Return to previous file: musselfarms03.pdf

3. Legislative framework for aquaculture

3.1 EXISTING AQUACULTURE LEGISLATION

Marine aquaculture ventures (i.e. marine farms including mussel farms) established between 1971 and 1991 were licensed under the Marine Farming Act 1971. Renewals and amendments to these licences are still considered under this act. Since 1991, proposals to establish marine farms have been considered under the Resource Management Act 1991 (RMA). Under the existing provisions of the RMA, regional councils both develop coastal plans that set controls for the establishment of marine farms, and assess applications for resource consents for marine farms. When preparing coastal plans and considering resource consents, regional councils must assess the actual or potential effects of marine farming on the environment. Among the effects to be considered are "any effect on ecosystems, including effects on plants or animals and any physical disturbances of habitat in the vicinity" (Schedule 4, RMA). Where marine farming is a restricted coastal activity (e.g. covers a large area, usually > 50 ha, or introduces exotic species into an area) the Minister of Conservation makes the final decision on resource consents. Marine farms also require a marine farming permit under the Fisheries Act 1996, which requires consideration of the farm's effect on wild fisheries (Fisheries 2002).

3.2 AQUACULTURE LAW REFORM

Rapid expansion of the marine aquaculture industry, particularly mussel farming, led to a moratorium on consideration of further aquaculture proposals pending aquaculture law reform. The moratorium, which is administered under the Resource Management (Aquaculture Moratorium) Amendment 2002, was to expire on 28 March 2004 but has been extended until December 2004. By this time, the government plans to have reformed aquaculture provisions of the various acts. Proposals for mussel farms notified before November 2001 are being considered under current legislation.

The central tenet of proposed aquaculture law reform is that Aquaculture Management Areas (AMAs) will be defined in Regional Coastal Plans drafted by regional councils. Regional councils will lead identification of AMAs, with Ministry of Fisheries, Ministry for the Environment, Maritime Safety Authority and Department of Conservation (DOC) providing assistance. DOC's role in the identification of AMAs includes providing information on and advocating for conservation values. Although legislation (e.g. Conservation Act, Fisheries Act, and RMA) has diffused responsibilities for some conservation values (e.g. maintenance of marine biodiversity and marine ecosystems, and protection of areas of special cultural interest) among several agencies, DOC alone has statutory responsibilities for protected species, as defined under the Wildlife Act 1953 and the Marine Mammals Protection Act 1978. Thus, DOC has a special and unique responsibility to advocate for protected species during the AMA identification process.

Implementation of aquaculture reforms involves a multi-agency group comprising Ministry of Fisheries, Ministry for the Environment, and DOC. An Aquaculture Reform RMA Implementation Plan has been prepared, in which lack of information has been identified as a major barrier to identification of AMAs. Proposals to rectify this lack of information are: stocktaking and transfer of existing information, identification of information gaps, and the development of "longer-term" research programmes to fill information gaps.

3.3 PROPOSED AQUACULTURE MANAGEMENT AREAS

Progress towards aquaculture reforms varies regionally. An overview of progress by different councils can be viewed on the Ministry for the Environment's website at:
http://www.mfe.govt.nz/issues/resource/aquaculture/implementation/council-activity.html

Further details for individual councils may be found on their websites.

4. Environmental effects of mussel farming

In this report, only those effects of green-lipped mussel cultivation that may reasonably be expected to affect protected species are considered. Environmental effects on other aspects of marine biodiversity and socio-economic effects (Burbridge et al. 2001), such as displacement of other stakeholders (e.g. fishers), changes in natural character and amenity values, and impediment to navigation, are not considered.

There is a considerable body of research on the environmental effects of mussel farming within and outside New Zealand, reviewed in detail elsewhere (Morrisey & Swales 1997; Kaiser et al. 1998; Inglis et al. 2000; Sinner 2000; Cole 2001; Kaiser 2001; Broekhuizen et al. 2002). Environmental effects may arise from mussel feeding habits, farm structures or activities associated with mussel cultivation. Documented environmental effects include: phytoplankton depletion, modifying the benthic environment and species assemblages, altering local hydrodynamics, increasing marine litter, and facilitating the spread of unwanted organisms. The severity and extent of environmental effects is influenced by many factors including size and age of the farm, stocking densities, water depth and flow regimes, season and climatic conditions.

4.1 EFFECTS ON PLANKTON COMMUNITIES—PHYTOPLANKTON DEPLETION

Green-lipped mussels feed on phytoplankton filtered from the water column. The large concentrations of mussels found in mussel farms can extract a significant proportion of phytoplankton, causing phytoplankton depletion (Waite 1989; Grange & Cole 1997; Inglis et al. 2000; Ogilvie et al. 2000; Cole 2001; Broekhuizen et al. 2002). The magnitude and extent of depletion is poorly understood, but probably vary depending on numerous factors such as farm size, crop density, water depth, currents and season. Phytoplankton can be reduced by up to 60% within farm boundaries (Waite 1989), and a 50 ha farm may consume >20% of phytoplankton passing through it (Broekhuizen et al. 2002). The phytoplankton depletion halos are usually limited to within 80 m of farm (Grange & Cole 1997), but may extend further in some instances (Cole 2001). High current velocities will increase the spatial extent of the halo, but also reduce the degree of depletion (Broekhuizen et al. 2002). There may be reduction in zooplankton levels, either as an indirect consequence of depletion of the phytoplankton on which it depends, or because some zooplankton are filtered from the water by the mussels and ejected as pseudofaeces (Cole 2001).

More complex ecosystem effects have been postulated for extensive areas of mussel cultivation (Inglis et al. 2000; Broekhuizen et al. 2002). Changes in plankton community composition, caused by the reduction in phyto-planktivores and selection of fast growing planktonic species, may affect primary productivity. High concentrations of mussel larvae during spawning periods may also affect plankton community composition as the mussel larvae enhance food supply for some planktivores, but compete with other plankton (Broekhuizen et al. 2002)

4.2 EFFECTS ON THE BENTHIC ENVIRONMENT

Mussel farms modify the benthic environment on the seabed below them in a number of ways. Deposits of live mussels, broken shells, and other farm debris build up below the growing lines (Fig. 7) and, in the absence of strong currents, these deposits increase sedimentation rates by reducing water flow across the seabed. The rain of faeces and pseudofaeces from the mussel crop leads to organic enrichment of the sediments below mussel farms (Kaspar et al. 1985; Gillespie 1989; De Jong 1994; Forrest 1994; Cole & Grange 1996; Inglis et al. 2000; Bolton-Ritchie 2001; Broekhuizen et al. 2002; Grange 2002). This nutrient enhancement may promote algal and phytoplankton growth rates within farms (Tenore et al 1982; Gibbs et al. 1992; Ogilvie et al. 2000). In farms where there is little water flow, organic enrichment of the benthos creates anaerobic and acidic conditions which result in elevated levels of sulphides and ammonium (Dahlbäck & Gunnarsson 1981; Kaspar & Boyer 1985; Kaspar et al. 1985; Tenore et al. 1985; De Jong 1994; Grant et al. 1995). Benthic effects are normally restricted to swathes of seabed directly below growing lines and less than 30 m wide. The extent and intensity of the effects vary seasonally with phytoplankton

Figure 7. Large seastars (*Coscinasterias calamaria*) feeding among debris on the seabed below mussel growing lines. (Photo: Roger Grace).

abundance, and are also affected by other factors such as farm age and size, stocking density and the hydrodynamic environment of the farm (Kaiser et al. 1998; Stenton-Dozey et al. 1999; Cole 2001; Grange 2002). Residual effects may be detectable up to 3 years after a mussel farm has been removed (Stenton-Dozey et al. 1999).

4.3 CHANGES IN SPECIES ASSEMBLAGES

Environmental changes associated with mussel farming (i.e. phytoplankton depletion, organic enrichment, and changed habitat heterogeneity) affect the composition of species assemblages in the water column as well as on, and in, the seabed around mussel farms. Generally, there is a shift in the food webs away from predominantly suspension-feeding organisms to deposit-feeding faunas (Grant et al. 1995; Inglis et al. 2000). Organic enrichment of the sediments beneath mussel farms and resulting anoxic conditions cause declines in the abundance of large, deep-burrowing species of molluscs, echinoderms, crustaceans and polychaetes (e.g. *Lumbrinereis* and *Aglaophamus*) (Inglis et al. 2000). However, organic enrichment, together with the accumulation of debris beneath farms, increases both the food available for scavengers. Where farms are located over seabeds of fine sediment or mud, they do increase habitat heterogeneity. This results in an increase in the abundance of surface-feeding and small, opportunistic species of gastropods, polychaetes, nemerteans and crustaceans on the seabed (Tenore et al. 1985; Grant et al. 1995; Stenton-Dozey et al. 1999; Inglis et al. 2000).

Seabed debris and clumps of live mussels on, and beneath, growing lines are colonised by a variety of organisms: ascidians (including *Ciona intestinalis*), bryozoans (including *Watersipora cucullata*, *Bugula* sp.), sponges, bivalves, calcareous polychaetes, and seaweeds (including *Codium fragile*, *Colpomenia sinuosa*, *Cystophora* spp.) (Kaspar et al. 1985; Davidson 1998; Inglis et al. 2000; Cole 2001). These aggregations provide a reef-like habitat for a variety of mobile fauna including fish, crustaceans, starfish, sea urchins, and other echinoderms (Mattsson & Linden 1983; Tenore et al. 1985; Cole & Grange 1996; Cole 2001). Where mussel farms are located over seabeds of fine sediment or mud, the variety and density of fish and crustaceans is usually greater in mussel farms than in adjacent areas (Carbines 1993; De Jong 1994; Forrest 1994; Grange 2002). Fish species commonly associated with mussel farms include mussel predators such as leatherjackets *Parika scaber*, spotty wrasse *Notolabrus celidotus*, as well as blue cod *Parapercis colias*, and parore *Girella tricuspidata* (in northern New Zealand). The three crabs species *Halicarcinus innominatus*, *Petrolisthes novaezelandiae* and *Notomithrax minor* were particularly abundant beneath mussel farms in the Coromandel. There are high densities of the starfish *Coscinasterias muricata* beneath many mussel farms (Gillespie 1989; De Jong 1994; Cole & Grange 1996).

Exclusion of trawling and dredging by mussel farms also affects the benthic fauna. Sedentary species disadvantaged by trawling and dredging, such as scallops *Pecten novaezelandiae* horse mussels *Atrina zelandica*, bryozoans, brachiopods, sponges, ascidians, and seaweeds, are sometimes more abundant beneath mussel farms than in nearby disturbed areas (Inglis et al. 2000).

It has been suggested that in regions with extensive mussel farms, pre-emptive settlement by mussel spat, as well as the consumption of spat from other invertebrates by farmed mussels, will result in green-lipped mussels displacing other invertebrate species from adjacent coastal waters (Broekhuizen et al. 2002). However, as yet there are no observations to support this postulate.

4.4 REPLICATING HISTORIC NATURAL ECOSYSTEM FUNCTIONS

Extensive natural beds of green-lipped mussels were a normal part of local ecosystems in many of the areas now used for green-lipped mussel cultivation (e.g. Tasman Bay, Marlborough Sounds, and Firth of Thames). Thus in these areas, effects arising from mussel feeding habits such as phytoplankton depletion, modifications to the benthic environment and species assemblages are to some extent replicating historic natural ecosystem functions. It is generally acknowledged that bivalve molluscs, such as mussels, play an important role in the retention of phosphorus and nitrogen in healthy estuarine ecosystems (Kaiser 2001). However, because cultivated mussels are grown in mid-water column, whereas natural beds of mussels were on the seabed, different types of phytoplankton may be filtered from the water column.

4.5 MARINE LITTER FROM MUSSEL FARM STRUCTURES

Although the Mussel Industry Council's Code of Practice (Robb & Davidson 2002) dictates that litter should be placed in bins on board barges, large amounts of litter from mussel farms can be found on the seabed under mussel farms and on nearby shores (Cole 2001). The litter includes rope, growing lines, the ties for securing them to backbones, and whole mussel floats.

4.6 HYDRODYNAMICS

Mussel farm lines and floats reduce wave action and current speeds within farms, but this effect is not well understood (Cole 2001). Current speeds within farms may be 30% of those outside farms (Cole 2001). Shell deposits on the seabed below farms slow the flow across the seabed and increase sedimentation rates (De Jong 1994; Cole & Grange 1996).

4.7 FACILITATING THE SPREAD OF PROBLEM ORGANISMS

Unwanted organisms, such as exotic pest species, harmful algal blooms, parasites and pathogens may be introduced or spread by the transfer of mussel farming equipment and mussel spat among areas (Inglis et al. 2000; Cole 2001; Kaiser 2001). Farms structures and the high density of cultured mussels may also act as reservoirs for the incubation of these or other problem organisms (Beveridge et al. 1994; Fuentes et al. 1995; Inglis et al. 2000). Exotic pest species found on mussel longlines include the ascidian *Ciona intestinalis*, macroalga *Undaria pinnatifida*, and mussels *Mytilus galloprovincialis* (Inglis et al. 2000; Cole 2001). Mussel farming has been implicated in the spread of invasive alien seaweeds such as *Undaria* among areas (Kaiser 2001). In the past, mussel farming activities may have accelerated the spread of harmful algal blooms (Inglis et al. 2000; Cole 2001; Kaiser 2001). Recent controls on the transfer of material between areas, and the development of methods to remove algal cysts from spat, may reduce this risk. It has also been suggested that blooms may be stimulated by increased release of ammonium and other micronutrients from the seabed around mussel farms. Although parasites of shellfish may be transferred in the course of mussel farming (e.g. mudworms and peacrabs), they are unlikely to affect unrelated taxa. The high densities of cultured mussels in mussel farms may facilitate the spread of facultative, or non-specific, pathogens that could spread to wildlife. Pathogens may be bacteria naturally present in the aquatic environment, or be from contamination with faeces (Cole 2001).

4.8 CUMULATIVE EFFECTS OF EXTENSIVE MUSSEL CULTIVATION

Although mussel farms do have adverse effects on their local environment, the industry is generally considered environmentally friendly. Presumably, this is either because the effects of mussel farms are not considered severe, or because although the effects may be severe locally, they are not sufficiently extensive to warrant concern. However, the proposed massive growth in mussel farming warrants re-consideration of the industry's effect on the environment. The cumulative and diffuse effects of large numbers of small farms, and the effects of very large mussel farms of several hundred hectares, have not been investigated and are not known. Inevitably, growth of mussel farming will increase the extent of affected coastal waters, while the cumulative nature of effects arising from extensive mussel cultivation may increase the severity of effects (Inglis et al. 2000; Broekhuizen et al. 2002).

5. Marine mammal and seabird faunas of New Zealand

The marine mammal and seabird faunas of New Zealand are significant components of global biodiversity. New Zealand has a rich and diverse marine mammal fauna. Of the world's 124 extant marine mammal species, 44 (35%) have been recorded in New Zealand waters. This includes 38 of 83 species of cetaceans (whales, dolphins and porpoises), and 6 of 36 species of pinnipeds (seals, walruses, sea lions and fur seals) (Baker 1983; Bryden et al. 1998; Rice 1998). Two species are endemic to New Zealand (i.e. only occur in New Zealand's waters): Hector's dolphin *Cephalorhynchus hectori*, and the New Zealand sea lion *Phocarctos hookeri*. New Zealand's seabird community is the largest and most complex one in the world (Robertson & Bell 1984; Taylor 2000a, 2000b). Of the worlds 349 seabird species, 140 (39%) have been reported within New Zealand waters. Eighty-four species of seabirds breed in New Zealand and 25 of these species are endemic to New Zealand (Heather & Robertson 1996).

5.1 LEGISLATION PROTECTING MARINE MAMMALS AND SEABIRDS IN NEW ZEALAND

All marine mammals and most seabirds within New Zealand's territorial waters are absolutely protected under the Marine Mammals Protection Act 1978 and the Wildlife Act 1953, respectively[1]. The Department of Conservation has statutory responsibility for administering both acts. Although intentional killing or harm to marine mammals and protected seabirds contravene these acts, incidental killing or harm in the course of legitimate activities such as boating, fishing, or aquaculture does not contravene the acts. The Marine Mammal Protection Act (Section 16) stipulates that anyone killing or harming a marine mammal while fishing, which includes aquaculture, must report the incident to a Marine Mammals Officer or Fisheries Officer.

Sections 15 and 298 of the Fisheries Act 1996 provide some regulation over the effects of fishing on protected species, as they allow regulation to remedy or mitigate any adverse effects on protected species, including prohibiting fishing or fishing methods in an area. These powers are usually exercised in consultation with the Minister of Conservation and have been used to limit non-target effects of wild catch fisheries on protected species, but have never been invoked to control the effects of aquaculture. It remains to be seen whether the powers extend to aquaculture. Sections 15 and 186 of the Fisheries Act authorise the Minister of Fisheries to require information on non-target fishing-related mortality, but Section 186 explicitly includes fish farmers and holders of spat-catching permits.

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1 Seabirds not receiving full protection are: black shag (*Phalacrocorax carbo*), little shag (*P. melanoleucos brevirostris*), pied shag (*P. varius*), mutton bird (*Puffinus griseus*), grey-faced petrel (*Pterodroma macroptera*) and black-backed gull (*Larus dominicanus*).

6. Mussel farming effects on marine mammals and seabirds

Although there is a large body of evidence on the environmental effects of mussel cultivation in New Zealand and overseas (Morrisey & Swales 1997; Kaiser et al. 1998; Inglis et al. 2000; Sinner 2000; Cole 2001; Kaiser 2001; Broekhuizen et al. 2002), published information on the effects of mussel cultivation on marine mammals or seabirds is sparse. All available information is used to predict such effects in Table 1. Information used includes: details of green-lipped mussel biology and cultivation; the published studies of the environmental effects of mussel cultivation described in the preceding section; the locations and extent of existing and proposed mussel farms (Figs 6A–I); published and casual observations of marine mammals and seabirds around mussel farms; and information on the distribution and behaviour of marine mammals and seabirds. It is important to note that, in most instances, there is no proof that the effects occur; the effects are merely predicted from the best existing information.

There is likely to be considerable variation among species, location and season, in the nature and severity of any effects. Effects on individual species may be either detrimental or beneficial. Possible detrimental effects include: entanglement, ingestion of litter, exclusion from traditional habitat by structures or disturbance, declines in prey abundance due to phytoplankton depletion or changes in the benthic environment, reduced foraging success, and the introduction and spread of pathogens or pest species. Possible beneficial effects include increases in prey abundance or foraging success, and the creation of new resting sites and foraging areas.

TABLE 1. POSSIBLE EFFECTS OF MUSSEL CULTIVATION ON MARINE MAMMALS AND SEABIRDS.

Entanglement in:	mussel farm structures
	spat catching structures
	litter from farms
Ingestion of:	litter from farms
Changed prey abundance due to:	phytoplankton depletion
	changes in benthos
	changed macro-species assemblages
	harvest of natural spat fall
Changed foraging success due to:	farm structures
Exclusion by:	farm structures
	reduced foraging success or prey availability
	disturbance (noise or boat activity)
Facilitate spread of:	pathogens
	pest species (e.g. toxic blooms and *Undaria*)
Creation of resting places:	on floats
	within farms

6.1 ENTANGLEMENT

6.1.1 Cetaceans

Cetacean experts believe that worldwide, about 60 000 cetaceans die each year from entanglement in fishing gear (proceedings of Cetacean Bycatch Workshop January 2002, Annapolis, MD organised by WWF, http://www.cetaceanbycatch.org). Although most cetacean entanglements are in nets, some are in lines. Documented overseas instances of cetaceans being entangled in lines include: 13 sperm whales (*Physeter macrocephalus*) entangled in underwater telecommunications cables (Slijper 1976), grey whales (*Eschrichtius robustus*) entangled and drowned in aquaculture lines in California (Stack pers. comm. in Slooten et al. 2000a), and bottlenose dolphins (*Tursiops truncatus*) entangled in crab-trap lines on the east coast of the United States (Noke & O'Dell 2002).

Within New Zealand waters there are several reports of whales being entangled in lines: in 1985 a southern right whale (*Eubalaena australis*) died entangled in a craypot line (Martin Cawthorn, pers. comm.); since 1996 two Bryde's whale (*Balaenoptera edeni* or *brydei*) reportedly died in separate incidents after entanglement in mussel spat collection ropes (see frontispiece); there have been five instances of humpback whales (*Megaptera novaeangliae*) found entangled in crayfish pot lines near Kaikoura, two during 2001 (Childerhouse 2002), one in 2002 and two in 2003. There have been no reports of dolphin entanglement in lines in New Zealand.

The risk of entanglement is probably greater with thinner or untensioned ropes, such as spat collecting ropes and lost ropes. Because they don't echolocate (Tyack & Clark 2000), baleen whales (e.g. Bryde's, southern right, and humpback) are prone to entanglement. Over 60 percent of northern right whales in the North Atlantic have entanglement scars on them, and at least two deaths during a three-year period could be attributed to entanglements (Hamilton et al. 1998). Because of their echolocation capabilities and small size, there is a lower risk of dolphins becoming entangled in lines.

6.1.2 Pinnipeds

Although pinnipeds frequently become entangled in fishing nets, none have been reported entangled in lines and they are unlikely to be entangled in mussel farm structures. There are reports of pinnipeds being entangled in marine litter.

6.1.3 Seabirds

Incidental capture of seabirds during fishing operation is a significant international problem (Taylor 2000a, 2000b), but there are no reports of seabird deaths as a result of entanglement in fixed lines of the type found in mussel farms or spat catching areas. However, in the Marlborough Sounds adult and young of the Australian gannet have been found entangled in rope ties from mussel farms incorporated into their nests (Butler 2003). Also, giant petrel (*Macronectes giganteus*) and southern black-backed gull (*Larus dominicanus*) are prone to entanglement in marine litter (Taylor 2000a, 2000b).

6.2 INGESTION OF LITTER

Marine litter, particularly plastics, is ingested by many seabirds, especially pelagic species of petrel and albatross (Taylor 2000a, 2000b). Ingested plastic can causes mortality by dehydration, gut blockage or toxins released in the intestines (Auman et al. 1998). Increase in the amounts of marine litter around mussel farms may therefore have a detrimental effect on local populations of seabirds and marine mammals.

6.3 CHANGES IN FORAGING SUCCESS

Mussel farm structures may reduce foraging success for some protected species by interfering with normal foraging behaviour and providing refuges for prey. Curtains of mussel growing lines 50–70 cm apart, extending down to 30 m and encrusted with mussels (Figs 2 and 5) may constitute barriers to underwater foraging for many species.

Together with other farm structures, they are likely to impede collaborative hunting for schooling fish by dolphins (e.g. dusky, common, and Hector's dolphin) and interfere with foraging of seabirds species that feed in open water on schooling fish (e.g. white-fronted tern *Sterna striata*, Hutton's and fluttering shearwater *Puffinus huttoni* and *P. gavial*). The effect is likely to be pronounced for dolphins, as the mussel-encrusted growing lines will interfere with dolphins' sonar signals and communication sounds, reducing dolphin's ability to hunt successfully within mussel cultivation areas.

6.4 TROPHIC EFFECTS—CHANGES IN PREY ABUNDANCE

Changes in components of lower trophic levels within the water column and on the seabed around mussel farms were described in preceding sections (e.g. phytoplankton depletion, organic enrichment of the benthos, and changes in species assemblages). These will affect prey abundance for apex predators such as marine mammals and seabirds. It may be expected that diversion of coastal ecosystem's primary production to cultivated mussels over extensive areas will reduce prey availability. However, there have been no studies of this issue and it is difficult to predict how changes at lower trophic levels will affect populations at higher levels (Grant 1996; Smith & Holliday 1998). Increases in the abundance and diversity of some prey species around mussel farms (Grange 2002) may increase available food supplies for some marine mammals and seabirds, while declines in abundance of preferred prey species may decrease food supplies for others.

6.5 DISTURBANCE

Increased human activity associated with mussel farms can have detrimental effects on seabirds and marine mammals. Roosting and nesting shags are disturbed by boat activity, though this disturbance may not be detrimental to shag populations (Butler 2003). There are several documented examples outside New Zealand where increases in human activity have led to decreased use, or abandonment, of areas by cetaceans, including: grey whales (Gard 1974; Bryant et al. 1984), humpback whales (Herman 1979; Glockner-Ferrari & Ferrari 1990), killer whales (*Orcinus orca*) (Morton & Symonds 2002) and Chilean dolphin (*Cephalorynchus eutropia*) (Dr Jorge Oporto, Corporation Terra Austalis for Nature Conservation, Valdivia, pers. comm.). Many cetacean species do not accommodate to noise and boat activity though some do become habituated (Richardson et al. 1985; Richardson & Wursig 1997). Some individuals are attracted to boats; dolphins often approach boats for play, while seals and seabirds both congregate around boats for food. Increased boat activity brings increased risk of boat strikes, which is a significant cause of injury or death for many cetaceans, especially large whales. Hector's dolphins are attracted to boats, which predisposes them to boat strike and entanglement in nets set from boats (Stone & Yoshinga 2000).

6.6 EXCLUSION

It is thought that some species of marine mammals and seabirds may avoid areas used for mussel cultivation. Avoidance of mussel farms could be a consequence of several factors including: behavioural preferences for open water, disturbance by high levels of human activities, and reduced food supply caused by farms interfering with foraging or reducing prey availability. There are observations of dolphins swimming within mussel farms in New Zealand (e.g. Slooten et al. 2001; Markowitz et al. in press), however a number of reports indicate some dolphin species avoid areas used for long-line cultivation of bivalves. In New Zealand, dusky dolphins (*Lagenorhynchus obscurus*) avoid areas of Admiralty Bay, in the Marlborough Sounds, occupied by mussel farms (Markowitz et al. 2002 and in press). In Australia, bottlenose dolphins (*Tursiops* sp.) were excluded from parts of their home range where long-lines for oyster cultivation were placed (Mann 1999; Mann & Janik 1999). In Chile, during the period 1980–90, the Chilean dolphin disappeared from bays where mussel farms were developed; however, recent observations of dolphins in the area indicate they may develop tolerance of mussel farms (Dr Jorge Oporto, pers. comm.). The Chilean dolphin is Hector's dolphin's closest relative, and exhibits similar behaviour and preference for inshore habitat.

Habitat fragmentation, resulting from exclusion from traditional areas within a species home range, can produce abrupt and dramatic shifts in distribution and abundance patterns that may affect local populations more profoundly than might be predicted from the extent of lost area. Habitat fragmentation can pose particularly high risk for threatened or vulnerable species with populations adversely affected by other factors. Isolation of populations following habitat fragmentation can result in inbreeding and reduced reproductive success.

6.7 CREATION OF RESTING PLACES

Mussel farms provide resting-places for seabirds (Fig. 8) and cetaceans. Gulls and shags frequently roost on mussel floats (Butler 2003). There are reports of dolphins resting in the relatively sheltered water within mussel farms (Martin Cawthorn and Ken Grange pers. comm.).

Figure 8. Seabirds resting on mussel buoys.

7. Threatened species in coastal waters

Five marine mammal taxa and 44 seabird taxa, classified as nationally threatened (Hitchmough 2002) occur in coastal waters where mussel farms exist or are proposed (Table 2). Sixteen of these taxa are acutely threatened (5 cetaceans and 11 seabirds). A further 13 seabird taxa are chronically threatened, and 20 seabird taxa are at risk. Two cetacean taxa and 19 seabird taxa are also classified as globally threatened in the IUCN Red List (IUCN 2002) (Table 2). Differences between the New Zealand national classifications (Hitchmough 2002) and global classifications (IUCN 2002) reflect differences in the scale being considered. The sub-categories for acutely threatened taxa in the New Zealand system (Nationally Critical, Nationally Endangered and Nationally Vulnerable) roughly equate with the three categories for threatened species used in the IUCN Red List (Critically Endangered, Endangered or Vulnerable). In either system, taxa in these three categories are facing a very high risk of extinction in the wild.

The management and conservation of populations of threatened species, particularly cetacean species, is problematic and requires precautionary approaches unnecessary for other species (Mayer & Simmonds 1996; Thompson

TABLE 2. THREATENED SEABIRDS AND MARINE MAMMALS FOUND IN COASTAL WATERS OF THE MAIN ISLANDS OF NEW ZEALAND.

New Zealand threat categories (Hitchmough 2002): 1, Critical; 2, Endangered; 3, Vulnerable; 4, Serious decline; 5, Gradual decline; 6, Range restricted; 7, Sparse. IUCN global threat categories: (IUCN 2002) 1, Critically endangered; 2, Endangered; 3,Vulnerable; 4, Data deficient; 5, Lower risk.

GROUP	COMMON NAME	TAXON	NZ	IUCN
Penguin	Eastern rockhopper penguin	*Eudyptes chrysocome filholi*	4	
	Fiordland crested penguin	*E. pachyrhynchus*	5	3
	Erect-crested penguin	*E. sclateri*	2	2
	White-flippered penguin	*Eudyptula minor albosignata*	3	
	Northern little blue penguin	*E. minor iredalei*	5	
	Southern little blue penguin	*E. minor minor*	5	
	Yellow-eyed penguin	*Megadyptes antipodes*	3	2
Albatross	Antipodes albatross	*Diomedia antipodensis*	6	3
	Southern royal albatross, toroa	*D. epomophora*	6	3
	Gibson's albatross	*D. gibsoni*	6	
	Northern royal albatross, toroa	*D. sanfordi*	3	2
	Light-mantled sooty albatross	*Phoebetria palpebrata*	5	4
	Southern Buller's mollymawk	*Thalassarche bulleri*	6	3
	Grey-headed mollymawk	*T. chrysostoma*	4	3
	Northern Buller's mollymawk	*Thalassarche* sp.	6	
	Salvin's mollymawk	*T. salvini*	6	3
	Shy mollymawk	*T. steadi*	6	
Petrel	Fulmar prion	*Pachyptila crassirostris crassirostris*	6	
	Lesser fulmar prion	*P. c. eatoni*	6	
	Antarctic prion	*P. desolata*	5	
	Kermadec white-faced storm petrel	*Pelagodroma marina albiclunis*	1	
	South Georgian diving petrel	*Pelecanoides georgicus*	1	
	White-chinned petrel	*Procellaria aequinoctialis*	6	3
	Grey petrel	*P. cinerea*	5	4
	Black petrel	*P. parkinsoni*	5	3
	Westland petrel	*P. westlandica*	6	3
	Chatham petrel	*Pterodroma axillaris*	2	1
	Cook's petrel, titi	*P. cookii*	5	2
	Mottled petrel	*P. inexpectata*	6	4
	Pycroft's petrel	*P. pycrofti*	6	3
	Buller's shearwater	*Puffinus bulleri*	6	3
	Flesh-footed shearwater	*P. carneipes*	5	
	Sooty shearwater	*P. griseus*	5	
	Hutton's shearwater	*P. huttoni*	2	2
	Wedge-tailed shearwater	*P. pacificus*	6	
Shag	New Zealand king shag	*Leucocarbo carunculatus*	6	3
	Stewart Island shag	*L. chalconotus*	3	3
	Black shag	*Phalacrocorax carbo novaehollandiae*	7	
	Little black shag	*P. sulcirostris*	7	
	Pied shag	*P. varius varius*	7	
Skua	Southern skua	*Catharacta antarctica lonnbergi*	7	
Tern	Black-fronted tern	*Sterna albostriata*	4	2
	Caspian tern	*S. caspia*	3	
	Fairy tern	*S. nereis davisae*	1	
Baleen whale	Bryde's whale	*Balaenoptera edeni*	1	4
	Southern right whale	*Eubalaena australis*	2	5
Toothed whale	North Island Hector's dolphin	*Cephalorhynchus hectori maui*	1	2
	South Island Hector's dolphin	*C. hectori hectori*	3	2
	Killer whale	*Orcinus orca*	1	4

et al. 2000). Typically threatened species are suffering from the cumulative effects of several stresses, which may be either natural or human-induced, and an additional stress may have disproportionate consequences. Furthermore the small population sizes, typical of threatened species, together with difficulties inherent in studying threatened species, can lead to low statistical power for any attempts to detect effects. By the time an effect can be demonstrated with a high level of confidence, the effect will be so large that it may be too late to recover from (Taylor & Gerrodette 1993).

Four threatened species have been identified as being particularly vulnerable to the detrimental effects of extensive areas of mussel cultivation in New Zealand: Hector's dolphin, Bryde's whale, southern right whale, and king shag (*Leucocarbo carunculatus*).

7.1 Hector's dolphin

Hector's dolphin, which is endemic to New Zealand, is probably the world's rarest marine dolphin. The species is classified as endangered on the IUCN Red List (IUCN 2002) and as acutely threatened nationally by Hitchmough (2002). Two subspecies are recognised: *Cephalorhynchus hectori hectori* from South Island waters, and *Cephalorhynchus hectori maui* or Maui's dolphin from the west coast of the North Island (Baker et al. 2002). The South Island Hector's dolphin is classified as nationally vulnerable, whereas Maui's dolphin is classified as nationally critical, which is the highest level of endangerment (Hitchmough 2002). Best estimate for the total population of the species is 7270 individuals (Slooten et al. 2002). Recent estimates of the Maui's dolphin population are 75 (Ferreira & Roberts 2003) and 134 (Martien et al. 1999) individuals. Hector's dolphins are slow breeders, achieving reproductive status between 7 and 9 years of age, and subsequently breeding at irregular intervals of 2 or more years (Slooten 1991; Slooten & Lad 1991). They can live up to 20 years, but have a high mortality rate, largely due to entanglement in fishing nets (Slooten et al. 2000b). Hector's dolphins are a coastal species, living mostly within 7 km of the shore in shallow water (<100 m) (Dawson & Slooten 1988). Extensive mussel farms are being proposed in many of the semi-sheltered embayments on the coast of the South Island (Banks Peninsula, Pegasus Bay, Clifford Bay, and Jackson Bay: Fig. 1) known to be important to Hector's dolphins.

Hector's dolphins feed on bottom-dwelling organisms such as crabs and mollusks, as well as demersal and pelagic fishes (Baker 1983; Slooten et al. 2000a). Changes in benthos and water column caused by mussel farms will change prey availability, but it is not possible to predict whether the changes will be beneficial or detrimental. It seems probable that curtains of mussel-encrusted growing lines will interfere with dolphins' sonar signals and communication sounds, reducing their ability to hunt successfully. Extensive mussel farms in traditional home ranges of dolphin groups could restrict their movement and eliminate areas for nursing, basking, or foraging, and cause habitat fragmentation. There is currently limited overlap between marine farms and Hector's dolphin habitat throughout New Zealand; however, there are reports of Hector's dolphins seen within mussel farms (Slooten et al. 2001; Martin Cawthorn pers. comm.). Genetic variation in Hector's dolphin exhibits a high degree of geographical structure (Pichler 2002) which is presumed to have arisen from the small home ranges (<100 km) of populations and limited dispersal between geographical areas. Habitat fragmentation caused by the construction of extensive mussel farms could further isolate local populations and result in inbreeding and reduced reproductive success.

7.2 Bryde's whale

Bryde's whales are rorqual whales (length c. 14 m) found in tropical and subtropical oceans throughout the world (Rice 1998). In New Zealand waters, the larger form of Bryde's whale, presumably *B. brydei*, are relatively common in the warm waters of Northland, the Hauraki Gulf, and Bay of Plenty (Baker 1983). The species is classified as data deficient on the IUCN Red List (IUCN 2002), and as acutely threatened and nationally endangered by Hitchmough (2002). Bryde's whales are thought to be semi-migratory, making local seasonal movements to follow schools of fish (O'Callaghan & Baker 2002). The Hauraki Gulf appears to be an important habitat for a population of Bryde's whales (O'Callaghan & Baker 2002). Despite the smallness of the population of whales and the extremely limited area of existing mussel spat catching farms present within their range, two Bryde's whales reportedly died following entanglement in spat catching lines since 1996 (frontispiece). In the absence of effective mitigation, planned massive increases in the extent of mussel farms and associated spat catching farms within Bryde's whales range will probably lead to further entanglement-induced mortality.

7.3 Southern right whale

Southern right whales are large stocky baleen whales (length c. 14 m) with a circumpolar distribution, from about 30º to 60ºS. They migrate between breeding areas in warmer coastal waters in lower latitudes during winter, to feeding areas in higher latitudes in summer. The species is classified as acutely threatened and nationally endangered by Hitchmough (2002), but as being "at lower risk of extinction/conservation dependent" on the IUCN Red List (IUCN 2002). The IUCN classification means that the species recovery is dependent on ongoing conservation programmes.

Historically, southern right whales were abundant within New Zealand waters, with a population estimated at 10 000 individuals (Dawbin 1986). The population was nearly extirpated by whaling, which began in the nineteenth century and persisted until 1970. Dawbin (1986) suggested that there were two populations in New Zealand waters, with separate winter calving grounds: one around the mainland and Kermadecs, and the other in the New Zealand subantarctic. More recently Richards (2002) proposed that there was a single population, with individuals visiting waters around the mainland and the Kermadecs in the course of seasonal migrations. The New Zealand subantarctic population is now between 740 and 1140 individuals and increasing slowly (Patenaude 2000). In contrast, the low number of sightings in waters around New Zealand mainland indicates the local population is small, probably containing only 4–11 reproductive females (Patenaude 2003). If there were two separate populations, the population in mainland waters has failed to recover and is extremely vulnerable; alternatively if there was a single New Zealand population it has suffered extreme range contraction (Patenaude 2003).

Genetic data indicate the New Zealand subantarctic population is isolated from other populations (Patenaude 2000), but the genetic provenance of the animals seen around the New Zealand mainland is unknown (Patenaude 2003).

Southern right whales are adapted to living close to the shore. They use coastal migration routes; females calve in shallow, sheltered waters (Baker 1983). The shallow, sheltered, coastal waters preferred by southern right whales are identical to the conditions required for mussel cultivation. Thus, recovery of southern right whales in waters around the New Zealand mainland is likely to be compromised by the extensive mussel farms proposed for Pegasus Bay, Hawke Bay, and Bay of Plenty. These farms are proposed for important habitats for the most critical component of the New Zealand mainland population (Patenaude 2003). They overlap the whale's coastal migration routes and traditional calving areas. Entanglement or exclusion are both likely. Entanglement-induced mortality of a single female could have a severe impact on the viability of the small population found in waters around the New Zealand mainland.

7.1.4 King shag

The king shag (*Leucocarbo carunculatus*) is an endemic New Zealand species. It is ranked as vulnerable on the IUCN Red List (IUCN 2002), and as nationally at risk because of its restricted range (Hitchmough 2002). The entire population of about 650 birds is confined to the outer Marlborough Sounds. There are many existing mussel farms throughout the species range, but they are generally small (2–5 ha) and in shallow water within 200 m of shore. King shag forage in water between 20 and 40 m deep, where they feed on bottom-feeding fish, such as flounder, caught by deep diving. Existing mussel farms extend along the inshore fringe of the deeper water used by foraging king shags, but there are proposals for extensive mid-bay mussel farms to be anchored in the deeper waters where they will overlap the king shag's foraging area. Changes in benthos and water column around farms that reduce prey availability could affect the king shag population (Butler 2003). King shags use mussel floats for roosting and have been observed feeding within mussel farms (Butler 2003). However, underwater mussel farm structures may impede foraging. It has also been suggested that increased level of human activity associated with additional mussel farms could adversely affect nesting king shags (Butler 2003).

8. Areas of special significance for wildlife

Currently there is little overlap between mussel farms and important wildlife habitats (Fig. 9). The proposed extension of mussel farms into important wildlife habitats will increase the risk of adverse effects. Some areas around the New Zealand coast have special significance for a wide range of wildlife. For instance: the waters from Tauranga to North Cape are used by many large breeding colonies of seabirds and are on important migratory routes; they are therefore particularly important for New Zealand's seabird community. The waters off East Cape, Kaikoura and south-west South Island, where the continental shelf comes close to the shore, are also important for a variety of pelagic seabirds and marine mammals. Other areas are significant for smaller numbers of species. Hauraki Gulf is important for cetaceans, particularly Bryde's whale and common dolphin (*Delphinus delphis*) (O'Callaghan & Baker 2002). The north-west coast of the North Island (especially between Manukau Harbour and Port Waikato) contains the remaining population of the critical endangered North Island Hector's or Maui's dolphin (Ferreira & Roberts 2003). Coastal waters around Banks Penisula are important for the South Island Hector's dolphin (Dawson & Slooten 1988). Hawke Bay is an area of global significance for calving and nursing pygmy sperm whale (*Kogia breviceps*) (Debbie Freeman, Department of Conservation, Napier, pers. comm.). Admiralty Bay in the Marlborough Sounds is an important wintering area for dusky dolphin from the east coast of the South Island (Harlin et al. 2003). The shallow coastal waters of Poverty Bay, Hawke Bay, Cloudy Bay and Pegasus Bay, were historically major calving areas for southern right whales. Large offshore mussel farm areas proposed for these areas lie across seasonal migration routes of southern right whales and humpback whales.

Continue to next file: musselfarms05.pdf