IMPACT OF AQUACULTURE

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1 OVERVIEW OF IMPACTS

Aquaculture in the South-east Marine Region is comprised of finfish and shellfish farming. Presently, no other species are farmed in the sea. The intensity and type of environmental impacts of aquaculture are dependant upon the species farmed, the intensity of production and on the farm location. Impacts of aquaculture are an increasingly important issue as aquaculture operations in the South-east Marine Region continue to expand.

Finfish and shellfish aquaculture impact on the environment in different ways. Finfish culture is usually an intensive industry that involves an addition of solids and nutrients to the marine environment, and is recognised as potentially causing environmental degradation through these inputs. A build up of organic material beneath fish farms can impact on the flora and fauna of an area, in some cases causing major changes to sediment chemistry and in turn affecting the overlying water column. Additional impacts may occur as a result of other farm discharges and waste products, for example from shore based stun and bleed operations. The escaping of exotic species, transmission and control of disease, and control of predatory species are also areas of concern in this type of aquaculture.

In contrast, shellfish farming usually results in a net removal of nutrients from the water column, and is generally considered to cause less environmental damage. Nevertheless, shellfish production can cause a build up of organic material on the seabed below as a result of particulate fallout from the shellfish or from the altered hydrodynamics around the farm. Additionally, a net removal of nutrients from the water column may have either positive or negative repercussions for the natural system. Positive impacts are apparent in nutrient enriched areas, while negative impacts can occur if the shellfish compete with other organisms for survival (eg. seagrass). Other potential negative impacts from shellfish farming include physical impacts associated with farming structures and farm operations, reductions in native stocks caused by the collection of result wild seed (eg. mussel culture) and impacts associated with the introduction of exotic species.

2 AQUACULTURE LOCATIONS

Impacts on the natural marine system can potentially occur in any of the areas in which aquaculture activities occur in the South-east Marine Region. Locations presently utilised for aquaculture in this region are patchy and widely separated. Current management techniques require reasonably sheltered, shallow waters such as bays and estuaries with good nutrient supply and moderate to high current flows. However, this industry is developing and expanding into new types of environments as techniques are developed and market demands increase.

A number of different species are currently farmed in each of the states included in the South-east Marine Region. In southern New South Wales, oysters (*Crassostrea gigas* and *Saccostrea glomerata)* are farmed in Tuross Lake, Wagonga Inlet, Bermagui river, Wapengo lake, Nelson Lagoon, Merimbula Lake, Pambula River, and Wonboyn River. The Blue mussel (*Mytilus edulis)* are cultured in Twofold Bay at Eden (N. Brown, NSW Fisheries, pers. comm.).

In Victoria the abalone industry is the fastest growing aquaculture industry sector (DNRE, 2000), with farms of *Haliotis laevigata* and *H. rubra* located predominantly in and around Port Phillip and Westernport Bays. Blue mussels are also farmed extensively in these bays using long-line culture methods (DNRE, 2000). There is currently no offshore finfish culture in Victoria, with new aquaculture areas designated but not yet approved (F. Gavine, DNRE Victoria, pers. comm.).

In South Australia farmed species include abalone *(Haliotis laevigata* and *H. rubra*), oysters (*Crassostrea gigas* and *Ostrea angasi),* Atlantic salmon (*Salmo salar*), and Southern bluefin tuna (*Thunnus maccoyii*). Tuna farming currently only occurs in the vicinity of Port Lincoln on the Eyre Peninsula and is therefore located outside the geographical boundaries of the South-east Marine Region. Atlantic salmon are farmed at Lacepede Bay and Rivoli Bay in the far south east of the state (Steven Clarke, PISA, pers. comm.), while abalone and oyster farming occur around Kangaroo Island, and oyster farming around the Gulf of St Vincent (FFI, 2000).

Species commercially farmed in Tasmania include abalone, scallops, mussels, oysters, rock lobsters, seahorses, trout and salmon (DPIWE, 2001), although culture of lobsters and seahorses is limited to land-based operations. Atlantic salmon and rainbow trout (*Oncorrhynchus mykiss*) are farmed predominantly in the south east of the state, and in Macquarie Harbour on the west coast, although a farm has also recently been established in the Tamar Estuary in the north. Shellfish species cultured on a commercial scale in Tasmania include the pacific oyster and the blue mussel (Crawford, 2001). Other shellfish species farmed in smaller quantities include the commercial scallop (*Pecten fumatus)* and the native flat oyster (*Ostrea angasi*) and, on a pilot commercial scale, the abalone species *Haliotis rubra* and *Halitus laevigata*.

3 SHELLFISH CULTURE

Commercial farming of shellfish is an important rural industry in the South-east Marine Region. The principal species grown include the oysters *Crassostrea gigas*, *Ostrea angasi* and *Saccostrea glomerata*, the native blue mussel *Mytilus edulis,* and both greenlip (*Haliotis laevigata*) and blacklip (*H. rubra*) abalone. A number of other species are farmed in the region, though presently at a much smaller scale, for example the scallop *Pecten fumatus*.

Shellfish farming is considered to have less environmental impact than finfish farming, although, because of the large area of coastline occupied by these farms, the potential for disturbance has increased (De Grave *et al*., 1998). Shellfish culture is generally concentrated in estuaries and coastal embayments where waters are sheltered and readily accessible, although farming has recently expanded into more exposed areas as suitable estuarine locations become limited (Crawford, 2001). Past research has provided mixed reports on the effects of shellfish farming on the marine environment, ranging from significant impacts to minimal effects (Crawford, 2001a).

Shellfish production levels in Australia are low compared with most areas overseas (Crawford, 2001; Gavine and McKinnon, 2001), with the associated environmental concerns therefore usually also relatively low (Gavine & McKinnon, 2001). Notably, the more damaging techniques, such as cultivation directly on the seabed and harvesting by dredging, generally do not occur in the South-east Marine Region.

3.1.1 Accumulation of Waste

Shellfish produce solid waste, consisting of faeces and pseudofaeces (DPIF, 1997). This particulate matter consists of organic and inorganic material and usually settles near a shellfish farm in higher concentrations than would occur naturally (Crawford, 2001). Shellfish farming can therefore result in the build-up of matter below the holding containers on racks or longlines (DPIF, 1996), with impacts on sediment quality predominantly arising from deposition of these solid wastes. The extent of the impact depends on the nature of the waste and the extent of the accumulation, which in turn is influenced by the location of the farm and farm management practices.

In an organically enriched environment in which accumulation of wastes exceeds the rate at which the biodeposits are broken down, impacts can occur. These impacts include the smothering of light-dependant plants (eg seagrasses) and impacts associated with increased activity of benthic fauna and microorganisms that consume the excess organic matter. This increased activity of microorganisms can lead to a depleted oxygen supply in both the sediment pore water and, in extreme cases, in bottom water (Crawford, 2001). This in turn can lead to changes in benthic flora and fauna and sediment nutrient fluxes, especially levels of carbon, nitrogen, oxygen and sulphur.

Most studies examining organic enrichment of the seabed from shellfish farming have concluded that the effect is generally small (Crawford, 2001). For example, the results obtained from three different farms in Tasmania, which have had relatively high levels of production over a number of years, indicated that shellfish farming is having minimal effect on the benthic environment (Crawford *et al*., 2001). This research supported overseas research in suggesting that the main effect of shellfish farms on the seabed is from the accumulation of waste shells and attached algae, rather than from the deposition of faeces and pseudofaeces (Crawford *et al*, 2001a; Grant *et al*, 1995)

3.1.2 Nutrients

Shellfish are predominantly farmed using techniques that rely on a net removal of nutrients from the water column. They consume detritus and phytoplankton and can thus have an impact on their abundance and composition in the water. This form of aquaculture can therefore potentially result in reduced phytoplankton concentrations, a net loss of nitrogen from the system, and a decrease in suspended matter. This result is viewed as a potentially positive effect in degraded estuaries, removing excess nutrients from the system. However, in areas relatively unaffected by human activities, it may result in a reduction of nutrients that are essential to the functioning of the ecosystem (Crawford, 2001).

3.1.3 Impacts associated with farming structures

Shellfish farming structures such as intertidal racks, trestles or longlines may alter the hydrodynamics of an area (Kaiser *et al.,* 1998), though such changes have been rarely documented (Crawford, 2001). Anecdotal evidence suggests that the effects of racking on hydrodynamics can be seen in some culture areas in Tasmania, with organic buildup evident underneath farm structures in areas of high current flow. Additionally, Thorne (1998) proposed that sediment accretion around racks at Pipeclay Lagoon in south-eastern Tasmania may be due to hydrodynamic modifications. Sediment accretion and compaction may also result from heavy machinery use in shellfish growing areas (Crawford, 2001). De Graves *et al.* (1998) concluded that the compaction and dispersal of sediments by heavy vehicle traffic may affect the composition and abundance of benthic species.

In addition, shading by the shellfish , farm infrastructure, and farm activities such as boat and vehicular traffic may have a detrimental impact on seagrass beds. The extent of this impact will depend on the species affected. For example, Thorne (1998) observed a reduction in seagrass cover (presumably *Heterozostera tasmanica*) under stocked oyster racks in Tasmania. He also noted that the seagrass appeared to recover in areas left unstocked for any length of time. This species is known to be capable of rapid regeneration (Crawford, 2001), however the potential for permanent loss is much higher for other species more sensitive to disturbance (eg. *Posidonia*).

3.1.4 Seedstock

Where seedstock is sourced from the wild there is potential for collection to have an impact on native stocks. This is not generally considered a cause for concern in the

South-east Marine Region. Hatchery produced spat is the preferred means of collection, and where seed is sourced from the wild, such as for mussel culture, the impacts are considered low due to the scale of the collection (Gavine & McKinnon, 2001, Christine Crawford, TAFI, pers. comm.).

3.1.5 Genetic integrity of wild stock and the introduction/translocation of pest species

The introduction and translocation of commercial shellfish species potentially poses a number of risks. These risks are outlined by the National Policy for the Translocation of Live Aquatic organisms (AFFA, 1999) and include environmental and ecological issues. Environmental issues include the potential for genetic shifts in wild populations, establishment of feral populations and impacts associated with the unintentional translocation of associated species.

As hatchery production of seed increases, the potential to alter the genetic characteristics of wild stocks will increase (Crawford, 2001). Translocated species may breed with other distinct populations of the same species, possibly resulting in a genetic shift in the local population, and a loss of genetic diversity. Similarly, hybridisation may occur between endemic species and translocated species where the species are genetically compatible.

The accidental introduction of exotic pathogens and subsequent infection of existing native species also poses a threat to the marine environment. These exotic pathogens may be introduced with the commercial species itself, or alternatively, shellfish culture may facilitate the transfer of endemic pathogens to new areas. The problems associated with the establishment of feral populations are described in Chapter 1.

3.1.6 Chemical usage

Chemical usage on shellfish farms is minimal (Crawford, 2001). Chromium, copper and arsenic treated pine is frequently used for intertidal racking, however the treatment process prevents the accumulation of these heavy metals in the environment (Crawford, 2001).

4 FINFISH CULTURE

The Australian salmonid industry dominates commercial production in the marine environment in southern Australia. Species farmed include Atlantic salmon and rainbow trout. Farming of salmonids is conducted predominantly in southern Tasmania and in Macquarie Harbour on Tasmania's west coast, although it is now being attempted in South Australia (NPI, 2001), and will soon be trialed in Victoria (Gavine & McKinnon, 2001 draft). Salmonids are produced in a semi-open system in which the fish are contained in a relatively uncontrolled environment, with control of water movement in and around the system virtually impossible (NPI, 2001).

In addition to the salmonids, a range of native fish are being cultured in southern Australia (NPI, 2001), for example yellowtail kingfish (*Seriola lalandi*) and snapper (*Pagrus auratus*), athough production is presently on a pilot scale. In Tasmania, a recent addition to the aquaculture industry is the farming of the fat bellied seahorse *Hippocampus abdominalis* (NPI, 2001). The seahorses are grown in tanks at a land-base facility in northern Tasmania, the discharge water considered unlikely to exceed national standards (NPI, 2001).

Impacts on the environment from marine finfish aquaculture are related to farm management practices, and are a result of on-farm feeding and fish husbandry practices and aspects of farm design. The extent and nature of the impacts vary with intensity of production, farm infrastructure and site location. The repercussions for the marine system depend on the capacity of the local environment to disperse or otherwise assimilate the wastes and to withstand changes caused by aquaculture infrastructure and operations.

4.1.1 Nutrient discharge and Accumulation of waste

Salmon farming operations result in the release of a number of wastes into the aquatic environment. These include uneaten fish food, fish excretory products and organic matter from net-cleaning that enter the water column and/or settle to the seabed. The major components of solid and dissolved waste are various forms of carbon, nitrogen and phosphorous (EAO, 1998; Ritz & Lewis, 1989). The effects on the food chain from this additional organic input are many and varied, the input leading to water column nutrient enrichment and accumulation of organic matter in the sediments.

In the water column, soluble nutrients can alter the species composition and density of phytoplankton, increasing the risk of toxic algal blooms (DPIF, 1997). The accumulation of organic matter on the seabed, especially in areas of poor current flow, can produce major changes in the sediment chemistry. Changes typically associated with severe organic enrichment are a reduction in sediment oxygen levels and the subsequent production and release of methane and toxic hydrogen sulphide (Pearson and Rosenberg, 1978). Changes in sediment chemistry in turn have effects on the substrate ecosystem, and may result in major changes to the species composition of sediment flora and fauna in affected areas (e.g. Ritz *et al*., 1989). Notably though, research has shown that these impacts are usually limited to a small area within close proximity to the cages (Brown *et al*, 1987; Gowen *et al*, 1988).

4.1.2 Farm structure and operations

A number of impacts may occur as a result of the physical farm infrastructure and operations. For example, the construction of wharf facilities and fish cage infrastructure. Benthic communities may be altered through habitat modification and disturbance such as through the effects of increased turbidity, shading and sedimentation. Possible behavioural responses of fauna may also result from disturbances in and around the farm, for example from the increased boating activity.

4.1.3 Disease and use of Chemotherapeutants

Outbreak of disease is more common in farming operations than the wild as a result of higher levels of stress in fish, high stocking densities and establishment of conditions conducive to incubation of disease organisms. Aquaculture provides opportunity for amplification of disease, though notably it also facilitates early detection of outbreaks due to frequency of testing to protect valuable fish stocks. Additionally, increased food resources near farm cages attract large concentrations of escaped and wild fishes, which may act as vectors for the transfer of disease and parasites to other native fish (Carss, 1990).

The use of chemotherapeutants, such as antibiotics, is a concern because residuals not absorbed by the fish can potentially enter the environment in uneaten feed and faeces. Information regarding the environmental effects of this is limited (NPI, 2001), and accumulation adjacent to farms is a concern (EAO, 1998). In Tasmania in recent years antibiotics have been used irregularly in very small quantities and not at all on some farms (DPIF, 1997). This is because virtually none of the major salmonid diseases occur in Tasmania (DPIF, 1997).

There is currently an insufficient understanding of the impacts of chemotherapeutant compounds used in aquaculture (Kevin Ellard, DPIWE, per comm.), and growing concerns over potential environmental effects necessitates careful selection of compounds used (NPI, 2001).

4.1.4 Other Chemicals

Chemicals are used in finfish aquaculture for a wide range of applications. Not only are they used in fish health, but also to control nuisance organisms on equipment such as nets, and to disinfect and improve water quality (NPI, 2001). The use of such chemicals raises a number of environmental concerns, and they must be registered with the National Registration Authority before use (NPI, 2001).

Antifoulants are an important part of the maintenance of nets and cages in marine farms (EAO, 1998), and are currently being used in the South-east Marine Region. Clean nets allow the unimpeded flow of water and oxygen through the net-cage, and the flushing of excreted and other waste material. Use of copper-based antifoulants is currently the standard global practice (Dr S. Hodson, Wattyl Aquaculture, pers. comm.), and while copper is an essential trace element in fish metabolism, extensive use for antifouling raises some concern that environmental levels will increase, with resultant damage to natural or farmed organisms (Lewis & Metaxas, 1991). However, research has suggested that in areas of adequate current flow, accumulation of copper is unlikely to occur either in adjacent waters (Lewis and Metaxas, 1991) or in fish tissues (Peterson *et al*., 1991).

4.1.5 Other wastes

Several categories of smaller scale outputs include fish bleeding operations, dead fish and offal disposal (see section 4.1.8) and marine debris. The current methods of harvesting and processing of farmed fish occasionally result in bloodwater being released back into the marine environment (NPI, 2001). There are some concerns that bloodwater dispelled at some farm sites may lead to a decrease in water quality (NPI, 2001).

Anecdotal evidence suggests that significant amounts of marine debris in estuarine and coastal environments is attributable to the aquaculture industry. Marine debris is a known hazard to marine fauna, and may result in impacts through entanglement or ingestion. This can lead to fatal injuries and health problems for marine creatures such as penguins and seals.

4.1.6 Escaping of Exotic Species

The establishment of farmed Atlantic salmon escapees in the natural environment is generally considered unlikely, since conditions in the South-east Marine Region are not highly compatible with those in the endemic range of this species.. Numerous attempted introductions overseas have failed in the establishment of self-sustaining populations, escapees having few skills for survival in the wild (EAO, 1998). Reproductive colonisation by Atlantic salmon outside their endemic range is considered improbable, but not impossible (EAO, 1998). Concerns with escaping species include predation on native fish, competition for resources and transmission of disease (EAO, 1998).

4.1.7 Sourcing Stock

The sourcing of stock from the wild for aquaculture has the potential to impact on wild populations. This is not however an issue for the Salmonid industry in the South-east Marine Region, where fry are hatched in freshwater facilities using brood stock maintained by the aquaculture industry (NPI, 2001). The native fish aquaculture industry has minimal impact in this regard due to its small size and experimental status.

4.1.8 Impact on cetaceans, seals and birds

The interaction between intensive salmon aquaculture and aquatic mammals and birds is based primarily on the presence of concentrated amounts of fish and fish feed, which represents a food source for these animals.

Seals cause major problems for fish-farm operators in the South-east Marine Region (Pemberton and Shaughnessy, 1993). Recent management of this problem has involved non-lethal measures such as the use of predator nets and the physical relocation of problem seals. The effect of this non-lethal interaction on seals is however a cause for concern, and investigations into the impacts are currently under way (Rosemary Gales, DPIWE, Pers. Comm.). In addition, entanglement and subsequent death of seals and cetaceans in fish farm nets has been identified as a problem, although again little information is currently available. Non-lethal impacts on other marine mammals may also be occurring (Rosemary Gales, DPIWE, Pers. Comm.).

The finfish aquaculture industry is also known to impact on predatory bird species in a number of ways. Death by entanglement in the salmon cage nets, designed to keep such predators out, is a concern. For example, anti-predator nets caused the death of three white-bellied sea eagles in August and September 2000 in Tasmania (Jason Wiersma. Pers comm). In addition, failure to adequately cover land pits used for dead fish and offal disposal is a concern for some sea birds. Birds feeding in these uncovered pits can become covered with oil, which is known to have serious ill effects on the birds (Nick Mooney, DPIWE, pers. comm.).

Additionally, it is possible for pathogens to be transmitted via the faeces of birds (eg see Willumsen, B., 1989), and for birds to act as intermediate hosts to parasites (EAO, 1998). There is also some question as to whether diseases can be transferred from farmed fish to birds and vice versa (EAO, 1998).

Table 1 Impacts of aquaculture on marine biota in the South-east Marine Region.

Source of Impact	Biota impacted	Nature of Impact
Shellfish Culture		
Deposition/ accumulation of organic matter	Benthic invertebrates	Potential loss or reduced diversity through smothering of benthic habitats and through oxygen depletion and hydrogen sulphide production during bacterial de-composition of organic matter; community domination by a small number of pollution indicator species, such as capetellid worms and other scavengers and deposit feeding species.
	Fish and sea birds	Avoidance/attraction responses to additional/altered food source, with associated changes to population distribution, species composition and abundance.
	Seagrass and attached algae	Loss or reduction in cover through the deposition of organic matter and the associated effects of light reduction and physical smothering.
Inorganic deposition	Benthic flora and fauna	Alteration of physical structure of the sediment and the effects of smothering.
Altered water column nutrient and suspended solid concentrations	Phytoplankton	Altered species composition and abundance.
	Seagrass and filter feeding organims	Reduction in cover/growth through increased competition for essential growth nutrients.
	Fish and higher trophic level organisms	Reduced food supply/habitat loss.
Farm structures and the use of heavy machinery and boats	Benthic invertebrates	Altered communities through habitat modification, compaction of sediments, and smothering near structures that act as accumulation points for wrack and sediments.
	Seagrass and attached algae	Removal of seagrass beds and habitat; reduction in beds caused by altered flows and habitats; impacts through shading effects of structures and machinery; effects of compaction from heavy machinery; and increased turbidity from farm boats.
Sourcing of seedstock from wild	Native stocks of taget species eg. The native	Reduced stocks of shellfish spat in their natural habitat, leading

Source of Impact	Biota impacted	Nature of Impact
	blue mussel	to a decrease in abundance.
Introduction of non endemic species and exotic pathogens	See Chaper 1	See Chapter 1
Translocation of exotic pathogens	Flora and fauna	Potential reduction in species abundance and diversity resulting from intolerance of endemic species to exotic pathogens.
Chemicals	All biota	Potential bio-accumulation of contaminants, particularly for filter feeding organisms eg. Shellfish.
Marine Debris	Benthic fauna and flora	Local smothering and loss of benthic habitat.
	Fish, sea birds, cetaceans and seals	Mortality or impacts on health through ingestion of, or entanglement in, debris.
Finfish Culture		
Organic depostion – eg. Faeces and excess fish food	See effects of organic depostion – shellfish culture (above).	Smothering and light reduction, altered sediment chemistry including oxygen depletion and production of toxic gases; similar, but more severe, impacts to those described above for shellfish culture.
Nutrient discharge	Shellfish	Potential contamination with microalgal biotoxins during bloom events caused by increased nutrient levels.
	Seagrass	Loss or reduced coverage due to growth of epiphytic algae and phytoplankton blooms.
	Algae	Smothering through growth of nuisance algae, resulting in reduced diversity and loss of some native species; altered species composition and abundance of microalgae due to blooms.
	Fish and seabirds	Avoidance and attraction responses, a result of modified food sources, leading to altered population distribution.
Antibiotics	All biota	Antibiotic resistance in sediment bacteria and non target organisms.
Disease	All biota	Spead of disease, potential loss of diversity and abundance.
Chemicals	Shellfish	Bio-accumulation and possible mortality through toxic effects.
	Benthic invertebrates	Lethal and sub-lethal effects resulting in alterations to species diversity and composition.
	Fish	Bio-accumulation, avoidance responses and changes in distribution patterns.

Source of Impact	**Biota impacted**	**Nature of Impact**
	Sea birds and marine mammals	Bio-accumulation in tissues.
Introduction of exotic species	See Chapter 1	See Chapter 1
Marine Debris	Fish, sea birds, cetaceans and seals	Impact of debris through ingestion or entanglement.
Predator control	Fish, sea-birds and cetaceans	Entanglement, resulting in injury and potentially death.
	Seals	Entanglement and injury or death, and behavioural changes resulting from non-lethal methods of predator control.
Disposal of dead fish to landfill	Sea birds	Oiling of feathers and ingestion of oil, leading to poor health or death.
Farm infrastructure and machinery	Benthic invertebrates	Altered communities through habitat modification and disturbance.
	Seagrass and attached algae	Physical disturbance of sediment and shading effects of structures.
	Fish, sea-birds, cetaceans and seals	Possible behavioural responses to farm disturbance resulting in altered distributions.

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