Environment Waikato Technical Report 2008/27

Evaluation of the Impacts of Finfish Farming on Marine Mammals in the Firth of Thames

www.ew.govt.nz
ISSN 1172-4005 (Print)
ISSN 1177-9284 (Online)

Environment Waikato
REGIONAL COUNCIL

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June 2008

Document #: 1318922

Approved for release by:
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Disclaimer

Acknowledgement

Rob Chappell of the Department of Conservation kindly provided the killer whale sightings data in section 3.3, in addition to stranding records summarised in section 3.6 and table 2. Previous stranding data were provided by Debbie Steel (formerly University of Auckland and currently Oregon State University). Thanks to Grant Hopkins of the Cawthron Institute in Nelson for providing the photos in figure 3.

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Executive summary

Aquaculture in New Zealand is dominated by the Greenshell™ mussel, however it is expected that finfish aquaculture will expand in coming years. Environmental Waikato is scoping a plan change that would allow finfish aquaculture to be developed within existing aquaculture management areas (AMA) currently used for mussel farming. This report seeks to identify those marine mammal species most likely to be at risk from such activities. Impacts, associated risks, and ecological consequences are identified and discussed.

The marine mammal species most likely to be encountered in the Firth of Thames include: short-beaked common dolphins (*Delphinus delphis*); bottlenose dolphins (*Tursiops truncates*); killer whales (orca; *Orcinus orca*); Bryde's whales *(Balaenoptera edeni/brydei*); and various species of beaked whales. Additionally, the neighbouring Hauraki Gulf contains a high diversity of marine mammals, including those already listed, as well as: humpback whales (*Megaptera novaeangliae*); southern right whale (*Eubalena australis*); pilot whales (*Globicephala* sp.); and minke whales (*Balaenoptera acutorostrata/bonaerensis*).

Three possible effects of finfish aquaculture on marine mammals were identified: entanglement; habitat exclusion; and vessel disturbance.

Entanglement will be a greater risk for small cetaceans such as short-beaked common dolphins and bottlenose dolphins. Entanglement risk is currently well-managed by the aquaculture industry in areas of New Zealand where salmon farms exist, and there have been only three known cases of dolphin fatalities after becoming entangled in predator nets in over 25 years. Operational practices and net designs have improved such that entanglement should be a minor risk, however this will need to be monitored.

Habitat exclusion and vessel disturbance are potential risks for many marine mammals that utilise the Firth. A paucity of data makes assessment difficult; however clear mitigation strategies exist should future surveys and monitoring determine these risks to be significant.

1 Introduction

Aquaculture in New Zealand is currently worth around $320 million annually[1], and the New Zealand aquaculture industry aims to increase this figure to $1 billion by 2025. Globally, the importance of aquaculture appears to be increasing, with expectations that by 2030 aquaculture production will match wild fisheries catch[2]. Against this backdrop of increasing economic performance and a drive to expand, the aquaculture industry in New Zealand has expressed a desire to maintain environmental sustainability.

The New Zealand aquaculture industry is still dominated by the production and sales of Greenshell™ mussels; however King Salmon is also an important component, with established operations in the Marlborough Sounds; Stewart Island; and Akaroa Harbour (Banks Peninsula). While the finfish sector of New Zealand's aquaculture industry has been relatively small to date, there is significant interest in developing new sites for salmon farming, in addition to trialling new species such as kingfish.

There are currently 1500 hectares of space allocated to marine farming within the Waikato region, with much of this already developed for mussel and oyster farming. Environment Waikato recognises the importance of finfish farming to the continued development of aquaculture in their region, but also acknowledge their obligations under the Resource Management Act to minimise adverse effects on indigenous flora and fauna.

Environment Waikato is considering a plan change that would allow finfish farms within the existing AMA in the Firth of Thames and around the Coromandel Peninsula (figure 1). The goal of this report is to identify species of marine mammals which may be potentially affected by farming of finfish or other species, as opposed to established mussel and oyster farms. Potential effects on these species will be discussed, together with likely risk of these effects occurring; and their ecological consequences.

2 Data sources

As with many areas of New Zealand, there are few systematic sightings data[3] available to describe marine mammal usage of the Firth of Thames. Information is therefore obtained from sighting records held by the Department of Conservation; and stranding records. A similar exercise was undertaken in 2006 (Du Fresne 2006), and those results provide a useful starting point here. Updated killer whale sighting records and stranding data were provided by Rob Chappell (Department of Conservation, Auckland).

[1] http://www.seafood.co.nz/aquaculture, accessed 05 May, 2008
[2] The New Zealand Aquaculture Strategy.
[3] i.e. sightings from systematic marine mammal surveys; as distinguished from stranding data, and sightings reported by members of the public.

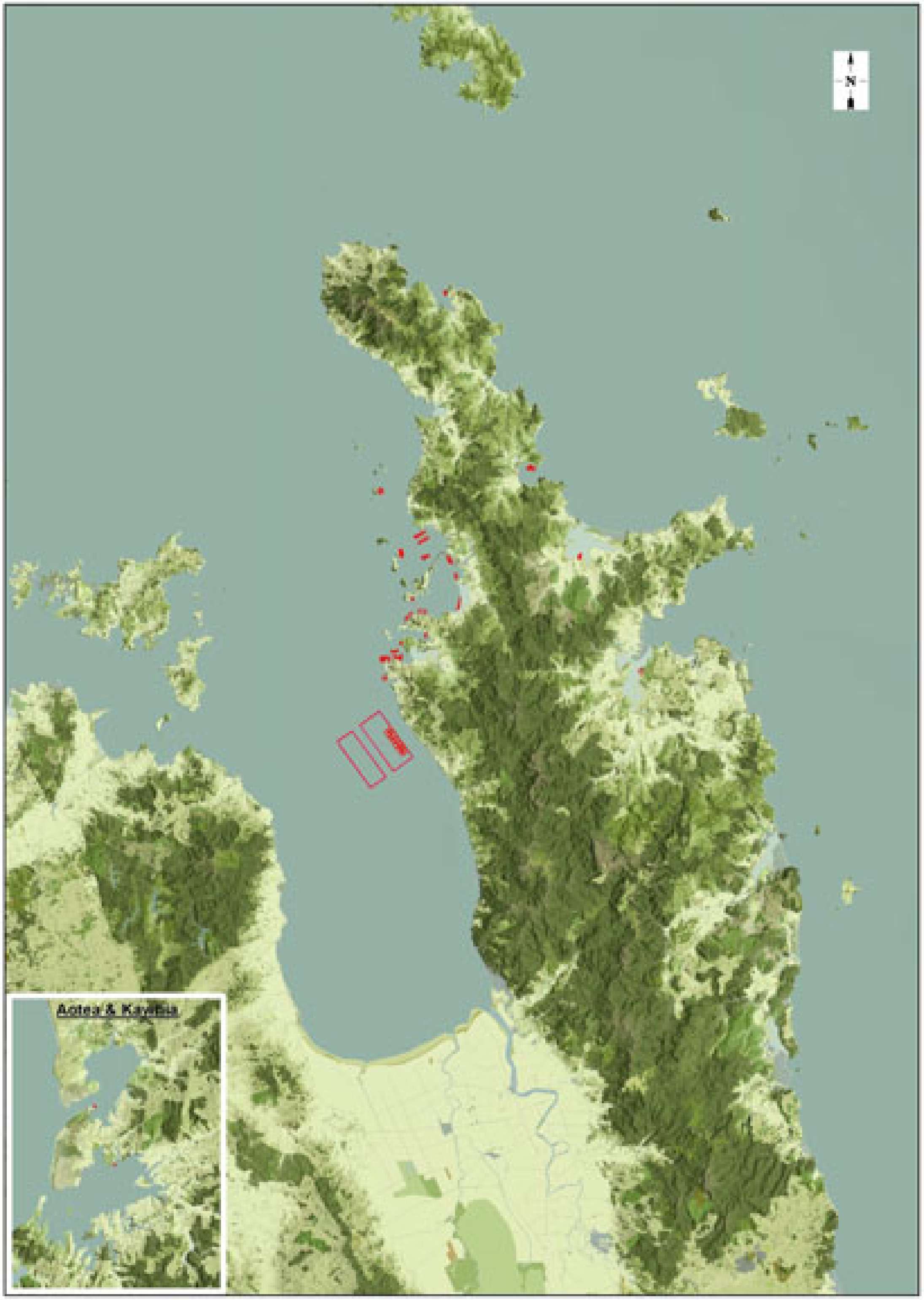

Figure 1: **Map showing existing aquaculture management areas within the Waikato region. Figure provided by Environment Waikato; 14 April, 2008.**

3 Marine mammal species encountered in the Firth of Thames

The list of 'primary' species compiled by Du Fresne (2006; and see table 1) covers those marine mammal species with confirmed sightings in the Firth of Thames; as well as species known to inhabit these waters. For the purpose of this report, beaked whales have been considered as one group. A summary of current knowledge is provided for each species, under the general headings of: status & threats; distribution; life history; and behaviour. For each species, a global status was obtained from the IUCN Red List of Threatened Species (see appendix 1 for definitions). New Zealand status was obtained from Hitchmough et al. (2005; see appendix 2 for definitions). General biological and ecological information came primarily from Jefferson et al. (2008); and Perrin et al. (2002). Literature searches were performed to provide further species-, issue-, and New Zealand-specific information.

Table 1: The primary cetacean species likely to be encountered in the Firth of Thames

Common name	Scientific name
Short-beaked common dolphin	*Delphinus delphis*
Bottlenose dolphin	*Tursiops truncatus*
Killer whale (orca)	*Orcinus orca*
Bryde's whales	*Balaenoptera edeni/brydei*
Beaked whales	*Genus: Berardius, Ziphius, Hyperoodon, Tasmacetus, Mesoplodon*

3.1 Short-beaked common dolphins – *Delphinus delphis*

Status & threats

- Global: lower risk - least concern[4].
- New Zealand: not threatened (secure overseas).

Though not considered globally threatened, many regional populations of common dolphins are thought to be in serious trouble, often as a result of incidental and directed catch (Reeves et al. 2003). For example, common dolphins in the Mediterranean are considered endangered (Jefferson et al. 2008), though in this case, it is possibly due to overfishing and prey depletion (Bearzi et al. 2006). Common dolphins are targets for tourism in some areas of New Zealand (Bay of Plenty/Coromandel, as well as Hauraki Gulf; Neumann & Orams 2005), which can result in behavioural changes (Stockin et al. 2008). Common dolphins are occasionally incidentally caught during jack mackerel trawls in New Zealand waters (Du Fresne et al. 2007), and appear to be susceptible to recreational bycatch in the Hauraki region (K. Stockin, Massey University, pers. comm.).

Distribution

Common dolphins are regularly seen from Bay of Islands to Kaikoura (Neumann, 2001), but also as far south as Fiordland (Lusseau & Slooten 2002). Common dolphins are the most abundant cetacean species in the Hauraki Gulf, and appear to be uniformly spread through-out the Gulf. Year round occurrence in this area and a high re-sighting rate amongst the 500 or so identified individuals indicates some degree of

4 Cetacean Specialist Group 1996. *Delphinus delphis*. In: IUCN 2007. *2007 IUCN Red List of Threatened Species.* <www.iucnredlist.org>. Downloaded on 04 May 2008.

residency in this area (Neumann & Orams 2005; K. Stockin, Massey University, pers. comm.). Neumann et al. (2002) noted higher abundance and site fidelity for common dolphins in Hauraki Gulf than in Mercury Bay (Coromandel Peninsula). Whereas elsewhere in the World common dolphins are thought of as a pelagic, open water species; in the Hauraki Gulf region they appear to inhabit coastal waters, and can be encountered in waters as shallow as 7m.

Life History

Calving intervals are 1-3 years (Jefferson et al. 2008). Age of sexual maturity seems to vary between populations, and ranges from 3 to 12 years for males, and 2 to 7 years for females (Perrin 2002). Longevity is thought to be at least 25 years (Jefferson et al. 2008). Contaminant loads of common dolphins in New Zealand are thought to be similar to Hector's dolphins (Stockin et al. 2007). Oceanic dolphins are often thought to have less exposure to point source pollution, and the relatively high concentrations of chlorinated biphenyls in common dolphins reported by Stockin et al. (2007) may be reflective of their preference for coastal waters. The mean pollutant transmissions between mother and calf were 42% and 46% for DDTs and PCBs (respectively).

Behaviour

Common dolphins are often encountered in large groups. Neumann & Orams (2005) report group sizes in Mercury Bay of 2 to 400, while O'Callaghan & Baker (2002) reported a mean group size in Hauraki Gulf of 117. Associations with other marine mammal species (e.g. Bryde's whales in the Hauraki Gulf; O'Callaghan & Baker 2002) are not uncommon.

Common dolphins feed on a variety of fish species (Neumann & Orams, 2005), including arrow squid (*Nototodarus* sp.), false trevally (Lactariidae; Stockin et al. 2005), and pilchards (K. Stockin, Massey University, pers. comm.). In the Bay of Plenty (and elsewhere in the world) common dolphins can undertake seasonal movements, which may be related to distribution of prey species (Neumann 2001; Neumann et al. 2002; Neumann & Orams 2005). It is not yet known if common dolphins in the Hauraki Gulf behave in a similar manner.

Common dolphins in the Bay of Plenty/Coromandel area, as well as Hauraki Gulf, are targeted by commercial tour operators. Behavioural responses of dolphins to boats seem to follow a previously observed pattern in Hector's dolphin (Bejder et al. 1999) of attraction-neutral-avoidance. In other words, dolphins are initially attracted to the vessel; become neutral towards it over time; and will eventually actively try to avoid the vessel. Additionally, a change in behaviour of feeding to travelling indicates that at least some of the time, dolphin activities may be disturbed by the presence of boats (Neumann and Orams 2005). Indeed, Stockin et al. (2008) found that foraging and resting bouts of common dolphins in the Hauraki Gulf were significantly disrupted by interactions with tour boats. Additionally, foraging dolphins took longer to return to their initial behavioural state after an interaction, with dolphins instead showing a preference towards socializing and milling.

3.2 Bottlenose dolphins – *Tursiops truncatus*

Status & threats

- Global: data deficient[5].
- New Zealand: range restricted (secure overseas).

Bottlenose dolphins (*Tursiops truncatus*) are widely distributed through out the world, inhabiting tropical and temperate waters (Wells & Scott 2002). While the species is not in danger of global extinction (Jefferson et al. 2008), several smaller, localised populations (including the Mediterranean and Black Seas; Sri Lanka; Peru; Taiwan and

[5] Cetacean Specialist Group 1996. *Tursiops truncatus*. In: IUCN 2007. *2007 IUCN Red List of Threatened Species.* <www.iucnredlist.org>. Downloaded on 04 May 2008.

Japan) are known or suspected to be under pressure from human activities such as directed and incidental catch, environmental degradation and live captures (Reeves et al. 2003).

In New Zealand waters, the primary threat to bottlenose dolphins is tourism interactions (Suisted & Neale 2004), with well developed bottlenose dolphin-focussed industries existing in Milford and Doubtful Sounds (Fiordland); and the Bay of Islands. The impacts and potential effects of this are discussed below, under 'behaviour'. Recently, other factors such as anthropogenic freshwater input (via the Manapouri Power Station tailrace) and over-fishing have been suggested as possible mechanisms behind an apparent decline in bottlenose dolphins in Doubtful Sound (Currey et al. 2007).

Distribution

Within New Zealand there are three discontinuous groupings of bottlenose dolphins: eastern North Island; northern South Island; and Fiordland. The southernmost resident bottlenose dolphins in the world are found in Fiordland, where they comprise three subpopulations[6]: those found in Doubtful Sound, Milford Sound and Dusky Sound. It has been suggested that there is little interchange among the three Fiordland sub-populations (Lusseau et al. 2003). In comparison, photo-identification catalogues from Hauraki Gulf and the Bay of Islands show that the majority of dolphins sighted in the Hauraki Gulf have been seen in both areas. Around 70% of the individuals match between the two areas, suggesting that this is a wide-ranging population covering the north-eastern part of the North Island (R. Constantine, University of Auckland, pers. comm.).

Life History

Bottlenose dolphins are thought to live to a maximum age of around 45 (males) to 50 years (females). In Doubtful Sound, at least one known individual seen in 2003 was likely aged between 30 and 40 years (Boisseau 2003).

Males reach sexual maturity at around 9-14 years, but do not achieve breeding status until later; females reach sexual maturity at 5-13 years. Gestation period is approximately 1 year. Calving in New Zealand populations appears to peak during summer months (Haase & Schneider 2001; Constantine 2002; Boisseau 2003). Elsewhere bottlenose dolphins also tend to give birth in spring or summer (Mann et al. 2000; Wells & Scott 2002). Calving intervals are generally three to six years (Mann et al. 2000; Wells & Scott 2002), though can be shorter particularly if a calf dies within the first year (Haase & Schneider 2001; Mann et al. 2000).

Calves achieve most of their growth during suckling (Wells & Scott 2002). Weaning occurs at between three and six years (Wells & Scott 2002), though can take up to nine years (Mann et al. 2000).

The annual birth rate in New Zealand populations is typically in the order of 5-8% (Constantine 2002; Boisseau 2003), though can reach as high as 11-14% (Haase & Schneider 2001; Constantine 2002).

Behaviour

Constantine (2002) found that the majority (79.6%, n = 160) of group size of bottlenose dolphins in the Bay of Islands was 2-20. Similarly, O'Callaghan & Baker (2002) encountered an average group size of 13.8 (n = 9) in the Hauraki Gulf.

Bottlenose dolphins tend to feed primarily on fish and, to a lesser extent, cephalopods throughout much of their range (Cockcroft & Ross 1990; Barros & Odell 1990; Blanco et al. 2001; Gowans et al. 2008). However, different social groups have been shown to

[6] Sub-populations as used here is defined by Hitchmough *et al.* (2005) as "Geographically or otherwise distinct groups in the population between which there is little exchange (typically one successful migrant individual or gamete per year or less)...." A population is defined by Hitchmough *et al.* (2005) as "The total number of individuals of the taxon that are resident, or breed in New Zealand."

have different prey preferences, which tend to reflect local prey distribution (Wells 2003, cited in Gowans et al. 2008). Additionally, bottlenose dolphins employ a diverse repertoire of feeding behaviours that are thought to reflect prey avoidance strategies, and may forage as a group or individually (Connor et al. 2000).

Studies on impacts of bottlenose dolphin tourism in the Bay of Islands have shown that dolphins increased avoidance behaviour towards swimmers over time (Constantine 2001); and that resting behaviour decreased as the number of tour boat trips increased (Constantine et al. 2004).

Studies in Fiordland have also shown a number of short-term responses to tour boats, including: decreases in resting behaviour (Lusseau 2003a; b); and increase in dive times and horizontal travel (*i.e.* avoidance; Lusseau 2004). Bottlenose dolphins in Milford Sound appear to exhibit different avoidance strategies during periods of heavy boat traffic. Specifically, if the dolphins experience a time lag between interactions of fewer than 68 minutes, area-avoidance becomes energetically cost-effective, and dolphins spend less time in Milford Sound (Lusseau 2004). This is because if dolphins are interacting with, or trying to avoid vessels, there is an associated cost, as they will tend to stop socialising, resting or feeding. With sufficient lag time between vessel interactions, this cost remains lower than that associated with leaving the area. However when this lag reduces to fewer than 68 minutes, it becomes energetically beneficial for the dolphins to avoid the area where there are tour vessels.

Despite attempts to model the long-term, population level effects of these responses (Lusseau et al. 2006), such effects are not well understood at present. However in Western Australia, studies have suggested that tour boat pressure can result in a decline in bottlenose dolphin population (Bejder et al. 2006).

3.3 Killer whales, or orca – *Orcinus orca*

Status & threats

- Global: lower risk – conservation dependent[7].
- New Zealand: nationally critical (secure overseas, data poor).

The iconic killer whales do not appear to be globally threatened, however it is well known that several small, regional populations of killer whales are vulnerable to over-exploitation and habitat degradation (Reeves et al. 2003; Jefferson et al. 2008). For example, killer whales are still killed in several fisheries, and can also become entangled in fishing gear. Live captures for oceanaria also still occur and can put populations under further pressure (Jefferson et al. 2008).

Within New Zealand, entanglements in fishing gear and boat strikes are probably the greatest threats to killer whales (Visser 1999a). Although Suisted & Neale (2004) conclude that "no significant human induced mortality is known", the killer whale population of New Zealand is small and therefore unlikely to be able to sustain high numbers of non-natural mortalities.

Distribution

There are potentially three sub-populations of killer whales in New Zealand waters: North and South Island populations; and an additional group that appears to move between the two islands (Visser 2000). Some killer whales have been known to travel an average of 170 km/day, covering up to 4000 km. The New Zealand killer whale population is thought to number around 200 (Suisted & Neale, 2004).

Figure 2 shows sighting locations of killer whales in the Firth of Thames/Coromandel region from 1994 – 2008. It is not surprising that there are 'hotspots' of sightings near

[7] Cetacean Specialist Group 1996. *Orcinus orca*. In: IUCN 2007. *2007 IUCN Red List of Threatened Species.* <www.iucnredlist.org>. Downloaded on 04 May 2008.

centers of human activity (e.g. Coromandel Harbour). This is not likely to reflect true distribution patterns, but does indicate that killer whales are frequent visitors to the area.

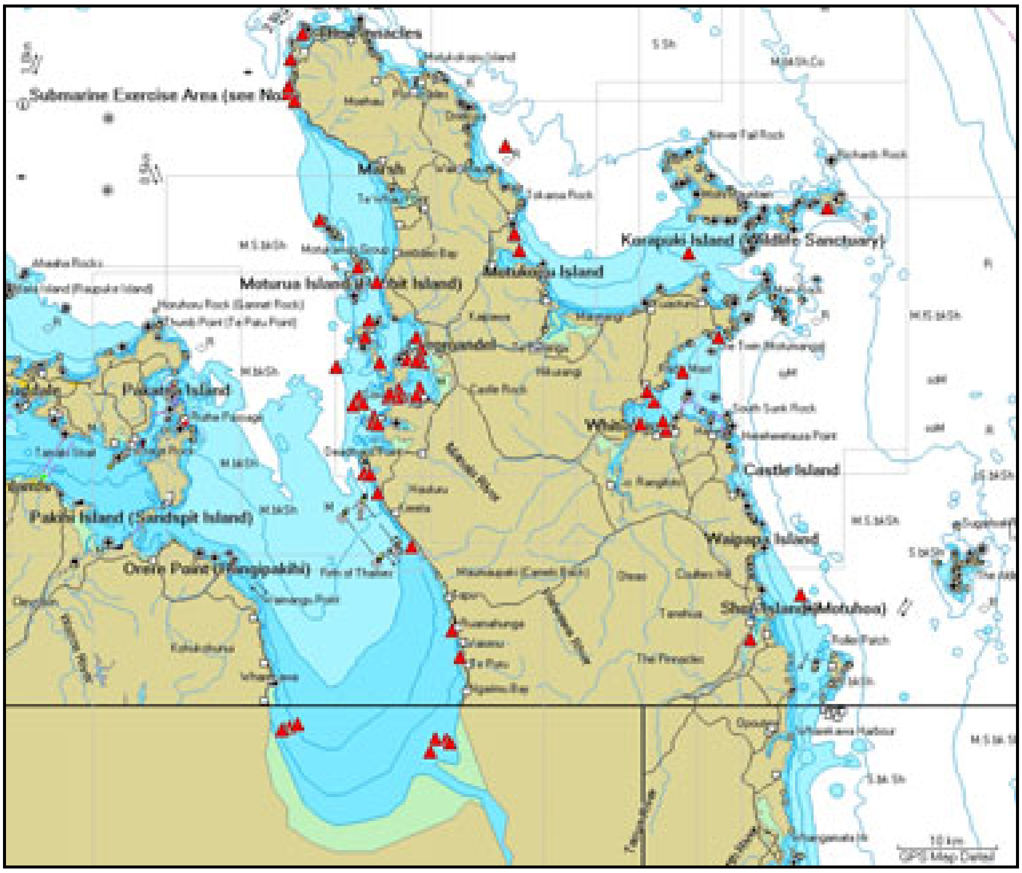

Figure 2: **Locations of Orca sightings (▲) in the Firth of Thames & Coromandel region, 1994 – 2008 (provided by R. Chappell, Department of Conservation, Auckland). Plotted using MapSource and BlueChart Pacific v9.5.**

Life History

Female killer whales live to a maximum of about 80 to 90 years, attaining sexual maturity at between 11 and 16 years, and reaching reproductive senescence at about 40 years (Ford 2002). Males on the other hand, reach sexual maturity at about 15 years but are thought to live to a maximum of 50 to 60 years.

Gestation in killer whales lasts for about 15 to 18 months, with weaning of young at about 1 or 2 years. Calving intervals can be around 5 years, thus each reproductive female may produce 5 or 6 calves over a 25 year reproductive span.

Behaviour

Killer whales in New Zealand appear to forage on rays, sharks, fin-fish and other cetaceans (Visser 2000). Their habit of benthic foraging for rays appears to be unique world-wide (Visser 1999b).

3.4 Bryde's whale – Balaenoptera edeni/brydei

Status & threats

– Global: data deficient[8].
– New Zealand: nationally critical (secure overseas, data poor).

[8] Cetacean Specialist Group 1996. *Balaenoptera edeni*. In: IUCN 2007. *2007 IUCN Red List of Threatened Species.* <www.iucnredlist.org>. Downloaded on 04 May 2008.

Though considered 'nationally critical', internationally, Bryde's whales are considered data deficient; primarily due to difficulties in determining precisely how many species and populations exisit (Reeves et al. 2003). *B. edeni* is the pygmy form of Bryde's whale which rarely exceeds 11.5m in length, whereas *B. brydei* is the ordinary form reaching between 14.6m (males) and 15.6m (females) in length. A third species, *B. omurai*, was described in 2003, further adding to the taxanomic confusion (Jefferson et al. 2008); though it should be noted this species' distribution is not thought to overlap with New Zealand waters. Suisted & Neale (2004) list *B. edeni* as being present in New Zealand waters, however Hitchmough et al. (2005) acknowledge that either form could be present. Lloyd (2003) also acknowledges a degree of uncertainty as to which form has suffered entanglement mortality in mussel spat collection ropes (see below), while Lloyd (2003) and O'Callaghan & Baker (2002) note that *B. brydei* is more likely to be the form present in New Zealand waters. Recently analysed genetic data suggest the Bryde's whales encountered in the Hauraki Gulf are the common offshore form, *B. brydei* (Wiseman et al. 2005). Baker & Madon (2007) also refer to *B. brydei* in their summary of distribution in the Hauraki Gulf and northeastern New Zealand.

Bryde's whales are still killed by some artisanal whalers, and recently by the Japanese in the North Pacific. Indeed, Japan has expressed an interest in resuming commercial whaling of the species (Reeves et al. 2003); and Bryde's whale meat has been confirmed as being on sale in Japan and South Korea (Baker et al. 2000). Elsewhere, habitat modification and noise disturbance are considered the most serious threats (Jefferson et al. 2008).

Bryde's whales in New Zealand waters are susceptible to boat strike (Wiseman et al. 2003; Baker & Madon 2007), tourism-related impacts, and entanglement. Behrens and Constantine (2008) reviewed stranding data held at the Museum of New Zealand (Te Papa Tongarewa) and Department of Conservation. They found that between 1989 and 2007, 13 out of 38 Bryde's whale carcasses reported from northern New Zealand or just over one third, were confirmed or suspected to have died from ship strike injuries. Lloyd (2003) reports that since 1996 two Bryde's whales have reportedly died as a result of entanglement in mussel spat collection ropes.

Distribution

Bryde's whales in New Zealand waters appear to be most common in the Hauraki Gulf (Suisted & Neale, 2004), but can be seen along the entire northeastern coast of New Zealand from Hauraki Gulf to North Cape (Baker & Madon 2007). Baker & Madon (2007) suggest that sightings in the Gulf tend to be higher during spring and summer months. Additionally, Bryde's whales are seen regularly in the Firth of Thames (Du Fresne 2006), though unfortunately the recent surveys of Baker & Madon (2007) only extended as far south as Thumb Point (Waiheke Island), so there are no systematic distribution data for the Firth.

Other reports suggest Bryde's whales can be encountered in the Northland (Constantine 1999) and Bay of Plenty regions. Bryde's whales are not known to undertake large migrations, but in temperate waters they appear to make local, seasonal movements. Repeated sightings of some individually identified whales in the Hauraki Gulf indicate that at least some animals are semi-resident in this area (Wiseman et al. 2005).

Bryde's whales sighted from a tour vessel operating in the Hauraki Gulf during summer 2000/01 were mostly seen individually and in loose aggregations (O'Callaghan & Baker 2002). They were sighted mostly around the 40m depth contour, often during feeding behaviours. Baker & Madon (2007) concluded that whale densities were highest in the inner part of the Gulf, in waters warmer than 14°C.

From 2001 to 2006, Wiseman (2008) conducted a number of boat-based surveys of Bryde's whales in the Hauraki Gulf. Open and closed population estimates of 46 and 159 (respectively) indicate a potentially small population, with an unclear degree of isolation. The Bryde's whales in this area are probably part of an open population (Wiseman 2008), but there are currently no population estimates for the wider northern New Zealand population (Behrens and Constantine 2008).

Life History

Sexual maturity is reached at length 11-11.4m (males) and 11.6-11.8m (females); corresponding to an average age of about 7 years (Kato 2002).

Baker & Madon (2007) suggest that calving likely occurs in late winter and early spring, either in New Zealand waters or the nearby oceanic Pacific. Gestation periods are about 11 months, with an average reproductive cycle of 2 years (Kato 2002).

Behaviour

Baker & Madon (2007) observed small pods of Bryde's whales feeding primarily on small fish, but speculate that crustaceans also form part of their diet. Baker & Madon (2007) also observed common dolphins, bottlenose dolphins, gannets, shearwaters, petrels and terns associating with Bryde's whales during feeding bouts. Travelling Bryde's whales were usually seen singly (Baker & Madon 2007).

3.5 Beaked whales (various species)

Status & threats

- Global: predominantly data deficient.
- New Zealand: data deficient[9].

The beaked whales have been considered as one group here for two reasons: 1) little is known about most beaked whale species, especially with specific reference to New Zealand waters; and 2) conservation issues for most species are likely to be similar. There are currently 21 recognised species of beaked whales, all belonging to the family Ziphiidae (Jefferson et al. 2008). Beaked whales of the genus *Mesoplodon* (of which there are 14, including Gray's beaked whale; Hector's beaked whale; and the strap-toothed beaked whale – see table 1) are the most poorly-known of all the large mammals (Jefferson et al. 2008), with many listed as 'data deficient' by IUCN.

Conservation issues for beaked whales include ship-strike; accumulation of biocontaminants; entanglement in deep-water gillnets; ingestion of debris; and sensitivity to underwater noise (such as Naval sonar exercises) which have been implicated in mass mortality and stranding events (Cox et al. 2006; MacLeod & Mitchell 2006; Jefferson et al. 2008).

Distribution

Distribution data for beaked whales are generally sparse, with few at-sea sightings. Table 2 summarises all beaked whales with known or suspected distributions that overlap with New Zealand waters (taken from Jefferson et al. 2008). New Zealand appears to be a stronghold of beaked whales and is especially known as having high numbers of Gray's beaked whale (Dalebout et al. 2004; Jefferson et al. 2008). New Zealand was recently identified as having the highest diversity out of 23 key areas globally for beaked whales, with records confirming at least 11 species from five genera (Macleod & Mitchell 2006).

[9] Especially: Gray's beaked whale; Hector's beaked whale; Straptooth whale; Southern bottlenose whale.

Table 2: **Beaked whales with known or suspected distribution overlap with New Zealand waters (Jefferson et al. 2008).**

Common name	Scientific Name	Distribution
Arnoux's beaked whale	*Berardius arnuxii*	Circumpolar, mostly south of 40°S
Cuvier's beaked whale	*Ziphius cavirostris*	All oceans from tropics to polar waters
Southern bottlenose whale	*Hyperoodon planifrons*	Circumpolar, south of 30°S, esp. 57°S - 70°S
Shepherd's beaked whale	*Tasmacetus shepherdi*	Circumpolar, temperate, south of 30°S
Blainville's beaked whale	*Mesoplodon densirostris*	Temperate and tropical waters, all oceans
Gray's beaked whale	*Mesoplodon grayi*	Circumpolar, cool temperate, south of 30°S. 'Hotspot' between NZ and Chatham Islands
Ginko-toothed beaked whale	*Mesoplodon ginkodens*	Temperate and tropical waters of Indo-Pacific
Hector's beaked whale	*Mesoplodon hectori*	Possibly circumpolar, cool temperate
True's beaked whale	*Mesoplodon mirus*	Possibly circumpolar, cool temperate
Strap-toothed beaked whale	*Mesoplodon layardii*	Circumpolar, cold temperate, 35°S - 60°S
Andrew's beaked whale	*Mesoplodon bowdoini*	Circumpolar, cool temperate, 32°S - 55°S (over half of stranding records from NZ).
Spade-toothed beaked whale	*Mesoplodon traversii*	Poorly known but possibly circumpolar, south of 30°S

Life History

The few data on life history characteristics of beaked whales come primarily from stranded animals and whale fisheries, and were recently summarized by MacLeod & D'Amico (2006). While maximum ages of 84 years (male) and 54 years (female) have been recorded, other recorded ages have ranged from 27 to 39 years. Sexual maturity seems to occur between 7 and 15 years, while gestation can last from 12 to 17 months.

Behaviour

MacLeod & D'Amico (2006) provide a comprehensive review on various behavioural aspects of beaked whales. Group sizes seem to be 1-20 individuals for many species (e.g. *Mesoplodon* spp.); while groups of up to 100 have been recorded for Longman's beaked whale and *Berardius* spp. Beaked whales are generally thought of as long and deep divers, spending much of their time underwater. Indeed, occurrence of beaked whales is often linked to seabed features such as slopes, canyons, escarpments and oceanic islands. Given their diving behaviour and apparent habitat preferences, it is perhaps not surprising that cephalopods (e.g. squid) and other deep water species (below 200m) are preferred prey items.

3.6 Known stranding events in the Firth of Thames

While stranding data do not necessarily reflect habitat usage, especially in the case of beachcast animals (those that have washed up dead), they can none-the-less provide a useful indication of the make-up of regional species assemblages. The data in Table 3 were provided by D. Steel (formerly Unversity of Auckland; currently Oregon State University) and R. Chappell (Department of Conservation, Auckland).

Table 3: Cetacean strandings in the Firth of Thames, 1993 – 2008.

Common name	Scientific name	Date	Location
Bryde's whale	*Balaenoptera edeni*	Mid-late 1994	Firth of Thames
Bryde's whale	*Balaenoptera edeni*	18 Nov 1995	Firth of Thames
Bryde's whale	*Balaenoptera edeni*	07 Nov 1997	Miranda
Bryde's whale	*Balaenoptera edeni*	07 Nov 1997	Miranda
Bryde's whale	*Balaenoptera edeni*	30 Aug 2004	Between Waitakaruru and Kaiaua
Bryde's whale	*Balaenoptera edeni*	23 Jun 2005	Colville Bay
Common dolphin	*Delphinus delphis*	24 Dec 2004	Te Kouma
Common dolphin	*Delphinus delphis*	23 Apr 2005	Between Waikawau and Te Mata
Common dolphin	*Delphinus delphis*	03 Jul 2005	Brickfield Bay
Common dolphin	*Delphinus delphis*	19 Sep 2005	Te Puru
Common dolphin	*Delphinus delphis*	03 Han 2006	Waitete Bay
Gray's beaked whale	*Mesoplodonn grayi*	21 Feb 2005	Waikawau Bay
Hector's beaked whale	*Mesoplodon hectori*	02 Feb 2007	Port Jackson
Long finned pilot whale	*Globicephala melas*	30 Oct 1997	Kawakawa
Long finned pilot whale	*Globicephala melas*	05 Jun 2005	Miranda
Long finned pilot whale	*Globicephala melas*	02 Feb 2007	East of Orere Point
Southern bottlenose whale	*Hyperoodon planifrons*	07 Dec 1994	Firth of Thames
Southern bottlenose whale	*Hyperoodon planifrons*	04 Jan 2005	Miranda
Southern bottlenose whale	*Hyperoodon planifrons*	04 Jan 2005	Miranda
Southern minke whale	*Balaenoptera bonaerensis*	12 Aug 2005	Motutapere Island
Straptooth whale	*Mesoplodon layardii*	30 May 1995	Kaiaua
Straptooth whale	*Mesoplodon layardii*	05 June 1997	Thames
Straptooth whale	*Mesoplodon layardii*	11 July 2001	Firth of Thames
Pygmy sperm whale	*Kogia breviceps*	26 Mar 2006	Thames
Pygmy sperm whale	*Kogia breviceps*	26 Mar 2006	Thames

These data (combined with various sighting reports) indicate that many cetaceans from the wider Hauraki Gulf area venture into the Firth of Thames.

3.7 Species known from Hauraki Gulf

In addition to the various species known to utilise the Firth of Thames, several other marine mammal species have been seen in the neighbouring waters of Hauraki Gulf, and could potentially visit the waters of the Firth occasionally. These species are summarised in the table below.

Table 4: Other marine mammal species known to occur in Hauraki Gulf (Du Fresne 2006); their conservation status (IUCN[10]; Hitchmough et al. 2005) and known threats (Jefferson et al. 2008).

Common Name	Scientific Name	Status		Threats
		Global	New Zealand	
New Zealand fur seal	*Arctocephalus forsteri*	Lower risk/least concern	Not threatened	Entanglement (fisheries), tourism interactions
Humpback whale	*Megaptera novaeangliae*	Vulnerable	Migrant	Entanglement, ship strike, habitat destruction, climate change
Southern right whale	*Eubalaena australis*	Lower risk/conservation dependent	Nationally endangered	Fisheries interactions, ship strike
Southern right whale dolpin	*Lissodelphis peronii*	Data deficient	Not threatened	Directed catch and bycatch in some areas of the world
Pilot whales	*Globicephala* sp.	Lower risk/conservation dependent	Not threatened	Bycatch
Minke whale (dwarf form of common, Antarctic)	*Balaenoptera acutorostrata/ bonaerensis*	Lower risk, but near threatened for common form	Not threatened (common), migrant (Antarctic)	Directed catch, entanglement, ship strike
False killer whale	*Pseudorca crassidens*	Lower risk/least concern	Not threatened	Incidental catch, other fisheries interactions

4 Potential effects of finfish farming on marine mammals of the Firth of Thames

Fin-fish farming in New Zealand has focussed almost exclusively on Chinook salmon. There are three areas where such farms can be found: Marlborough Sounds (where there are four operational farms); Akaroa Harbour; and Stewart Island. In all three regions, farms have experienced some level of interaction with New Zealand fur seals, including cage damage and predation (Kemper et al. 2003). New Zealand fur seals are occasional visitors to the Hauraki Gulf area, but there are no known colonies or rookeries. The likely frequency of interactions between fur seals and fin-fish farms in the Firth of Thames is therefore small. In comparison, interactions with dolphins are minimal, and there appear to be no known New Zealand cases of interactions with large whales.

Overseas, documented cases of interactions between cetaceans and finfish farms occur mainly in Australia (Kemper & Gibbs 2001; Kemper et al. 2003) and Chile (Heinrich & Hammond 2006). These interactions are generally negative, and include lethal entanglements, habitat exclusion and illegal shooting. The potential for positive interactions such as increased prey near fish farms is recognised, but these are much harder to quantify. The most likely positive interactions will come from fish aggregations that result from waste feed. Localised increases in fish abundance have been demonstrated for coastal fin-fish farms (e.g. Dempster et al. 2004; Machias et al. 2004). Such a food source may attract dolphins to the area, and this has been

[10] Information downloaded from www.iucnredlist.org 13 May 2008.

previously hypothesised (Kemper & Gibbs 2001) but not yet proven (Kemper et al. 2003).

Thus, three main (potential) effects of finfish aquaculture on marine mammals will be considered: entanglement; habitat exclusion; and a possible indirect effect of vessel disturbance (ship strike, underwater noise) as a result of increased boat traffic around farm sites. Positive effects such as attraction to a food source (which could potentially increase exposure to negative effects such as entanglement) are not considered here, as no supporting evidence was found in the literature. Each effect will be discussed in detail, including supporting data and/or evidence from New Zealand and overseas. In addition, those species considered most vulnerable to the various potential impacts will be listed.

4.1 Entanglement

4.1.1 Description of effect

The entanglement of cetaceans in fishing gear is a well documented phenomenon, resulting in some 300,000 cetacean mortalities per year (Read et al. 2006). In comparison there are relatively few documented instances of cetacean entanglement in marine farms. In New Zealand two Bryde's whales have reportedly died after becoming entangled in mussel spat collection lines (Lloyd 2003). In the case of small cetaceans (dolphins) it is generally accepted that provided farms are well maintained, the risk entanglement is probably low (Lloyd 2003; and see discussion below).

Entanglement in mussel farms is a concern for large cetacean species such as the baleen whales, particularly as the recent trend in New Zealand coastal waters is to develop large, offshore farms which can overlap with migratory paths of humpback and southern right whales. Lloyd (2003) concludes that planned increases in mussel farms within Bryde's whale range will probably lead to further entanglement-induced mortality. Such conclusions are not without basis: entanglement of baleen whales such as right whales and humpback whales is well documented (Clapham et al. 1999; Knowlton & Kraus 2001).

Fish farms can often be targeted by pinnipeds such as the New Zealand fur seal, resulting in predation of stock and net damage. As a result, it is common for farms to install predator nets to prevent access to fish stock and farm structures (figure 3). However, these nets can result in entanglements of cetaceans. While fur seals are not abundant in the Hauraki Gulf/Firth of Thames region, predator nets should be installed as occasional interactions with seals and other predators are still likely to occur.

In Australia, bottlenose and short-beaked common dolphins have become fatally entangled in predator nets of tuna feed lots (Kemper & Gibbs 2001) and salmon farms (Kemper et al. 2003). Between 1990 and 1999, 29 dolphins were fatally entangled in southern blue-fin tuna lots, with several additional suspected deaths occurring during the same period (Kemper & Gibbs 2001). The authors concluded that dolphins were being attracted to and feeding in, the area of the cages. Their recommendations for minimising entanglements included reducing mesh size of predator nets to less than 8cm and reducing tuna food waste and therefore the food source for other fish in the area.

Several fatal entanglements of common bottlenose dolphins (five reported up to 2000) and short-beaked common dolphins (four reported up to 2000) have occurred in salmon farms in Tasmania (Kemper et al. 2003). The entanglements may have occurred where anti-predator nets were not enclosed at the bottom, allowing dolphins to become trapped between nets and fish pens. Entanglements typically occurred in anti-predator nets with mesh size greater than 6cm.

Fatal entanglements of bottlenose dolphins have also occurred in fin-fish farms on the north-eastern coast of Sardinia, Italy (Díaz López & Bernal Shirai 2007). Once again, the nets in question had a 15cm mesh size and were quite loose in the water column.

In New Zealand, there have been three known cases where cetaceans have died as a result of entanglement or entrapment in salmon farm anti-predator nets. They all occurred in the Marlborough Sounds (M. Aviss & B. Cash, Department of Conservation, Picton, and A. Baxter, Department of Conservation, Nelson, pers. comm.): two in 1999 and one in 2005. The two cases in 1999 were both dusky dolphins, and happened at the same salmon farm. Operational practices for changing predator nets have since been improved to reduce the chance of this happening again. Previously, each fish cage had its own separate predator net, whereas now the farms use all encompassing 'mega-nets', which are thought to be far less likely to result in a cetacean entanglement (figure 3). In the other case (which occurred in February 2005), a Hector's dolphin became trapped under a predator net, though the carcass was not retrieved and therefore cause of death not determined.

Figure 3: Predator nets around Salmon farms, Marlborough Sounds (photos courtesy of Grant Hopkins, Cawthron Institute).

In general, cetacean entanglement risk can be minimised by enclosing predator nets at the bottom; keeping nets taut; using mesh size <6cm; and keeping nets well maintained (e.g. repairing holes immediately). Reducing feed waste as much as possible will also limit fish aggregations near farms, which may reduce the amount of time dolphins are likely to spend near fish farms. Such practices are already largely adopted by the New Zealand industry, in addition to operational procedures for changing nets that are designed to further minimise cetacean entanglement risk.

There have been no known entanglements of marine mammals in New Zealand since changes to net design and net changing protocols were introduced, suggesting that the risk has been reduced to very small levels, if not eliminated entirely. It should still be recognised however that entanglement (particularly of small cetaceans) is a bigger risk in fin-fish farm predator nets than mussel farms. Other forms of fisheries-related entanglements threaten the viability of Hector's and Maui's dolphins (Dawson & Slooten 2005; Slooten et al. 2006). The same cannot currently be said for entanglement in fin-fish farms, the risk of which appears to be well managed by industry. However, should cetacean entanglements increase at any point in the future, it may become necessary to independently monitor and audit predator net design and maintenance practices.

4.1.2 Species likely to be affected – entanglement

There are very few reported large cetacean (whales) interactions with finfish farms (but see Kemper & Gibbs 2001; Kemper et al. 2003). Therefore, the species most likely to be affected by entanglement in the Firth of Thames are common dolphins and bottlenose dolphins. This is in contrast to mussel farms, where it is generally thought that large whales are at greater risk.

4.2 Habitat exclusion

4.2.1 Description

In parts of Chile, spatial overlap between mariculture and small cetaceans is extensive (Heinrich & Hammond 2006), with some authors reporting that Chilean dolphins may now be excluded by salmon farms from bays and fiords they traditionally used (Reeves et al. 2003). It is worth noting that Chile is second only to Norway in production levels of salmonids (Kemper et al. 2003), and farm overlap with cetaceans and direct competition for space in New Zealand should be significantly less at the present time.

Indirect exclusion of cetaceans from areas containing fish farms can occur through use of acoustic harassment devices (AHDs), which are generally used to dissuade pinnipeds (e.g. fur seals) from feeding on farm stock. Exclusion has been reported for killer whales (Morton & Symonds 2002) and harbour porpoise (Olesuik et al. 2002). AHDs have been trialled in New Zealand, with a built-in attenuation programme designed to reduce the amplitude and intensity of the signal, thereby minimising potential displacement of cetaceans. These trials were abandoned when, after some initial success, pinnipeds appeared to become habituated to the devices. Some authors have suggested that AHDs could act as a 'dinner bell', alerting animals to the presence of a food source (Würsig & Gailey 2002). AHDs are currently not in use in New Zealand finfish farms.

Currently, displacement of cetaceans by fish-farming activities seems to be unlikely in New Zealand waters. The scale of fin-fish farming in New Zealand is small compared to countries such as Chile and Norway, and while there is some overlap with cetacean habitat, very little of this occurs in what may be described as 'critical habitat'. Should the scale of fin-fish farming undergo a significant increase in New Zealand waters, this situation may change. With any expansion of marine farming activities, it is important to choose the location of farms carefully, so as to minimise the potential for displacement. Similarly, should AHDs be adopted at any point in the future, care will be needed to avoid displacement of cetaceans.

Compared to mussel farms, habitat exclusion resulting from fish farms is more absolute. In the case of mussel farms, small cetaceans can still enter farm areas and swim between lines, and have often been observed to do so. Such relatively free access does not necessarily mean there are no habitat effects though. In the case of dusky dolphins in Admiralty Bay, it is thought that mussel farms may interfere with the coordinated feeding behaviour of the dolphins (Markowitz et al. 2004; Vaughn et al. 2007). Therefore, even though dolphins are not excluded *per se* from farm areas, it may represent sub-optimal habitat that they utilise less frequently.

While there are no other examples of cases in New Zealand where mussel farms are known or suspected to result in habitat exclusion for marine mammals, there have been no before-after/control-impact studies done to investigate habitat exclusion of marine mammals by marine farms.

4.2.2 Species likely to be affected – habitat exclusion

Any species that is known or suspected to utilise the same area as is used for aquaculture may by affected by habitat exclusion. Thus all of the marine mammal species known or suspected to utilise the Firth of Thames should be considered at risk from habitat exclusion by finfish farms. However, the scale of potential fish farm development in the Firth of Thames (75 hectares) is a small part of potential habitat. This could still cause negative impacts if it was known to be an area that was particularly critical for a species, such as for feeding or breeding. While the Firth is almost certainly used by some species for such activities, they are not thought to do so exclusively, or with high levels of residency (though this could be addressed with some baseline monitoring – see section 6 below). Therefore, while exclusion from habitat occupied by fin-fish farms is highly likely, the overall impact should be minor.

4.3 Vessel disturbance – ship strike & underwater noise

4.3.1 Description

Further aquaculture development in the Firth of Thames may result in an increased volume of boat traffic. This has the potential to affect cetaceans in two ways: vessel strikes and impacts of underwater noise.

Vessel strikes are a documented risk to cetaceans in the Hauraki Gulf (Baker & Madon 2007). The large whales such as humpbacks, southern right whales and Bryde's whales are all clearly susceptible to vessel strike (Laist et al. 2001; Baker & Madon 2007). However, boat strike is also a risk for smaller cetaceans (e.g. Hector's dolphin; Stone & Yoshinaga 2000). Historical records show that whales struck by vessels travelling at 13-15 knots or faster, are more likely to be killed or suffer severe injury (Laist et al. 2001).

In addition to boat strikes, vessel traffic associated with aquaculture has the potential to increase the amount of underwater noise that marine mammals are exposed to. Marine mammals rely heavily on sound to interpret their environment and it has been suggested their acoustically sensitive ears are especially vulnerable to noise disturbance (Reeves 1992) or the disruption of communication signals. There have been a range of observed responses of cetacean species to noise disturbance from displacement (Morton & Symonds 2002), to avoidance (Williams et al. 2002a,b), increased dive time and shortened surface intervals (Richardson et al. 1985) and changes in underwater acoustic behaviour (Foote et al. 2004).

The key to mitigation of vessel disturbance, the most obvious of which is ship strike, is to slow vessels to speeds unlikely to cause injury or death should as collision occur; and minimise the overlap of shipping channels with known marine mammal habitat (Laist et al. 2001; Merrick & Cole 2007).

4.3.2 Species likely to be affected – ship strike

Large whales are most likely to be affected by ship strike, but any slow-moving species that spends a great deal of time at or near the surface will be susceptible (Clapham et al. 1999). All species may be affected by vessel noise.

5 Risk and ecological consequences of identified effects

This section considers the likely risk of the identified effects from section 4, and the ecological consequences to those species most vulnerable to each. In determining possible ecological consequences, the conservation status, distribution and relevant ecological characteristics of each species or species group are considered. Table 5 (below) summarises the differences in impacts between mussel and fish farms.

5.1 Entanglement

The New Zealand aquaculture industry appears to be managing the risk of entanglement of marine mammals in predator nets (see section 4.1.1 and figure 3). Consequently, the risk of entanglement is currently considered low. However, because of its potential direct and negative affect, it needs to be carefully monitored as finfish aquaculture expands. The risk of entanglement in mussel farms is low for small cetaceans, and higher for whales. However the current overlap of mussel farms with whale habitat and migratory routes is low but likely to expand in the future.

Small cetaceans (mainly common and bottlenose dolphins) and seals are most at risk from entanglement. While neither bottlenose or common dolphins are considered endangered nationally, and are secure overseas, additional impacts such as entanglement (should it occur) would need to be considered alongside other known threats or causes of mortality, such as tourism pressure and bycatch, both of which are known threats for common dolphins in the region. The risk of seal entanglement is probably lower than that of dolphins, because of the low number of seals in the Hauraki Gulf, and should be mitigated through the same measures that have been adopted in other areas. However this risk could increase if rookeries and/or colonies are established in the Firth of Thames.

5.2 Habitat exclusion

The species most at risk from habitat exclusion are those that are known to utilise the area in which the marine farms may be established. In the Firth of Thames these include (but might not be limited to) common and bottlenose dolphins, killer whales, and Bryde's whales. In considering the risk factor and ecological consequence, it is reasonable to assume that if marine farms are placed in marine mammal habitat, the risk of habitat exclusion is high. Habitat exclusion by fish farms differs to that by mussel farms in that it is absolute. However in the case of mussel farms this may give a perception that the impact is minimal or non-existent, when in fact disturbance (if not full exclusion) has still occurred.

However, measuring habitat exclusion will be difficult, and is currently hampered by a lack of systematic marine mammal surveys in the Firth of Thames region. Furthermore, and importantly, determining the biological significance of displacement (e.g. reduced reproductive success) is even harder. The best possible approach towards mitigation is to avoid placing marine farms in areas of key marine mammal habitat. This could include areas known to be used for foraging and nursery areas. Whether such areas exist in the Firth is not yet known and could be addressed with appropriately designed surveys.

5.3 Vessel disturbance

Vessel strike is a documented risk for species such as Bryde's whales in the Hauraki Gulf. In general, large whales and any other slow-moving species that spends a lot of time at or near the water surface may be at risk. All species will be affected by vessel noise, and the relative risk compared to that associated with mussel farms smilar.

The magnitude of this risk will be determined in part by the level to which boat traffic in the Firth increases, and by the safe boating practices employed by the vessels' crew. Establishing designated vessel routes and safe transit areas for marine mammals, in addition to vessel speed restrictions would help to mitigate the issue of ship strike, should it become problematic. Speed restrictions would also help to reduce effects of vessel noise.

Table 5: Summary of impacts associated with aquaculture; and the differences between mussel and fish farms.

Effect	Mussel Farms	Fish Farms	Difference	Context of Impact
Entanglement	Large whales may become entangled in mussel lines. Small whales, dolphins and seals unlikely to become entangled.	Dolphins and seals may become entangled in exclusion nets. Large whales unlikely to become entangled.	Increased risk of entanglement for dolphins and seals.	Entanglement risk is currently well managed, and provided this continues it should continue to be a low risk.
Exclusion	Large whales may be excluded by the presence of mussel lines. Small whales, dolphins and seals can maintain access, but disturbance may affect their use of the area.	All mammals are physically excluded.	Total exclusion of area in fish farms due to predator nets.	On its own, complete exclusion of marine mammals from 75 Ha of Wilson Bay is unlikely to have a significant impact on marine mammals. However, the compounding effects of all activities, which exclude marine mammals, will need to be carefully managed.
Vessel strikes	Tends to affect large, slow moving, species that spend long periods on the surface. Small cetaceans are known to be at risk from fast-moving vessels.	Tends to affect large, slow moving, species that spend long periods on the surface. Small cetaceans are known to be at risk from fast-moving vessels.	No change, assuming similar frequencies of vessel movements and types of vessel.	Vessel strikes would need to be considered alongside the extent and impact of strikes in the neighbouring Hauraki Gulf, but could be minimised through careful planning of vessel lanes and speed restrictions.
Noise	Can affect all cetacean species	Can affect all cetacean species	No change, assuming similar frequencies of vessel movements and types of vessel.	Underwater noise can result in habitat exclusion, and can mask communication signals or cause temporary/permanent hearing loss. Such affects are more likely to result from chronic exposure to high noise, e.g. from high-speed boats.

6 Research recommendations

For many of the identified impacts discussed here, a thorough risk assessment is hampered by the lack of systematic survey data describing the usage of the Firth of

Thames by marine mammals. While a number of species clearly utilise the Firth as part of their home range, the relative importance of the Firth compared with neighbouring areas such as the Hauraki Gulf is not known. For example, while habitat exclusion resulting from fish farms is probably a small risk with low impact, given that the proposed area of 75 ha is a tiny fraction of the overall Firth of Thames, impacts could be higher if this happened to be an area which was critical feeding and/or breeding habitat, for example.

Thus it is strongly recommended that systematic surveys of the Firth be conducted. These surveys should consider all potential aquaculture areas, in addition to likely routes for boat traffic servicing the farms. Aerial surveys could be a useful monitoring tool, in that large areas can be covered relatively quickly. Fine-grained habitat use could be provided by a combination of boat surveys, cliff-top surveys (if there are appropriate sites), and acoustic surveys (e.g. using acoustic data loggers).

Results from baseline surveys will help to determine to what extent monitoring studies are required, and will help to guide mitigation, should this be deemed necessary. Mitigation options could include clearly defining shipping lanes and speed restrictions to minimize ship strike and noise disturbance; placing farms away from any identified critical habitat; and adopting similar practices concerning predator net design and feed waste minimisation.

7 Conclusions

This report has identified three main areas of risk to marine mammals that may result from finfish aquaculture in the Firth of Thames. In general, the aquaculture industry in New Zealand has taken a proactive and apparently successful approach to minimising entanglement risk. The operational practices adopted by operations in areas such as the Marlborough Sounds concerning design and maintenance of predator nets, and minimising feed waste would be recommended for the Firth of Thames. This is particularly important, given that entanglement seems to be a greater risk for small cetaceans in fish farms compared to mussel farms.

The other risk areas of habitat exclusion and vessel disturbance currently require more robust data to properly address them. In general, what little information there is on marine mammals in the Firth of Thames comes from opportunistic and anecdotal sources, making robust risk assessment difficult. Such research will be especially important to address habitat exclusion, which tends to be absolute compared to mussel farms. Ship strikes are a clear risk in the high traffic areas of Hauraki Gulf. For some species such as Bryde’s whales that seem especially vulnerable, even small incidences of ship strike resulting from increased boat traffic in the Firth would be compounding existing impacts. The potential risk and associated impacts associated with vessel disturbance is the same for both mussel and fish farming, if the level of boat traffic and types of vessels are similar.

For both habitat exclusion and vessel disturbance there are clear paths towards mitigation that can be taken, should this be necessary. Given the high marine mammal diversity of the neighbouring Hauraki Gulf and the apparent importance of this area to whales and dolphins, baseline and operational monitoring programmes would be justified to more thoroughly address these issues.

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Appendix 1: Definitions of conservation status used by IUCN

Critically endangered (CR)
A taxon is Critically Endangered when the best available evidence indicates that it is facing an *extremely high* risk of extinction in the wild.

Endangered (EN)
A taxon is Endangered when the best available evidence indicates that it is facing a very high risk of extinction in the wild.

Vulnerable (VU)
A taxon is Vulnerable when the best available evidence indicates that it is facing a high risk of extinction in the wild.

Near threatened (NT)
A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

Least concern (LC)
A taxon is Least Concern when it does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Data deficient (DD)
A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

Appendix 2: Definitions of conservation status as used by Department of Conservation.

Criteria for classifying New Zealand species differ slightly from that used by the IUCN in order to take into consideration the small size of New Zealand, and the large number of taxa with naturally restricted ranges and small population sizes (Molloy et al. 2002).

Vagrant
For the purposes of this document, vagrants are taxa that are found unexpectedly and rarely in New Zealand, and whose presence in our region is naturally transitory.

Coloniser
Colonisers are taxa that have arrived in New Zealand without direct or indirect help from humans and have been successfully reproducing in the wild for less than 50 years.

Migrant
Taxa that predictably and cyclically visit New Zealand as part of their normal life cycle, but do not breed here are included in the category Migrant.

Data Deficient
Certain criteria and/or definitions must be met for a taxon to be listed in a category. Where information is so lacking that an assessment is not possible, the taxon is assigned to the Data Deficient category.

Acutely Threatened
The categories in the 'Acutely Threatened' division—**Nationally Critical, Nationally Endangered** and **Nationally Vulnerable**—equate with the IUCN categories of Critically Endangered, Endangered and Vulnerable. Taxa in these three categories are facing a very high risk of extinction in the wild, as defined by criteria that quantify:

- Total population size
- Area of occupancy
- Fragmentation of populations
- Declines in total population
- Declines in habitat area
- Predicted declines due to existing threats

Chronically Threatened
Taxa listed in either of the two categories in the 'Chronically Threatened' grouping (**Serious Decline** and **Gradual Decline**) also face extinction, but are buffered slightly by either a large total population, or a slow decline rate (see Section 6).

At Risk
Taxa that do not meet the criteria for Acutely Threatened or Chronically Threatened, but have either restricted ranges or small scattered sub-populations, are listed in one of two categories (**Range Restricted** and **Sparse**) that fall under the division 'At Risk'. Although these taxa are not currently in decline, their population characteristics mean a new threat could rapidly deplete their population(s).