National Aquaculture Council

Aquatic Animal Welfare Guidelines

Guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption.

An Initiative of the National Aquaculture Council of Australia

Australian Government
Department of Agriculture, Fisheries and Forestry

AQUATIC ANIMAL WELFARE GUIDELINES

Guidelines on welfare of fish and crustaceans in aquaculture and/or in live holding systems for human consumption

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These guidelines are an initiative of the National Aquaculture Council of Australia

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1. Introduction

1.1 Rationale for the development and adoption of aquatic animal welfare guidelines

Over the past few years, the welfare of aquatic animals has been subject to an increasing profile, both nationally and internationally, and the trend is set to continue.

1.1.1 Global governmental interest

The Office International des Epizooties (OIE), the world animal health organisation, indicated in March 2002 that animal welfare issues were coming under increased public scrutiny, and that this scrutiny included aquatic animals. Since then, as part of the objectives of the OIE 2001-2005 strategic plan, a working group of specialists from five continents has been assembled to investigate the scientific aspects of animal welfare. The recommendations and guidelines developed by this permanent working group will be applicable to all OIE member countries, of which Australia is one.

International scrutiny of aquatic animal welfare by official bodies, however, is not currently restricted to the OIE. The European Union (EU) has instituted a number of initiatives regarding animal welfare, including adoption in 1998 of the "Convention for the Protection of Animals Kept for Farming Purposes" and the "Convention for the Protection of Animals for Slaughter". As part of this process, "Recommendations for the Welfare of Different Animal Species" have been developed, and continue to be developed. It is understood that recommendations regarding aquaculture species are in the process of development and ratification. The EU is proactively discussing animal welfare at the World Trade Organisation, the inference being that welfare issues will become important in continued access to specific markets where import to third countries is concerned.

1.1.2 Non-governmental organisations and the consumer

In parallel with official scrutiny, the profile of aquatic animal welfare amongst the consumer base has been increased, especially in Europe. A number of non-governmental organisations (NGOs), such as the Farm Animal Welfare Council (FAWC) and Compassion in World Farming (CIWF), have published reviews of aquaculture in the United Kingdom and detailed recommendations that they consider would improve the welfare of the cultured fish. Whilst some of the recommendations, and the precepts they are based on, may be questioned the result has been to increase consumer awareness of welfare issues associated with farmed finfish. European retailers may start requiring assurance schemes for aquatic animal welfare as part of their general move towards incorporating animal welfare issues into their marketing philosophies. In addition, the Royal Society for the Prevention of Cruelty to Animals (RSPCA) in the United Kingdom has incorporated finfish aquaculture into its Freedom Foods scheme, and to that end has produced a detailed Code of Practice. Primary producers may register to become part of this audited assurance scheme.

Within Australia a number of documents have been produced that incorporate welfare issues, either as general principles of humane treatment or detailing handling and killing of animals for food purposes. These have been listed below, under the section on complementary documentation.

1.1.3 Benefits to the producer – decreasing stress during growout

The adoption of welfare guidelines by an industry may therefore become increasingly important in continued market acceptance at a national, retailer and consumer level. It is also recognised that the adoption of practices that address important welfare risks can produce improvements in the overall health and productivity of the animals being cultured. Suboptimal husbandry procedures have the potential to induce robust physiological stress responses in all animals, including aquatic animals. The physiological changes associated with chronic stress render the animal more susceptible to diseases. The health implications may range from the appearance of a previously unreported disease to the increased incidence of an established disease and depression of growth rate. The result may be sudden increased mortality, chronic increased mortality or decreased productivity. Stress itself may also result in poorer feed use by the animals, thus producing poor feed conversion efficiency. To illustrate; scientific studies have shown that light, thermal and osmotic stress in fish all result in decreased food conversion efficiency. Ultimately all these factors will impact upon production costs, and hence the margin to the producer.

1.1.4 Benefits to the producer – improved slaughter, better product quality

Consideration of welfare parameters both during growout, and especially at the time of harvest can produce tangible improvements in quality of the final product. It has been shown that high levels of stress pre-harvest result in a greater depletion of muscle energy reserves and the induction of a more intense rigor mortis a shorter time after death. Limiting crowding intensity pre-harvest is known to produce firmer flesh, less bruising, less scale loss and decreased incidence of gaping (separation of myomeres). The careful control of crowding combined with a method of harvest that minimises time out of water and time to complete stunning will result in prolonged time to rigor mortis, with associated improvements in flesh quality, processing performance and shelf life.

1.2 Nociception, pain sensation and stress in fish and crustaceans

1.2.1 Definitions

To appropriately address welfare issues in aquatic animals it is necessary to appreciate the range of potential responses to adverse stimuli. It has been shown that this can take the form of:-

- no measurable response,
- a nociceptive response,
- a pain response or
- a stress response;

each characterised by a different level of neurological or physiological processing within the animal.

Nociception can be defined as the detection of noxious, tissue-damaging or harmful stimuli, the subconscious processing of that information in the lower levels of the central nervous system sometimes accompanied by a reflex response.

Pain, in comparison, is defined by the International Association for the Study of Pain (IASP) as an unpleasant sensory and emotional experience associated with actual or potential tissue damage. This definition of pain therefore relies upon the conscious, emotional processing of nociceptive stimuli and is always a psychological state.

Stress responses take the form of physiological changes within the animal that alter its respiratory, cardiovascular, hormonal and metabolic states. Short-term stress responses are a normal, necessary survival tool in animals. When stressors become chronic, however, they have the potential to become harmful to the overall well-being of the animal.

1.2.2 Understanding pain perception

The pathways associated with perception of pain have been elucidated through neurological science. In general, nociceptive stimuli are detected by free nerve endings. These sensory structures transmit the activity to the spinal cord via nerves. These nerves link to others within the spinal cord where they may induce a simple reflex resulting in a withdrawal reflex, which is an escape response devoid of conscious processing.

In addition spinal nerves connect to the higher centres of the central nervous system in the brainstem (the reticular formation), and in the midbrain (the thalamus). From here, the brain transmits information to other parts of the body and also generates innate behavioural responses to the stimuli. These innate behaviours are known to include vocalisation, facial expression and more extensive withdrawal responses. Nociceptive information is processed and transmitted in a complex network to the cortex of the brain where the sensation is perceived.

Negative feedback on the nociceptive system is achieved via naturally occurring opioids, and is controlled in the brainstem and areas of the cortex.

It is important to remember that neural activity at the level of the midbrain and brainstem is not consciously perceived. In the human nervous system the complex network with the cortical structures are required to allow the conscious processing of the stimuli.

Specialised areas of the cortex in humans are involved in generating the unpleasant or aversive nature of pain. Patients who have undergone surgery to remove this area in the hope of eliminating severe, chronic pain report that they are still aware of the nociceptive stimuli, but that it is no longer stressful or unpleasant. Networks of the frontal cortex and these specialised areas allow humans to relate the current stimulus to previous experience and perceived threat to initiate pain and fear responses.

1.2.3 Anatomy of the nervous system in aquatic animals

Having reviewed the neurological capacity of humans, we can compare directly those structures existing in fish. “Primitive” fish such as sharks & rays (Elasmobranchs) are known to possess free nerve endings in their skin but they have no neurones which enter the spinal cord, and show no interruption of behaviour following severe nociceptive stimuli. It is widely accepted that these fish probably lack even nociceptive activity.

More evolutionarily developed fish, the teleosts, however have been shown to possess unmyelinated fibres together with a nociceptive function. In addition many of the nerve pathways running up the spinal cord to the thalamus and reticular formation are intact in teleost fish, however they lack the complex cortical structures present in higher animals.

Unfortunately this information does not directly indicate anything about the functionality of the sensory system in fish. The elasmobranchs that possess nociceptive associated central nervous structures do not appear to have nociceptive capability. The debate on the degree to which fish are able to process nociceptive information has intensified recently and it is worthwhile to summarise the issues under discussion.

1.2.4 The debate on pain perception in fish

Looking purely at pain perception according to the IASP definition would suggest that the possibility of pain sensation as humans experience it is extremely unlikely. One side of the debate states that the projection of human experiences onto less complex animals (anthropomorphism) is flawed. By accepting, as demonstrated in humans, that pain sensation requires higher conscious processing, and that this processing occurs in complex cortical networks that, anatomically speaking, are missing in fish then it must be concluded that fish are incapable of higher processing and pain perception since they lack the complex cortical structures that are the site of higher nociceptive processing in humans. It may be queried whether other areas of the midbrain may be involved in pain perception, such as the processing of visual information in birds that takes place in the midbrain as opposed to the visual cortex. However, despite neuroanatomical studies of the fish brain no regions have been discovered that duplicate the complex neural networks necessary.

Previous studies had concluded that the demonstration of pain perception, or at least some conscious recognition of aversive stimuli, was possible in fish through behavioural approaches.

- Electrical shocking that resulted in either frenzied swimming behaviour or avoidance of an object was argued to demonstrate pain sensation in the fish tested. The administration of morphine (an opioid) to the water resulted in decreased response to the electric shock.
- Carp were reported to alter their feeding and nesting behaviour following hooking, and some reports indicated an avoidance of hooks thereafter.
- Fish that received irritant injections in their lips were reported to display increased respiratory rate (albeit accepted as physiological) avoidance of pelleted feed, rocking behaviour and lip rubbing on gravel and tank walls. These changes were interpreted as indicating guarding of painful lips from hard feed, rocking as comfort behaviour and rubbing to ease the pain. When morphine was administered the incidence of the abnormal behaviours was reduced.
- The demonstrated learning capacity of fish, both for conspecific recognition and mapping would indicate that there may be a mapping, memory or mental representation capability in the central nervous system of fish and it has been hypothesised that should fish be capable of simple mental representations they may have the potential to suffer. This is not the same as pain sensation.

The extrapolation of pain sensation from these behavioural observations is complicated by a number of experimentally determined factors, which lead to the following conclusions: -

- Studies have indicated that nociceptor activity, via its stimulation of the reticular formation, can induce innate behavioural changes, and pre-wired motor programmes and thus behavioural change on its own does not provide conclusive evidence of pain perception.
- Psychological studies have demonstrated a number of examples of associative learning occurring without conscious awareness; therefore the interpretation of learned behaviour in a study is complicated.
- The presence of equivalent nerves, pathways and neurochemicals in mammals and fish, has been quoted as evidence of pain perception. However, the neurological components identified are merely part of the nociceptive system in animals, exist in elasmobranchs (which have very poor responses) and require further processing at higher levels in mammals to result in pain sensation.
- The nociceptive system utilises natural opioids in the negative feedback control systems. The response of an animal to an analgesic, such as morphine (an opioid), does not necessarily indicate that pain sensation was involved in the response. The majority of the behavioural studies use morphine as an analgesic. Any response to morphine must also be considered in the light of its activity at a purely nociceptive level.

Currently science cannot definitively answer the question of whether fish feel pain. However, both sides of the scientific divide indicate that, regardless of the ability of fish to perceive pain, nociceptive stimuli have the ability to induce robust stress responses in fish that, uncontrolled, are harmful to the overall well-being of the animals and that more research is required to identify appropriate welfare criteria.

1.2.5 Noxious recognition in crustacea

The situation in crustacea is even more confused. Examining the central nervous system of crustacea in comparison to teleost fish it is obvious that the ganglionic nature of the nervous system renders it even less likely that a sufficient complexity of neurone networks could exist. If anything, it diminishes the possibility of awareness and sensory emotion; however, it cannot be fully ruled out at this stage. Behaviours such as spatial and conspecific recognition have been reported, but the scientific literature is extremely limited in its examination of pain sensation in crustacea.

Experiments on decorticate mammals have shown complex stereotypical responses to noxious stimuli in the absence of conscious awareness. It is likely that this is representative of the situation in invertebrates. Invertebrates show little evidence that responses continue beyond the primary stimulus. Eisemann, an insect physiologist, states that “no example is known to us of an insect showing protective behaviour towards injured parts, such as limping after leg injury or declining to feed…on the contrary, our experience has been that insects will continue with normal activities even after severe injury or removal of body parts.” In addition, the same scientist also relates the functional simplicity of the nervous system with an inability to sense pain, stating that most behaviour patterns are pre-programmed and indicating that a capacity for learning exists even in decapitated insects and isolated ganglia.

The balance of current scientific evidence would suggest that responses to aversive stimuli in crustaceans are likely to be reflex withdrawal or escape responses and that it is unlikely that there is the conscious emotional response to that stimulus that may be considered to be pain.

1.2.6 Relating pain sensation and welfare in general

The investigation of pain sensation in aquatic animals is an interesting scientific exercise, and ultimately the results will have impact on welfare. However in the area of aquaculture this tends to be restricted to procedures involving direct physical impact to the animal, such as humane slaughter. For the rest of the growing cycle it is more important to remember that chronic exposure to aversive situations is likely to produce a stress response that not only has adverse effects on the welfare of the animal, but also on production parameters. To this end the development of guidelines, designed to reduce stressors and thus improve both welfare and production, may be beneficial.

1.2.7 Balanced welfare assessments

A difficulty arises in the assessment of welfare in aquatic animals, and how to set guidelines that will have positive effects for the animals. There is a need to balance the ethical philosophy of animal welfare with the objectivity of science when developing welfare standards. There are a number of basic approaches to animal welfare assessment: -

- The ethically philosophical approaches – these systems define the welfare of the animals in terms of feelings, emotions and overarching principles of welfare expectation (the “freedoms”). This approach may be usefully employed in the broad consideration of welfare. At specific levels, however, it lacks definition, consistency and there seems no way to objectively measure compliance.
- The natural behaviour approach – this approach concentrates on natural behaviours in natural environments. It is now recognised that some of the “natural” behaviours are in fact adaptations to cope with what is effectively a very harsh environment. The natural behaviours have not been consistently defined, and more importantly, no work has shown what welfare risk is associated with not performing some of the behaviours.
- The choices approach – this is based on the premise that when faced with a choice the animal will pick the one best suited to its welfare. There are a couple of issues with this approach. The first is that the short-term choices made by the animal may not actually represent the most suitable long-term solution. Secondly, the choice made will vary with physiological state
- The Homeostasis approach - this model defines the welfare of an animal in terms of what it is doing physiologically, immunologically and behaviourally to cope with its environment and what the cost is to the animal of so doing. Not only does it give two direct risks to examine, but it also provides some objective measurements that can be made (growth rate, reproductive performance, etc.). Through scientific study the principal component risks to the welfare of the animals may be determined by assessing their responses to changes in those parameters. Not only are the major risks identified, they may also be quantified objectively.

Whilst it is important to remember the overarching philosophical basis of animal welfare, it is essential that welfare standards avoid subjective or perception based judgements. Welfare standards in aquaculture production should be science based, objective, consistent and measurable. By ensuring that standards are objectively based, an industry encourages welfare management systems that can be consistently assessed across sectors, produce measurable and defined benefits to the animals, and minimises unnecessary costs. Of all the potential systems, the homeostasis approach seems the most constructive for developing meaningful welfare indices.

1.3 Scope of the guidelines

1.3.1 Sectors included within the guidelines

These guidelines have been developed to include finfish in aquaculture, crustacea in aquaculture and both finfish and crustacea in live holding systems for human consumption.

These guidelines are applicable to closed, semi-closed and semi-open aquaculture systems. A closed aquaculture system is one where the operator has good control over both the water and the organisms (e.g. a recirculating tank based system or aquaria). A semi-closed system is one where the operator has good control over the organisms and limited control over the water flow (e.g. pond culture, through-flow tank based systems). A semi-open system allows the operator good control over the organisms, but no control over the water flow (e.g. floating netpen farm).

1.3.2 Exclusions from the guidelines

These guidelines do not include lower order animals such as bivalve and univalve molluscs given the complexities of developing a scientific basis for evaluating pain perception in these animals, and the very low likelihood that conscious sensation does exist in such animals.

The recreational fishing sector, through its peak national body, Recfish Australia, has already produced its own code of practice ("The National Code of Practice for Recreational and Sport Fishing) and additionally has accepted and promoted Position Statement PSN23 issued by the National Consultative Committee on Animal Welfare (NCCAW) covering animal welfare aspects of recreational fishing. The ornamental fish industry, through the Pet Industry Joint Advisory Council (PIJAC), likewise has developed it's a "Code of Practice for Aquarium Operations". Some States and Territories have in addition Codes of Practice covering ornamental fish (e.g. Code of Practice for the Operation of Pet Shops, Victoria). The use of aquatic animals in scientific research is covered by the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes. These areas currently being adequately serviced in terms of codes of practice are not considered in this document.

The commercial fishery sectors, containing wide variation in practices and practitioners, lies outside the remit of the National Aquaculture Council and thus have not been incorporated in this document.

1.3.3 Guideline objectives and duties of care

This document is designed to be a framework guidance document, from which it is envisaged sector specific Codes of Practice may be developed. As such the information is not designed to provide specific measures, action levels or audit standards for individual farming systems or species, but to highlight areas for inclusion in specific Codes of Practice and justify the approach for the industry, and the market place. Where objective information is lacking it is hoped that the intention of participating sectors to develop, and operate under, robustly designed standards that demonstrably improve animal well-being, production and market access should encourage the expansion of research necessary to define principal components of welfare risk and measures to improve upon them. Codes of Practice developed under the auspices of this framework document should contain information and advice specific to the species and culture systems utilised.

In addition to any Codes of Practice developed, industries should be aware of, and comply with, all relevant legislation or regulatory requirements in the State or Territory in which they operate. Welfare issues pertinent to aquatic animals may be present in animal welfare Acts of parliament, statutory regulations produced pursuant to Acts, or in controls associated with fisheries or aquaculture legislation. A list of relevant legislation is given below for each State or Territory. It is the responsibility of the operator to become familiar with the legislation and to comply with the relevant requirements.

1.4 Complementary documentation

1.4.1 State/Territory legislation

Australian Capital Territory:

Animal Welfare Act 1992	Covers fish and crustacea held for human consumption
Animal Welfare Regulations 2001	
Fisheries Act 2000	Legislative control of aquaculture
Fisheries Regulations 2001	

New South Wales:

Prevention of Cruelty to Animals Act 1979	Covers fish and crustacea held where food is prepared or for direct retail sale for human consumption
Prevention of Cruelty to Animals (General) Regulations 1996	
Fisheries Management Act 1994	Legislative control of aquaculture
Fisheries Management (Aquaculture) Regulations 2001	

Northern Territory:

Animal Welfare Act 1999	Covers live fish in captivity and live crustacea held where food is prepared or for direct retail sale for human consumption
Animal Welfare Regulations 2000	
Fisheries Act 1988	Legislative control of aquaculture
Fisheries Regulations 1992	

Queensland:

Animal Care and Protection Act 2001	Covers live fish and some live invertebrates
Animal Care and Protection Regulations 2002	
Fisheries Act 1994	Legislative control of aquaculture
Fisheries Regulations 1995	
Fisheries regulations 1995 Revision Notice	

South Australia:

Prevention of Cruelty to Animals Act 1995	Aquatic animals excluded
Prevention of Cruelty to Animals Regulations 2000	
Fisheries Act 1982	Legislative control of aquaculture
Fisheries (Exotic Fish, Fish Farming and Fish Diseases) Regulations 2000	
Aquaculture Act 2001	
Aquaculture Regulations 2002	

Tasmania:

Animal Welfare Act 1993	Covers live fish only
Animal Welfare Regulations 1993 (and 1994, 1995, 1997 amendments)	
Inland Fisheries Act 1995	Legislative control of aquaculture
Marine Farming Planning Act 1995	
Living Marine Resources Management Act 1995 (and 2000 amendment)	

Victoria:

Prevention of Cruelty to Animals Act 1986	Covers live fish and crustacea
Prevention of Cruelty to Animals Regulations 1997	
Fisheries Act 1995	Legislative control of aquaculture
Fisheries Regulations 1998	

Western Australia:

Animal Welfare Act 2002	Covers live vertebrates or prescribed live invertebrates other than humans or fish
Animal Welfare (General) Regulations 2003	
Fisheries Resources Management Act 1994	Legislative control of aquaculture
Fisheries Resources Management Regulations 1995	

Readers should ensure that they are aware of any amendments made to the above legislation. In addition, readers should be aware that further amendments to the legislation could be made in the future.

1.4.2 Codes of Practice

- Australian Seafood Users Manual – G.K. Yearsley et al. (2000), Queensland Department of Primary Industries, Queensland
- Code of Conduct for Australian Aquaculture – Australian Aquaculture Forum
- Fish handling (Fact Sheet 18) – Department of Primary Industries, Water and Environment, Tasmania
- Guidelines on Fish and Crustacean Welfare – Department of Natural Resources and Environment, Victoria
- Tasmanian Salmonid Farming Industry – Code of Practice (2004), Tasmanian Salmonid Growers Association Ltd.

1.4.3 Recommended reading and references used in these Guidelines

a. Bondad-Reantaso MG, McGladdery SE, East I and Subasinghe RP (Eds) (2001), “Asia Diagnostic Guide to Aquatic Animal Diseases”, FAO Fisheries Technical Paper No. 402, Supplement 2, FAO, Rome.

b. Brown, L; (Ed). Aquaculture for Veterinarians. Pergamon Press (1993)

c. Crear B and Allen G (2002),”Guide for the rock lobster industry. No. 1. Optimising water quality – oxygen”, Tas Aquaculture and Fisheries Institute.

d. Evans, L.H.; Jones, J.B. (Eds). Proceedings of the International Symposium on Lobster Health Management [Adelaide, September 1999], Curtin University Press, Perth.

e. Lobster Institute website:
www.lobster.um.maine.edu/library/publications/holding tank/7749.html
www.lobster.um.maine.edu/library/publications/holding tank/7972.html

f. MPEDA/NACA (2003),”Shrimp Health Management Extension Manual.”

g. New South Wales Department of Primary Industries, Animal Welfare Unit (2004) "Avoiding Cruelty in Shellfish Preparation", www.agric.nsw.gov.au/reader/aw-pamphlet/shellfish-prep.htm

h. PIRSA factsheets:

   i. “Water quality in freshwater ponds” - www.pir.sa.gov.au/pages/aquaculture/species_profiles/water_quality_fs.pdf

   ii. “The importance of regular crayfish harvesting and management" - www.pir.sa.gov.au/pages/aquaculture/species_profiles/crayfish_harvesting_and_popula.pdf

   iii. "Hides and habitats for crayfish production" - www.pir.sa.gov.au/pages/aquaculture/species_profiles/hides_and_habitats.pdf

   iv. "The importance of pond ecology in freshwater crayfish nutrition" - www.pir.sa.gov.au/pages/aquaculture/species_profiles/pond_ecology_and_nutrition.pdf

i. Rottman RW, Francis-Floyd R and Durborow R (1992),” The role of Stress in Fish Disease”, Southern Regional Aquaculture Centre, Pub. No. 474

j. Tasmanian Salmonid Growers Association Ltd,
Tasmanian Salmonid Farming Industry Code of Practice (June 2004)

k. Tucker, John W. (2000), "Marine Fish Culture", Kluwer Academic Publishers, Dordrecht, The Netherlands.

l. Wedemeyer, Gary A. (1996), "Physiology of fish in intensive culture systems", Chapman & Hall, New York.

m. Yearsley GK, Onley AC and Brown FK (Eds.) (2000), ”Australian seafood users manual”, Queensland Department of Primary Industries and Fisheries Research and Development Corporation, Brisbane, QLD

1.5 Acknowledgements

Some of the information recommending times and conditions for live-storage and humane slaughter methods of various finfish and crustaceans, is taken from the Australian seafood users manual (2000) (Eds. G.K. Yearsley, A.C. Onley and F.K. Brown) with permission of the publisher, the Department of Primary Industries, Queensland.

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2.Welfare of finfish in aquaculture

2.1. Water quality

This is a complex matrix of inter-related parameters, and different species of finfish have differing sets of parameters within which their environmental requirements are met. Where water quality parameters fall chronically or grossly outside the fish's requirements, welfare, growth, and eventually survival are compromised.

2.1.1. Oxygen

With few exceptions fish can only obtain oxygen from their surrounding water. Oxygen dissolved in the water is often the first limiting factor compromising fish performance and welfare in aquaculture. Oxygen solubility decreases with increasing water temperature, and increasing salinity. The oxygen demand of an individual fish increases with temperature, level of physical activity (eg swimming) and level of physiological activity (eg digesting food). As a fish's ability to extract oxygen depends on the relative saturations of surrounding water and their blood, it becomes important to consider both degree of saturation (expressed as a percentage) as well as absolute concentration (measured as parts per million or milligrams per litre).

Fish vary widely in their requirements for oxygen, but few species are capable of good growth at oxygen concentrations below 50%, and 35% should be considered the lower threshold from a welfare perspective. Similarly it is generally accepted that absolute oxygen concentration should exceed 4 mg/l to ensure good welfare.

2.1.2. Metabolites

Metabolites, the waste products from respiration and digestion, are released by fish directly into the surrounding water and if they are not sufficiently diluted, neutralised, or removed they can build up to harmful levels.

Ammonia is the primary metabolic waste product from fish, more or less continuously excreted from the gills and the digestive tract. When ammonia is excreted, it reacts with water to rapidly reach an equilibrium mixture between a less toxic form (ammonium ion NH_4^+) and a more toxic unionised form (ammonia NH_3). The proportion staying as toxic ammonia is greater at higher pH value (more alkaline waters), and at higher temperatures. Because of the relationship between salinity and pH, ammonia can also be a problem in closed or recirculating seawater systems. Ammonia is highly toxic to fish, causing damage to the delicate gill tissue at relatively low levels. Toxic levels of unionised ammonia vary considerably with species and environmental conditions but the following levels are suggested as safe for chronic exposure from both production and welfare perspectives:-

Sensitive species (eg salmonids) in freshwater	< 0.002 mg/l
Less sensitive species (eg non-salmonids) in freshwater	< 0.01 mg/l
Marine species	< 0.05 mg/l

Nitrites, a product of the natural degradation of ammonia compounds, can also build to toxic levels and therefore compromise production and welfare. Nitrites are not a common problem in open systems, but can reach toxic levels in recirculating or closed systems. The toxic effect of nitrite is strongly mitigated by chloride ions, thus nitrite is rarely a problem in seawater systems. For chronic exposure in freshwater systems, 0.1 mg/l is suggested as safe from both production and welfare perspectives.

Faecal material is rarely toxic in its own right, but its degradation does cause deoxygenation of the water, production of additional nitrogenous compounds and development of toxic gasses. In addition, faecal material will contribute to organic suspended solids that can lead to gill diseases. No specific limits can be suggested but in general accumulation of faecal matter within a fish holding system should not be allowed.

2.1.3. Suspended solids

A certain amount of turbidity in aquaculture systems is quite common but excessive levels of suspended solids can cause stress by clogging gills and/or producing mechanical gill damage if the material is an irritant. Signs include excess mucus production and swelling of the gill filaments, both of which interfere with oxygen uptake. In aquaculture generally, suspended solids are only problematical during transient natural events such as river floods or heavy wave action, but harmful levels can also be caused by aquaculture activity such as net cleaning, channel flushing, or pond draining. Different species of finfish exhibit a wide range of tolerance to suspended solids, with carp and catfish able to tolerate levels as high as 10,000 mg/l, whilst salmonids may become obviously stressed at 100 mg/l. It is not possible to set definitive limits but the following levels are suggested as safe for chronic exposure from both production and welfare perspectives:-

Sensitive species (eg salmonids) in freshwater	< 50 mg/l
Less sensitive species (eg non-salmonids) in freshwater	< 200 mg/l
Marine species	< 100 mg/l

2.1.4. Salinity

Salinity in natural waters may vary from 1 to 40 parts per thousand (ppt), with oceanic seawater being approximately 36 ppt. Water quality criteria for salinity vary with species and life-stages, and different species may have a narrow or broad range of tolerance for salinity. Fish held in water of salinity significantly outside their range of tolerance have difficulty in maintaining fluid and electrolyte balance. This may cause stress either due to excess water retention (haemodilution) or excessive water loss and dehydration, analogous to terrestrial animals deprived of access to drinking water. Even within the range of tolerance, rapid changes are more stressful than gradual changes. Hence fish should be maintained at salinities within the natural range for that species and life-stage, and any change in salinity should be introduced gradually.

2.1.5. Other

Other water quality parameters that should be assessed include dissolved carbon dioxide, water hardness, pH, and the presence of harmful algae or jellyfish.

Dissolved carbon dioxide levels may increase in a closed system. Chronic exposure to increased levels may result in health and welfare problems. It may therefore be appropriate to consider monitoring carbon dioxide levels on an infrequent basis and where identified as an issue the installation of degassing equipment to remove excess carbon dioxide.

Water hardness may affect the relative toxicity of certain treatments; therefore knowledge of the degree of hardness is essential prior to any treatment of the fish.

Fish will tolerate varying pH levels according to species. Water should be monitored to ensure that pH remains within an appropriate range for the species stocked. In addition increasing pH will exacerbate any problems with ammonia build up in the system.

During risk periods in marine systems, it may prove beneficial to monitor water for algal cells either by the estimation of turbidity (via a secchi disc) or identification and quantification of algal cells. Algae can negatively impact on fish health and welfare through direct irritation of the gills and mucosal surfaces, depletion of dissolved oxygen or by production of toxins. The early identification of harmful algae may allow mitigation measures, such as pen relocation, to be carried out.

In certain regions and at certain times toxic jellyfish are known to swarm, and it is beneficial to monitor water for jellyfish abundance when such a threat is posed. In regions where such threats are likely, pre-emptive and or mitigation measures should be prepared in advance.

2.2. Water temperature

2.2.1. Natural range and avoiding thermal shock

Different species of fish have different ranges of temperatures within which they thrive, and the range itself may be broad or narrow. Being "cold-blooded", the body temperature of a fish varies with that of surrounding waters and fish must adjust their metabolism accordingly. Fish held in water of temperature significantly outside their range of tolerance become stressed, and even within the range of tolerance, rapid changes are more stressful than gradual changes. Temperatures towards the lower end of optimal temperature range are generally less stressful because they induce torpor, whilst higher temperatures are more stressful either because of the temperature itself or from the combined effect of reduced oxygen content of the warmer water and the increased metabolic oxygen demand in the fish (a 10°C rise in water temperature will induce a 2 to 3 fold increase in metabolic requirements in the fish). Increasing temperatures are generally more stressful than decreasing temperatures, and maximum rates of change of ≤ 2°C/hr to a maximum of ≤ 10°C/day have been suggested.

Fish should be maintained at temperatures within the natural range for that species and life-stage, and any change in temperature should be gradual.

2.3. Food and feeding

2.3.1. Nutritional balance, safe food

As the diet of fish in most modern aquaculture is either supplemented with or entirely composed of processed feed it is incumbent on the aquaculturist to ensure that the diet meets the nutritional requirements of the fish, and is free from known fish pathogens and contaminants. Adherence to these principles clearly benefits both production and welfare goals. There is now sufficient knowledge of nutritional requirements and of feed manufacturing technology to allow an appropriate diet to be manufactured for most aquaculture species.

Where whole or unprocessed fish are fed, they should be sourced and treated in such a way as to reduce the risk of disease or contaminants entering the holding system.

2.3.2. Delivery to minimise aggression and wastage

Most of the farmed fish species are aggressive, opportunistic feeders, and feed should therefore be dispensed in a manner which allows all fish in a holding unit the opportunity to access feed. Chronic failure to address this requirement is likely to create social hierarchies within each fish holding unit, whereby dominant individuals or groups will consume or guard food beyond growth requirements and subservient individuals or groups will starve.

Conversely, delivery of more food than can be consumed in a reasonable time is likely to lead to waste and accumulation of decaying material, which in turn would adversely affect the fish in the holding unit by for example, causing deoxygenation of the water , production of nitrogenous waste products and toxic gasses

The use of experienced feeding personnel, cameras, feedback loops, feeding tables and feed plans may be considered to ensure the most appropriate supply of feed to the fish.

2.3.3. Fasting regimes

Whilst fish in the wild are accustomed to irregular and often limiting food supply, aquaculture generally aims to supply as much feed as can be converted to growth. However, as feeding and digestion of food increases oxygen demand, it is common and accepted industry practice to withhold feed prior to handling, treatment, or transport of fish to reduce the potential for stressful hypoxic incidents. Such fasting periods may vary from hours to days depending on the conditions and species.

At some stages of their life-cycle, during spawning for instance, fish become naturally disinterested in feeding. Under these circumstances it is not harmful or stressful to discontinue feeding for periods extending to several weeks, but always with due regard to the provision below concerning periodic checking of the appetite.

Feed may be withheld for therapeutic or prophylactic purposes where the excessive supply of nutrient rich material may exacerbate gastrointestinal conditions and lead to increased morbidity and mortality, as well as decreased welfare.

Fishes' metabolic rate and hence their appetites vary considerably with water temperature, and hence it is useful to consider fasting periods in terms of "degree days"; two days fasting at 10 ^{0}C being a 20 degree days fast, which would be equivalent to four days fasting at 5 ^{0}C, etc. It is suggested that for routine aquaculture operations interruptive fasts of up to 50 degree days would not be unduly stressful. Further it is suggested that longer fasts are also acceptable under certain circumstances, providing the fish' appetites are periodically checked by test feeding.

2.4. Stocking density

2.4.1. Not an absolute measure of welfare

Quantifying the adequate space for each fish in an aquaculture environment is a complex question. Most aquaculture finfish are shoaling species, appearing to thrive at higher than "natural" densities providing they are immersed in an adequate supply of good quality water and are supplied with sufficient food to avoid competition. For example, Atlantic salmon smolt have been shown to perform well (ie grow rapidly, with little or no fin erosion, skin abrasions, etc) in intensive recirculation systems at stocking densities of 80 to 100 kg/ m^3. Yet in freshwater lake culture the same fish may exhibit stress related symptoms at stocking densities as low as 12 kg/m^3.

In aquaculture, stocking density in itself is clearly not a universal measure of welfare; rather it is an empirical measure of welfare relevant to a particular system. Assuming that the system is suitable for the species and life-stage, fish welfare and performance in a particular operation will be enhanced when target stocking density takes into account the prevailing environmental conditions.

2.4.2. Use of water quality parameters as feedback

Environmental conditions are rarely static and a pragmatic way to take account of environmental conditions is to use changing water quality parameters as feedback in assessing stocking density. Hence maintenance of tolerable levels of oxygen, metabolites, and suspended solids, integrated with changes in temperature, will be a good guide as to the appropriateness of stocking density in the system. Chronic drift outside of desirable parameters will require remedial action; either improving water quality, or reducing density.

2.4.3. Need to develop welfare indices

Whilst any good stockman will recognise stress induced by crowding, it would be useful to develop indices of welfare specific to each of the major finfish species under aquaculture (eg gill condition, fin condition, scale loss, etc) and consideration given, in the marine environment, to the impact of site conditions, pen design and maintenance on the suitable biomass per holding unit.

2.5. Equipment

2.5.1. Construction and maintenance

Holding units, transfer systems, and handling equipment should all be designed and maintained so as to avoid fish coming into contact with sharp edges and abrasive surfaces at any stage. The external mucus layer of the skin is the first line of defence against infective pathogens and plays an important role in fluid balance. Significant damage or loss of this fragile layer will at least cause distress to the fish and diminish performance. Other skin layers have equally important roles in the maintenance of the health and wellbeing of the individual and are susceptible to physical damage.

2.5.2. Lighting

Where fish are exposed to bright sunlight in clear and shallow water, fish can suffer from sunburn. Where such conditions are likely, fish should have access to deeper water and/or shade from direct sunlight.

Modern aquaculture practices frequently use photoperiod manipulation to control maturation cycles. In such installations care should be taken to avoid instantaneous change from light to complete darkness and vice-versa, as the sudden change causes a panic reaction in fish.

2.5.3. Velocity of water flow

In tank culture, where water velocity is entirely under the operator's control, it is important to ensure that the fish are generally able to hold their position against the current. Excessive current speeds are capable of exhausting fish to the point of distress.

2.5.4. Protection from predators

Fish holding units should be designed to prevent fish escape and to exclude predators. As close presence of predators will also disturb fish, sometimes to the point of panic, measures such as acoustic deterrents, predator exclusion nets and fences are recommended. Predator deterrent devices and exclusion structures must be regularly inspected and maintained, both to check their proper functioning and to ensure that neither the predators themselves nor the fish being protected are inadvertently harmed.

2.6. Husbandry practices

2.6.1. Handling

The external mucus layer of the skin is the first line of defence against infective pathogens and plays an important role in fluid balance. Significant damage or loss of this fragile layer will at least cause distress to the fish and diminish performance.

Removal from water and handling should be avoided whenever possible. Where handling is necessary, equipment and procedures used should aim to minimise abrasion, scale loss or undue fish stress. Fish that are to be removed from water for routine husbandry practices (health and weight checks, etc) should first be sedated or anaesthetised, and returned to the water as rapidly as possible. Whenever large fish are handled out of water (eg Broodstock), adequate support should be provided to the body of the fish. Where manual handling is necessary, operators should ensure that their hands are wet.

2.6.2. Crowding & grading

As with most livestock, it is periodically necessary to crowd fish to smaller spaces in order to better observe, treat, grade, or move fish from one holding unit to another. Whilst necessary for good husbandry, such crowding can be stressful to the fish and it is important that personnel undertaking these operations remain alert to signs of stress and other welfare issues. Rapidly dropping dissolved oxygen levels, significant increase in suspended solids (stirred up from fouled nets or pond bottoms), panicked swimming into obstacles, and entrapment in handling gear are all potential risks to welfare during crowding operations. Crowding operations should be properly supervised with appropriate regular checks on fish behaviour and water quality.

In any given population fish will frequently exhibit a wide range of growth rates, and if left unchecked the disparity in size will increase. Thus grading fish by size or weight in aquaculture operations is necessary both for production planning (harvest strategy) and for good fish husbandry (reduce dominance, offer appropriate feed size, appropriate net size, etc). Routine grading operations are also a good opportunity to remove any fish that are obviously debilitated or diseased (runts, deformities, gross lesions, etc). These fish, which often provide a focus for disease, must be humanely destroyed, and properly disposed of with farm mortalities.

2.6.3. Transport of live fish

It is sometimes necessary to transfer live fish over long distances either by road (transport tanker) or by sea (towing pens), and this process has the potential to cause sufficient stress so as to compromise welfare as well as subsequent fish health.

Feed should be withheld from fish for 24 to 48 hours before transport so as to reduce oxygen demand and minimise waste production during transport.

Transport tankers should be of a design which avoids mechanical damage, facilitates rapid loading and unloading, and equipped with oxygen and/or aeration equipment. Fish should be assessed for health status and size prior to loading so that tanks are not loaded with compromised fish or overloaded beyond design capacity. Dissolved oxygen levels, and fish behaviour, should be checked at appropriate intervals if transport tanks are not fitted with automatic continuous dissolved oxygen monitoring systems. Whilst adequate oxygenation during transport is essential, the build-up of carbon dioxide during transport can also cause health and welfare problems, and aeration by compressed air or water spray to dissipate the carbon dioxide may also be required on longer trips. Discharge of fish from transport tanks should aim to minimise handling and stress, which usually translates to a compromise between rapid transfer from tank to receiving water and avoidance of rough handling.

In some types of aquaculture fish may be successfully moved, over long distances and over a period of days, by towing the entire pen in which they are housed. Whilst most finfish aquaculture species are capable of significant swimming speeds, care must be taken to keep the towing speed to a rate the fish can readily maintain for the duration of the journey. It is essential that the integrity and the shape of the towed net is maintained to allow sufficient volume for the fish to swim. The towed pen should be checked at regular interval to ensure that exhausted fish are not pushed against the trailing end of the net, or that fouling accumulated at the leading end of the net has not decreased water flow through the pen. Rough weather, large predators, and harmful biota such as algal blooms and jellyfish swarms are also potential stressors during transport, against which vigilance and an appropriate response plan are the only option.

2.7. Health

There is a very clear link between the health, welfare, and growth performance of fish, thus aquaculture management practices should always aim to optimise fish health.

2.7.1. Surveillance and monitoring

An active health surveillance program facilitates early detection of diseases and enables a rapid response to be mounted. Periodic monitoring of the stock by sampling and lab analysis provides valuable information on the pathogens or disorders latent in that particular stock in that environment. A health plan, incorporating a structured program of surveillance and monitoring by farm staff assisted by professional health service providers such as fish veterinarians and diagnostic labs, is highly recommended for all aquaculture enterprises.

Suspected health problems, including unusual or unexplained fish appearance or behaviour should be investigated promptly. If the cause is not readily apparent (eg. mechanical injury, low dissolved oxygen, known disease etc), then assistance from a fish health service provider should be sought.

2.7.2. Treatments

Whilst some health and welfare problems can be fixed by innocuous treatments (such as a temporary change in salinity) or by changing management practices (flow rate, diet, structural modifications, etc), pharmaceutical treatments are sometimes required when there is no other method to control a disease incident or when welfare is compromised.

Therapeutants used to treat fish must comply with State/Territory regulations, and treatments must only be undertaken with the appropriate authorisation (eg veterinary prescription) and strictly according to the appropriate instructions. Fish should be closely monitored for the duration of the treatments to ensure that the treatment is being applied effectively and without causing stress sufficient to compromise welfare of the fish. Where possible an assessment of the efficacy of the treatment should be carried out to reduce potential for resistance development and future welfare issues (e.g. post-treatment parasite counts carried out following a parasite treatment will highlight any loss of efficacy of the active agent used, allowing the use of a different class of agent on a subsequent treatment).

2.7.3. Destruction of damaged and/or sick fish

Injured, very sick, or severely deformed fish should be culled from the population and humanely destroyed whenever possible. Individual fish may be humanely destroyed by delivering a sharp blow to the top of the head, destroying the brain by means of a spike (ike-jime), overdose of anaesthetic or other means of rendering them rapidly insensible.

2.8. Humane slaughter

Farmed fish must be humanely killed, which means the method of killing must be rapid, and must at least render the fish insensible until death occurs. As stressful slaughter methods can have significant impact on the flesh quality (intense rigor, gaping, soft and/or discoloured flesh, shorter shelf life, etc) it is also in the direct commercial interest of aquaculture operators to implement humane slaughter practices.

2.8.1. Methods and Equipment

Fish should be fasted for a period of 2 to 3 days prior to slaughter, in order to evacuate the gut. Stressors such as crowding, handling, and rapid swimming should be kept to a minimum in the period leading up to slaughter. Unless an “instant-death” method such as ike-jime is being used, fish must be either sedated or stunned prior to slaughter and bleeding.

A food grade anaesthetic registered for use in commercial aquaculture (product name AquiS) is available in Australia, and this has proven to be effective in sedating fish prior to slaughter.

A percussive blow delivered at the right strength and location on the top of the head remains a very effective method of rendering fish at least insensible, after which fish can be bled out. The traditional manually delivered blow can now be replaced by a commercially available automated percussive device that vastly improves speed and safety of operations whilst also improving welfare by reducing the potential for inaccuracies and removing the potential for fatigue in the manual operator. This equipment is recommended as the method of choice for salmonids and many species of finfish farmed around the world. The use of an ice slurry diffused with carbon dioxide as a bath to induce narcosis is not recommended, as the continuous stream of carbon dioxide cause the pH of the water to rapidly drop to stressfully low levels. Fish being introduced into such a bath commonly suffer temporary but acute distress before becoming narcotised, and the resulting activity demonstrably affects flesh quality.

Other fish such as Barramundi appear not to suffer any distress when introduced directly into ice slurry, and rapidly become sedated to the point of insensibility.

Ike-jime (spiking the brain) is the most appropriate method for humane slaughter of large fish such as Tuna.

For all of the humane slaughter methods, it is important that personnel involved in harvest understand the aims of humane slaughter and have enough training to carry it out successfully.

3.Welfare of crustacea in aquaculture

3.1 Introduction

Given the structure of the central nervous system in crustacea, and the difficulty in concluding that there is conscious awareness it is necessary to examine welfare issues from the point of reducing stress and maximising the health status of the animals. In this manner not only are the major principal components of welfare risk thought to be addressed, but the producer benefits from improved production efficiency.

The wellbeing of the animals may be directly related to a number of factors including: -

- Water quality;
- Pond management, preparation and habitat;
- Health monitoring and addressing disease risks;
- Population management;
- Equipment, handling; and
- Humane harvesting methods

By addressing each issue, this guideline document seeks to outline the generic principles for developing farm procedures that maintain the welfare status of the animals.

3.2 Water Quality

Crustacea spend the majority of their time immersed in water on the culture facility; they rely on it to supply their oxygen requirements, provide some degree of nutrition and remove waste products such as carbon dioxide and nitrogenous metabolic wastes. It is therefore unsurprising that the maintenance of high water quality is central to ensuring good welfare in crustacea.

3.2.1 *Water source and preparation*

Depending on the species of crustacean being farmed, the water will be sourced from a variety of locations. In all cases the suitability of the water supply in terms of volume and composition must be assessed prior to development of an aquaculture facility. Freshwater crustacea may be grown in purpose built ponds, dams or held in tank based systems with water being sourced from bores, rainfall or from water catchments. Saltwater crustacea will generally be grown in ponds utilising saline groundwater or pump ashore from the marine environment (the high-flow, flow through systems commonly used to hold commercial catches of Rock Lobster are discussed separately under section 4 – Live Holding Systems). For both freshwater and saline pond or tank culture it is beneficial to hold water in a reservoir area for 7 to 14 days prior to introduction to the culture system. This period allows suspended solids to settle out and facilitates the development of an initial phytoplankton bloom, both of which make water quality management in the culture system easier, reflected in more stable water conditions.

Filtration of the incoming water is considered beneficial as it removes organisms from the intake water that could act as predators on the crustacea, competitors for feed and carriers of disease harmful to the cultured crustacea.

3.2.2 Water quality parameters

Specific parameters that need to be considered in the development of farm management plans are: -

- Water temperature;
- Dissolved oxygen;
- pH;
- Alkalinity;
- Salinity;
- Turbidity; and
- Nitrogenous waste levels

3.2.2.1 Water temperature

Crustacea should be kept at water temperatures that lie within their normal temperature range. It is poor welfare and makes poor risk management and economic sense to attempt to grow crustacea outside their normal temperature tolerances. The ideal water temperature will vary according to the species cultured, but the following temperature ranges are suggested in publicly available literature: -

- Yabbies (Cherax destructor): 25 - 28°C, no growth occurs below 15°C or above 34°C, and mortalities occur at 36°C.
- Marron (Cherax tenuimanus): 17 - 25°C, no growth occurs below 12.5°C and mortalities occur above 30°C.
- Prawns: 28 - 32°C

Temperatures at the lower end of the range may be beneficial as they will reduce the potential for build up of toxic nitrogenous waste compounds.

3.2.2.2 Dissolved oxygen

Low dissolved oxygen (DO) is a chronic stressor to crustacea. In general it is accepted that levels should be maintained above 4 – 6 mg/l for good welfare. Crustacea can tolerate lower dissolved oxygen levels than finfish, however chronically reduced DO levels of 2 – 3 mg/l produce stress and render crustacea more susceptible to disease.

It may be necessary to introduce some form of aeration to ponds, especially overnight when plankton blooms consume dissolved oxygen. Build up of organic wastes or decomposition of dead benthic algae will also consume oxygen. Aeration must be considered to improve welfare if there is significant degradation in quality of the pond bottom, or an abrupt increase in turbidity of the water, or if animals are seen surfacing on the pond.

3.2.2.3 pH

Water pH should be maintained at levels appropriate for the species being farmed. In practice pH levels of 7.5 – 8.5 are considered appropriate for the welfare of most species. Low pH levels cause stress to the animals in addition to reacting with the calcium carbonate in the shell causing chronic soft shell problems. pH levels of more than 8.5 increase the risk of ammonia toxicity, however many species can tolerate levels up to pH 9, although chronic exposure will cause stress in the animals. Fluctuation in pH is also considered stressful to the animals and water must be monitored and treated to avoid pH changes of greater than 0.5 units over a 24 hour period.

Lime may be used to raise pH should levels fall below 7.5. Should levels rise above 8.5 it may be necessary to carry out water exchange. Up to 10% water volume may be exchanged at any time without causing undue stress to the animals; exchange of greater proportions should only be carried out in an emergency and with close monitoring of the animals.

3.2.2.4 Alkalinity

The alkalinity of water determines to a degree the buffering capacity of the system and hence the stability of the pH. Since rapid changes of pH are stressful and may increase the risk of unstable algal bloom production within the culture facility it is important that alkalinity is assessed and monitored. Published literature indicates that freshwater crayfish benefit from an alkalinity of between 50 and 300 mg/l, whilst prawns are best held in waters of between 80 and 120 mg/l.

3.2.2.5 Salinity

Salinity of waters should be maintained within ranges appropriate for the species of crustacean being cultured. In general freshwater crustacea should be held in waters with a salinity not exceeding 4 – 6 ppt, although they may tolerate higher salinities (17 – 25 ppt depending on species). The presence of some salt in freshwater may actually be beneficial to freshwater crustacea in that it decreases the potential for fouling and parasitic infestation. The salinity of waters used to hold marine prawns should be within the species natural tolerance range, although in areas of particular endemic diseases it may be beneficial to alter the salinity levels. High salinity levels may cause unstable algal blooms that stress the animals.

3.2.2.6 Turbidity

Since nutrition of the crustacea is partly linked to the production of beneficial algal blooms in the culture water it is necessary to monitor the development and maintenance of blooms. This is most easily achieved by measuring turbidity of the waters using a secchi disc. Literature suggests the suitability of readings in the range 30 – 60 cm. Careful fertilisation of culture waters, especially in the early stages of crustacean culture, may be carried out to ensure the production of a stable bloom. Unstable blooms cause stress in the animals and increase the risk of disease. Ponds should be monitored regularly with the aim of encouraging a stable green appearance in the water. Clear water, filamentous benthic algae and dead benthic algae should be avoided as they increase the risk of stress and disease.

3.2.2.7 Nitrogenous wastes

Similarly to finfish the build up of nitrogenous waste compounds should be avoided in the culture systems. Ammonia is most toxic to crustacea, followed by ammonium, nitrite and nitrate. Regular water samples should be taken to determine levels. Published literature indicates that various species of crustacea have widely different tolerances to nitrogenous waste products. For example ammonia tolerance is reported as varying between 0.1 and 2 mg/l. It is therefore recommended that water monitoring is carried out so as to maintain nitrogenous wastes at levels appropriate for the species being stocked. Where necessary professional guidance should be sought in establishing appropriate parameters.

3.3 Pond preparation, management and habitat

Pond culture systems for crustacea develop into a complex ecosystem supporting good water quality and animal wellbeing and health.

3.3.1 Pond preparation

Pond bottoms should be examined prior to stocking and, where necessary, organic sludge debris removed or ploughed and exposed to air. This is particularly important if a layer of black material is present as this represents a concentrated organic layer that has the potential to transmit disease or decompose releasing nitrogenous waste products and/or harmful gasses. The use of lime may be considered to achieve optimal pH and alkalinity of both the soil and water.

3.3.2 Pond management and feeding

Ponds should be examined routinely during production to assess the benthic environment (colour, smell and presence of benthic algae) and remedial action taken as required. Poor benthic conditions during growout have been linked with chronic bacterial infections resulting in thin paper-like carapaces and loose shell syndrome.

Crustacea feed on plant material (including phytoplankton), animal material (including insects and zooplankton) and detritus in the ponds. Supplementary feeding may be used to encourage growth of the animals. Supplementary feeding has the potential, if poorly managed, to cause deterioration of the water quality therefore it is essential that feeding rates be tailored to the requirements of the animal and the water temperature, with decreased volume or frequency in cooler waters. Processed pellet feed is greatly preferred as it reduces the risk of disease introduction. However, fresh, cooked feed that is fish (not crustacean) based may be used in the later stages of growout. In this case it is most important that water quality and feed wastage is carefully monitored. Feeding areas in the ponds should be monitored and changed if necessary to avoid the development of areas of poor benthic condition with resultant adverse stress effects on the feeding animals.

3.3.3 Pond habitat

It may be beneficial for the welfare of cultured crustacea to provide hides and habitat areas in growout ponds. These provide shelter for the animals from conspecifics, predators and bright sunlight, and result in increased surface area of the pond bottom. This will effectively reduce the stocking rate (animals/m2) in addition to providing increased substrate for the development of beneficial bacteria and biofilms upon which the animals may feed. Excessive habitat constructions may however have an adverse effect on welfare through the interference with water circulation.

3.4 Health monitoring and addressing disease risks

Water temperature at the time of stocking should be considered to ensure they are most appropriate for the species being farmed, and may have impact on susceptibility of juveniles to any endemic diseases.

Overstocking of the systems must be avoided as this increases disease risks and increases stress on the animals due to the inability of the system to cope with oxygen demand and metabolic wastes. It may also increase dominance interactions in the animals.

Poor quality seedstock, i.e. those displaying low activity levels, higher than normal transport mortalities, smaller than expected size or increased size range, should not be used. Minimising transport times from the hatchery to the growout facility to less than 6 hours reduces initial stress on the animals and improves welfare. Juveniles should be examined at the hatchery to check colour, size and activity. Weak or dead animals should be removed immediately following transport and disposed of. Gradual addition of pond water to transport water is beneficial in the acclimation of the animals to the growout system and will reduce the stress of transfer.

To ensure that health problems are detected early, and to protect the wellbeing of the population, it is beneficial to carry out regular sampling of the animals to check for body colour, missing appendages, fouling of the shell or gills, gut content and feed uptake, muscle condition and growth rate. Dead animals should be removed daily; weak animals should be removed and killed humanely (see Sections 3.7 and 4.4.3.7). All dead animals should be disposed of properly.

Any treatments should be carried out using currently approved compounds, following diagnosis of a problem and strictly in accordance with the instructions of an aquatic animal health professional.

3.5 Population management

Population management is necessary when overstocking develops, or when extensive size differences occur. It is considered essential in freshwater crayfish ponds where a number of generations may co-exist in the ponds. Size disparity may result in size and dominance hierarchies developing that result in inhibition and stress on individuals as a result of direct aggression, predation and competition for food and shelter.

In addition population management will ensure that the carrying capacity of the system is not exceeded, and removes larger animals that may be reaching maturity and thus utilising feed for reproductive development as opposed to muscle development.

3.6 Equipment use and handling

Equipment used to handle crustacea should be designed for the species and size range on the farm. Raceways, channels, ponds and handling equipment should be designed to prevent physical damage to the animals.

Protection from predators should be provided in the form of filters on intake water supply, and where appropriate, bird nets over ponds and hides in the pond. Clear water, in addition to representing a stressor on the animals due to unstable or inappropriate algal growth, also renders the animals more susceptible to predators.

3.7 Humane harvesting methods

Harvesting may take place via traps set in the pond or by draining down a pond and either trapping animals in the outflow channel or by direct collection of animals off the pond bottom.

Where traps are used in the pond they must be checked and emptied daily to avoid long periods of fasting or the trapping of small and large animals together for long periods that may result in aggressive behaviour and/or predation.

If animals are collected in traps in outflow channels they must be regularly emptied to avoid crushing effects on the animals caught first. Those harvested directly from the empty pond must be gathered quickly and not left to die through dehydration.

For live transport, animals should be cooled and transported moist in thermally stable containers. Those being processed immediately must be anaesthetised prior to processing operations. Immersion in ice slurry for 20 minutes has the effect of rendering most crustacea insensible before eventual death and is recommended as a humane slaughter technique (see section *4.4.3.7 Killing crustacea humanely*).

4.Welfare of Aquatic Animals in Live Holding Systems

4.1 Preface

4.1.1 Introduction

It is important that animals held live for human consumption, whether in retail, wholesale or food preparation areas, are subject to humane management, transport, handling and slaughter procedures. There have been a few instances of public concern related to the standards of husbandry and welfare in retail outlets, and it is likely that given increased media attention that the general public will become more aware of this area. Adherence to good management and welfare practices will not only decrease the likelihood of consumer concern and improve the perception of the industry, but will also help to maintain food quality standards, food safety and animal survival.

4.1.2 Legal requirements

It is important that operators are aware of, familiar with, and adhere to the legislative requirements in their State or Territory as regards animal welfare. The coverage of legislation in the various States and Territories is summarised in Table 1 below, although it is the responsibility of the individual to confirm the complete requirements of the legislation.

Table 1: Summary of coverage of animal welfare legislation in the States and Territories of Australia

State/Territory	Fish	Crustacea
Australian Capital Territory	yes	those held for human consumption
New South Wales	yes	those held for human consumption
Northern Territory	yes	those held for human consumption
Queensland	yes	yes
South Australia	no	no
Tasmania	yes	no
Victoria	yes	yes
Western Australia	no	no*

* Prescribed live invertebrates are covered, although none are currently prescribed. Aquatic animals are covered by the Fish Resources Management Act 1994. The aim is to use codes of practice to cover aquaculture industries and facilities holding live animals for human consumption.

4.1.3 Product integrity and quality

In general all seafood offered for sale should:

- comply with government regulations (such as transport methods, storage conditions, labelling, size and type of seafood);
- be safe for human consumption (satisfying the requirements of any quality assurance program applicable);
- be in good general health and body condition;
- not be suffering clinical disease that either renders the food unsafe for consumption or in any other way jeopardises the quality and appearance of the seafood; and
- be handled and displayed in a humane manner.

4.2 General guidelines for finfish holding systems

4.2.1 Basic considerations

When holding finfish live in tank systems a number of general principles must be considered. Systems should be designed and operated so as to ensure the most appropriate conditions for the animals being stored live. The following should be taken into consideration: -

- Water temperature and salinity must be controlled at levels appropriate to the species being held.
- Dissolved oxygen (DO) levels should be maintained at a suitable level and checked frequently. A level of at least 70% saturation has been suggested as appropriate. Sub-optimal levels of DO, whilst not immediately lethal, may stress fish and result in chronically increased mortality.
- Water should be filtered to remove suspended solids and biological wastes.
- A water monitoring program should be established to routinely measure water chemical parameters including: -
    - pH
    - hardness
    - dissolved carbon dioxide (if holding for extended periods)
    - ammonia/ammonium
    - nitrites and nitrates
    - metals/pollutants (infrequently)
- Large water volumes are more chemically stable than smaller volumes. It may be appropriate to link several tanks to a single filter system. Use a number of systems if it is necessary to hold different types of animals requiring different conditions.
- The water chemistry in cold water systems tends to be more stable than in warm water systems. Marine systems may suffer increases in salinity due to evaporation and need to be monitored and diluted if necessary.
- It may be beneficial to keep the fish at temperatures at the cooler end of their natural temperature range to decrease oxygen requirements and appetite.
- Keep the fish out of bright lights as much as possible. Bright light has been shown to be a stressor and may reduce survival rates.
- Do not attempt to put more stock into a holding tank than it is designed to hold; this will vary with species.

When holding finfish in live tank systems the following management routines are suggested: -

Freshwater holding aquaria

- DAILY – check fish condition and behaviour, water temperature and DO
- WEEKLY – check pH and nitrogenous wastes, clean tanks, clean filters (suggested maxima are: ammonia 0.01 mg/L, nitrite 0.1 mg/L and nitrate 50 mg/L)
- MONTHLY – clean pumps and valves, check lighting

Marine holding aquaria

- DAILY – check fish condition and behaviour, water temperature, DO and filter operation
- WEEKLY – check pH and nitrogenous wastes, clean tanks, clean filters (suggested maxima are: ammonia 0.05 mg/L, nitrite 0.1 mg/L and nitrate 20 mg/L; a decline in pH is also suggestive of a decrease in water quality)
- MONTHLY – clean pumps and valves, check lighting

Signs of unsatisfactory conditions in holding tanks include:

- Foam on the water surface;
- Cloudy water; and
- Slime and algal growth on the tank walls.

4.2.2 Management practices

4.2.2.1 Transport

- Minimise the number of times fish are removed from the water, and work as quickly as possible when transferring fish for transport.
- Transport tanks should be large enough to allow movement of fish, and have no sharp corners or edges that might injure a fish.
- Maintain high levels of DO during transport.
- Salt (0.3 – 1.0 %) may be added to transport water to minimise osmotic stress and the risk of bacterial infection (in the case of freshwater fish).
- Keep water temperatures down to maximise oxygen saturation of the water and decrease the metabolic rate of the fish.
- Check for sick, injured or dead animals upon arrival at the destination. Remove sick and injured fish and kill them humanely. Dead fish should also be removed. All dead fish should be disposed of by bagging and consignment to landfill.
- Transport water should be disposed of into the sewage water system and not into a stormwater drain. This minimises the risk of disease transfer to local waters.

4.2.2.2 Acclimation

It is important to properly acclimatise newly arrived fish to the holding system. Where fish have arrived in transport bags it is best to open the bags and aerate the water to encourage recovery from any transport stress, then gradually add water from the holding tank so the fish do not experience rapid changes in pH, temperature, salinity or chemical composition.

4.2.2.3 Handling

Handling of fish should be carried out as quickly and gently as possible, minimising any time out of water. Where possible knitted mesh nets should be used in preference to knotted nets to reduce injury and scale loss. If it is necessary to touch the fish, this should be done with wet hands to minimise loss of protective mucus layers. Ensuring DO levels are maintained will help the recovery of fish from handling.

4.2.2.4 Stocking

- As previously indicated, tanks should not be stocked with a greater number of animals than they were designed for.
- Do not mix incompatible species in the same tank. Incompatibility may result from aggressive or predatory behaviour, size disparity or different environmental requirements.
- Keeping careful records of origin and arrival dates of fish batches helps stock rotation. Stock should be used in the order of arrival where possible to minimise holding periods.

4.2.2.5 Feeding

Fish are not normally fed in holding systems. Feeding can result in increased organic loading in the water; increased excretion of nitrogenous waste products and the fish will use more oxygen from the water during digestion. Rigorous stock rotation should ensure that fish are sold or used before they require feeding. Where fish are to be held for extended periods, especially in warm waters, the system must be designed to cater for the increased nitrogenous waste load.

4.2.2.6 Checking

Holding tanks should be regularly checked and sick, injured or dead fish removed. Injured and sick fish should be killed humanely; it is not acceptable to allow fish to suffocate. Dispose of dead or culled fish by bagging and consignment to landfill. Sick fish should not be used for food.

4.2.2.7 Killing fish humanely

All live fish to be used for food must be killed humanely before processing.

Keep fish handling to a minimum prior to killing to reduce stress. For maximum product quality and minimum stress to a finfish the ike-jime (live killing) method can be used. This instant killing method reduces the accumulation of metabolic waste products in the fish, minimises physical damage (including loss of scales) caused by any body movements and keeps the finfish intact apart from a small hole in the head.

A spike is inserted directly into the brain causing immediate brain death and the cessation of all motion. Ike-jime followed by immediate chilling in ice slurry prolongs the onset and duration of rigor mortis. Deterioration of the flesh occurs mostly following the loss of rigor mortis, therefore prolonging the whole process of onset and gradual post-rigor relaxation should result in better product quality and a longer shelf life.

Observing a skilled operator, or some practice on anaesthetised or dead animals is required to perfect the ike-jime technique. The position and angle of the spike entry required differs between species and one example of each species may need to be cut lengthwise through the head to locate the position of the brain. When spiked correctly, a fish will exhibit a short but violent convulsion (due to the physical stimulation of the brain) before relaxing.

To use the ike-jime technique:

1) Hold the fish firmly and insert a spike into the brain. This should be done as soon as possible after removal from the water.
2) Bleed the fish in a manner appropriate to the type of fish species.
3) Place the fish in ice slurry until core temperature reaches required level.
4) Remove fish from ice slurry and store or undertake further activities as required.
5) Ike-jime is preferred to piercing the spinal cord or beheading.

Percussive stunning, i.e. striking the fish firmly on the top of the head over the brain, followed by bleeding and immediate chilling may be equally effective in ensuring a rapid and humane death and high product quality. It does take a degree of skill in hitting the correct area of the head with sufficient force to disrupt the brain, and may be tiring to the operator if a large number of fish need to be killed. If the blow misses the required contact point it will be ineffective at stunning and may produce bruising of the flesh.

Eels may be killed by piercing the spinal cord with a knife or skewer inserted through the back of the head or any method that causes immediate destruction of the brain.

4.3 Specific guidelines for finfish holding systems

This section contains species-specific holding parameters suggested as appropriate in published literature. Operators wishing to assess the suitability of particular parameters or systems for their particular species should seek professional advice.

Species	Temperature (°C)		Salinity	Notes
	Natural range	Ideal holding		
Barramundi (*Lates calcarifer*)	15 - 32	22 - 25	Wide tolerance; ideally 3 – 35 ppt	
Silver perch (*Bidyanus bidyanus*)	10 - 30	15 - 18	Freshwater; ideally 3 – 5 ppt	Avoid salinity changes ≥ 2 ppt
Golden perch (*Macquaria ambigua*)	4 - 37	10 - 30	Freshwater	Can tolerate salinities up to 33 ppt
Sleepy cod (*Oxyeleotris lineolatus*)	20 - 28	Not specified	Freshwater	Salinities up to 5 ppt may be beneficial
Murray cod (*Maccullochella peelii peelii*)	10 - 30	Not specified	Freshwater	Salinities up to 5 ppt may be beneficial
Eels (*Anguilla* spp.)	10 - 30	Not specified	Freshwater	Subtropical species. Can tolerate brackish or sea water
Reef fish		23 - 25	35 ppt	

Fish may be held for several days to weeks, however extended holding periods may require feeding, which may have adverse effects on water quality.

4.4 General guidelines for holding crustacea in and out of water

4.4.1 Basic considerations

When holding crustacea live in tank systems a number of general principles must be considered. Systems should be designed and operated so as to ensure the most appropriate conditions for the animals being stored live. Live holding systems can range from relatively small volume, intensive recirculation units used in restaurants and fish shops, to high-flow, flow-through systems commonly used to hold commercial catches of Rock Lobster.

The high-flow, flow trough systems holding locally caught species tend to use clean oceanic water to which the species are already acclimatised and hence temperature and salinity are rarely an issue. Adequate levels of dissolved oxygen and low levels of metabolites are still requisites for good health and welfare, and regular monitoring of these parameters must be undertaken so that flow rates may be adjusted to the requirements of the biomass in the system.

Recirculating tank and aquaria systems can vary greatly in size and degree of technological sophistication, but all of the following guidelines should be taken into consideration: -

- Water temperature and salinity must be controlled at levels appropriate to the species being held.
- Dissolved oxygen (DO) levels should be maintained at a suitable level and checked frequently. Whilst crustacea may tolerate lower oxygen levels than finfish, a level of at least 5 mg/L has been suggested as appropriate. Sub-optimal levels of DO, whilst not immediately lethal, may stress crustacea and result in chronically increased mortality.
- Water should be filtered to remove suspended solids and biological wastes.
- A water monitoring program should be established to routinely measure water chemical parameters including: -
    - pH
    - hardness
    - dissolved carbon dioxide (if holding for extended periods)
    - ammonia/ammonium
    - nitrites and nitrates
    - metals/pollutants (infrequently)
- Large water volumes are more chemically stable than smaller volumes. It may be appropriate to link several tanks to a single filter system. Use a number of systems if it is necessary to hold different types of animals requiring different conditions.
- Marine systems may suffer increases in salinity due to evaporation and need to be monitored and diluted if necessary.
- It may be beneficial to keep the crustacea slightly cooler than its normal ambient temperature to decrease oxygen requirements and appetite.

- Keep crustacea out of bright lights as much as possible. Bright light has been shown to be a stressor and may reduce survival rates.
- Do not attempt to put more stock into a holding tank than it is designed to hold.

Suggested management routines are detailed below: -

Freshwater holding aquaria

- DAILY – check animal condition and behaviour, water temperature and dissolved oxygen
- WEEKLY – check pH and nitrogenous wastes, clean tanks, clean filters
- MONTHLY – clean pumps and valves, check lighting

Marine holding aquaria

- DAILY – check animal condition and behaviour, water temperature, dissolved oxygen and filter operation
- WEEKLY – check pH and nitrogenous wastes, clean tanks, clean filters (a decline in pH is also suggestive of a decrease in water quality)
- MONTHLY – clean pumps and valves, check lighting

Signs of unsatisfactory conditions in holding tanks include:

- Foam on the water surface;
- Cloudy water; and
- Slime and algal growth on the tank walls.

4.4.2 Holding crustacea out of water

- Keep the animals cool and moist. This reduces the stress associated with being stored in air. The temperature to which it is cooled depends on the tolerances of the species. Make sure you have a reliable thermometer.
- Do not cool the animals too much. Different species have different cold tolerances and excessively cold temperatures can cause direct mortalities.
- Do not allow the animals to come into direct contact with ice.
- Keep the animals out of bright light as this may cause stress and reduce survival rates.
- Avoid undue disturbance to the animals during holding periods.

4.4.3 Management practices

4.4.3.1 Transport

- Minimise the number of times animals are removed from the water, and work as quickly as possible when transporting.

- Transport tanks should be large enough to accommodate the animals, and have no sharp corners or edges that cause injury.
- Maintain high levels of DO during transport.
- For freshwater crustacea, 5 to 10 grams of coarse salt per litre may be added to transport water to minimise osmotic stress and the risk of bacterial infection.
- Keep water temperatures down to maximise oxygen saturation of the water and decrease the metabolic rate of the animals.
- Check for sick, injured or dead animals upon arrival at the destination. Remove sick and injured animals and kill them humanely. Dead animals should also be removed. All dead crustacea should be disposed of by bagging and consignment to landfill.
- Transport water should be disposed of into the sewage water system and not into a stormwater drain. This minimises the risk of disease transfer to local waters.

4.4.3.2 Acclimation

It is important to properly acclimate newly arrived animals to the holding system. Water temperature changes, if necessary, should be gradual with a maximum instantaneous change of less than 5 °C. Marine crustacea should not be subject to large variations in salinity, either higher or lower as this results in osmotic stress, and may be linked with turgid lobster syndrome. To avoid drowning crabs that have been stored or transported in air it is important to dip the crabs in water a few times to allow trapped air to escape. Crabs should not be held out of water for extended periods (generally greater than 6 hours) as their gills tend to dry out and restrict oxygen exchange.

4.4.3.3 Handling

Handling of crustacea should be carried out as quickly and gently as possible. Avoid picking up animals by their claws or limbs to prevent shedding. Ensuring DO levels are maintained will help the recovery of animals from handling.

4.4.3.4 Stocking

- As previously indicated, tanks should not be stocked with a greater number of animals than they were designed for.
- Do not mix incompatible species in the same tank. Incompatibility may result from aggressive or predatory behaviour, size disparity or different environmental requirements.
- Do not store crustacea if badly damaged, weak (limp legs and tail), dead or recently moulted (soft shells).
- Keeping careful records of origin and arrival dates of animal batches helps stock rotation. Stock should be used in the order of arrival where possible to minimise holding periods.

4.4.3.5 Feeding

Do not feed crustacea in holding systems. This can result in increased organic loading in the water; increased excretion of nitrogenous waste products and the animals will use more oxygen from the water during digestion. Rigorous stock rotation should ensure that animals are sold or used before they require feeding. In the absence of feeding cannibalism is a risk. Claws (but not limbs) should be tied to prevent injury or cannibalism, and to make handling of the animals quicker and easier resulting in less stress.

4.4.3.6 Checking

Holding tanks should be regularly checked and sick, injured or dead animals removed. Injured and sick animals should be killed humanely. Dispose of dead or culled crustacea by bagging and consignment to landfill. Sick crustacea should not be used for food. It is important also to remove shed legs or claws as these rapidly cause increased ammonia levels in the water and can result in mass mortalities.

4.4.3.7 Killing crustacea humanely

All live crustacea to be used for food must be killed humanely before processing.

Anaesthetising crustacea

It is important to anaesthetize seafood before killing it. Chilling is a common method used and acts to prevent stress to the animals and any resultant loss of quality. In addition it makes the animals easier to handle and humanely kill.

When the body temperature of crustaceans is reduced far enough the animal will die without suffering. The animal can be assumed to be dead if no movement is detected when handled.

This chilling can be achieved either in ice slurry, or by dry chilling individual animals (chiller temperature must be -10 to –20 °C).

Note – Australian research has shown that the immersion of crustacea in slush ice for up to 18 hours causes no loss in the edible quality of the tail flesh. To make ice slurry: -

- Fill a container (such as an esky) with crushed ice, and then add salt water (roughly 35 ppt) to make an ice to water ratio of 3:1 (consistency of wet cement) and a temperature of –1 °C.
- The animals should be immersed in this slurry for at least 20 minutes.
- Make sure there is enough ice to maintain the correct temperature throughout the process.

If the above method is not practical it is suggested that the central nerves be quickly destroyed (as described below).

Killing crustacea

(a) Crabs

Crabs have two main nerves centres, both lie medially in the body. One is located at the front of the animal under a shallow depression; the second lies towards the rear of the animal and may have a small hole positioned over it. It is possible to attempt destruction of nerve centres through a number of approaches:

- Lift the abdominal flap (tail flap) and insert a knife, or pithing instrument, all the way through the hind nerve centre, followed by a similarly rapid pith of the front nerve centre via the shallow depression at the front of the body, or
- Rapidly remove the carapace (top shell) and directly destroy the front and hind nerve centres.

(b) Rock Lobster and Crayfish

Lobsters have a chain of nerve centres (ganglia) running down the midline of their body. These nerve centres should be destroyed by rapidly cutting through the midline, lengthways, with a large sharp knife.

The cut is made in two sections, starting in the midline near the junction of the tail and the thorax. The first cut is directed directly forwards toward the head, the second backwards towards the tail. Following the completed sectioning any visible nerve centres can be rapidly removed.

Smaller crustacea such as marron are best killed by splitting longitudinally with a single knife blow. Insert a knife between the eyes and then push down along the length of the body in one quick movement.

These procedures should not take more than 10 seconds and should only be done by a skilled operator.

Unacceptable methods

- Transverse sectioning of lobsters or crayfish, i.e. separating tail from head of live lobsters, crayfish or similar animals
- Cutting tissue or flesh from live animals
- Boiling crustacea before anaesthetizing.
- Serving live crustacean to diners

4.5 Specific guidelines for holding crustacea in and out of water

This section contains species-specific holding parameters, indicated to be appropriate, and derived partly from published literature. Operators wishing to assess the suitability of particular parameters or systems for their particular species should seek professional advice.

4.5.1 Bugs and Rock lobsters

Out of water			In water		
Maximum time	**Temperature**	**Other conditions**	**Maximum time**	**Temperature**	**Other conditions**
Bugs 12 hours **Rock lobsters** 12 hours, and longer for some species	Generally cool, but not in chiller as it is too cold **Balmain bug** 6°C **Moreton Bay bug** 12-15°C **Southern rock lobster** 6-10°C **Western rock lobster** 14-20°C **Tropical rock lobster** 20-25°C	Keep covered for darkness & containment. Allow air exchange (not airtight). Check and replace coolant as necessary. Keep from direct contact with ice or melt-water. Keep moist but not wet, eg. cover with clean, damp sack. Remove dead or moribund animals.	2 weeks (will survive longer but may lose condition if not fed)	**Balmain bug** 5-10°C **Moreton Bay bug** 17-20°C **Southern rock lobster** 6-10°C **Western rock lobster** 14-20°C ° **Tropical rock lobster** 20-22°C	– usually ~ 35 ppt – aerate & filter – check daily & remove dead & weak individuals

4.5.2 Prawns

Out of water			In water		
Maximum time	**Temperature**	**Other conditions**	**Maximum time**	**Temperature**	**Salinity**
Kuruma 2 - 3 days **Other species** 6 hours	12 – 15 °C	Store in source packaging. Keep moist but not wet.	Usually a few days	**Black tiger prawn** 17-20°C **Most tropical species** 15 – 20°C	Ideally 35 ppt for black tiger prawns, but will tolerate lower.

4.5.3 Crabs

Out of water			In water		
Maximum time	**Temperature**	**Other conditions**	**Maximum time**	**Temperature**	**Salinity**
Mud crabs 3 days **Other crabs** Up to 6 hours depending on the species	**Mud crabs** 16-25°C (they live longer at the lower end of temperature range) **Other crabs** Varies with species- generally cool, but do not place in chiller as it is too cold	Keep covered for darkness & containment. Allow air exchange (not airtight). Check and replace coolant as necessary. Keep from direct contact with ice or melt-water. Need high humidity, (80-90%), eg. cover with clean, damp sack. Remove dead or moribund animals.	1 week	**Mud crabs** 17-25°C (but 2 - 3°C higher in very northern areas of Australia) **Other crabs** Varies with species	**Mud crabs** 15-35 ppt **Other crabs** 35 ppt or close to natural environment

4.5.4 Freshwater crayfish

Out of Water			In Water		
Maximum time	**Temperature**	**Other conditions**	**Maximum time**	**Temperature**	**Salinity**
3 days	**Marron and yabby** 12 - 20°C room temperature is suitable, but less stress results if cooled may be stored in a chiller but temperature must be monitored closely	Keep covered for darkness & containment. Allow air exchange (not airtight). Check and replace coolant as necessary. Keep from direct contact with ice or melt-water. Keep damp but not wet, eg. cover with clean, damp sack. Remove dead or moribund animals.	A few weeks	**Marron and yabby** 12-25°C **Redclaw** 20-25°C	3 - 5 ppt