Ministry for Primary Industries
Manatū Ahu Matua

LITERATURE REVIEW OF ECOLOGICAL EFFECTS OF AQUACULTURE

Effects on Marine Mammals

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4

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4.1 Feed-added species (salmon, kingfish, hapuku)

4.1.1 Overview of marine mammal issues

Interactions between marine mammals and aquaculture result from an overlap between the spatial location of the aquaculture facilities and the habitats and/or migration routes of the marine mammal species. Such interactions have been relatively minor issues with New Zealand farms to date given the small scale of the current finfish aquaculture industry here. However, overseas experience with these issues (e.g., Kemper & Gibbs 2001; Kemper et al. 2003; Heinrich & Hammond 2006) suggests the potential for adverse effects still exists with continued growth in both marine mammal populations and larger scale, offshore finfish farm developments. Several overseas studies (Würsig & Gailey 2002; Kemper et al. 2003; Wright 2008) have characterised the possible interactions, which include:

- competition for space (habitat modification or exclusion);
- potential for entanglement;
- underwater noise disturbance;
- attraction to artificial lighting;
- possible flow-on effects due to alterations in trophic pathways.

4.1.2 Main factors affecting the marine mammal issues

The physical location of the farm within important habitats or migration routes of New Zealand marine mammal species is the main factor that then leads to potentially adverse interactions or avoidance issues. Once a farm is within the distribution range of a species, the types of gear and equipment employed, as well as operational procedures around regular farm activities, influence the probability and scale of the impacts discussed above. These factors and possible mitigation techniques are discussed in further detail in the management strategies below.

4.1.3 Significance of effects

The adverse effects of aquaculture on marine mammals are not presently considered significant issues given the small size of the New Zealand finfish industry. While there is some current overlap with cetacean and pinniped habitats, very little of this occurs in what may be described as critical habitat. In addition, the consequences of a physical interaction are considered minor in most cases, as the outcomes are generally expected to affect individuals (e.g., fur seal injury) or result in only small-scale avoidance or attraction.

However, overseas studies and current finfish development plans in New Zealand suggest that these effects may need to be reconsidered in relation to any larger scale and offshore developments in New Zealand waters. For instance, as multiple farms or several types of aquaculture begin to overlap in their locations, marine mammal populations may be excluded from particular bays or regions depending on the species and its sensitivity to such activities. In the case of depleted populations (e.g., southern right whales), the issues of low population size and a fairly isolated population structure make these species more vulnerable to such impacts than other species. Hence, the simple exclusion of a few individuals from important habitats, such as nursery grounds, could have much larger scale and longer lasting repercussions on the population's recovery making a previously minor impact much more serious and broader in its implications.

Alternatively, as aquaculture increases in scale, so will the risk of physical interactions with some marine mammals. Based on some species' inherent curiosity and tendency to remain within inshore waters, it is expected that individuals will be initially attracted to farm activities and most likely investigate any structures at close range. While the risk of entanglement does not necessarily increase with scale (given appropriate precautions and best practice methods), the effect of an actual entanglement does if farms begin to encroach upon the habitats of threatened or endangered species. For instance, a single incidental mortality, particular a pregnant or reproductive female, would be catastrophic for a small population like Maui's dolphins, which currently number less than 100 (Slooten et al. 2006).

This large variation in the significance of aquaculture impacts on New Zealand marine mammals makes developing and implementing one set of effective management guidelines or standards extremely difficult. It will therefore be important that farm locations are carefully selected so as to minimise effects.

4.1.4 Current management or mitigation strategies

At present, potential risks are identified and managed on a case-by-case basis, for example, by selecting farm locations to avoid or minimise the likelihood of overlap with marine mammal migration routes and/or known habitats. Unfortunately, detailed information on abundance, distribution and critical habitats is available for only a handful of New Zealand's marine mammals, despite recent advances in survey techniques and large-scale improvement in data quality from remote sensing technology. To date, marine mammal research in New Zealand has been concentrated in locations nearest to universities or other research providers (e.g., Hauraki Gulf or Banks Peninsula), or has focused on unique or endangered species (e.g., Hector's dolphins) with little known about the habits of other, more prevalent, species.

However, in the absence of adequate marine mammal information, the risks associated with physical interactions can be further minimised by adopting maintenance and operational guidelines and standards for farm structures as well as any noise-generating equipment. Some examples include enclosing predator nets at the bottom, keeping nets taut, using mesh sizes of less than 6 cm (Kemper et al. 2003) and keeping nets well maintained (e.g., repairing holes). In the same context, farms should keep the use of underwater lights to a minimum (both above and below the water line) and only use appropriate levels of submerged lighting. Similarly, efforts to reduce feed waste will minimise fish aggregation and may also reduce the amount of time some species (e.g., dolphins) spend near finfish farms.

Finally, monitoring records of the presence (and absence) of marine mammal species in the vicinity or general region of the farm site along with any detailed observations of their time spent under or around the farm structure should be compiled when possible, including night-time feeding activity around illuminated cages. A well-kept database can be used by marine mammal experts to understand which species are more attracted to particular farm structures and what aspects of the farm they may be using or interacting with the most. Such information collection is a crucial step towards further investigating and developing appropriate mitigation methods.

4.1.5 Environmental quality standards

Currently, there are no operational standards (qualitative or quantitative) for New Zealand aquaculture in relation to marine mammal issues, and only a few guidelines or codes of conduct specific to marine mammals are currently in use overseas. At present, an international working group led by the World Wildlife Fund (WWF) is developing finfish farming criteria, indicators and standards, most of which are qualitative in relation to ecosystem and local wildlife issues (SAD 2011).

Most overseas guidelines (e.g., NMFS 2002; AAF 2005; BCSFA 2005) recognise that clear and consistent farm siting criteria that identify and consider potential overlap with wildlife or critical habitats prior to farm placement would have the greatest effect in limiting interactions with marine mammals. SAD (2011, Indicator 2.4.1) and the NMFS Code of Conduct (2002) suggest that indicators around siting criteria should include the following:

- identification of proximity to critical, sensitive or protected habitats and species (including protected areas or areas of high conservation values);
- description of the potential impacts the farm might have on biodiversity, with focus on those habitats or species;
- a description of strategies and current and future programmes underway to eliminate or minimise any identified impacts the farm might have and to monitor outcomes of these programmes and strategies;
- revisited and amended periodically to respond to new information and technology;
- inclusion of adequate parameters in the monitoring and assessment process to allow evaluation of impact;
- strategies and programmes should be combined with careful record keeping, and monitoring and assessment of impacts at a frequency commensurate with risk.

Perhaps the most reliable indicator of the actual consequences of any interactions with wildlife that do occur is records of entanglement and/or mortalities in aquaculture facilities. SAD (2011, Criteria 2.5) has suggested that appropriate numeric standards for this indicator would set the number of mortalities to zero for any endangered or red-listed marine mammal species. In the case of a lethal incident occurring, SAD (2011) recommends having in place indicators that provide evidence that an assessment of the risk of lethal incident(s) has been undertaken and demonstration of concrete steps taken by the farm to reduce the risk of future incidences, and that information on any lethal incidents is publicly accessible.

In order to discourage predation or attraction by marine mammals, in particular pinnipeds, overseas guidelines (Chile 2001; NMFS 2002; BCSFA 2005) also suggest all farms have a documented predator avoidance plan and follow developed limits around net protocols and maintenance. Similar "best practice" methods are also encouraged around noise-

generating equipment and the use of artificial lighting (BCSGA 2001; SAD 2011).

4.1.6 Knowledge gaps

As discussed previously, the most important factor in limiting adverse effects of finfish aquaculture on marine mammals in New Zealand is to avoid overlapping with critical habitats and/or traditional migration routes. As baseline information on most New Zealand marine mammals is sparse or limited in its nature, future research needs to focus on those species most likely to come in contact with aquaculture in the future.

In addition, ongoing research into the types of design and maintenance features and operational procedures that minimise entanglement risk should be supported. For example, cage technology in South Australia has developed and improved to the point where predators are excluded by the cage structures themselves (Taylor et al. 2010). In this context, any improvements in reducing food waste or efficient light use will also help minimise marine mammal interactions. While effective management can help reduce most risks, the performance of improved technologies or procedure can only be measured in situ by continuous monitoring and recording of actual incidents.

4.1.7: Descriptions of main effects and their significance

Table 4.1: Habitat modification and/or exclusion caused by farming of feed-added species.

Description of effect(s)	The presence of farm structures and their associated activities can potentially exclude or modify how particular species of marine mammals use critical or sensitive habitats. Present research has highlighted that the nature of the exclusion greatly depends on the type of culture method and the particular marine mammal species present in the cultivation area. Whales and particular dolphin species tend to be more sensitive to such disturbances, while pinnipeds and other dolphin species (such as common and bottlenose dolphins) may actually be attracted to the novel structures and/or habitat.
Spatial scale	*Local* to *regional* scale – Avoidance may be only from the farm area itself but most likely will involve a bay or region, depending on species and population dynamics.
Duration	*Short* to *long term* – Exclusion may be temporary for migrating species or until resident species habituate to the structures and/or activities or avoidance may be for the farms' duration to permanent.
Management options	Site selection to minimise or avoid the likelihood of spatial overlap with species' home ranges, critical breeding and foraging habitats and/or migration routes. Continuous monitoring of presence (and absence) of marine mammal species in the vicinity or general region of the farm site is recommended. Monitoring could also include detailed observations of any time spent under or around the farm structure, which may later be compiled and analysed by experts. Given the impacts associated with acoustic deterrent devices (ADDs) and/or acoustic harassment devices (AHDs) and the availability of other, potentially less harmful and more effective deterrence practices, guidelines should encourage farms not to use ADDs/AHDs and require that their use be phased out on future certified farms.
Knowledge gaps	Ongoing research into the home ranges and locations of important habitats for most populations and sub-populations of marine mammal species in New Zealand. Siting guidelines should be developed to promote clarity, consistency and precaution in the permit process. The criteria should be revisited and amended periodically to respond to new information and technology.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

Overseas research (e.g., Kemper & Gibbs 2001; Kemper et al. 2003; Watson-Capps & Mann 2005; Heinrich 2006) on the potential for aquaculture to exclude marine mammals from critical habitats and/or historical migration routes has highlighted that the nature of exclusion greatly depends on the type of culture method and the particular marine mammal species present in the cultivation area. In general, aquaculture structures occupy a portion of the water column, effectively creating a three-dimensional structure, which marine mammals

have to choose whether to navigate through or around (Würsig & Gailey 2002; Markowitz et al. 2004). In relation to cetaceans (whales and dolphins), overseas evidence has ranged from migrating whales travelling straight through and destroying finfish farm structures (Kemper & Gibbs 2001; Kemper et al. 2003) to complete avoidance of bays occupied with farms by smaller dolphin species (Heinrich & Hammond 2006; Ribeiro et al. 2007). Alternatively, pinnipeds (seal and sea lions, see Table 4.2: Entanglement) and some dolphin species, such as common and bottlenose dolphins (as observed in the Marlborough Sounds – R. Forrest pers. comm.), are often attracted to these novel structures, especially finfish cages as they offer a novel food source.

Exclusion of cetaceans from areas containing fish farms can also potentially occur indirectly through the use of acoustic deterrent devices or acoustic harassment devices (ADDs or AHDs), which are sometimes used at farms to dissuade seals from feeding on farm stock. Exclusion has been reported overseas for killer whales (Morton & Symonds 2002) and harbour porpoises (Olesiuk et al. 2002). ADDs have been trialled at New Zealand finfish farms but are currently not in use because they were unsuccessful. Internationally, acoustic devices are now considered ineffective at preventing predation by pinnipeds, and several overseas organisations have recommended phasing them out of use (e.g., Kemper et al. 2003; SAD 2011).

Table 4.2: Entanglement caused by farming of feed-added species.

Description of effect(s)	Physical interactions between aquaculture and marine mammals can lead to an increased risk of entanglement in structures, predator nets or non-biological wastes from farm production. The risk of entanglement increases as finfish farms tend to attract predators to the caged fish themselves or to associated aggregations of wild fish.
Spatial scale	*Local* to *regional* scale – Impact occurs at the site but may have larger scale consequences at the population level, depending on the species status and population range.
Duration	*Short* to *long term* – Minor injury to individuals to death of critically endangered animals that can have long-term consequences for vulnerable populations.
Management options	Physical interactions: • Site selection to minimise or avoid the likelihood of spatial overlap with species' home ranges, critical breeding and foraging habitats and/or migration routes. • Continuous monitoring of presence (and absence) of marine mammal species in the vicinity or general region of the farm site, detailed observations of any time spent under or around the farm structure, compiled and analysed by experts. • Strict guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines and nets. • Support the development and use of diets and feeding strategies that minimise adverse impacts. • Provision for disposal and/or processing of non-biological wastes to minimise the risk of attraction and entanglement. Predator interactions: • Locate farms more than 20 km from well-established pinniped haul-out sites or breeding colonies. • Maintain a documented predator avoidance plan that uses only benign, non-lethal deterrents such as predator netting, specialised weighting, semi-rigid or stiffened nets, electric fences or proper husbandry of caged fish. • Given the impacts associated with ADDs/AHDs and the availability of other, potentially less harmful and more effective deterrence practices, guidelines should encourage farms not to use ADDs/AHDs and require that their use be phased out on future certified farms. • Up-to-date and complete maintenance records specific to each net, including operational measures such as enclosing predator nets at the bottom, keeping nets taut, keeping nets well maintained (e.g., repairing holes).

Table 4.2: Entanglement (continued)

Knowledge gaps	Physical interactions: • Home ranges and locations of important habitats for most populations and sub-populations of marine mammal species in New Zealand. • Improved data on factors (i.e., location to haul-outs) affecting entanglement rates. • Knowledge on the types of design and maintenance features, and operational procedures that minimise entanglement risk. • Ongoing research efforts to reducing feed waste will minimise fish aggregation, which may also reduce the amount of time some species spend near finfish farms. Predator interactions: • Ongoing discussions and research around proper maintenance and design of predator nets and development of protocols for net changing. • Better reporting, improved data on factors (e.g. net design) affecting entanglement.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

Incidences of marine mammal entanglement are very few in New Zealand despite over 25 years of sea-cage salmon farming, due in part to the relatively small scale of this industry and operational procedures that minimise entanglement risk at New Zealand farms (Forrest et al. 2007). However, the presence of marine mammals near farms can result in an increased risk of entanglement, especially if farms are poorly designed, installed or maintained as is evident in reports from overseas (e.g., Kemper & Gibbs 2001; Allen & Bejder 2003; Kemper et al. 2003; Coughran 2005; Díaz López & Bernal-Shirai 2007). The risk of entanglement also increases as finfish farms tend to attract predators (such as dolphins, seals or sharks) to the caged fish themselves or to the associated aggregations of wild fish. An increased predator presence can cause major problems for farmers through direct predation, destruction of gear, fish escapements through damaged nets and reduced fish growth and performance (Kemper et al. 2003; M. Gillard, New Zealand King Salmon pers. comm.). As a consequence, salmon cages in the Marlborough Sounds, for example, are surrounded by predator nets that are designed to prevent predator access to the fish stock and the farm structures.

Fatal entanglements of dolphins in predator nets of finfish farms have been reported from Australia (Kemper & Gibbs 2001; Kemper et al. 2003), Italy (Díaz López & Bernal Shirai 2007) and four cases in New Zealand (M. Aviss, Department of Conservation, Picton pers. comm.). This may reflect the attraction of dolphins to a food source (Kemper & Gibbs 2001), although such interactions between finfish farms and cetaceans have not been proven (Kemper et al. 2003). There are two reported incidences of New Zealand fur seal entanglement and drowning at salmon farms, one of which involved a seal being caught beneath a predator net resting on the seabed and another being caught between the predator net and salmon net (A. Baxter, Department of Conservation, Nelson pers. comm.). Overseas, pinniped predation is a much greater problem that has resulted in the development of ADDs and AHDs, as discussed in further detail above. Through a joint process involving the New Zealand salmon industry and Department of Conservation, net design and operational practices for changing predator nets have been improved to minimise the risk of entanglement and reduce the need for acoustic devices.

Table 4.3: Underwater noise caused by farming of feed-added species.

Description of effect(s)	Underwater noise associated with regular, ongoing farm activities (including vessels) may either exclude or attract marine mammals. Overseas research has noted that the use of underwater noise devices (ADD/AHDs) to prevent pinniped predation have also resulted in dolphin displacement from areas with active devices. Whales and certain dolphin species tend to be more sensitive to such disturbances, while pinnipeds and other dolphin species (such as common and bottlenose dolphins) may actually be attracted to the novel noise source.
Spatial scale	*Local* to *regional* scale – Impact occurs at the site but the scale is dependent on the frequency and intensity of sounds generated and the hearing and/or vocalising range of the marine mammal.
Duration	*Short* to *long term* – Dependent on the frequency and intensity of sounds generated and the hearing and/or vocalising range of species.
Management options	Site noise: • Site selection to minimise or avoid the likelihood of spatial overlap with range restricted species' home ranges, critical breeding and foraging habitats and/or migration routes. • Continuous monitoring of the presence (and absence) of marine mammal species in the vicinity or general region of the farm site, detailed observations of any time spent under or around farm structure, and compiled analysed by experts. • Monitor and regularly review on-farm management and maintenance practices to minimise the risk of underwater noise pollution. ADDs/AHDs: • Given the impacts associated with ADDs/AHDs and the availability of other, potentially less harmful and more effective deterrence practices, guidelines should encourage farms not to use ADDs/AHDs and require that their use be phased out on future certified farms.
Knowledge gaps	• Siting criteria should be developed to promote clarity, consistency and precaution in the permit process. The criteria should be revisited and amended periodically to respond to new information and technology. • Long-term health implications for marine mammals associated with certain underwater noise exposure.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

Associated closely with habitat exclusion is habitat degradation in the form of underwater noise disturbance. The level and persistence of underwater noises associated with finfish farming may be minimal relative to other underwater noise sources, such as commercial vessels, but will vary according to farm features (e.g., type, size), habitat characteristics (e.g., location, depth, type of bottom sediments, shape of coastline) and compounding factors, such as the number of farms and/or other noise sources in nearby regions. Currently, no New Zealand or overseas studies have specifically analysed the effect of noise production in association with aquaculture on marine mammals. Overseas research has demonstrated that whales may be more sensitive to increased noise production in their habitats or along migration routes (Gard 1974; Herman 1979; Bryant et al. 1984; Glockner-Ferrari & Ferrari 1990). Most odontocete (i.e., toothed whales and dolphins) and pinniped species demonstrate few avoidance behaviours and considerable tolerance of most underwater noises with a few exceptions (Richardson 1995). In fact, the curiosity and temporary attraction of dolphins to boat noise will be familiar to most recreational or commercial vessel users, and this has been recognised in the literature (Carwardine 1995; Dawson et al. 2000).

The use of ADDs or AHDs to prevent pinnipeds, predation, as described in the previous sections has resulted in the displacement of killer whales (Morton & Symonds 2002) and harbour porpoises (Olesuik et al. 2002) from areas with active devices and their eventual return when the devices were removed. Several overseas organisations (e.g. Kemper et al. 2003; SAD 2011) have recommended the phasing out of ADDs and AHDs given the hearing-associated impacts on pinnipeds and cetaceans.

Table 4.4: Attraction to artificial lighting caused by farming of feed-added species

Description of effect(s)	The use of submerged underwater lights to aid in caged fish maturation may inadvertently attract marine mammals to the aggregation of wild fish or lead to increased predation activity on caged fish.
Spatial scale	*Local* to *bay* scale – Impact occurs at site but may attract individuals from further away.
Duration	*Short term* – Mammals may temporarily visit once while migrating to other grounds or remain for the seasonal period in which lights are used.
Management options	Site selection to minimise or avoid the likelihood of spatial overlap with range restricted species' home ranges, critical breeding and foraging habitats and/or migration routes. Continuous monitoring of the presence (and absence) of marine mammal species in the vicinity or general region of the farm site, detailed observations of any time spent under or around farm structure, compiled and analysed by experts. Minimise the use of lights on site, and, where possible, lights should be shielded from all but essential directions. If spot lights must be used, they should be positioned as high above the water as possible so that penetration is maximised and reflection is minimised. Monitor and regularly review on-farm management and maintenance practices to minimise the potential entanglement risks associated with light attraction.
Knowledge gaps	Siting criteria should be developed to promote clarity, consistency and precaution in the permit process. The criteria should be revisited and amended periodically to respond to new information and technology. Research into the possible effects that positive attraction to artificial light use associated with marine aquaculture may have on marine mammals.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

The use of submerged lighting within salmon farms may attract aggregations of wild fish to the finfish cages at night (McConnell et al. 2010; Cornelisen & Quarterman 2010). As the "footprint" of submerged artificial lights is mainly confined within the cage structures and to mid-water depths, marine mammals will more likely be attracted to any increase in noise and activity of caged or wild fish in response to the lights rather than the lights themselves.

To date, very few studies overseas or within New Zealand have focused on the submerged lights associated with finfish farms (SAD 2010; McConnell et al. 2010). These studies suggest that large aggregations of schooling baitfish, such as yellow-eyed mullet or herring, are often associated with lit areas in the cages. Baitfish are important prey for several marine mammal species and their aggregation is likely to enhance night-time predation by marine mammals, such as seals or dolphins, along the edge of the cages. For example, a study on feeding by harbour seals in a British Columbia river demonstrated that artificial lighting on bridges was partly responsible for enhanced night-time predation on salmon smolt (Yurk & Trites 2000). While marine mammal attraction to farms using submerged lights will be highly localised in its effect, the greater risk of any attraction to farm structures is potential entanglement issues.

4.1.8 Indirect effects

The potential for wider, more indirect ecosystem effects on marine mammals due to finfish culture also includes food-web interactions (Black 2001, Kaiser 2001; Würsig & Gailey 2002; Kemper et al. 2003), biotoxin and pathogen (disease) outbreaks (Geraci et al. 1999; Kaiser 2001) and antibiotic use (Buschmann et al. 1996; Kaiser 2001). While these potential indirect interactions between marine mammals and aquaculture have been considered in the literature (Würsig & Gailey 2002; Kemper et al. 2003), no actual research on any indirect effect has yet been documented.

4.2 Filter-feeders (green-lipped mussels and Pacific oysters)

4.2.1 Overview of marine mammal issues

Interactions between marine mammals and aquaculture result from an overlap between the spatial location of the facilities and the habitats and/or migration routes of the species. Such interactions have been relatively minor issues with New Zealand farms to date given the small scale of the current aquaculture industry here. However, overseas experience with these issues (e.g., Kemper & Gibbs 2001; Kemper et al. 2003; Heinrich & Hammond 2006) suggests the potential for adverse effects still exists with continued growth in both marine mammal populations and larger scale, offshore farm developments. Several overseas studies (Würsig & Gailey 2002; Kemper et al. 2003; Wright 2008) have characterised the possible interactions, which include:

- competition for space (habitat modification or exclusion);
- potential for entanglement;
- underwater noise disturbance;
- possible flow-on effects due to alterations in trophic pathways.

4.2.2 Main factors affecting the marine mammal issues

The physical location of the farm within important habitats or migration routes of New Zealand marine mammal species is the main factor that then leads to potentially adverse interactions or avoidance issues. Once a farm is within the distribution range of a species, the types of gear and equipment employed, as well as operational procedures around regular farm activities, influence the probability and scale of the impacts discussed above. These factors and possible mitigation techniques are discussed in further detail in the management strategies below.

4.2.3 Significance of effects

The adverse effects of aquaculture on marine mammals are not presently considered significant issues. While there is some current overlap with cetacean and pinniped habitats, very little of this occurs in what may be described as critical habitat. In addition, the consequences of a physical interaction are considered minor in most cases, as the outcomes are generally expected to affect individuals or result in only small-scale avoidance or attraction.

However, overseas studies and current aquaculture development plans in New Zealand suggest that these effects may need to be reconsidered in relation to any larger scale and offshore developments in New Zealand waters. For instance, as multiple farms or several types of aquaculture begin to overlap in their locations, marine mammal populations may be excluded from particular bays or regions depending on the species and its sensitivity to such activities. In the case of depleted populations (e.g., southern right whales), the issues of low population size and a fairly isolated population structure make these species more vulnerable to such impacts than other species. Hence, the simple exclusion of a few individuals from important habitats, such as nursery grounds, could have much larger scale and longer lasting repercussions on the population's recovery making a previously minor impact much more serious and broader in its implications.

Alternatively, as aquaculture increases in scale, so will the risk of physical interactions with some marine mammals. Based on some species' inherent curiosity and tendency to remain within inshore waters, it is expected that individuals will be initially attracted to farm activities and most likely investigate any structures at close range. While the risk of entanglement does not necessarily increase with scale (given appropriate precautions and best practice methods), the effect of an actual entanglement does if farms begin to encroach upon the habitats of threatened or endangered species. For instance, a single incidental mortality, in particular a pregnant or reproductive female, would be catastrophic for a small population like Maui's dolphins, which currently number less than 100 (Slooten et al. 2006).

This large variation in the significance of aquaculture impacts on New Zealand marine mammals makes developing and implementing one set of effective management guidelines or standards extremely difficult. It will therefore be important that farm locations are carefully selected so as to minimise further effects.

4.2.4 Current management or mitigation strategies

At present, potential risks are identified and managed on a case-by-case basis, for example, by selecting farm locations to avoid or minimise the likelihood of overlap with marine mammal migration routes and/or known habitats. Unfortunately, detailed information on abundance, distribution and critical habitats is available for only a handful of New Zealand's marine mammals, despite recent advances in survey techniques and large-scale improvement in data quality from remote sensing technology. To date, marine mammal research in New Zealand has been concentrated in locations nearest to universities or other research providers (e.g., Hauraki Gulf or Banks Peninsula), or has focused on unique or endangered species (e.g., Hector's

dolphins) with little known about the habits of other, more prevalent, species.

However, in the absence of adequate marine mammal information, the risks associated with accidental interactions can be further minimised by adopting maintenance and operational guidelines and standards for farm structures as well as any noise-generating equipment. Alternatively, pinnipeds and dolphins may be attracted to the structures and/or wild fish aggregations that are often associated with the farms. Any resulting entanglement risks can be minimised by adopting regular maintenance measures around farm structures and keeping lines well maintained.

Finally, monitoring records of the presence (and absence) of marine mammal species in the vicinity or general region of the farm site along with any detailed observations of their time spent under or around the farm structure should be compiled when possible. A well-kept database can be used by marine mammal experts to understand which species are more attracted to particular farm structures and what aspects of the farm they may be using or interacting with the most. Such information is crucial towards further investigating and developing appropriate mitigation methods.

4.2.5 Environmental quality standards

Currently, there are no operational standards (qualitative or quantitative) for New Zealand aquaculture in relation to marine mammal issues, and only a few guidelines or codes of conduct specific to marine mammals are currently in use overseas. At present, an international working group led by WWF is developing aquaculture farming criteria, indicators and standards, most of which are qualitative in relation to ecosystem and local wildlife issues (BADS 2010).

In general, overseas guidelines (e.g., BCSGA 2001; NMFS 2002; AAF 2005) recognise that clear and consistent farm siting criteria that identify and consider potential overlap with wildlife or their critical habitats prior to farm placement would have the largest effect in limiting interactions with marine mammals. SAD (2011, Indicator 2.4.1) and the NMFS Code of Conduct (2002) suggest that indicators around siting criteria include the following:

- identification of proximity to critical, sensitive or protected habitats and species (including protected areas or areas of high conservation values);
- description of the potential impacts the farm might have on biodiversity, with focus on those habitats or species;
- a description of strategies and current and future programmes underway to eliminate or minimise any identified impacts the farm might have and to monitor outcomes of these programmes and strategies;
- revisited and amended periodically to respond to new information and technology;
- inclusion of adequate parameters in the monitoring and assessment process to allow evaluation of impact;
- strategies and programmes should be combined with careful record keeping and monitoring and assessment of impacts at a frequency commensurate with risk.

Perhaps the most reliable indicator of the actual consequences of any interactions with wildlife that do occur is records of entanglement and/or mortalities in aquaculture facilities. SAD (2011, Criteria 2.5) has suggested that appropriate numeric standards for this indicator would set the number of mortalities to zero for any endangered or red-listed marine mammal species. In the case of a lethal incident occurring, SAD (2011) recommends having in place indicators that provide evidence that an assessment of the risk of lethal incident(s) has been undertaken and demonstration of concrete steps taken by the farm to reduce the risk of future incidences, and that information on any lethal incidents is publicly accessible.

In order to further reduce entanglement risks, overseas guidelines (BCSGA 2001; Chile 2001; NMFS 2002) suggest that all farms follow developed limits around maintenance. BADS (2010) and other overseas organisations (BCSGA 2001) also recognise the need for guidelines around underwater noise associated with farm activities and non-biological waste from farm production, as such items can be a potential entanglement or health risk for marine mammals as well as having other adverse effects on other wildlife and nearby environments.

4.2.6 Knowledge gaps

As discussed previously, the most important factor in limiting adverse effects of aquaculture on marine mammals in New Zealand is to avoid overlapping with critical habitats and/or traditional migration routes. As baseline information on most New Zealand marine mammal species is sparse or limited in its nature, future research needs to focus on those species most likely to come in contact with aquaculture in the future.

In addition, ongoing research into the types of design and maintenance features and operational procedures that minimise entanglement risk should be supported. While effective management can help reduce most risks, the performance of improved technologies or procedure can only be measured in situ by continuous monitoring and recording of actual incidents.

4.2.7: Descriptions of main effects and their significance

Table 4.5: Habitat modification and/or exclusion caused by farming of filter-feeders.

Description of effect(s)	The presence of farm structures and their associated activities can potentially exclude or modify how particular species of marine mammals use critical or sensitive habitats. Present research has highlighted that the nature of the exclusion greatly depends on the type of culture method and the particular marine mammal species present in the cultivation area. Whales and particular dolphin species tend to be more sensitive to such disturbances, while pinnipeds and other dolphin species (such as common and bottlenose dolphins) may actually be attracted to the novel structures and/or habitat.
Spatial scale	*Local* to *regional* scale – Avoidance may be only from the farm area itself but most likely will involve a bay or region, depending on species and population dynamics.
Duration	*Short* to *long term* – Exclusion may be temporary for migrating species or until resident species habituate to the structures and/or activities or avoidance may be for the farms' duration to permanent.
Management options	Site selection to minimise or avoid the likelihood of spatial overlap with species' home ranges, critical breeding and foraging habitats and/or migration routes. Continuous monitoring of presence (and absence) of marine mammal species in the vicinity or general region of the farm site is recommended. Monitoring could also include detailed observations of any time spent under or around the farm structure, which may later be compiled and analysed by experts.
Knowledge gaps	Ongoing research into the home ranges and locations of important habitats for most populations and sub-populations of marine mammal species in New Zealand. Siting guidelines should be developed to promote clarity, consistency and precaution in the permit process. The criteria should be revisited and amended periodically to respond to new information and technology.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

Mussel farm droppers typically extend vertically from floats at the surface through the water column to within a short distance above the seabed and, as Markowitz et al. (2004) demonstrated with sonar, these vertical structures can appear as visual or acoustic barriers that can potentially exclude marine mammals from habitats previously used for feeding, calving and/or migration activities. Studies in New Zealand have so far only addressed interactions between mussel farms with Hector's (Slooten et al. 2001) and dusky dolphins (Markowitz et al. 2004; Vaughn & Würsig 2006; Duprey 2007; Pearson et al. 2007). Collectively, these works suggest that while some marine mammal species are not completely displaced from regions as a whole, they do not appear to be utilising habitats occupied by shellfish farms in the same manner as prior to the farms' establishment. Pinnipeds are perhaps the one group of marine mammal species that will not be excluded from habitats by mussel farming.

Overseas research highlights that the nature of habitat exclusion greatly depends on the type of culture method and the particular species of marine mammal present in the cultivation area (e.g., Kemper et al. 2003; Watson-Capps & Mann 2005; Heinrich 2006; Ribeiro et al. 2007). Given that some marine mammal exclusion effects occur, the question remains as to the significance of this effect for particular species.

Table 4.6: Entanglement caused by farming of filter-feeders.

Description of effect(s)	Physical interactions between aquaculture and marine mammals can lead to an increased risk of entanglement in structures or non-biological wastes from farm production. The risk of entanglement increases as predators tend to be attracted to associated aggregations of wild fish.
Spatial scale	*Local* to *regional* scale – Impact occurs at site but may have larger scale consequences at the population level, depending on the species status and population range.
Duration	*Short* to *long term* – Minor injury to individuals to death of critically endangered animals that can have long-term consequences for vulnerable populations.
Management options	Site selection to minimise or avoid the likelihood of spatial overlap with species' home ranges, critical breeding and foraging habitats and/or migration routes. Continuous monitoring of presence (and absence) of marine mammal species in the vicinity or general region of the farm site, detailed observations of any time spent under or around the farm structure, compiled and analysed by experts. Strict guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines, buoys or floats. Provision for disposal and/or processing of non-biological wastes to minimise the risk of attraction and entanglement.
Knowledge gaps	Ongoing research into the home ranges and locations of important habitats for most populations and sub-populations of marine mammal species in New Zealand. Better reporting and improved data on factors (i.e., location to haul-outs or farm design) affecting entanglement rates. Ongoing research into the types of design and maintenance features, and operational procedures that minimise entanglement risk.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

Mussel farming structures can occupy a large portion of the water column effectively creating three-dimensional structures while other forms of shellfish farming, such as oyster farming, can occupy a significant area of intertidal habitat that resident marine mammals have to actively navigate or manoeuvre around (Würsig & Gailey 2002; Markowitz et al. 2004; Watson-Capps & Mann 2005). To our knowledge, there have been only three cases (one disputed) of whales entangling in shellfish farms in Australia and New Zealand with no known fatal entanglements of pinnipeds or dolphins.

In Western Australia, a humpback calf became entangled with a crop line in its mouth (Coughran 2005). The calf, after having picked up the line, panicked and rolled with the line which had to be cut free from its connection to the farm's anchor due to the strong tension on the 20 mm line. Off Great Barrier Island in New Zealand, a Bryde's whale (*Balaenoptera brydei*) was entangled and found dead in a spat collection rope from a mussel farm (Seafood New Zealand 1996). The spat line was lodged tightly through the base of the animal's mouth indicating that a high level of force would have been necessary to cause the entanglement. However, whether the whale was alive at the time of entanglement has been disputed by industry representatives because no official necropsy was performed.

Many species of marine mammals are known for their curious nature and they are often attracted to novel objects, such as floating debris and/or lines. While some incidences of dolphin entanglement in thin lines have been reported from overseas, none have been associated with shellfish aquaculture. On other occasions, New Zealand marine mammals have been entangled in non-biological marine waste or debris (e.g., Mattlin & Cawthorn 1986; Derraik 2002). These reports, as well as reports from overseas, indicate that loose, thin lines or buoys and floats pose the greatest entanglement threat to marine mammals. As such, potential entanglement risks at New Zealand shellfish farms are likely to be low, because backbone lines are kept under considerable tension, the lack of loose lines or the location within intertidal regions. However, based on overseas evidence, the risk of entanglement occurring would obviously increase if a farm were situated within the historical migratory paths of New Zealand whales.

Table 4.7: Underwater noise caused by farming of filter-feeders.

Description of effect(s)	Underwater noise associated with regular, ongoing farm activities (including vessels) may either exclude or attract marine mammals. Whales and particular dolphin species tend to be more sensitive to such disturbances, while pinnipeds and other dolphin species (such as common and bottlenose dolphins) may actually be attracted to the novel noise source.
Spatial scale	*Local* to *regional* scale – Impact occurs at the site but the scale is dependent on the frequency and intensity of sounds generated and the hearing and/or vocalising range of the mammal species.
Duration	*Short* to *long term* – Dependent on the frequency and intensity of sounds generated and the hearing and/or vocalising range of species.
Management options	Site selection to minimise or avoid the likelihood of spatial overlap with range restricted species' home ranges, critical breeding and foraging habitats and/or migration routes. Continuous monitoring of the presence (and absence) of marine mammal species in the vicinity or general region of the farm site, detailed observations of any time spent under or around the farm structure, compiled and analysed by experts. Monitor and regularly review on-farm management and maintenance practices to minimise the risk of underwater noise pollution.
Knowledge gaps	Siting criteria should be developed to promote clarity, consistency and precaution in the permit process. The criteria should be revisited and amended periodically to respond to new information and technology. Long-term health implications for marine mammals associated with certain underwater noise exposure.

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Summary

Associated closely with habitat exclusion is habitat degradation in the form of underwater noise disturbance. Underwater noise in the oceans has recently made headlines as a fairly widespread, yet largely unknown, problem for marine mammals, particularly the larger whale species (Nowacek et al. 2007; Weilgart 2007; Wright 2008). The level and persistence of any underwater noises associated with mussel farming may be minimal relative to other underwater noise sources, such as commercial vessels, but will vary according to farm features (e.g., type, size), habitat characteristics (e.g., location, depth, types of bottom sediments, shape of coastline) and compounding factors, such as the number of farms and/or other noise sources in nearby regions.

Currently, no New Zealand or overseas studies have specifically analysed noise production in association with aquaculture and marine mammals. Overseas research has demonstrated that whales may be more sensitive to increased noise production in their habitats or along migration routes (Gard 1974; Herman 1979; Bryant et al. 1984; Glockner-Ferrari & Ferrari 1990), however, most odontocete (i.e., toothed whales and dolphins) and pinniped species demonstrate few avoidance behaviours and considerable tolerance of most underwater noises with a few exceptions (Richardson 1995). In fact, the curiosity and temporary attraction of dolphins to boat noise will be familiar to most recreational or commercial vessel users, and this has been recognised in the literature (Carwardine 1995; Dawson et al. 2000).

4.2.8 Indirect effects

The potential for wider, more indirect ecosystem effects on marine mammals due to mussel aquaculture also includes food-web interactions (Black 2001; Kaiser 2001; Würsig & Gailey 2002; Kemper et al. 2003), biotoxin and pathogen (disease) outbreaks (Geraci et al. 1999; Kaiser 2001) and antibiotic use (Buschmann et al. 1996; Kaiser 2001). While these potential indirect interactions between marine mammals and shellfish aquaculture have been considered in the literature (Würsig & Gailey 2002; Kemper et al. 2003), no actual research on any indirect effect has yet been documented.

4.3 Lower trophic level species (*Undaria* and sea cucumbers)

4.3.1 Overview of marine mammal issues

Very little has been documented on the possible adverse interactions between seaweed or herbivorous species culture and marine mammals. While the physical presence of the farm will have similar risks (i.e., habitat modification and entanglement risks) to other types of aquaculture structures, the overall impacts are expected to be less. As discussed previously, the most important factor in limiting adverse effects of aquaculture on marine mammals in New Zealand is to avoid overlapping with critical habitats and/or traditional migration routes. As baseline information on most New Zealand marine mammals is sparse or limited in its nature, future research needs to focus on those species most likely to come in contact with aquaculture in the future.

In addition, ongoing research into the types of design and maintenance features and operational procedures that minimise entanglement risk should be supported. While effective management can help reduce most risks, the performance of improved technologies or procedure can only be measured in situ by continuous monitoring and recording of actual incidents.

4.3.2: Descriptions of main effects and their significance

Table 4.8: Habitat modification and/or exclusion caused by farming of lower trophic level species.

Description of effect(s)	The presence of farm structures and their associated activities can potentially exclude or modify how particular species of marine mammals use critical or sensitive habitats. Present research has highlighted that the nature of the exclusion greatly depends on the type of culture method and the particular marine mammal species present in the cultivation area. Whales and particular dolphin species tend to be more sensitive to such disturbances, while pinnipeds and other dolphin species (such as common and bottlenose dolphins) may actually be attracted to the novel structures and/or habitat.
Spatial scale	*Local* to *regional* scale – Avoidance may be only from the farm area itself but most likely will involve a bay or region depending on species and population dynamics.
Duration	*Short* to *long term* – Exclusion may be temporary for migrating species or until resident species habituate to the structures and/or activities, or avoidance may be for the farms' duration to permanent.
Management options	Site selection to minimise or avoid the likelihood of spatial overlap with species' home ranges, critical breeding and foraging habitats and/or migration routes. Continuous monitoring of presence (and absence) of marine mammal species in the vicinity or general region of the farm site is recommended. Monitoring could also include detailed observations of any time spent under or around the farm structure, which may later be compiled and analysed by experts.
Knowledge gaps	Ongoing research into the home ranges and locations of important habitats for most populations and sub-populations of marine mammal species in New Zealand. Siting guidelines should be developed to promote clarity, consistency and precaution in the permit process. The criteria should be revisited and amended periodically to respond to new information and technology.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

Overseas research highlights that the nature of habitat exclusion greatly depends on the type of culture method and the particular species of marine mammal present in the cultivation area (e.g., Kemper et al. 2003; Watson-Capps & Mann 2005; Heinrich 2006; Ribeiro et al. 2007). Given that some marine mammal exclusion effects occur, the question remains as to the significance of this effect for particular species. It will therefore be important that farm locations are carefully selected so as to minimise the potential for adverse effects.

Table 4.9: Entanglement caused by farming of lower trophic level species.

Description of effect(s)	Physical interactions between aquaculture and marine mammals can lead to an increased risk of entanglement in structures or non-biological wastes from farm production. The risk of entanglement increases as it tends to attract predators to any associated aggregations of wild fish.
Spatial scale	*Local* to *regional* scale – Impact occurs at site but may have larger scale consequences at the population level depending on the species status and population range.
Duration	*Short* to *long term* – Minor injury to individual to death of critically endangered animal that can have long term consequence for vulnerable populations.
Management options	Site selection to minimise or avoid the likelihood of spatial overlap with species' home ranges, critical breeding and foraging habitats and/or migration routes. Continuous monitoring of presence (and absence) of marine mammal species in the vicinity or general region of the farm site, detailed observations of any time spent under or around the farm structure, compiled and analysed by experts. Strict guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines, buoys or floats. Provision for disposal and/or processing of non-biological wastes to minimise the risk of attraction and entanglement.
Knowledge gaps	Ongoing research into the home ranges and locations of important habitats for most populations and sub-populations of marine mammal species in New Zealand. Better reporting and improved data on factors (i.e., location to haul-outs or farm design) affecting entanglement rates. Ongoing research into the types of design and maintenance features, and operational procedures that minimise entanglement risk.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

Marine farming structures can occupy a large portion of the water column effectively creating three-dimensional structures while other forms of farming can occupy a significant area of intertidal habitat that resident marine mammals have to actively navigate or manoeuvre around (Würsig & Gailey 2002; Markowitz et al. 2004; Watson-Capps & Mann 2005). Components of marine farming structures such as loose, thin lines or buoys and floats pose the greatest entanglement threat to marine mammals as evident by reports from both New Zealand and overseas. As such, potential entanglement risks at New Zealand farms are likely to be low when lines are kept under considerable tension and the lack of loose lines limited or when located within intertidal regions. However, based on overseas evidence, the risk of entanglement occurring would obviously increase if a farm were situated within the historical migratory paths of New Zealand whales.

Table 4.10: Underwater noise caused by farming of lower trophic level species.

Description of effect(s)	Underwater noise associated with regular, ongoing farm activities (including vessels) may either exclude or attract marine mammals. Whales and particular dolphin species tend to be more sensitive to such disturbances, while pinnipeds and other dolphin species (such as common and bottlenose dolphins) may actually be attracted to the novel noise source.
Spatial scale	*Local* to *regional* scale – Impact occurs at the site but the scale is dependent on the frequency and intensity of sounds generated and the hearing and/or vocalising range of the mammal species.
Duration	*Short* to *long term* – Dependent on the frequency and intensity of sounds generated and the hearing and/or vocalising range of the species.
Management options	Site selection to minimise or avoid the likelihood of spatial overlap with range restricted species' home ranges, critical breeding and foraging habitats and/or migration routes. Continuous monitoring of the presence (and absence) of marine mammal species in the vicinity or general region of the farm site, detailed observations of any time spent under or around the farm structure, compiled and analysed by experts. Monitor and regularly review on-farm management and maintenance practices to minimise the risk of underwater noise pollution.
Knowledge gaps	Siting criteria should be developed to promote clarity, consistency and precaution in the permit process. The criteria should be revisited and amended periodically to respond to new information and technology. Long-term health implications for marine mammals associated with certain underwater noise exposure.

* Italicised text in this table is defined in chapter 1 – Introduction.

Summary

Associated closely with habitat exclusion is habitat degradation in the form of underwater noise disturbance. The level and persistence of any associated underwater noises with aquaculture may be minimal relative to other underwater noise sources, such as commercial vessels, but will vary according to farm features (e.g., type, size), habitat characteristics (e.g., location, depth, types of bottom sediments, shape of coastline) and compounding factors, such as the number of farms and/or other noise sources in nearby regions.

Currently, no New Zealand or overseas studies have specifically analysed noise production in association with aquaculture and marine mammals. Overseas research has demonstrated that whales may be more sensitive to increased noise production in their habitats or along migration routes (Gard 1974; Herman 1979; Bryant et al. 1984; Glockner-Ferrari & Ferrari 1990), however, most odontocete (i.e., toothed whales and dolphins) and pinniped species demonstrate few avoidance behaviours and considerable tolerance of most underwater noises with a few exceptions (Richardson 1995). In fact, the curiosity and temporary attraction of dolphins to boat noise will be familiar to most recreational or commercial vessel users, and this has been recognised in the literature (Carwardine 1995; Dawson et al. 2000).

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