes	No	Yes

Table A10 Molluscs

Disease	Listed in the OIE *Aquatic animal health code* (2015)	Listed regionally (OIE/NACA) (2015)	Exotic to Australia
1. Infection with *Bonamia ostreae*	Yes	No	Yes
2. Infection with *Bonamia* species	No	No	No
3. Infection with *Bonamia exitiosa*	Yes	Yes	Yes
4. Infection with *Mikrocytos mackini*	No	No	Yes
5. Infection with *Marteilia refringens*	Yes	No	Yes
6. Infection with *Marteilia sydneyi*	No	No	No
7. Infection with *Marteilioides chungmuensis*	No	Yes	Yes
8. Infection with *Perkinsus marinus*	Yes	No	Yes
9. Infection with *Perkinsus olseni*	Yes	Yes	No
10. Infection with *Xenohaliotis californiensis*	Yes	Yes	Yes
11. Iridoviroses	No	No	Yes
12. Abalone viral ganglioneuritis[b]	Yes	Yes	No
13. Ostreid herpesvirus 1 μ variant (OsHV-1 μvar)	No	No	No

Table A11 Crustaceans

Disease	Listed in the OIE *Aquatic animal health code* (2015)	Listed regionally (OIE/NACA) (2015)	Exotic to Australia
1. Taura syndrome	Yes	Yes	Yes
2. White spot disease	Yes	Yes	Yes
3. Yellowhead disease—yellowhead virus	Yes	Yes	Yes
4. Gill-associated virus	No	No	No
5. Infectious hypodermal and haematopoietic necrosis	Yes	Yes	No
6. Crayfish plague (*Aphanomyces astaci*)	Yes	No	Yes
7. White tail disease	Yes	Yes	No
8. Infectious myonecrosis	Yes	Yes	Yes
9. *Monodon* slow growth syndrome	No	Yes	Yes
10. Necrotising hepatopancreatitis	Yes	Yes	Yes
11. Acute hepatopancreatic necrosis disease (AHPND)	No	Yes	Yes

Table A12 Amphibians

Disease	Listed in the OIE *Aquatic animal health code* (2015)	Listed regionally (OIE/NACA) (2015)	Exotic to Australia
1. Infection with *Batrachochytrium dendrobatidis*	Yes	Yes	No
2. Infection with ranavirus	Yes	Yes	No

NACA = Network of Aquaculture Centres in Asia–Pacific; OIE = World Organisation for Animal Health
a ISKNV-like viruses are those defined on page 7 of Biosecurity Australia 2010, *Importation of freshwater ornamental fish: review of biosecurity risks associated with gourami iridovirus and related viruses*, provisional final import risk analysis report, Department of Agriculture, Canberra.
b Included within the OIE-listed disease 'infection with abalone herpes-like virus'.
c Listed by the OIE as an emerging disease.

Appendix 5

Table A13 Aquatic animal disease emergency contact numbers in Australia

Organisation	Position	Telephone
CSIRO Australian Animal Health Laboratory, Fish Diseases Laboratory, Geelong	Aquatic animal health specialists	03 5227 5118
Office of the Chief Veterinary Officer, Australian Government Department of Agriculture	Australian Chief Veterinary Officer	02 6272 4644
Animal disease watch hotline	All states	1800 675 888
Department of Primary Industries, Parks, Water and Environment, Tasmania	Fish health unit	03 6165 3260
	CVO	03 6165 3261
Department of Environment and Primary Industries, Victoria	Fish health specialist	03 9217 4171
	CVO	03 9217 4114
Department of Primary Industries, New South Wales	Aquatic biosecurity unit	02 6391 3239
NSW Agriculture	CVO	02 6391 3577
Department of Agriculture, Fisheries and Forestry, Queensland	Fish pathologist, Coopers Plains	07 32766062
	CVO	07 3087 8014
Department of Primary Industry and Fisheries, Northern Territory	Fish pathologist	08 8999 2354
	CVO	08 8999 2130
Department of Fisheries, Western Australia	Fish pathologist	08 9203 0173
	Director General	08 9482 7370
Department of Primary Industries and Regions, South Australia	Fish health specialist	08 8226 3975
	CVO	08 8207 7970
ACT Veterinary Services	CVO	02 6207 2357

CVO = chief veterinary officer

Appendix 6

Drug and other chemical use in aquaculture

If therapy is considered as a control measure for infectious diseases in aquatic animals, a number of issues need to be examined. Firstly, no treatments are currently available for viral diseases. Use of drugs is not an effective option, and vaccination is at the experimental stages only. For serious viral diseases, especially diseases listed by the World Organisations for Animal Health (OIE), slaughter and disinfection—a major exercise—needs to be considered.

Vaccination against bacterial diseases is used as a preventive measure—for example, Intervet manufactures and supplies vaccines for the Tasmanian salmonid industry. Other vaccines for prophylaxis against certain bacterial diseases (e.g. furunculosis in salmon) are used overseas.

Many treatments are available for bacterial and parasitic diseases of fish. Selecting the most appropriate treatment requires knowledge of efficacy, ease of application, human safety, target animal safety, regulatory aspects, toxicity, side effects, potential problems associated with resistance and tissue residues, environmental impacts of chemical use, and costs.

Drugs not registered for use in aquatic animals in Australia can be given emergency use status with the agreement of the chief veterinary officer of the state or territory in question. Drugs can be used off-label by a veterinarian if the chemicals are registered for use in another species. However, liability aspects of off-label use need to be considered.

When using chemicals in the environment, close cooperation with the local environmental protection agency will be needed.

References relevant to these issues, which are not addressed in this manual, are listed below. They include a report of the National Taskforce on Aquaculture Drugs and Chemicals (1998), which was established in 1995 to examine the approval process for drug and chemical use in aquaculture. These references are available at short notice from the CSIRO Australian Animal Health Laboratory (Geelong) and the Office of the Chief Veterinary Officer, Australian Government Department of Agriculture (Canberra).

References relevant to drug and chemical use

Alderman, DJ, Rosenthal, H, Smith, P, Stewart, J & Weston, D 1994, *Chemicals used in mariculture*, ICES Cooperative Research Report 202, International Council for the Exploration of the Sea, Copenhagen.

Avault, JW 1997, 'Control of diseases and calculations for chemical treatments, some fundamentals reviewed', *Aquaculture Magazine*, vol. 23, no. 3, pp. 80–3.

Brown, L (ed.) 1993, *Aquaculture for veterinarians: fish husbandry and medicine*, Pergamon Press Ltd, Oxford.

Burka, JF, Hammell, KL, Horsberg, TE, Johnson, GR, Rainnie, DJ & Speare, DJ 1997, 'Drugs in salmonid aquaculture: a review', *Journal of Veterimary Pharmacology and Therapeutics*, vol. 20, no. 5, pp. 333–49.

Carson, J 1990, 'Chemotherapy of bacterial diseases of fish', in *Fin fish diseases: refresher course for veterinarians*, Post Graduate Committee in Veterinary Science, University of Sydney, Proceedings 128, pp. 81–8.

Langdon, JS 1990, 'Major protozoan and metazoan parasitic diseases of Australian finfish', in *Fin fish diseases: refresher course for veterinarians*, Post Graduate Committee in Veterinary Science, University of Sydney, Proceedings 128, pp. 233–55.

Langdon, JS 1992, 'Major protozoan and metazoan parasitic diseases of Australian finfish', in *Fin fish workshop: refresher course for veterinarians*, Post Graduate Committee in Veterinary Science, University of Sydney, Proceedings 182, pp. 1–26.

Langdon, JS 1992, 'Viral diseases in Australian–Asian finfish', in *Fin fish workshop: refresher course for veterinarians*, Post Graduate Committee in Veterinary Science, University of Sydney, Proceedings 182, pp. 22–45.

Michel, C & Alderman, DJ (eds) 1992, *Chemotherapy in aquaculture: from theory to reality*, Office International des Epizooties, Paris.

National Taskforce on Aquaculture Drugs and Chemicals 1998, Minutes of teleconference meeting held on 3 December 1998.

Percival, S 1997, *Registration of aquaculture chemicals*, progress report, FRDC Project 96/314, December 1997.

Stoskopf, MK (ed.) 1988, *Tropical fish medicine*, Veterinary Clinics of North America, vol. 18, no. 2, WB Saunders Co., Philadelphia.

Stoskopf, MK (ed.) 1993, *Fish medicine*, WB Saunders Co., Philadelphia.

References

ABARES 2013, *Australian fisheries statistics 2012*, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, frdc.com.au/knowledge/publications/Pages/australian_fisheries_stats.aspx.

Brusle, J 1997, *Ciguatera fish poisoning: a review. Sanitary and economic aspects*, Les Editions, INSERM, Paris.

DAFF 2013, *Ross* Lobegeiger *report to farmers: aquaculture production summary for Queensland 2011–12*, Queensland Department of Agriculture, Fisheries and Forestry, Brisbane, daff.qld.gov.au/__data/assets/pdf_file/0004/66307/report-to-farmers.pdf.

Econsearch 2013, *The economic impact of aquaculture on the South Australian state and regional economies, 2011/12*, report to PIRSA Fisheries and Aquaculture, Econsearch, Adelaide.

FRDC 2003, *From Antarctica to the tropics: a snapshot of the Australian fishing industry*, Fisheries Research and Development Corporation, Canberra.

Hui, YH, Pierson, MD & Gorham, JR (eds) 2001a, *Foodborne disease handbook*, 2nd edn, vol. 1, *Bacterial pathogens*, CRC Publishing.

Hui, YH, Sattar, SA, Murrell, KD, Nip, WK & Stanfield, PS (eds) 2001b, *Foodborne disease handbook*, 2nd edn, vol. 2, *Viruses, parasites, pathogens, and HACCP*, CRC Publishing.

Hui, YH, Kitts, D & Stanfield, PS (eds) 2001c, *Foodborne disease handbook*, 2nd edn, vol. 4 *Seafood and environmental toxins*, Marcel Dekker Publishing.

Lawley, RA & Gibbs, P (eds) 1998, *Microbiology handbook 3: fish and seafood*, Leatherhead Food RA, Surrey.

Nowak, B, Crane, M & Jones, B 2005, *Aquatic Animal Health Subprogram: development of national investigation and reporting protocols for fish kills in recreational and capture fisheries*, final report, FRDC project 2005/620, Fisheries Research and Development Corporation, Canberra.

NSW DPI 2013, *Aquaculture production report 2011–2012*, New South Wales Department of Primary Industries, Orange, dpi.nsw.gov.au/__data/assets/pdf_file/0006/458142/Aquaculture-Production-Report-2011-2012.pdf.

O'Sullivan, D & Savage, J 2009, *Status of Australian aquaculture in 2006/2007*, Austasia Aquaculture Trade Directory 2009.

Riemann, H & Cliver, DO 2006, *Foodborne infections and intoxications*, 3rd edn, Academic Press.

Stoskopf, MK 1992, *Fish medicine*, Saunders Company, Philadelphia.

Subasinghe, RP, McGladdery, SE & Hill, BJ (eds) 2004, *Surveillance and zoning for aquatic animal diseases*, FAO Fisheries Technical Paper no. 451, Food and Agriculture Organization of the United Nations, Rome.

USFDA 1998, *Big bad bug book: foodborne pathogenic microorganisms and natural toxins handbook*, Center for Food Safety and Applied Nutrition, United States Food and Drug Administration, Silver Spring, Maryland.

WHO 1989, *Report to the WHO Consultation on Public Health Aspects of Seafood-borne Zoonotic Diseases*, World Health Organization, Geneva.