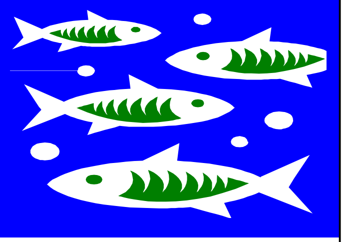
Welfare underwater: issues with aquatic animals



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Contents

Introduction

Interest in the welfare of aquatic animals is at an historic high, with each new scientific enquiry into whether or not fish experience pain making news and fuelling discussion. These discussions may lead to changes in the way we define what are the most humane methods of handling and killing fish and crustaceans within both the commercial and recreational sectors. There are also widespread concerns over the future of our larger marine animals, with debate over the relevance of the International Whaling Commission and its ability to control the killing of whales. In aquaculture, the expansion of farming of both marine and freshwater species has raised issues over the welfare of farmed fish. Indeed, the way we use or care for all kinds of aquatic animals is being examined on a range of different levels, from the fishing and seafood industries, recreational fishing, aquarium displays, aquaculture, to our treatment of aquatic animals as pets.

The RSPCA Australia annual Scientific Seminars provide a forum for the dissemination of information on topical animal welfare issues to a wide audience. The 2004 RSPCA Australia Scientific Seminar, *Welfare underwater: issues with aquatic animals*, examined recent developments in our understanding of, and interactions with, marine and freshwater animals under the following three themes:

- humane treatment and humane killing
- providing an appropriate captive environment
- the impacts of human interactions.

The 2004 Seminar was chaired by Professor Ivan Caple, Dean of the Faculty of Veterinary Science at the University of Melbourne, and opened by Dr Hugh Wirth, President of RSPCA Australia.

The first session focused on providing an appropriate captive environment, and commenced with a description of the day-to-day role of the veterinarian responsible for the health and welfare of the inhabitants of the Melbourne Aquarium. Robert Jones stressed the importance of maintaining a healthy fish population: the key factor in this being the provision of an appropriate environment. In addition, behavioural monitoring of the fish is crucial and any problems should be addressed through intervention and appropriate enrichment of the tank environment.

The focus moved from the aquarium to the aquaculture environment in Simon Bennison's paper, which described the role of the National Aquaculture Council (NAC) and the main welfare issues in the aquaculture industry. There is increasing awareness of animal welfare issues within the industry, which is running parallel with rapid growth in a number of sectors. The NAC aims to encourage improvements in aquatic animal welfare by incorporating humane practices into developing management regimes.

Session two examined the issues of humane treatment and killing of aquatic animals. Colin Johnston addressed the question of whether fish feel pain with a descriptive tour of the nervous system of the fish and a critique of the recent scientific evidence on pain perception. His paper identified the difficulties associated with interpreting experimental data on this subject, and questioned whether pain perception is central to the welfare debate. The jury is still out on the question of whether fish feel pain, but whatever the final conclusion, it is clear that welfare standards are still required for aquatic animal industries. It was emphasised that such standards should be science-based, robust and provide true benefits for the animals concerned.

Caleb Gardner began his paper on aquatic crustacean welfare with some examples of the great diversity of this group of invertebrates. The extreme variation in size, morphology and methods of harvest of crustaceans creates difficulties for designing optimal welfare strategies. Understanding the anatomy of the crustacean nervous system is crucial in determining humane slaughter methods, however it seems that the requirement in some markets for intact quality products may be at odds with humane treatment.

Alastair Smart brought his experiences from salmon farming nations to the Seminar in his paper on fish welfare at harvest, showing the different methods of harvesting used around the world. Fish slaughter has potential to cause significant pain and suffering, yet most commercial slaughter methods do not satisfy the accepted definitions of humane killing. This paper described the development of a mechanised percussive stunning method for commercial fish harvesting. Encouragingly, fishing industries appear to be increasingly interested in improving slaughter methods, since there is a direct connection between fish welfare and the quality of the final product.

The final presentation in this session provided a change of both emphasis and scale. Michael Stoddart focused on Australia's involvement with the International Whaling Commission and current research on cetaceans in the Southern Ocean. The Australian Government has long held the stance that there is no humane way to kill whales, and this forms one of the key principles of Australia's objection to whaling in any form. This paper scrutinises the "whales eat fish" fallacy promoted by pro-whaling nations, and describes the recent development of non-invasive methods for analysing the diet of cetaceans and other aquatic animals.

Session three concentrated on the impacts of human interactions on aquatic animals. Brad Page graphically illustrated the disturbing impacts that discarded fishing equipment has on seals and sea lions in the waters off Kangaroo Island in South Australia. While government and industry have identified the need to reduce impacts of fishing on non-target species, so far this has had little impact on this specific problem. The paper discusses how education programs and incentives are needed to change traditional practices and, in particular, to actively reduce seal and sea lion entanglements and injuries.

The impact of tourism on aquatic animals was the theme of the next paper. Mark Orams described how the past two decades have seen a massive growth in aquatic-based tourism, with both direct and indirect impacts on wildlife. This has lead to the realisation that tourism may not be the inherently sustainable industry that was previously thought. The impacts of tourism on the aquatic environment are complex and it was suggested that each situation requires a tailor-made solution. The paper posed the question of whether we can meet this challenge and manage environmental tourism in a way that minimises or avoids negative impacts in the future.

The final paper of the Seminar discussed the issue of bycatch - the unwanted extras caught through the use of non-selective fishing techniques. Emma Bradshaw discussed the role of the organisation SeaNet, which works to minimise bycatch and encourage best practice in commercial fisheries. Her paper demonstrated some of the new techniques developed to reduce non-target impacts and the post-release survival of bycaught animals. SeaNet works closely with industry to develop and trial new methods, disseminate information and encourage the uptake of these techniques.

The 2004 RSPCA Australia Scientific Seminar was attended by over 100 participants, including animal welfare and fisheries departmental government officers, research scientists and veterinarians, representatives of aquatic animal industries, animal welfare groups and other non-government organisations, and interested members of the public. These proceedings are provided as a record for participants of the presentations they attended, and as a permanent resource to those who were unable to attend the Seminar.

A happy shark is a smiling shark? The captive aquarium environment

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Introduction

I graduated from Melbourne University in 1977 with Bachelor of Veterinary Science (Honours). With the exception of one year in large animal practice (many moons ago), I have been a small animal Veterinarian and own a small animal Veterinary Hospital in Dandenong. I have always had an interest in exotic animal medicine. Five years ago I commenced a Masters in Aquaculture, at Deakin University, Warrnambool, which I will finally finish at the end of this year. I commenced as Consultant Veterinarian to the Melbourne Aquarium in October 1999 – the Aquarium opened in January 2000.

The Melbourne Aquarium is based in the central business district on the banks of the Yarra River and has become a major tourist attraction since opening. The Aquarium houses more than 550 species of fish with approximately 10,000 various aquatic creatures (includes invertebrates as well). I must preface all my comments by stating that I have no experience at other aquariums. Hence, all my comments are based upon the situation at the Melbourne Aquarium.

Veterinary program

I am employed by the Aquarium on a permanent basis, as their Consultant Veterinarian, with a weekly visit every Wednesday. Initially, when I started we had a holding facility at Avalon (near Geelong). Here fish were put through a quarantine period to minimize pathogen and parasite issues.

My normal Wednesday commences with a complete tour of the entire facility either with the Curator, Assistant Curator or the Senior Aquarists (professional fish keepers). I must comment on the support staff at the Aquarium. The aquarists have generally a science/marine science degree and one also has a Master's in aquaculture. They take great pride in their work and maintaining their displays. Our aim is always to detect problems early and take appropriate measures. During my weekly visits, the aquarists will discuss any issues during the week or point out any fish that they are concerned about. At the end of the tour, any sick fish will be examined more closely and appropriate treatment commenced.

Most of the fish are known individually, with many having been with us from the first year. In some cases we even microchip as a permanent means of identification. Any fish that have died within the last 24 hours will be subject to a post-mortem. The number of fish involved will vary from none to three each week. The aim of this is obviously to attempt to ascertain the cause of death and what can be done to prevent any further deaths.

By the next morning, the aquarist team will have received an email with my weekly report and any directions for treatment during the coming week. I am available for telephone consultation and emergency visits (which are few) on as-needed basis. I have trained the aquarists to conduct basic diagnostics themselves, such as skin scrapes and post-mortems, and we use digital photography and the internet to assist.

Melbourne Aquarium - the "underwater zoo"

The Aquarium, besides being a major tourist attraction, has a strong focus on education. The main species kept are local temperate species and much of the signage discusses the importance of environmental protection of the waterways – both fresh and seawater. There are over ten teachers permanently on staff who take many school groups on guided educational tours. Last year 66,000 students from many schools attended the Aquarium's education program. The fish are constantly on display to the public and we are very aware that we need to maintain them in a healthy state.

The captive environment

To provide a satisfactory captive environment means providing the fish with the following:

- excellent water quality
- appropriate tank size/decor
- good quality and balanced feed
- monitoring for behavioural problems and providing environmental enrichment.

Excellent water quality

Fish obviously live, and are immersed, in water. Without doubt water quality is the most important factor in maintaining a healthy fish population. Many fish can die directly from a water quality problem such as ammonia toxicity. However, even minor water quality problems can depress the fish's immune system and allow secondary infections to develop. A common example of this is white spot, which is a protozoan parasite (Ichthyophthirius multifiliis or Ich) that flares up, for example, after a chiller crash where the temperature rises 3–5°C in a 12-hour period.

The captive environment can either be run as an open or closed system. Examples of an open system would be sea cages or trout raceways off to the side of a stream. Some aquaria even operate on a flow through system, ie they are constantly flushing out their systems by introducing new water to reduce toxic waste accumulation. The Melbourne Aquarium runs on a closed or recirculating system. This is because we do not have a good reliable source of seawater close to our facility. The Aquarium replaces only between 5 to 10% of its water each month. At 2.2 million litres our oceanarium is one of the largest closed systems in the Southern Hemisphere.

From the water, the fish extract oxygen via their gills. Boney fish (teleosts) have developed a very effective counter-current mechanism such that 80% of oxygen will be extracted from the water in each pass through the mouth and gills. Oxygen saturation varies with temperature. Cooler water can hold more oxygen than warmer water. We measure dissolved oxygen (DO), which is the percentage of oxygen saturation in the water, using a simple hand-held probe. We aim for 100% DO and this is rarely an issue due to all the filtration involved in our systems. Supersaturation (DO>100%) can be an issue and cause “gas bubble disease”; not unlike the bends in divers. Hypoxia can also be an issue in aquaculture ponds (a variety of mechanical aerators are available) and in high density recirculating systems. In some situations oxygen is injected via a venturi effect to maintain satisfactory DO levels.

Into this water fish also excrete their faeces and urine. Fish excrete ammonia as their main protein waste – they do not convert it to urea as most mammals do. This ammonia is excreted largely via their gills. In water there is a balance between the un-ionised form NH_3 versus the ionised (less toxic) form NH_4+. Ammonia is highly toxic, with the un-ionised form occurring at higher rate in water with a high pH, such as in marine systems. There are charts that will give the percentage of each form at various temperature and pH levels. As a general guide, for every 1 pH unit increase, there will be a ten-fold increase in the level of un-ionised toxic ammonia present in water. The same applies with a 10°C increase in water temperature as well. Thus, tropical marine tanks are more prone to ammonia toxicity. The level of to ammonia in the water that can cause toxicity varies with species. At Melbourne Aquarium we aim for levels less than 0.09 ppm (mg/l). Nitrate levels between 40 and 100 ppm (mg/l) do not cause any health problems.

The removal of ammonia presents another issue. Ammonia is broken down via bacteria to nitrite and then nitrate. This is a two-step oxidative process that uses two different bacteria, Nitrobacter and Nitrosomonas. Nitrate is much less toxic than ammonia. This process occurs in a biofilter, through which the water trickles. A biofilter involves the use of plastic spheres called bioballs that increase the surface area to allow the bacteria to act on the ammonia in the water.

In any new system, it takes time for a biofilter to establish and too heavy a fish load can cause toxicity issues or “new tank syndrome”, requiring lots of water changes. There are now commercially available bacteria to load a filter and reduce the time until a satisfactory stocking density can be achieved. Mechanical filtration is very important to remove particulate mater. This involves the use of massive sand filters (not unlike pool filters), which are then backwashed to waste on a weekly basis. We also use protein skimmers, which remove much proteinaceous wastes as well as ozone (O_3) and ultraviolet to reduce the pathogen load on the system. We regularly take gill biopsies as an investigative tool for parasites and check the gill quality as a means of monitoring our water quality.

The aquarists have a great focus on water quality. Mechanical failures are the biggest potential problem we face and so a complete systems check is done twice daily to check water temperature, dissolved oxygen level as well as an equipment check. The various water chemistry parameters for each display will be checked 2-4 times weekly to ensure that appropriate levels are maintained. Initially any new tanks will be checked daily or even twice daily until the nitrogen cycle is established. The following are measured for each display using a spectrophotometer:

- salinity
- ammonia
- nitrite
- nitrate
- phosphate

The various environments that we have are:

- tropical freshwater, 25-27°C
- tropical marine, 23-27°C
- temperate freshwater, 12-21°C
- temperate marine, 14-22°C

Heating and cooling are obviously used in many of our displays so that the water temperature is at the correct level for the fish in the display to correlate with the normal temperature in their natural environment.

Appropriate tank size and décor

As the Aquarium is not production-orientated, we do not have a heavy stocking rate. Thus the size of the displays is related to the species involved. Our display tanks range from 200 litres up to the 2.2 million litres of the oceanarium. Many are in the 4,000 to 8,000 litre range.

All of our displays have a sand bottom to mimic the natural environment. We also have a lot of artificial rockwork and artificial seaweed. This is designed to provide some hiding sites, as well to enhance the displays visually.

Good quality and balanced feed

The fish are fed a variety of diets, trying to mimic their natural diet. We use a various fish and shellfish, which are stored frozen. These come from the Footscray fish market and of human consumption standard. For our sea dragons and seahorses, we are supplied with live mysids (a small crustacean) 2-3 times weekly. Artemia are used with several species. Some fish are fed commercial fish flakes or pellets and also a gel mix is made up fresh each day. Nori is fed to many of our tropical marines. Many of our fish are on vitamin and mineral supplements to prevent any deficiencies that can occur with a frozen fish diet. Iodine deficiency (causing goitre – an enlarged thyroid) is well documented in marine fish kept in a closed system and therefore iodine is regularly supplemented.

Nutrition in aquaculture has become a highly specialised area, with several commercial feed companies operating on Australia. There are now diets available for various species and at different growth stages.

The time and method of feeding is varied as much as possible to diminish habit formation. There is a diver feeding presentation 1-2 times per day in the oceanarium for the public to view.

Monitoring behavioural problems and providing environmental enrichment

Many fish species are schooling animals that like to live in close proximity to each other. Fish swim largely in groups and so their behaviour in a tank is often not altered. We have varied currents in the oceanarium depending on the depth. Thus fish swim in a variety of directions. There are some aquaculture-derived species that exhibit less stress and fewer behavioural problems when kept at higher stocking density than at lower densities, eg eels, Murray cod and barramundi.

We occasionally get some fin nipping: if this continues, then the culprit will be removed from display to give the remaining fish a chance to recover and de-stress. Often when the fish is placed back on display, the other fish have established their niches and the problem does not recur. If it does recur, then the dominant fish will be placed into another display or released (if possible as there are major difficulties with this).

So far, we have not really experienced any major behavioural issues. “Mitch”, our large male grey nurse shark was doing rapid laps of the oceanarium about two years ago. These sharks normally cruise slowly. This happened for a month or so and the Aquarium staff were getting concerned. I was having discussions with a veterinary behavioural specialist, and we were considering using some medication when the problem stopped. The problem recurred a year later and at that time Mitch was also showing interest in the two female grey nurse sharks. We believe that this is behaviour was pheromonally driven, with the females being “in season”. Mitch has just finished another period of this behaviour.

Periodically the water flow is altered so the various currents alter direction in the oceanarium. In many of our small- to medium-sized displays, we use wave dump buckets to mimic wave action.

We use some “live rock” in some of our smaller displays for nutritional reasons as well as to provide some behavioural enrichment. This rock has algae etc. growing on it so that the fish can pick at the rock. These rocks are then regenerated off-display.

Most of our displays are on about a 12-hour light/dark cycle and we do not at this stage try to alter daylight length. In our oceanarium, we do alter the temperature through a summer/winter cycle (21/16°C) to encourage normal cycles, especially reproductive cycles.

Last year, I hosted a behavioural veterinarian’s interest group on a tour of the entire facility to discuss fish behaviour in general.

Health and welfare

In many cases the fish in my care are probably healthier and safer than if they lived on the wild. The majority of fish are known individually (some of the schooling fish are an obvious exception) and are monitored carefully. The fish are well fed, in fact, avoiding obesity is one of our major issues. As mentioned previously, we have focused dramatically on reducing all parasite loads and by monitoring water quality maintain healthy fish.

Sharks and rays

The Aquarium maintains a variety of large sharks and rays. The grey nurse shark is now an endangered species on the east coast of Australia with only between 300 and 500 left in the wild. This is due to its very slow reproductive strategy and the hunting and over-fishing that has occurred in the last 50 years. We have commenced a research project on captive breeding, with even the remote possibility of the release of offspring back into the wild in the future. This is a major conservation project, involving a Master’s student at the Monash University Reproduction Unit and BHP Billiton has been a major sponsor. We have had matings of our seven gill sharks and are hoping for offspring within the next few months. We have recently completed the building of a large shark nursery tank to safely house any pups that are born in our oceanarium.

Marine turtles

The Aquarium also rehabilitates stranded turtles. In the last two years, there have been four stranded marine turtles (three green and one flatback) that have ended up in the cooler Victorian waters. One of the green turtles died within 2-3 days (the finder had placed it in a warm water bath before contacting the authorities!) and the rest are making excellent recoveries, with the first to be returned to Queensland within the next 2-3 months. The turtles are initially kept in 3000-litre quarantine tubs to stabilise, and are then released into the oceanarium.

Sea snakes

The Aquarium maintains a collection of Hardwick sea snakes in our coral lagoon for the Melbourne University Venom Research Unit for anti-venom research. Later this year we will have Irrakanji seajellies on display for a similar reason.

Animal welfare in the Australian aquaculture industry

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Summary

The National Aquaculture Council (NAC) is responsible for the development of policy concerning most issues that generically cover the various aquaculture industries. This paper provides an overview of the role of the NAC, some background on the main welfare issues in the aquaculture industry, and some of the strategies in place or under development to address these issues and in doing so providing an appropriate culture environment.

The NAC promotes the development and adoption of an animal welfare philosophy across all sectors. There is a rapidly increasing awareness of animal welfare issues throughout the industry that have in many cases been driven by consumers through observations in the retail and wholesale sector.

The aquaculture industry has been the fastest growing primary industry sector in Australia in recent years and the industry is now playing catch-up in a number of husbandry and management practises. Animal welfare is one area that is now being given considerable attention in order for industry to incorporate best practices into the their day-to-day environmental management systems and husbandry management regimes.

Australian aquaculture is made of a variety of industries. There is an extensive range of species under culture (approximately 70) in Australia. The industry comprises seven main sectors (production greater than A$10 million) consisting of tuna, pearls, salmonids, prawns, edible oysters, micro algae and barramundi. It is anticipated that yellowtail kingfish will soon join these ranks.

The issue of animal welfare covers all aspects of the aquaculture industry including producers, researchers, retailers, wholesalers and freighters. The NAC has taken on the responsibility of promoting the need for industry to incorporate best practices for animal welfare in their day-to-day operations. Some of the specific welfare issues that are being addressed include:

- farm management
- stocking densities
- transport/harvest
- species requirements
- predator control
- humane slaughter
- policy development
- codes of practice.

What has been done to date?

A draft National Animal Welfare Strategy has been produced by the federal Department of Agriculture, Fisheries and Forestry and is currently in its fourth draft. This document is intended to provide a national framework that will ensure the welfare of all animals in Australia is promoted and protected by the development and adoption of sound animal welfare standards and practices.

During this drafting process a number of initiatives in the aquaculture industry have been identified. Some of these are listed in Table 1. Guidelines for post-harvest animal welfare have been developed by the Aquaculture Council of Western Australia and are currently in use. A number of other documents have been developed by various sectors that incorporate best practices on animal welfare.

Administration of animal welfare

The majority of the aquaculture industries are covered by State legislation on animal welfare. Industry sectors and companies recognise the importance of the state of the fish at time of harvest, particularly in regard to flesh quality and have developed practices and staff training that ensures quality and animal welfare issues are not compromised. Most industry organisations are working collaboratively with state government jurisdictions and with local animal welfare organisations.

Codes of practice

Industry is in the process of developing a number of codes of practice to cover animal welfare issues. They are being picked up in the implementation of ecological sustainable development frameworks that are now being applied to all sectors and businesses. These frameworks include compliance to practices relating to animal welfare. They too are being implemented through the application of environmental management systems (EMS). These EMS's will, in many cases be third-party audited and the results incorporated in to public environmental reports.

Five freedoms

While the fundamental principles of alleviating suffering applies to aquacultured animals it is not appropriate to simply transpose practices developed for higher order terrestrial animals to aquatic animals. For example:

- higher stocking density does not necessarily equate to lower welfare
- periods of starvation are a natural part of fish life history, eg one week prior to slaughter
- provision of ample feed overcomes natural foraging behaviour.

Having said this, aquaculturists will need to adopt practices that take into consideration the five freedoms: freedom from hunger, thirst and malnutrition; freedom from fear and distress; freedom from physical and thermal discomfort; freedom from pain, injury and disease; and freedom to express normal patterns of behaviour.

Humane slaughter

It has always been the intention of industry to seek the most humane method approved by the community and legislators to slaughter fish. Percussion stunners are currently the preferred technique for finfish slaughter. Many of those used in Australia have been developed in Australia and are now being adopted by companies internationally. Significant research is being invested into humane slaughter and industry will have to adapt to changes as deemed necessary.

Certification

It is an objective of some sectors to head towards a certification system similar to that in Scotland with Freedom Foods.

Market access

The industry is conscious of consumer requirements that industry can demonstrate they are producing fish on a sustainable basis and in accordance with internationally recognised codes that includes humane treatment of stock. A consequence of not adopting this approach is likely to be loss of access to some international and possibly domestic markets.

Animal welfare standards

To be meaningful, welfare standards must be scientifically based rather than subjective (ie emotionally based). Industry has not as yet developed specific animal welfare standards. In developing animal welfare standards regard must be given to consistency in standards.

The NAC will promote the guidelines developed by the World Health Organisation (WHO) and the Office International des Epizooties (OIE).

Community awareness

Industry is committed to working closely with community groups to develop guidelines and Codes of Practice that meet their expectations.

The future

Industry and government are seeking cooperation from all stakeholders to ensure the practices adopted by the whole of chain are in keeping with legislation and community expectations.

The NAC is adopting a process that allows for continual review of guidelines and policy that relate to animal welfare issues. This is being done in cooperation with numerous State and Federal agencies. It will then be the NAC's responsibility to make sure that industry educates and trains its staff appropriately in order to address animal welfare issues.

The NAC will continue to participate in the development of the National Animal Welfare Strategy.

Education and training

Communication, education and training are some of the key issues facing the industry to ensure adoption and implementation of best practices concerning animal welfare. The NAC will develop a communication plan to ensure the various sectors are aware of their responsibilities and promote the adoption and implementation of best practices.

The incorporation of these practices into environmental management systems (EMS) will be one technique to achieve these outcomes. The NAC is currently promoting the adoption and implementation of an EMS framework in approximately 30 key businesses across Australia through an Aquaculture Action Agenda initiative. Animal welfare will be addressed in the management systems.

State legislation

The challenge is to work through the different legislation that applies in each State. There are attempts to obtain uniform legislation across the States however this must be driven by all stakeholders with a commitment from the various governments. It will be important to make sure the national standards are closely aligned with the various States' legislation.

The NAC will also make sure the guidelines meet international requirements.

Nociception and nociperception in fish: where does the debate fit in primary industries?

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Summary

One of the long-standing debates in aquatic animal welfare is whether fish can feel pain similar in nature to that experienced by humans. Whilst the detection of noxious tissue-damaging stimuli, and some of the responses to that, is classified as nociception, it requires conscious processing and awareness to classify it as pain. The difficulty in robustly interpreting experimental signs as evidence of this conscious awareness is obvious in the scientific literature.

The central nervous system of fish has been studied and the presence or absence of specific brain regions, known to be involved in emotional processing of nociceptive information, determined. Nociceptive pathways have been detected in fish, but the ability of the fish to consciously process this information into pain is still in debate. The question has been approached by comparing the neurobiology of fish with humans and by behavioural observation, but without ultimate agreement on either a suitable definition of pain or its perception by the fish.

Regardless of this, it is agreed that noxious stimuli do have the potential to induce harmful physiological stress responses in fish, and that uncontrolled, these can lead to poor wellbeing of the individual.

So, is pain perception central to the welfare debate? Whilst the ultimate answer may have impact in a number of areas, it can be argued that there are many other factors that play a role in an individual's well-being. A number of approaches have been used to examine these other factors, some with more consistency than others. Welfare standards in turn have been developed using some of these approaches; again it is important that these standards are credible, robust, consistent and provide true welfare benefits for the animals.

Legislation will continue to represent a solid backbone to evolve from, but welfare standards or codes of practice will, in all likelihood, develop in importance both nationally and internationally. Primary industry government, producers and scientists must help to ensure that these standards produce actual welfare benefits, are consistent, measurable and robust in order to benefit both the animals and the country.

Definitions associated with nociception and its perception

Nociception may be defined as the detection of noxious, tissue-damaging or harmful stimuli (Wall 1999; FSBI 2002; Sneddon, Braithwaite and Gentle 2003), its processing within subcortical regions of the central nervous system without conscious awareness (Rose 2002) sometimes accompanied by a reflex response (Sneddon et al. 2003).

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 according to the IASP is always a psychological state.

This obviously presents extreme problems when considering fish; science currently is unable to measure an emotional or psychological response in these animals, and whilst the science of emotional measurement in animals is progressing it is likely that agreed standards are not within easy reach.

Pain perception pathways

In humans, at least, the pathways associated with perception of pain have been elucidated through neurology, neurosurgery, neuropsychology, functional magnetic resonance imaging (fMRI) and positron emission tomography (PET). Both Jones (1997) and Rose (2002) provide detailed reviews of current understanding as regards the nociceptive and pain perception pathways in humans. In general, nociceptive stimuli are detected by free nerve endings. These sensory structures transmit the activity to the spinal cord via two types of nerve fibre, small diameter myelinated neurones (A-δ fibres) and small diameter unmyelinated neurones (C fibres). The A-δ fibres are marginally faster than the C fibres and are responsible for transmitting the acute response, whilst the C-fibres transmit more chronic stimuli. The afferent neurones from free nerve endings synapse within the spinal cord where they may induce a simple reflex arc resulting in a withdrawal reflex, which is an escape response devoid of conscious processing.

In addition spinal neurones may send axons to the higher centres of the central nervous system via the spinothalamic tract in the ventrolateral region of the spinal cord. The spinothalamic tract is known to innervate the reticular formation in the brainstem, and the thalamus in the midbrain. The reticular formation processes nociceptive activity and transmits information to the thalamus for further distribution 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 relayed to the thalamus, either directly, or via the reticular formation, is distributed to two main regions within the thalamus; the medial thalamic nucleus and the lateral thalamic nucleus. The lateral thalamic nucleus is involved in the localisation and mapping of the stimuli and passes data to the somatosensory cortex, preserving spatial information. It is within the somatosensory cortex that humans process the ascending data to determine temporal, spatial and immediate intensity information. The medial thalamic nucleus does not preserve spatial data but forms the initiating portion of the cognition, affect and response selection. It performs this function through its intricate and complex neuronal radiations to the cortical structures, namely the anterior cingulate gyrus, the prefrontal cortex and the anterior insula.

It is important to remember that neural activity at the level of the midbrain and brainstem is not consciously perceived, the complex radiations to the cortical structures are required in the human nervous system to allow the conscious processing of the stimuli. Negative feedback on the nociceptive system is achieved via naturally occurring opioids, and is controlled by the reticular formation and the anterior cingulate gyrus.

The anterior cingulate gyrus, a cortical structure lying just above the corpus callosum, is responsible for generating the unpleasant or aversive nature of pain. Patients who have undergone surgery to ablate the anterior cingulate gyrus 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. Together with the medial thalamic nuclei, the anterior cingulate gyrus forms a complex neural network with the prefrontal cortex, a uniquely primate structure, to further process the information. This processing is referred to as a cognitive and evaluative stage, and allows humans to relate the current stimulus to previous experience and perceived threat to initiate pain and fear responses. A complex neuronal radiation from the amygdala (a part of the limbic system of the midbrain) is also heavily involved in the generation of fear.

Neuroanatomy of fish

Having reviewed the neurological capacity of humans, we can compare directly those structures existing in fish. Elasmobranchs (primitive fish) are known to possess free nerve endings in their skin but they have very few unmyelinated neurones, none of which enter the spinal cord, and show no interruption of behaviour following severe nociceptive stimuli (Rose 2002). It is widely accepted that these fish probably lack even nociceptive activity (FSBI 2002).

More evolutionarily developed fish, the teleosts, however have been shown to possess unmyelinated fibres, and recently, the existence of A-δ and C fibres has been demonstrated, together with a nociceptive function (Sneddon et al. 2003). Indeed the central structures such as the ventral spinothalamic tract and lateral spinal tract terminating at multiple midbrain levels have been identified in both elasmobranchs, which appear to lack nociception, and teleosts (Rose 2002). In addition it has been demonstrated that fish lack many cortical structures including the prefrontal cortex and the anterior cingulate gyrus.

This information, unfortunately, 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 main theories propounded currently.

The scientific debate on pain perception

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. Rose (2002) states that the projection of human experiences onto less complex animals (anthropomorphism) is flawed. By accepting that pain sensation requires higher conscious processing, and that this processing occurs, as we have previously seen, in complex neuronal cortical networks that, anatomically speaking, are missing in fish then it must be concluded that fish are incapable of higher processing. The experience of pain per se requires conscious awareness, anaesthesia in humans illustrates that nociception is conserved subconsciously but the patient suffers no pain as their conscious levels are isolated from the nociceptive input. Rose argues that fish are therefore incapable of pain perception since they lack the complex cortical structures such as anterior cingulate gyrus and prefrontal cortex that are the site of higher nociceptive processing in humans. Rose queries whether other areas of the midbrain may be involved in pain perception. After all, the processing of visual information in birds takes place in the midbrain optic tectum as opposed to the visual cortex (FSBI 2002). Rose however indicates that despite neuroanatomical studies of the fish brain no regions have been discovered that duplicate the complex neural networks of the anterior cingulate gyrus and prefrontal cortex.

Previous studies had concluded that pain perception, or at least some conscious recognition of nociceptive stimuli, was possible in fish through three main behavioural approaches. Early studies correlated a behavioural change to noxious stimuli as equating pain sensation, Rose indicated that nociceptor activity via its stimulation of the reticular formation can induce innate behavioural changes, and pre-wired motor programmes and thus does not provide conclusive evidence of pain perception. Similarly Rose highlights that a learning ability does not necessarily equate with consciousness. He quotes studies by MacPhail in 1998 that demonstrated a number of examples of associative learning occurring without conscious awareness. Finally Rose indicates that the presence of equivalent nerves, pathways and neurochemicals between mammals and fish, does not necessarily indicate pain perception. The neurological components identified are part of the nociceptive system in animals, exist in elasmobranchs and require further processing at conscious levels to result in pain sensation. Rose also indicates that nociceptive systems utilise natural opioids (enkephalins, substance-P and β-endorphins) in their negative feedback control systems. The response of an animal to an analgesic, such as an opioid, does not therefore indicate that pain sensation was involved in the response, but merely that the nociceptive system has been inhibited by the opioid. Although the inhibitory function of opioids at a nociceptive level does not preclude a central analgesic function.

An alternative approach to attempt to determine if pain sensation is possible in fish is through behavioural studies. The approach has validity since animal welfare research has utilised behavioural observations on many occasions, but it requires robust studies and careful definition. In 2003, Sneddon et al. published the results of a study in rainbow trout that utilised behavioural observations. They redefined pain from the IASP definition, instead stating that any noxious event that induces sufficient adverse effects on the physiology and behaviour of a fish, that is painful to humans, is likely also to be painful to the fish. They went onto indicate that to be accepted as such the response would need to include withdrawal, continue after the stimulus is removed and that the fish should demonstrate avoidance behaviour.

Initially, Sneddon demonstrated the presence of two types of nociceptor and the A-δ and C fibres, combined with neural activity consistent with a nociceptor response, thus indicating the presence of a nociceptive system in teleost fish. The group hoped to demonstrate behavioural changes that could be attributed to pain following the injection of noxious material into the lips of the rainbow trout. Acetic acid and bee venom were used as noxious agents, whilst saline was used as a control. Sneddon and colleagues noted increased respiratory rate in all groups, but accepted that it may represent a physiological response to the noxious agents. A delayed return to feeding was cited as evidence of guarding behaviour, similar to the reluctance to use an injured limb displayed in mammals. Lip rubbing was observed in those animals injected with acetic acid, albeit without quantification of the frequency, and a strange rocking motion was noted in fish injected with the noxious agents. Sneddon indicated that the lip rubbing may have been an effort to ease discomfort and was equated with the human action of rubbing an aching body part to ease pain, whilst the rocking motion was theorised to be comfort behaviour.

The importance of robust experimental design is however illustrated by the response from Rose (2003) in a critique of the paper when he stated that the behavioural observations were not necessarily indicative of pain sensation and displayed inconsistencies of conclusion. Rose queried why fish would avoid food because of painful lips, but would rub them on hard gravel or tank surfaces. Further the definition used by Sneddon to indicate pain, namely the presence of a withdrawal response, extended behavioural change and learning/avoidance response, could be queried as not definitively indicating pain given the ability of extended behavioural responses and some associative learning to take place without conscious awareness.

Both Sneddon and Rose 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.

This statement is mirrored elsewhere (FSBI 2002; Braithwaite and Huntingford 2004), where it is identified that more research is required to identify appropriate welfare criteria. In a recent review, Braithwaite and Huntingford (2004), suggest that animal pain should be defined differently to human pain, namely via the removal of the emotional component. This approach would require a highly developed definition to avoid the possibility of behavioural responses to nociception being accepted as evidence of pain perception. Braithwaite and Huntingford (2004) indicate that a different approach to that of Sneddon (2003) is required, and suggest that another series of experiments utilising avoidance behaviour of novel objects, on the background of a noxious stimuli, with or without opioid analgesic would indicate pain sensation interfering with the avoidance behaviour. Whether the opioid is working at a nociceptive level or not, or if the interference of behaviour is cognitive or non-cognitive is unclear at this time. The use of an analgesic compound that has a role in the negative feedback of the nociceptive system complicates resultant conclusions.

The learning capacity of fish, both for conspecific recognition and mapping would indicate that there may be a memory or mental representation capability in the central nervous system of fish. Indeed an area of teleost brain, the lateral pallium, which is analogous to the hippocampus in mammals and is thought to be involved in memory, has been identified (Broglio, Rodriguez and Salas 2003). Braithwaite and Huntingford hypothesise that should fish be capable of simple mental representations they may have the potential to suffer.

Currently, science cannot definitively answer the question of whether fish feel pain, and claims that current experiments show this are premature. It is clear that more research is needed; research directed much more towards the cognitive conscious processing of nociception. The science of emotion is young and much work needs to be done before a definitive answer is produced. However, what is generally agreed is that chronic noxious stimuli can produce harmful physiological stress responses in fish, and that uncontrolled, these can lead to poor wellbeing of the individual.

Measuring welfare in aquatic animals

As pointed out by Rose (2002), FSBI (2002), Sneddon et al. (2003) and Braithwaite and Huntingford (2004), fish respond to noxious stimuli with a physiological stress response. Welfare criteria should therefore seek to address and control the factors that induce stress responses with appropriate welfare and husbandry considerations (Braithwaite and Huntingford 2004).

How animal welfare may be measured in animals, and adapted to aquatic animals is a source of debate currently. A number of welfare approaches have been utilised in other food production industries, such as chickens and pigs, and is usefully reviewed by Barnett and Hemsworth (2003). There are five broad approaches that can be defined, each with its own advantages and disadvantages.

The "feelings" based approach defines welfare in terms of emotions, aiming to reduce negative emotions in favour of positive emotions. The difficulty in utilising such an approach is that the emotional repertoire of even higher order mammals is quite restricted; include the real difficulty of science as it currently exists to objectively measure emotion, and consider that varying mental states are quite capable of producing similar physiological changes, and the problems with utilising this approach to develop useful, consistent welfare criteria is obvious.

In recognition of these issues early welfare research was based on the "nature of the species". This approach concentrates on natural behaviours in natural environments, and indeed this approach has been carried forward partly into the five freedoms. The "nature of the species" approach is intuitively nice, however whilst this natural behaviour approach has probably been the longest standing method there are some areas where it has not developed as fully as it perhaps should have. It is now recognised that some of the "natural" behaviours are in fact adaptations to cope with what is effectively a very harsh environment. So, how necessary are some of these behaviours when considering the domesticated situation? 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 next approach was to hand the decision making over to the animal involved. Give that animal a choice, and it will pick the one best suited to its welfare. The theory appears to be simple, objective and reasonably logical, but 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. If an animal is hungry its choice will tend to be towards food or the satiation of its appetite; if it has recently been fed, the choices it makes may well be directed towards other body requirements, such as shelter.

The five freedoms approach originates from the United Kingdom, and is a philosophically ethical approach to animal welfare. Its application to aquatic animals has however been questioned. In the United Kingdom the RSPCA Freedom Foods scheme has adapted the five freedoms for use in its welfare standards for farmed Atlantic salmon. The difficulty of using the five freedoms is that there has been a lack of definition in some of the terms, especially where aquatic animals are involved.

This lack of definition makes the development of consistent and objective standards difficult to achieve. Different proponents of this system will have different views on what are acceptable standards.

The "homeostasis" approach states that "*the welfare of an individual is its state as regards its attempts to cope with its environment*". Basically, 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. The good thing about this approach is that it examines welfare risks from two aspects:

- what changes occur in the animal to cope
- and what the biological cost is of that adaptation.

Not only does it give two direct risks to examine, but it provides some objective measurements that can be made. It is possible to measure physiological changes, and biological cost (growth rate, reproductive performance, etc) in animals. Whilst this approach has been used to benefit in a couple of industries, there has been concern that subtle risks to welfare may be missed. The contention is however that subtle risks result in subtle changes, changes that may well still be measurable. Other questions that have been raised include concerns over the adequacy of the definition of welfare. Can it be said that poor welfare results from poor adaptation? The second question is much harder, does the approach somehow need to have the "feelings" aspect built into it? If so, how does one do that, without losing the innate objectivity and measurability of the homeostasis approach? Thirdly, is it too conservative? Does the absence of measurable change indicate good welfare? Not necessarily but it does suggest that the animal is unstressed. Conversely, it may actually be an advantage; if through study a factor is found that does cause a response, then that factor must be important to the animal, so this approach allows an analysis of the principle components of the welfare risk.

Of the five approaches, none is perfect, nor will one system satisfy all the stakeholders. However, in terms employed by government; that is science based, objective, consistent and measurable, the homeostasis approach seems the most constructive for developing meaningful welfare indices.

Given the scientific robustness of development utilising the homeostasis model, how should "feelings" and "emotions" be dealt with? It has been suggested that since these ephemeral neural processes are difficult to define and, currently, impossible to measure in animals, that they should be excluded from the model. Is it not better, the argument goes, for defined welfare benefits to be discovered and implemented using scientific measurables in a system like the homeostasis model, than; by considering the imponderables of emotion to be consumed in debate in an area where meaningful measurements cannot be made, and actually delay useful discoveries. Such is the dilemma that must be considered and dealt with if useful welfare indices are to be developed.

The implementation of welfare standards

The aquaculture industry has been the subject of a number of reviews from bodies such as Compassion in World Farming (CIWF), Farm Animal Welfare Council (FAWC), World Wildlife Fund (WWF) and Friends of the Earth (FOE). All of these bodies made recommendations regarding acceptable stocking density, slaughter method and parasite and disease control procedures. Some of the recommendations were derived from a perceived environmental concern, some from a perceived welfare concern. It should be noted that CIWF, WWF and FOE have objections to aquaculture and their reports were quite severe in their interpretation and publicity.

Other agencies worldwide are also addressing the animal welfare issue including the European Union, the Office International des Epizooties (OIE), the Australian Government, major retailers and the RSCPA (UK). Some of these groups have produced detailed welfare standards. These standards are designed to be prescriptive. In order to produce meaningful welfare benefits and to position the industries domestically and internationally without unwarranted burdens on producers any welfare standards must be objective, consistent, science-based and measurable.

An example of the difficulty in assigning welfare standards based on a perception is probably the definition of stocking densities. The salmon industry in Scotland commonly utilises a stocking density between 15 and 17 kg/m^3. WWF and FOE would like to see this reduced according to their reports. FAWC, retailers and the RSPCA (UK) specify 15 kg/m^3 as the maximum stocking density for welfare purposes. CIWF goes further and recommends that stocking densities be reduced to 10 kg/m^3. The argument is that lower stocking density means better welfare, less disease and less injury. This is an overly simplistic approach to a complex situation and when examined, none of the above recommendations can be attributed to any particular piece of scientific evidence. Low stocking density does not necessarily equate to good welfare, nor does a higher stocking density necessarily equate to poor welfare. To illustrate; it has been found that increased stocking density is not a major welfare factor at up to 22-24 kg/m^3 in Atlantic salmon (Bell et al. 2002). Physiological parameters in salmon were unaffected by stocking densities of up to 100 kg/m^3 (Kjartansson et al. 1988). Pectoral fin damage was unrelated to stocking density below 80 kg/m^3 (Soderberg, Meade and Redell 1993). The rate of spread of an infectious viral disease was unaffected by reduction in stocking density to as low as 2 kg/m^3 (Bowden et al. 2003). It is apparent that there must be principal components of the welfare status other than the stocking density; some of these are suggested in the paper by Bell et al. (2002).

Where then is the benefit to the animal or the industry in setting a subjective standard for stocking density when the issue needs to be approached from another direction, utilising some properly defined welfare indices? The imposition of standards that are not scientifically based, and do not necessarily result in a true welfare benefit, risks diverting resources away from areas where true benefits may be found for the animals.

The role of primary industries government

The role of primary industries government departments must be to support the industries in the development and adoption of welfare philosophy. This could partly be achieved through the review and update of legislation as necessary, although this is a slow process due to the amount of consultation that must be carried out prior to any changes. There must be recognition that welfare research forms part of the development of a sustainable industry, and this needs to be considered in funding discussions.

Groups, regardless of their affiliation, producing welfare standards must expect them to be critically reviewed by industry and government to ensure that they are scientifically based, objective, capable of consistent measurement and provide evidence of an expected welfare benefit. In this way it may be hoped that resources are utilised most effectively, that true welfare benefits result and that internationally Australian product is recognised objectively as being of high welfare standards, thus avoiding the potential for subjective differences in opinion between industries and countries.

Extension of the principles involved in the determination of science-based welfare standards and the identification of principle components of welfare risk via, for example, the homeostasis approach is an important aspect of communicating the essence of suitable and appropriate objective standards within aquaculture. It is equally important that all parties provide objective advice to consumers to justify and quantify the welfare benefits that derive from the standards.

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Treating the prawn well on its way to the barbie: welfare of aquatic crustaceans

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Summary

Numerous species of edible crustaceans are consumed in Australia falling broadly into categories of prawns, lobsters, freshwater crayfish, and crabs. This diversity creates difficulties for developing welfare strategies, as systems appropriate for one group may be inappropriate for others. Methods of harvest also vary with most production obtained through wild fisheries although there is substantial production of prawns in culture and much smaller production of cultured freshwater crayfish. Many species are simply killed by chilling immediately after capture such as trawled or cultured prawns, trawled slipper lobsters (bugs), and blue swimmer (manna crabs), while other species such as rock lobsters and spanner crabs are transported alive to processing facilities before cooking. Live transport has become increasingly important for exported product and to a lesser extent for domestic product. This method of “processing” is especially important for rock lobsters, giant crabs and karuma prawns. There is a range of other specific handling issues associated with crustacean products such as short term holding of crabs for soft-shell production, trimming or punching of the tail fan in recreational lobsters, eye ablation for broodstock prawn maturation, and implanting of tags for stock assessment.

The need for consideration of welfare is related to the complexity of the nervous system and the ability of individuals to suffer. Pain is a difficult, or perhaps impossible, aspect to measure in animals other than humans, so it is usually inferred from changes in behaviour that seem to indicate distress. While it is obvious that crustaceans respond to unpleasant stimuli there is no consensus that this implies suffering. In the absence of objective evidence one way or the other the more conservative approach is to assume potential suffering occurs and avoid processes that may produce it.

Information on the anatomy of the nervous systems provides some clues about relative suffering between groups and also contributes to the design of techniques for rapid killing. As with all arthropods, the main nerve cord in crustaceans is ventral with ganglia. There is typically a single ganglion in each segment and these control motor and sensory functions so that in many ways each segment is autonomous. The central nervous system is small and located around the oesophagus. The anatomy of the nervous system means that it is not possible to kill crustaceans by trauma to a central nervous system as with vertebrates. One possible exception are crabs where the fusion of segments has led to the nervous system being condensed into 2 main ganglia so that crabs can be killed by “spiking” these areas. Most other crustaceans can only be killed by physical damage to the nervous system when the animal is bisected although this exposes the flesh, which can reduce product quality when cooked.

Due to the difficulty in using physical damage to the nerve cord as a technique for killing crustaceans, techniques involving changing the environment are more widely used. Options include changing the temperature, pH and salinity. Chilling appears very effective for many species although less so for animals from temperate waters. Placing crustaceans into boiling water kills them rapidly but appears to cause initial shock. Changing the pH, such as by increasing the concentration of dissolved carbon dioxide appears unsuitable as it appears to cause distress. Altering salinity is widely used in industry where crustaceans are “drowned” in freshwater although this appears to cause suffering based on the prolonged thrashing of animals before they die. Food grade chemicals have been developed and are another alternative. Compounding the difficulty in recommending methods for killing crustaceans is the need to maintain product quality. Limb loss or autonomy during killing is an important consideration for industry as this leads to loss of weight and reduction in marketability.

Diversity of species, fishing and processing methods

The development of guidelines for the treatment of crustaceans is complicated by the diversity of species that are harvested for food. The group includes an estimated 30,000 thousand species from marine, freshwater and terrestrial habitats; slaters, brine shrimp, barnacles, lice, amphipods, prawns, lobsters, crabs are all crustaceans. Clearly we would not expect welfare to be considered across this range, in the same way that we wouldn't expect welfare to be important across the range of chordate taxa from tunicates to mammals.

Previous discussions on welfare of crustaceans have focused on the decapod group, which includes the largest species with the most developed nervous systems. This group also contains the most important crustaceans for direct human consumption such as prawns, lobsters, freshwater crayfish, and crabs. Diversity within decapods is large with an estimated 10,000 species so welfare strategies appropriate for one group may be inappropriate for others.

Welfare issues are often linked to the capture and product handling processes and these are highly varied in decapod crustaceans. Most production is obtained through wild fisheries although there is substantial production of prawns in culture and much smaller production of aquacultured freshwater crayfish. Many species are simply killed by chilling immediately after capture such as trawled or cultured prawns, trawled slipper lobsters (bugs), and blue swimmer (manna crabs), while other species such as rock lobsters and spanner crabs are transported alive to processing facilities before cooking.

Live transport to the point of retail sale has become increasingly important for exported product and to a lesser extent for domestic product. This method of "processing" is important for rock lobsters, giant crabs and karuma prawns. There is a range of other specific handling issues associated with some crustacean products such as short term holding of crabs for soft-shell production, trimming or punching of the tail fan in recreational lobsters, eye ablation for broodstock prawn maturation, and implanting of tags for stock assessment.

Is there a need for consideration of crustacean welfare?

The need for consideration of welfare in crustaceans generates debate because the nervous system is much less developed than in vertebrates. While there has been impetus for change to animal welfare legislation in some States, this has been driven largely by perceptions of consumers in restaurants where live decapods are killed, rather than from scientific demonstration of nociception by crustaceans. The ability of animals to detect and process pain in a similar way to our understanding of pain as humans is difficult to measure in other animals. While it is obvious that crustaceans respond to unpleasant stimuli, there is no consensus that this implies suffering.

The anatomically simple nervous system of crustaceans argues against the need to consider welfare issues with functioning of segments largely controlled by individual ganglia along the ventral nerve cord. In sessile barnacles and crabs there is concrescence of the ganglia into a single immense thoracic ganglia that operates in conjunction with the smaller central nervous system. Although the crustacean nervous system appears simple, surprisingly complex behaviours have been recorded and emphasise the need for caution in interpretation of complexity from anatomy. Stomatopods or mantis shrimps have one of the most complex visual systems known with complex colour discrimination that is used extensively in social interactions (Chiao et al. 2000). Agonistic behaviours between individuals are also complex beyond that normally associated with invertebrates (Wortham-Neal 2002). Behavioural observations such as these suggest that consideration of crustacean welfare may be warranted despite the simple anatomy of the nervous system.

In the absence of objective evidence one way or the other the more conservative approach is to assume potential suffering occurs and avoid processes that may produce it. This approach is practical where consideration of crustacean welfare coincides with good product handling practice, such as in the killing of tropical crabs in ice slurry. The issue is more difficult where processing techniques required to produce high quality product would be avoided on welfare considerations. An example here is the use of freshwater baths to kill rock lobsters by osmotic shock and rupture of epithelial cells. This process causes animals to thrash violently before dying and would be avoided on welfare grounds (Baker 1955). However, killing lobsters in freshwater is standard industry practice as it substantially reduces the incidence of leg loss through autotomy and thus improves marketability. Further research on nociception of crustaceans is required to provide objective guidance on this issue.

Humane killing of crustaceans

Several research studies have been focussed on methods to kill crustaceans without causing them apparent distress, as judged by thrashing, limb loss or tearing at the body with chelae. Many of these were conducted using chemical methods, as the aim was to improve the quality of museum species where toxicity of treatments is not of concern (Gohar 1937; Mahoney 1966).

Chemical baths have also been tested for killing crustaceans humanely for human consumption. Gardner (1997) showed that clove oil has potential for killing crustaceans humanely although the long-term chronic effects on humans are not yet known (Soto and Burhanuddin 1995). An additional problem with this method is that the oil has a strong smell, which alters the taste of the meat.

A product based on clove oil, AQUI-S™, is approved for use with food fish in New Zealand with zero withholding time; it produced paralysis in giant crabs *Pseudocarcinus gigas* although higher doses were required than with clove oil (Gardner 1997). Unlike clove oil, AQUI-S™ does not have a strong odour so is less likely to affect the taste of the meat. Further trials are warranted to assess the use of AQUI-S™ in the killing of crustaceans and to assess the effect on meat quality utilising human sensory evaluation. Regulation of use of this product with food in different countries may also be an issue. Aside from applications in killing crustaceans, food-grade chemical baths may have value in reducing stress and thus improving product quality where animals are freighted alive.

Physical methods for destroying the nervous system of crustaceans have been tried with limited success. The anatomy of the crustacean nervous system means that it's difficult to kill crustaceans by trauma to a central nervous system as with vertebrates. Crabs have only two main nerve centres and Baker (1955) described a method utilised by British fishers in the 1950s for killing crabs for human consumption by "sticking" these centres with an awl. Other crustaceans have a more decentralised nervous system and can only be killed by physical damage when the animal is bisected, although this exposes the flesh, which can reduce product quality when cooked.

Due to the difficulty in using physical damage to the nerve cord as a technique for killing crustaceans, techniques involving changing the environment are of broader application. Options include changing the temperature, pH and salinity.

A gradual increase in temperature was described as an effective and humane method of anaesthetising and killing large crustaceans by Gunter (1961) and was subsequently recommended by Smaldon and Lee (1979). This method was effective at paralysing giant crabs (Gardner 1997) although animals showed signs of distress. Baker (1955) had also tested the response of crabs to gradual increase in temperature and concluded that the method was unacceptable on humanitarian grounds as indications of distress, such as autotomy, occurred unless the crab was already in poor health. Following publication of Gunter's (1961) conclusion on the use of gradual heating, objections were raised to the method on the basis that there was no evidence of an anaesthetic effect (Baker 1962; Schmidt-Nielsen 1962).

Chilling appears very effective for many species although less so for animals from temperate waters. Crustaceans generally appear to exhibit few signs of distress although autotomy can occur. Chilling has drawbacks that affect its use in all species, it is generally a slow and inconsistent technique (Brown et al. 1996) and has been criticised for being ethically dubious as it involves subjecting the crab to conditions that it would normally avoid (Schmidt-Nielsen 1962).

Placing crustaceans into boiling water kills them rapidly but appears to cause initial shock. Limb-loss through autotomy is a common problem. Changing the pH through increasing the concentration of dissolved carbon dioxide appears unsuitable as it appears to cause distress. Gardner (1997) reported that crabs exposed to this treatment tore at their sternums with their chelae exposing internal organs.

Killing crustaceans by freshwater bath is one of the most widely used methods in Australia and is especially useful for the processing of rock lobsters. Fishers and processors call this method "drowning". Autotomy in lobsters is strongly influenced by salinity as complete autotomy in western rock lobster *Panulirus cygnus* can be induced by simply touching the carapace with gloves coated in a thin layer of salt (Davidson and Hosking 2002). Hyposaline water appears to have the reverse effect as it prevents limb loss, in addition to killing the lobster. However, while this method is useful for maintaining product quality, it causes severe trauma (Baker 1955, 1962; Gardner 1997).

Conclusions

The diversity of crustaceans makes formulation of welfare strategies difficult. The decentralised nervous system of most species prevents the use of percussive methods for rapidly killing animals, as can be done with vertebrates. Chilling appears to be a humane and effective method for killing most crustaceans, although it is less effective with temperate species and the ethics of the method have been criticised. Ice slurries are an effective method to rapidly lower the temperature of crustaceans but care must be taken with marine species to allow water to drain, otherwise animals will be killed by the decline in salinity rather than temperature.

Unfortunately, product quality objectives and welfare objectives do not always coincide with crustaceans. Freshwater baths are used by industry to maintain product quality by avoiding limb loss, however, these are not a humane option for killing. Choosing between these opposing objectives is difficult without improved understanding of the level of pain detection or nociception in crustaceans, which is an area that would benefit from further research.

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Fish welfare at harvest: killing me softly

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Introduction

Food quality is increasingly becoming a global concept as suppliers and retailers become larger and fewer. Food should be safe and traceable to the farm. In addition, the ethical aspects concerning food production, such as protection of the environment and animal welfare have been identified as important issues to consumers. Most countries have legislation covering the welfare of mammals and birds, however few have legislation applying to fish, although this is rapidly changing.

Fish welfare at slaughter is of special importance as this has potential to cause significant, stress, pain and suffering (Kestin 1994; Chervova 1997; Robb et al. 2000). A slaughter method is considered to be humane when unconsciousness is induced immediately by stunning and is irrecoverable (MAFF 1995). The slaughter of wild fish is not covered in this paper but it represents an area of growing concern. Most wild fish die by anoxia in air followed by chilling without exsanguination.

Farmed fish slaughter methods

There are a wide variety of slaughter techniques used between and within farmed fish species, as follows:

- exposure to air
- ice slurry
- bleeding
- gutting
- anaesthesia
- carbon dioxide
- electrostunning
- ike jime (spiking)
- percussive stunning.

Atlantic and Pacific salmon are slaughtered by either direct placement on ice without gill cut, a gill cut without prior stunning, carbon dioxide narcosis followed by a gill cut, percussive stunning (manual with a 'priest', or mechanised with a pneumatic stunning device) followed by a gill cut, anaesthesia followed by percussive stun and gill cut, or live chilling followed by a gill cut. Most seabass (*Dicentrarchus labrax*) and seabream (*Sparus aurata*) are slaughtered by live immersion chilling in chilled water or an ice slurry. Tuna (*Thunnus* spp.) are mainly slaughtered by "ike jime" (a spike is inserted into the brain via the pineal window and a wire is run down the spinal column) and bled via the pectoral arteries. Much of Japan's yellowtail (*Seriola quinqueradiata*) industry is also slaughtered by the ike jime method although mechanised percussive stunning of yellowtail is growing. In some countries large tuna are slaughtered with firearms, or by electrostunning via electrified harpoons and spears. Eels are predominantly slaughtered in the Netherlands by the so-called 'salt bath' (Van de Vis et al. 2001), in which fishes are deslimed in dry salt for approximately 20 minutes before gutting. Another industrial method consists of live chilling before gutting. In Germany, eels are electrically stunned in water prior to desliming and gutting (Robb et al. 2002). Rainbow trout in freshwater are predominantly slaughtered at portion size (350–400 g) either by immersion in ice slurry, by leaving them in air, or by immersion in a water bath saturated with carbon dioxide gas. In New Zealand, some farms utilise AQUI-S ™, a food grade anaesthetic, to anaesthetise fish during crowding for subsequent slaughter by percussive stun or spiking (B Goodrick pers. comm.).

In general, the slaughter methods that are slower result in more movement by the fish that is generally perceived as being aversive. The only movement seen using the faster methods, (ie percussive stunning and spiking) occurs during pre-slaughter handling. While some believe that there is a developing consensus that fish feel pain, and respond to this pain with aversive movements, this is yet to be decisively proven. However, there is a strong perception of concern from people viewing slaughter operations when they observe fish exhibiting aversive behaviour. The perception of fish retailers reflect this attitude and many have set standards for suppliers that focus on minimizing stress and suffering. In the UK, the RSPCA have developed Welfare Standards for Farmed Atlantic Salmon, enabling salmon farmers to receive Freedom Food accreditation, and the Freedom Food logo on their products identifies them as conforming to these standards. These standards state that:

> "*The method of killing used must rapidly, and without pain and distress, render the fish insensible, until death supervenes. An efficiently applied percussive blow is the only permitted killing method at present. This method is highly effective when applied properly. Humane mechanical percussive devices are now available commercially and these must be used in preference to a manual percussive blow for slaughter (except emergency killing). The particular mechanical device must be approved by RSPCA Farm Animals Department prior to use. It is important to monitor killing to ensure that the strength and location of the blow is such that the fish does not regain consciousness before death. The RSPCA will monitor the situation and if humane alternatives to percussive stunning become available, as research and technology develops, these will also be considered. However, no slaughter method, other than a percussive blow, may be used unless previously agreed with the RSPCA Farm Animals Department*" (RSPCA (UK), 2002).

The fish farming industry has generally adopted a proactive husbandry approach to welfare throughout the production cycle and including the slaughter process. This approach makes commercial sense as improving welfare leads to improved quality and yields (Angus et al. 1995; Erikson et al. 1996; Jerret et al. 1996; Sigholt et al. 1997; Tobiassen and Sørensen 1999). There are other issues associated with the slaughter process such as staff welfare, training and logistics, that are not part of this discussion but are also very important for decision making in slaughter methodology and protocols.

Humane slaughter methods

In regard to welfare, slaughter methods mentioned above, in which fish are not rendered unconscious immediately, are deemed unsatisfactory (FAWC 1996). Furthermore, it is also unsatisfactory for fish to exhibit aversive behaviour such as vigorous escape attempts. Electrical stunning, percussive stunning and ike jime have been found to be humane if applied properly. However, specific precautions are necessary for each method. For electrical stunning, minimal currents need to be defined for each species, in order to achieve an immediate loss of consciousness (Van de Vis et al. 2001). Electrical stunning is prone to cause bone fracturing, haemorrhaging, and blood-spotting and therefore currently there are few commercial operations using electrical stunning. For spiking of the brain, a high level of precision and expertise is required and there are staff welfare issues involved with using spikes or knives while manually handling live fish. Moreover, it is possible that parts of the brain which are not destroyed continue to function after the spiking (Robb 2001). Spiking is probably not feasible for humane slaughter in industry (Van de Vis et al. 2001) apart from individual manual application with large fish like tuna, and it has not been successfully mechanised for commercial operation with smaller fish. As to percussive stunning, a pneumatic automated device (Figure 1) is preferred to a manually applied club, since the latter generates fatigue and can lead to imprecise or insufficiently strong blows. Substantial progress has been made in the development of commercially viable pneumatic stunning machines and these are now widely used by the farmed salmon and yellowtail industries. Fish are now able to be directed to machines without manual handling, in water, up to the point of stun. The quality and welfare benefits of this technology, and in many cases logistical improvements, have attracted interest from many farmed and wild fishery operations, and this method of slaughter shows most promise to develop and spread over a range of fish species and locations.

Figure 1 SI~5 Pneumatic Auto Stunning System in operation in Canada (picture supplied by www.seafoodinnovations.com.au)

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Cetacean research in the Southern Ocean

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Introduction

The history of human-whale interactions has not always been good. From near extinction through hunting during the first part of the 20th century some species are now recovering quite strongly. Yet an imperative to continue hunting, in the face of an international ban on hunting continues to exist, and is being expressed in an increasing number of nations. Whale-watching is being developed around the world as a new tourist objective, with significant results for regional economies.

The cetaceans are one of the most difficult groups of mammals to study in the wild. Unlike most other marine mammals that spend at least part of their lives on dry land, cetaceans never leave the water. Research into their biology must be conducted at sea, and this places enormous constraints on researchers who cannot readily attach tracking devices or obtain skin biopsies. Yet without a systematic body of research to hand conservation measures are, at best, based on guesswork.

In July 2003, the Australian Antarctic Division (an agency of the Department of the Environment and Heritage) was given responsibility for Australia's policy development concerning cetaceans in international and Antarctic waters, and a new systematic study has been implemented. This paper will review the national context in which Australia's research into Southern Ocean cetaceans is conducted and discusses a new development in cetacean dietary research.

The policy environment

The Australian Government is about to celebrate the silver jubilee of it abandonment of commercial whaling and the embrace of whale conservation. For the past 25 years Government policy has been to conserve whales and to work in the International Whaling Commission to foster the development of whale sanctuaries and other measures for conservation. It does not condone the killing of whales for any purpose or the use of lethal techniques in field research. Its position is that there is no way to kill a whale humanely.

Australia's policy objectives are:

- to pursue a permanent international ban on commercial whaling
- to promote whale sanctuaries and regional cetacean conservation
- to seek an end to scientific whaling and to promote non-lethal research
- to prevent expansion of whaling types and operations.

To deliver the policy objectives some tools for effective engagement have been developed:

- to campaign effectively in international forums
- to promote Australia's position through international relations
- to work in partnership with stakeholders
- to maintain and review annually a comprehensive, integrated strategy.

During 2003, at IWC 55, Australia argued for retention of the moratorium on commercial whaling, criticised so-called "scientific whaling", and strongly supported the creation of a conservation committee in the IWC. It was a year in which we saw the re-entry of Iceland into the group of nations undertaking "scientific whaling" with a target of 38 minke whales (cf Japan's 440 from the Antarctic) and in which Norway took a commercial catch of 645. (Norway has announced a target of 670 in 2004.) Australia and 22 other nations signed a demarche on the Government of Iceland.

The agenda for 2004 at IWC 56 includes developing the capacity to strengthen our scientific input to policy debate (see below), to contribute to discussions leading to retention of the South Pacific Whale Sanctuary, to oppose proposals for 'scientific whaling' in the Southern Ocean Sanctuary, and to continue to support the Berlin Initiative that there be a conservation committee of IWC.

Scientific input to policy development

Australia has not before adopted a systematic approach to research on cetaceans in the Southern Ocean, instead relying upon university and other groups to undertake a variety of projects lacking any overall strategic coherence. Transference of responsibility to the AAD has provided the opportunity for the development of a coherent, integrated program of study. The overall objective for the program of scientific research is to:

> "*Develop Australia's capacity and ability to provide scientific support for our national policy objectives for international whale conservation*."

The specific program of research embraces the following topics:

1 Further develop, and take a lead role in the international debate on relationships between whales and fishers ("whales eat fish") with a view to:

- supporting Australia's policy on ecosystem-based management of the marine environment
- determining linkages between whales and their prey, ensuring that uncertainty is determined as accurately as possible
- demonstrating uncertainty and risks associated with ecosystem manipulation
- supporting the development of management systems for fisheries that improve yields, without requiring the culling of predators
- developing food-web models that include fisheries and whales
- critically evaluating food-web models developed by others.

2 Take a major role in further developing the scientific basis for the establishment and long-term maintenance of ocean basin-scale whale sanctuaries, with a particular view to providing scientific justification for the retention of the Southern Ocean whale sanctuary, the South Pacific whale sanctuary and, more generally, provide a scientific basis for the development of clear science-based objectives for whale sanctuaries.

3 Deliver high-quality strategic advice to the IWC in the following areas:

- critically evaluate and contribute to the determinants of the inputs into the RMP model (abundance estimation, spatial and temporal determination of stocks, and the incorporation of ecosystem considerations)
- continue and further develop non-lethal approaches to the study of cetaceans with particular emphasis on diet and movement patterns
- continue and further develop linkages and multi-disciplinary programs that ensure ecosystem considerations are incorporated in the science conducted by the IWC Scientific Committee.

Non-lethal dietary studies

I wish now to examine one aspect of the above in enough detail to demonstrate how a new approach to an important question can reduce stress and suffering to wildlife whilst delivering high quality biological data.

A major justification for 'scientific whaling' is the requirement to understand the diet of whales. There is no doubt that large whales eat fish, and sometimes in spectacular quantities. The "whales-eat-fish" argument, developed by Japan and used as its justification for "scientific whaling", is predicated on this observation, coupled with the now all-too-common observation that catches of commercial fish are declining. There is a simple and seductive logic in the argument that if whales eat fish, reduction of the number of whales will make more fish available for human consumption. This argument is over-simplistic and fatally flawed. It requires that whales do not eat anything other than fish, and that no other marine species that eat fish are themselves eaten by whales. This over-simple caricature of the marine environment is not matched by reality. Whales live in a complex feeding environment in which they eat a range of species. Some of these species are themselves significant predators on fish. If the whale population is reduced the check on the populations of these predators is lifted and they multiply to the point where they exert a greater pressure on fish stocks than occurred prior to the whale cull. Simple reflection on the fact that whales and fish have coexisted for millions of years, with stocks of fish far higher than they are today, indicates that the reason for the decline in fish numbers is not directly or solely caused by whale numbers.

How can we determine the diet of whales without resorting to lethal methods? At the AAD we are developing a technique that will do just that. Dietary studies are conducted in a number of ways. The lethal technique, as used by “scientific whalers” is a direct method; opening the stomach provides quickly obtained and accurate knowledge of what is in the stomach. The diet of a species can be deduced by examining a large number of stomachs over a long period of time, such that seasonal age and sex differences in diet may be observed.

A second method is to collect the faecal droppings and examine the skeletal particles that they contain. Our work on fur seal diet at Heard Island over the past 8 weeks has done just that. Seal faeces can be collected from the breeding grounds with ease. Fragments of carapaces of crustaceans, and “ear” bones and other indigestible parts of fish can be used to identify species eaten can be obtained. If the samples are complete enough a good measure of the amounts of each species eaten. A problem with this technique is that only hard and bony fragments withstand the passage through the gut; soft-bodied creatures leave nothing that can be identified by this method.

At the AAD we are developing a method to determine diet buy looking at DNA material of prey excreted in faeces. The method does not require the presence of hard parts; the presence of a species in the diet will be revealed by its DNA in the faeces. Although cetaceans defecate at sea, it is possible to collect faeces by hand, using a dip-net and a small boat. While this practice is more difficult in rough and cold Antarctic waters than in temperate latitudes, it is not impossible. Once collected, the faeces can be subjected to analyses and identify the prey without the researchers having had to make physical contact with the predator. We are developing a substantial library of DNA templates against which we can test faeces of whales. During the past summer we have used this technique on fur seals on Heard Island, where we have had the opportunity of cross-checking using microscopic analyses of faeces for calibration and verification. Netted samples collected in the feeding grounds up to 600 km away are used as the stock from which we can build our reference library. We cannot undertake the molecular biology until the field party returns to Australia but we are confident we will find a close match between what is available where the predators are feeding and what they are actually eating.

Our next challenge is to successfully scoop whale faeces from the Southern Ocean; an activity that we will attempt during the next Antarctic field season. We are increasingly using this technique for studies on seal diet.

This work is part of a suite of studies that the AAD is developing to develop research techniques that reduce, as far as possible, the need for animal handling. The use of small, light “smart tags” for tracking movement and diving behaviour reduces wildlife stress as these new generation devices can be attached quickly and painlessly. Tags are glued to feathers or fur and are shed during the annual moult. Built-in homing bleepers assist field staff to retrieve the devices for refurbishment and reuse. The AAD’s web site displays the movement patterns for fur seals, king and macaroni penguins, black-browed and light-mantled sooty albatross tagged at Heard Island between December 2003 and February 2004. In this study the tagged predators ‘told’ the research vessel where they were feeding, allowing net- and acoustic-sampling to be carried out in the locality (URL: http://aadcmaps.aad.gov.au/aadc/argos/deployments.cfm). Such data are absolutely necessary if we are to build accurate and detailed food-webs for the Southern Ocean, and to enable sustainable fish and krill catches to be determined.

Oceans are deceptive places. The uniformity of their surfaces belies the great differences and ecological complexities lying below. We understand far less about marine biodiversity than we do about terrestrial biodiversity, making sustainable management procedures difficult to develop. In the Antarctic research program we will continue to conduct research on vertebrates – including on cetaceans – but will continue to develop techniques that are ethically acceptable and that reduce incidences of behavioural change, injury and death. As my colleague Dr Nick Gales, and his co-workers aptly put it:

> "*Marine mammal research interacts with public attitudes, economics, politics and ethics in an interesting manner. The science itself has a role in informing and influencing public attitudes, while the actual conduct of the science is subject to the judgement of the public … The compelling challenge for those who conduct marine mammal research is to address the issues relevant to the advancement of marine mammal science, management and conservation, while contributing to, and ideally informing, ethical debates and values.*"

AAD's new studies on cetaceans in the Southern Ocean are rising to that challenge.

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Seal entanglements in marine debris before and after government and industry intervention

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Summary

In recent years, Australian governments and fishing industry associations have developed guiding principles aimed at reducing the impact of fishing on non-target species and the benthos and increasing community awareness of their efforts. To determine whether they reduced seal entanglement in lost fishing gear and other marine debris, we analysed Australian sea lion and New Zealand fur seal entanglement data collected from Kangaroo Island, South Australia. Contrary to our expectations, we found that entanglement rates did not decrease in recent years. The Australian sea lion entanglement rate (1.3% in 2002) and the New Zealand fur seal entanglement rate (0.9% in 2002) are the third and fourth highest reported for any seal species. Australian sea lions were most frequently entangled in monofilament gillnet that most likely originated from the shark fishery, which operates in the region where sea lions forage - south and east of Kangaroo Island. In contrast, New Zealand fur seals were most commonly entangled in loops of packing tape and trawl net fragments suspected to be from regional rock lobster and trawl fisheries. Based on recent entanglement studies, we estimate that almost 1500 seals die from entanglement each year in Australia. We discuss remedies such as education programs and government incentives that may reduce entanglement rates.

The full paper presented by Brad Page at the 2004 Seminar is published in the Marine Pollution Bulletin and is referenced as:

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A copy of this paper can be obtained through the Science Direct website. For a direct link to the paper go to: http://dx.doi.org. In the text box on this site you will then need to type the following link: doi:10.1016/j.marpolbul.2004.01.006

Fish are friends, not food! What the growth in tourism has meant for aquatic animals

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Summary

It is widely recognised that tourism is one of the world's largest and fastest growing industries. Historically, coastal environments have played an important role as locations for recreation and as attractions upon which tourism development has been based. More recently, new technology, improved safety and increasing demand have resulted in massive growth in the use of aquatic environments for recreation and tourism. This use has had significant impacts on wildlife in both a direct and indirect sense. As a consequence it is now increasingly understood that tourism is not the inherently sustainable industry that it was once touted to be. A significant management challenge exists. Demand for high quality aquatic-based recreation experiences continues to grow while the corresponding availability of such environs is diminishing. Thus, significant conflicts are arising. Simplistic management approaches will not solve this dilemma, rather creative, dynamic and ongoing applications tailor-made to the needs of specific areas are needed to ensure the future of these popular tourism attractions. The use of aquatic environments for tourism and the implications for wildlife will be one of the significant environmental management challenges for the 21st century.

Fisheries bycatch – a problem for welfare and conservation

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Summary

Fisheries bycatch is that part of the catch which is caught but discarded, either because it has no market value, or because regulations prevent it from being retained, as in the case of protected species. Bycatch also includes that part of the catch that is not landed, but killed as a result of interaction with fishing gear and/or subsequent predation.

Bycatch occurs because the gears (nets and hooks) used during fishing operations are non-selective for the target species. As a result, every animal attracted to the baited hook or within range of the net is caught. The methods used to fish also contribute to bycatch both temporally and spatially. For example, fishing during times when seabirds, attracted to baited hooks are active and netting at depths where bycatch such as turtles are known to forage.

SeaNet is an environmental extension service to the Australian seafood industry and provides information and advice on improved fishing gear, technology and methods. Our primary objective is to work with the fishing industry to minimise bycatch and encourage environmental best practice by industry.

SeaNet is active in five States across Australia, and in association with fisheries researchers has facilitated the introduction and adoption of many techniques and gears to reduce bycatch. The fishing industry is still regarded by many to be the "rapers and pillagers" of the sea, even though the majority of Australians enjoy what is arguably the best seafood in the world. With the assistance of SeaNet, industry has proven to be a willing participant in the development, trialling and adoption of bycatch mitigation techniques and gears.

Australian fishers have a respect for the resource that supplies them with their livelihood and the animals with which they interact. Together we can ensure that interactions with non-target species are soon a thing of the past and that the post release survival of animals with which we do interact, despite industry's best practice, is maximised.

What is bycatch?

Bycatch is the incidental capture of non-target species, that is, all the species caught by a fisher other than those he intended to catch. It includes the animals that die on deck and those that survive, but which due to injury, disorientation or stress are preyed upon following release by seabirds or larger fish. Bycatch also includes those animals that die as a result of interactions with fishing gears (nets, hooks and lines) while it is deployed, such as turtles, dolphins and seals.

Bycatch species

Bycatch can include any marine animal, including non-commercial fish and Crustacea and the juveniles of commercially valuable species. It can also include threatened species such as turtles, cetaceans, sygnathids (seahorses and sea dragons), sharks, seals and seabirds.

Why does bycatch occur?

Bycatch occurs primarily because the fishing gears and/or techniques are "non-selective", ie they are not designed to catch only the target species. It also occurs due to spatial and temporal considerations. For example, you would avoid trawling in areas known to be turtle feeding areas. When to fish is also important, various fisheries now operate only at night to avoid interactions with seabirds.

Impacts of Bycatch

The repercussions of bycatch can be far-reaching. Future commercial stocks are depleted when juveniles are caught and removed from the future breeding population. Bycatch can promote ecological imbalance by upsetting the dynamics of the food chain and there is the obvious consequence of the injury, pain and suffering experienced by the individuals.

Populations of protected species are reduced. This is due to the loss of individuals, plus the reduced breeding potential which threatens the success of future generations.

SeaNet – who we are

SeaNet is a fisheries extension service to the Australian seafood industry. We are funded by the Federal Government through the National Heritage Trust and have been in operation since 1999. SeaNet is currently active across most of Australia including Queensland, New South Wales, Victoria, South Australia and Western Australia, and has an officer working specifically with the Eastern Tuna and Billfish Fishery (ETBF).

SeaNet – what we do

The fundamental role of SeaNet is to enhance the sustainability of commercial fisheries nationwide. We achieve this by working with industry to trial improved fishing gears and technologies. This includes best practice methods covering where, when and how to fish more sustainably. We also trial bycatch deterrents and gears which improve bycatch separation, increasing the live release of bycatch species.

Effective communication is imperative to implementing change. SeaNet facilitates communication between the three major stakeholder groups in the seafood industry - research, fishers and management. With the development of good communication and effective bycatch mitigation methods, SeaNet extends these results between different fisheries and within the same fishery at different locations around the country.

Practical examples of bycatch mitigation

Pingers

A pinger is a simple, cost-effective device designed to reduce the bycatch of marine mammals in fishing nets (see Figure 1). Pingers emit pulses of sound within the auditory range of marine mammals, alerting them to the presence of the pinger and the net to which they are attached. Trials in the European Union have proved highly successful with reductions in marine mammal bycatch recorded at 93, 92 and 85%. Similarly a 95% reduction was observed in the Californian offshore gillnet fishery.

Trials of pingers in Queensland concluded in 2003 and pingers are now being used on a voluntary basis by industry. They are also used on the protective shark nets in bathing areas along the coast of New South Wales and Queensland.

Discard Chutes

Discard chutes were designed to improve the rate of post release survival of bycatch. Often bycatch when released alive, is preyed upon by seabirds. This commonly occurs when the bycatch is released at the surface and/or when injured, stressed or disorientated.

Two types of discard chute have been designed, the simple and the cod-end (see Figure 2). The simple version is attached to the side of the boat during fishing and bycatch released into the chute. As the mouth of the chute opens under the surface, the fish return to the sea, out of the reach of scavenging seabirds.

The cod-end chute works in a similar fashion but the bycatch is retained. This allows the fish to be released at a later time when bird activity has ceased, or in a different bird-free location. These discard chutes have proven so successful in reducing bycatch they are now required by law from one hour prior to sunrise to one hour after sunset in the New South Wales Estuary General Fishery.

Seabirds and long-lining

The tuna industry is highly valuable to the Australian economy, with a single bluefin tuna selling for up to A$260,000 on the export market. Long-lining is the primary method used in the tuna industry and the associated death of seabirds has received significant public attention in recent years. Long-lining incorporates tens of kilometres of line which can bear up to 1200 baited hooks per set. The hooks are deployed at the surface, the seabirds are attracted by the bait, become hooked and drown as the gear is deployed under the surface.

The bycatch of Albatross is of particular concern as they are long-lived, to 80-plus years and have a very low reproductive rate. As a result, 16 of the 21 species are now considered threatened worldwide.

In an effort to reduce the toll on Albatross and other seabirds, SeaNet is currently trialling an underwater bait-setting chute (see Figure 3) with fishers in the Eastern Tuna and Billfish Fishery. The chute deploys the baited hooks below the water surface, thereby preventing seabirds from taking the bait.

Trialling these devices was an industry initiative, proving that commercial fishers are pro-active in improving sustainability. The potential of this device to minimise the decline of already dwindling seabird populations is recognised and supported by WWF, Greenpeace and the Humane Society.

De-hookers and line-cutters

De-hookers and line-cutters facilitate the quick and efficient release of hooked and/or entangled bycatch, thereby increasing their chances of post-release survival. Veterinarians confirm that the most important aspect of survival for some species is removal of the hook and at the very least, cutting the trailing line as short as possible.

A de-hooking device is a tool used to remove hooks from animals hooked in the mouth and throat, gullet or externally. The beauty of the de-hooker is in its ability to remove the hook without further damage to the animal. As the hook is being removed, the point is protected by the offset bend and cannot re-engage (see Figure 4). The device allows much faster and easier removal of previously inaccessible hooks: the sooner the hook is removed, the greater the chance of survival. Post-release survival is maximised as infections leading from rusting hooks are eliminated, stress is minimised and the dangers of trailing fishing line are avoided.

A line-cutter is a device for safely and effectively cutting line from entangled animals that are too large to be brought on board, for example rays, sharks, dugongs and turtles. The “V” shaped cutting blade prevents injury to both the animal and operator and the extendable pole ensures access to the animal, irrespective of the freeboard height of the vessel (see Figure 5).

Sets of de-hookers and line-cutters have been trialled successfully in the Eastern Tuna and Billfish Fishery and have since been expanded to the Western Tuna and Billfish Fishery in Western Australia.

Public perception of the industry

Despite the love affair most Australians have with fresh seafood, the general attitude towards the fishers who provide us with those “prawns on the barbie” is commonly one of disdain; the term “rapers and pillagers” of the sea is often used synonymously with the industry.

However, this perception is largely false: fishers, in fact, do respect the resource that provides them with their livelihood, and the animals with which they interact. Industry is on our side! Fishers regularly donate their time, vessels, gears and local knowledge to assist SeaNet Officers improve fishing practices. They voluntarily take part in trials of bycatch reduction devices, self-govern through voluntary closures and report on environmental problems such as fish kills, pollution and marine pests.

Commercial fishers are the stewards of the sea and without their valuable knowledge and experience, a sustainable industry would be a distant ideal.

Figure 1 A Cairns (Lien) pinger

Figure 2 The simple (left) and cod-end (right) versions of the underwater discard chute

Figure 3 The underwater bait setting chute is helping to reduce the toll on seabirds in the tuna fishery

Figure 4 The head of a de-hooker (note how the barb is protected by the offset bend

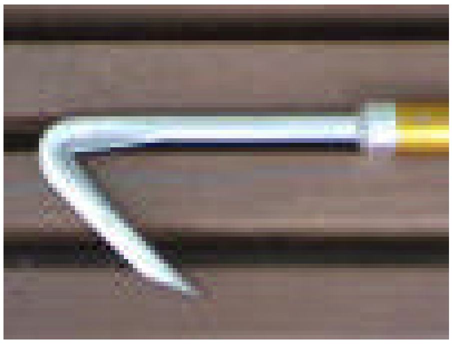

Figure 5 The head of a line-cutter (note how the blade is protected in the “V”)