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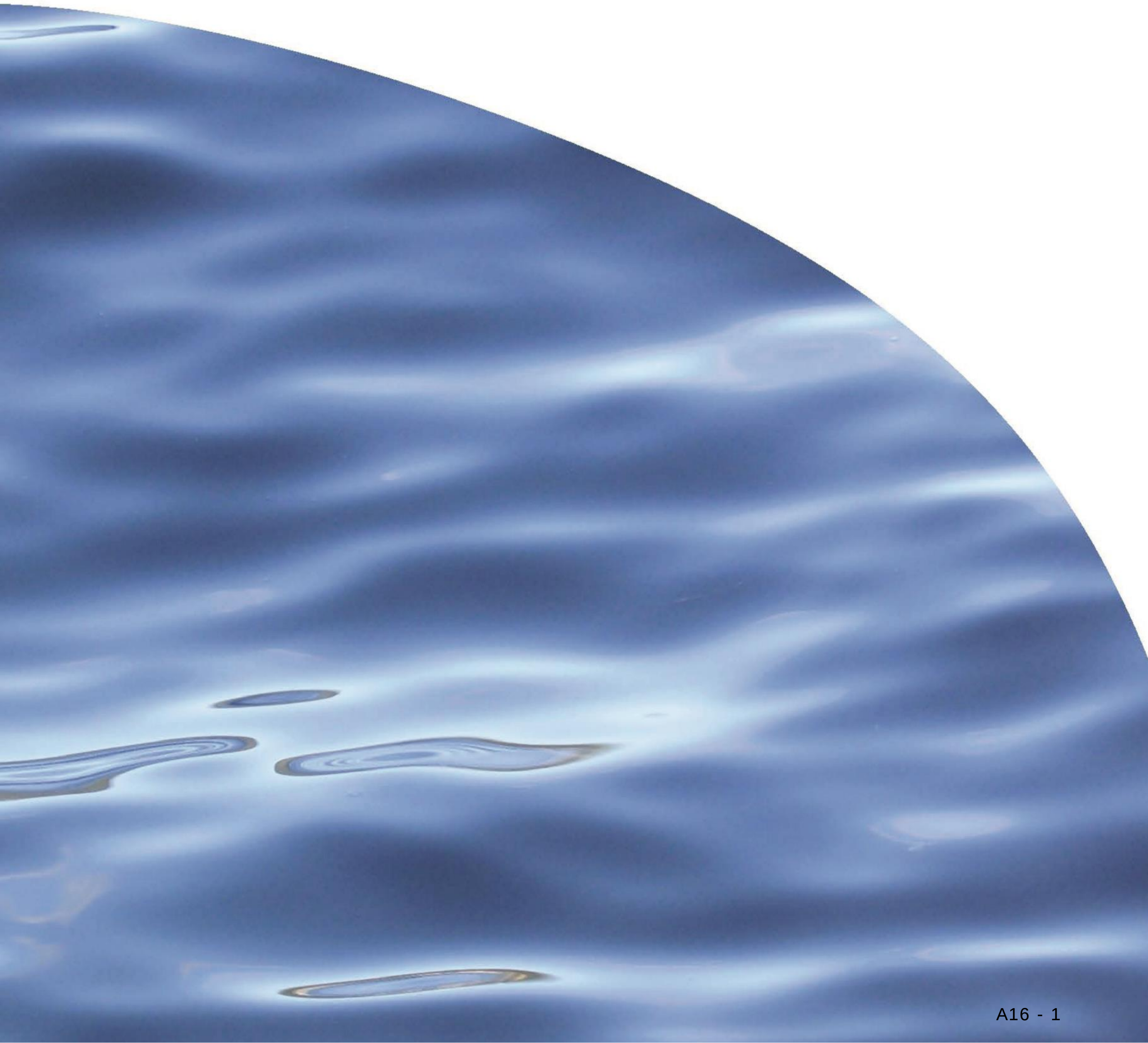
MARINE MAMMALS ASSESSMENT

REPORT NO. 2869

ASSESSMENT OF EFFECTS ON MARINE MAMMALS FROM THE LYTTELTON PORT COMPANY CHANNEL DEEPENING PROJECT



ASSESSMENT OF EFFECTS ON MARINE MAMMALS FROM LYTTELTON PORT COMPANY CHANNEL DEEPENING PROJECT

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EXECUTIVE SUMMARY

Lyttelton Port Company Limited (LPC) is proposing a Channel Deepening Project (CDP) to deepen and extend its existing approach channel to accommodate larger vessels. This work will involve the dredging of approximately 18 million cubic metres of benthic sediments from the existing navigation channel and an extension of the channel approximately 4 km out into Pegasus Bay. Additional dredging will also take place within the ship-turning basin and some berth areas of the Harbour. The associated disposal of dredge spoil is proposed to occur approximately 5.9 km from Godley Head at its nearest point, in average water depths of 20 m. To maintain depths within the extended navigation channel, it is proposed to establish a new offshore spoil ground for future maintenance dredging. This will be located approximately 2.25 km offshore from Godley Head.

Both the dredging and disposal aspects of this project are situated within the Banks Peninsula Marine Mammal Sanctuary, and as Lyttelton Harbour/Whakaraupō is known for its regular sightings of endangered Hector's dolphin, Cawthron Institute was contracted to provide an assessment of effects on any relevant cetacean (dolphins and whales) and pinniped (seal and sea lions) populations. This report outlines the current scientific understanding of the potential effects of dredging and disposal activities (both direct and indirect) on marine mammals, specifically those populations utilising the Pegasus Bay coastal ecosystem, and assesses these effects in context of the resource consent proposal.

Out of the more than 25 cetacean species that have been sighted or have stranded within Banks Peninsula waters, only eight species frequent the inshore waters of Pegasus Bay near Lyttelton Harbour/Whakaraupō. Hector's dolphin (*Cephalorhynchus hectori hectori*) and New Zealand fur seals (*Arctocephalus forsteri*) are the only year-round residents that feed on local fish populations and breed with inshore waters of several bays and both harbours, and therefore likely to be affected by the proposed project. The only other species of concern is the southern right whale (*Eubalaena australis*) given that it is more vulnerable to anthropogenic impacts due to its coastal tendencies, low population numbers and its known collision risks. Due to historical and on-going disturbances, Lyttelton Harbour/Whakaraupō and Pegasus Bay coastal waters are not considered significant habitats for any of the discussed species, but instead represent a small, less pristine fraction of similar habitats available to support those marine mammals utilising this larger coastal region.

Interactions between marine mammals and coastal development usually result from a direct overlap between the spatial location of the development and the habitats of the species. The potential direct effects of dredging and disposal activities that are most relevant to marine mammal species in Pegasus Bay regions include: potential vessel strikes, increased underwater noise production and possibly the risk of entanglement. While these effects have the greatest potential consequences to the relevant species (i.e. injury of death), the actual likelihoods were considered low and the overall risk levels deemed acceptable with suggested mitigation actions.

Indirect effects of dredging and disposal activities on marine mammals may result from physical changes to the habitat itself that adversely affect the health of the local ecosystem and / or impinge on important prey resources. Given the location and habitats associated with the CDP, the review of possible indirect effects to the ecosystem focused on: quality of spoil, ecological effects to benthos and associated fish assemblages, and the effects of any resulting turbidity plumes. Overall, any indirect effects of CDP activities will be less than minor and are not expected to have any detrimental or long-term effects on local or visiting marine mammals in the region.

It is acknowledged that the proposed ongoing maintenance dredging of the deepened and extended channel will represent an incremental expansion of the existing program. However no additional risks to or effects on marine mammals have been identified for the ongoing use of the proposed offshore maintenance spoil ground.

A suggested monitoring programme is proposed that could be used to assess the effectiveness of any mitigation measures employed and inform future dredging projects.

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1. SCOPE OF WORK

1.1. Description of proposal

For a full description of the activities, location and methodologies proposed as part of the Channel Deepening Project (CDP) refer to Section Two (Project Description) of the Assessment of Environmental Effects.

1.2. Scope of assessment

The primary objective of this investigation was to provide a desktop assessment of potential effects on marine mammals from the CDP. Specifically, this assessment of effects incorporates the following components:

1. summary of the existing environment in terms of those marine mammal species most susceptible to any effects of the proposal, and
2. evaluation of resident and transient marine mammal populations utilising and / or influenced by the Pegasus Bay coastal ecosystem (in particular southern Pegasus Bay and Lyttelton Harbour/Whakaraupō).

The second part of the report comprehensively assesses the actual and potential effects of the CDP and ongoing maintenance dredging on the relevant marine mammal species, with possible mitigation options, and is intended to support the final resource consent application. It specifically:

1. reviews the national and international literature on the effects of dredging and disposal activities on marine mammals, specifically addressing direct and indirect effects,
2. places any potential impacts in context of the actual project area and environment, based on other relevant assessment of effects reports (e.g. underwater noise, ecology, spoil disposal modelling),
3. categorises the overall risk of any resulting effects in terms of their possible scale, duration/persistence, likelihood and possible consequences, and
4. discusses possible mitigation options and monitoring conditions based on the final risk assessment of any potential effects.

2. DESCRIPTION OF EXISTING ENVIRONMENT

2.1. General site description

Sneddon et al. (2016) provides a detailed description of where both the dredging sites and proposed spoil disposal sites sit within the context of the greater Banks Peninsula and Pegasus Bay coastal marine environments. Lyttelton Harbour/Whakaraupō and the proposed capital and offshore maintenance dredge disposal sites also lie within the boundaries of the Banks Peninsula Marine Mammal Sanctuary (BPMMS; Figure 1 inset). This sanctuary is New Zealand's first marine mammal sanctuary and was created in 1988 to protect endangered Hector's dolphins from being incidentally caught in both commercial and recreational gillnet fisheries (Dawson & Slooten 1993). This sanctuary originally encompassed the coastal waters within four nautical miles of the shoreline around the Peninsula from Godley Head to Lake Forsyth. As entanglement in set-nets was threatening the dolphins' continued survival, no commercial set-nets were allowed within the BPMMS and the setting of nets by amateur fishers was restricted to only particular seasons.

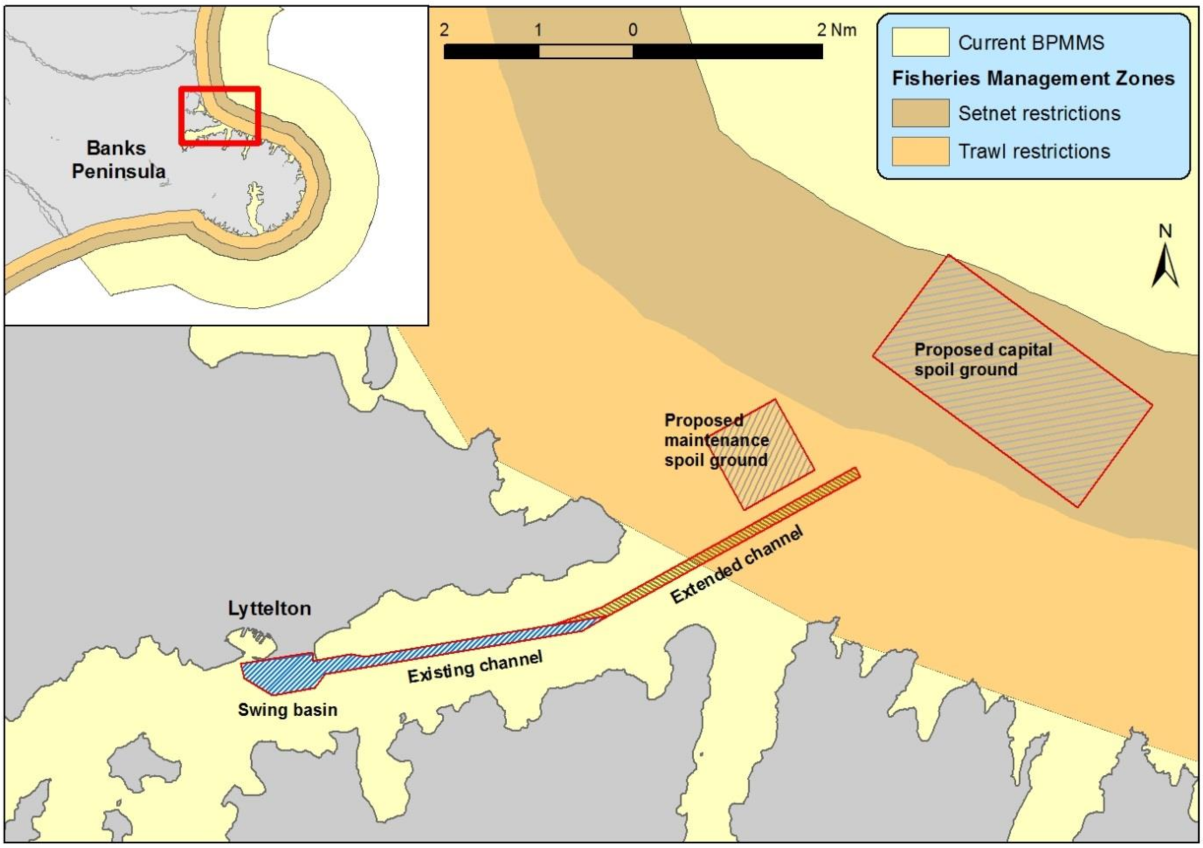

Figure 1 The locations of the proposed dredge and disposal sites within the context of the Banks Peninsula Marine Mammal Sanctuary and MPI fisheries management zones (inset).

As of 2008, the Department of Conservation redefined the purpose and expanded the boundaries of the existing BPMMS to complement accompanying New Zealand-wide changes in inshore fishing restrictions by the Ministry of Primary Industries (MPI). The purpose of the BPMMS is now to complement fisheries restriction zones by managing non-fishing threats on local marine mammal populations, specifically mining and seismic surveying. Changes also included moving the offshore boundary from 4 Nm to 12 Nm and extending the northern and southern boundaries. The sanctuary does not, in its original or current mandate, restrict any form of dredging or other types of coastal development within sanctuary waters.

2.2. General species summary

More than half of all the cetacean (whales, dolphins and porpoises) and pinniped (seals and sea lions) species known to exist worldwide live or migrate through New Zealand waters. At least 25 different species have stranded or have been sighted throughout inshore and offshore regions of Banks Peninsula. However, detailed information on abundance, distribution and critical habitats is available only for a limited number of New Zealand's marine mammals, despite recent advances in survey techniques. To date, marine mammal research around Banks Peninsula has focused mainly on the endangered Hector's dolphin (*Cephalorhynchus hectori hectori*) and to a lesser extent, on the New Zealand fur seal (*Arctocephalus forsteri*).

In the absence of any long-term and spatially-explicit baseline research on other marine mammals in the region, species information and sighting data were collated from ongoing research (*i.e*. Canterbury and Otago Universities, MPI / DOC aerial surveys) along the east coast of the South Island as well as opportunistic sightings and stranding databases (e.g. Department of Conservation seismic database, public sightings, tourism reports, fisheries observers etc.). This information was used to evaluate those species most likely to be affected by the proposed project and to determine what is currently known about any seasonal and distribution trends within the general area.

Figure 2 highlights the various marine mammal species found to frequent the Banks Peninsula and Pegasus Bay regions. Numerous sightings have been reported around eastern bays, in which deeper waters associated with the Pegasus Canyon and continental shelf break (c. 150 m isobath) occur relatively close to the coastline. Other sightings occur within one of the two large and relatively shallow bays located to the north (Pegasus Bay) and south (Canterbury Bight) of the Peninsula itself. It is important to note that each reported sighting does not necessarily represent unique animals. Consequently, the number of sightings in Figure 2 does not reflect the actual abundance of these species within these regions. In addition, the location and the time of year that most opportunistic sightings are recorded may reflect a closer proximity to larger towns or harbours and / or where the majority of coastal activities (e.g. tour boats, recreational fishing, diving etc.) tend to occur.

A list of the most prevalent species found to reside or regularly visit the coastal waters of southern Pegasus Bay, and in particular Lyttelton Harbour/Whakaraupō, is presented in Table 1 with additional details in Appendix 1. These species have been defined into three main categories that describe their distribution trends within this particular region. Note that the distribution and commonality inferences for lesser studied species, discussed below and in Appendix 1, are expected to change with time and more scientific information.

1. Resident—a species that lives (either remaining to feed and/or breed) within Pegasus Bay and surrounding waters either permanently (year-round) or for regular time periods (seasonally)
2. Migrant—a species that regularly travels through parts of Pegasus Bay and surrounding waters, remaining for only short or temporary time periods that may be predictable seasonally
3. Visitor—a species that may wander into Pegasus Bay and surrounding waters intermittently, depending on Pegasus Bay's proximity to the species' normal distribution range, visits may occur seasonally, infrequently or rarely.

When considering potential implications of coastal developments on local marine mammal population, the importance of Lyttelton Harbour/Whakaraupō waters needs to be placed in the context of the species' regional and New Zealand-wide distributions given that several of these species' normal distributions range across 100-1,000 km (see Appendix 1). For instance, while southern right whales may be considered only a seasonal migrant in Peninsula waters, this particular stretch of water may provide an important corridor that this species uses to locate or travel to important nursery habitats further north. In the absence of adequate population information, the potential risks to marine mammal species associated with various anthropogenic activities can still be assessed based on the species' life-history dynamics (e.g. species-specific sensitivities, conservation listing, life span, main prey sources) gathered within New Zealand (e.g. local and national databases, New Zealand Threat Classification System, NABIS) and internationally (e.g. peer-reviewed journals, IUCN Red List of Threatened Species).

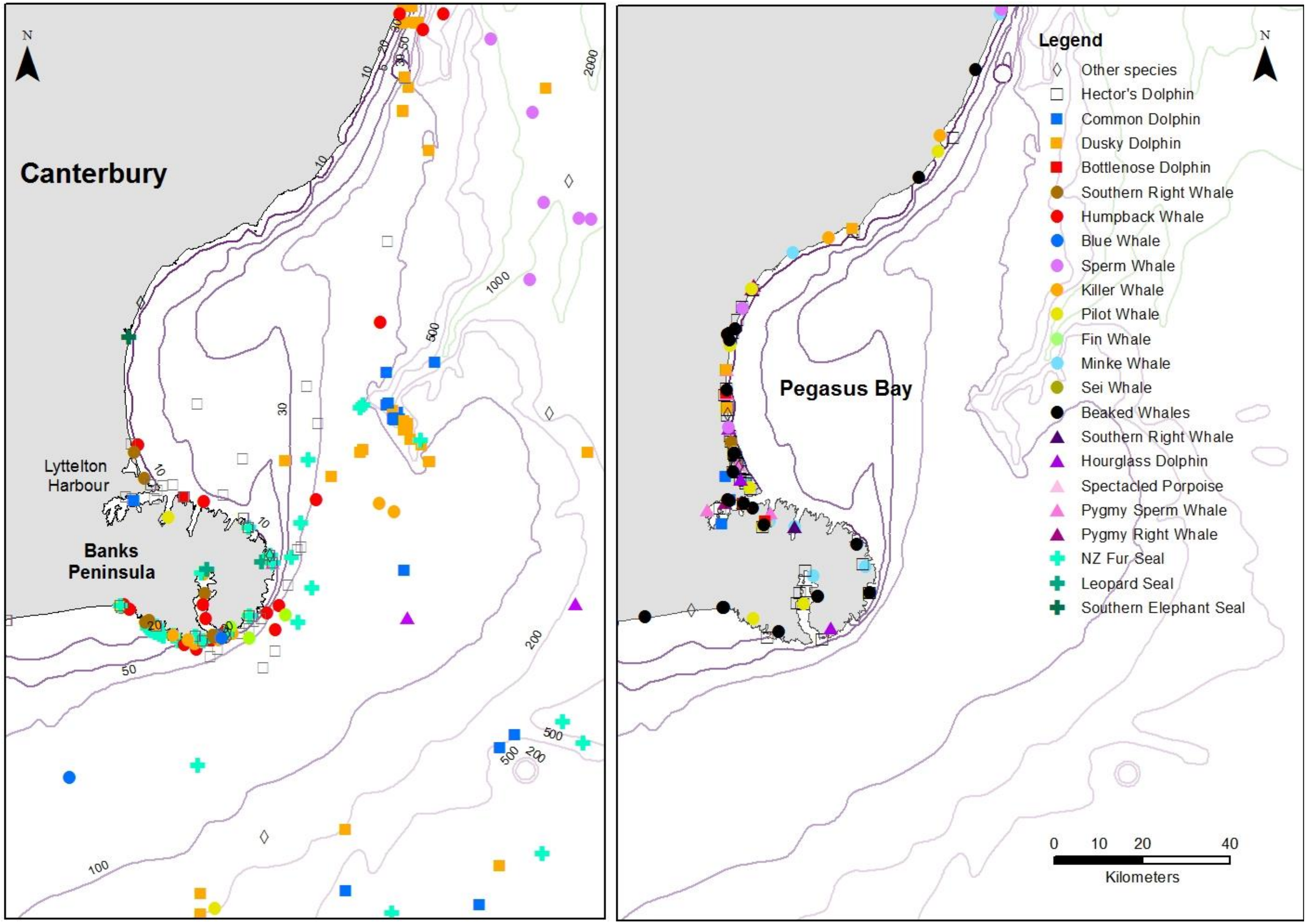

Figure 2. A summary of research and opportunistic sightings (left) and strandings (right) of marine mammals prevalent in Banks Peninsula coastal waters (MacKenzie & Clement 2014; DOC sighting and stranding databases). Note: to emphasise the other species data, sightings of Hector's dolphins are minimised (light grey outlined squares) above and discussed in more detail in Section 2.2.1 and Appendix 1.

Table 1. The residency patterns of marine mammal species known to frequent Pegasus Bay and nearby waters along with potential species-specific effects from dredging activities. Species conservation threat status is listed for both the New Zealand system (Baker et al. 2016) and international IUCN system (version 3.1). See Appendix 1 for species-specific details.

Common name	Species name	NZ threat classification		IUCN red listing	Residency category in Northland	Potential effects of dredging activities (Todd et al. 2015) *
RESIDENTS						
Hector's dolphin	*Cephalorhynchus hectori hectori*	NZ native & resident, evaluated, threatened	Nationally Endangered	Endangered	Year-round Resident	Disturbance from increased shipping traffic & noise levels, destruction & alteration of habitat, redistribution of prey species & remobilisation of contaminants
NZ fur seal	*Arctocephalus forsteri*	NZ native & resident, evaluated	Not Threatened	Least Concern	Seasonal to Year-Round Resident	Habitat alterations, increased turbidity & changes to prey availability, masking, incidental capture or injury, avoidance to increased shipping traffic
MIGRANTS						
Southern right whale	*Eubalaena australis*	NZ native & resident, evaluated, threatened	Nationally Vulnerable	Least Concern	Seasonal Migrant	Collision with a dredging vessel, habitat avoidance, behavioural changes & masking
Humpback whale (Oceanic pop. only)	*Megaptera novaeangliae*	NZ native, evaluated	Migrant	Endangered	Seasonal Migrant	Movement away from habitat, noise pollution, habitat degradation, behavioural alterations, masking of conspecifics at close range (< 1 km), alterations to migration routes & avoidance
VISITORS						
Dusky dolphin	*Lagenorhynchus obscurus*	NZ native & resident, evaluated	Not Threatened	Data Deficient	Seasonal to Year-Round Resident	Increased shipping traffic, changes to behaviour or avoidance of coastal habitat due to increased noise levels & habitat destruction
Common dolphin	*Delphinus delphis/capensis*	NZ native & resident, evaluated	Not Threatened	Least Concern	Seasonal to Year-Round Resident	Habitat alterations & changes to prey distribution
Orca (killer whale)	*Orcinus orca*	NZ native & resident, threatened	Nationally Critical	Data Deficient	Seasonal to Infrequent Visitor	Increased boat traffic, masking, alterations to prey availability, habitat avoidance or behaviour alterations
Bottlenose dolphin	*Tursiops truncatus*	NZ native & resident, evaluated	Nationally Endangered	Least Concern	Infrequent to Rare Visitor	Altered feeding patterns, increased shipping traffic & potential disturbance to the nursing areas

* Proposed effects by Todd et al. (2015) are highly dependent on the location, the scale and context of the project (e.g. equipment used, duration, spoil volumes) as well as species.

The marine mammals most likely to be affected by the proposed project include those species that frequent Lyttelton Harbour/Whakaraupō and Pegasus Bay waters year-round or on a semi-regular basis, including Hector's dolphin (*Cephalorhynchus hectori hectori*) and the New Zealand fur seal (*Arctocephalus forsteri*). Other species of concern include those that are more vulnerable to anthropogenic impacts due to various life-history dynamics (e.g. low population numbers, coastal tendencies) or species-specific sensitivities (e.g. collision risks), and in this case, includes southern right whales (*Eubalaena australis*). These species are discussed in more detail below (Sections 2.2.1 and 2.2.3).

Other species that visit the region include dolphins or migrating whale species that venture into more shallow coastal waters (Table 1, see Appendix 1 for more details). Dusky dolphins (*Lagenorhynchus obscurus*), common dolphins (*Delphinus delphis*) and killer whales (*Orcinus orca*) are occasionally sighted in both coastal and offshore waters of the Peninsula and Pegasus Bay throughout the year and/or seasonally. Bottlenose dolphins (*Tursiops truncatus*) are less common, despite their known tendency to slowly work their way around the various bays and harbours before travelling off again. Humpback whales (*Megaptera novaeangliae*) are also known to seasonally migrate through these waters on their way north in winter and south again in the spring. Unlike right whales, humpbacks tend to travel in straight lines from headland to headland, only occasionally passing inshore to bays, bights and/or harbours.

Several deep-water species with more offshore tendencies (e.g. pilot whales, several species of beaked whales, sperm whales, pygmy sperm whales and pygmy right whales) were also noted as stranding along Pegasus Bay coastlines (Figure 2; DOC databases; Berkenbusch et al. 2013; Baker 2001; Brabyn 1990). However, with few consistencies in timing and no actual sighting data for some species, it is unlikely that Pegasus Bay or nearby inshore waters serves as part of these species' normal home ranges. Instead, it is more likely these species simply pass by Peninsula waters further offshore as part of their normal migration or movement patterns around New Zealand.

While neither the Peninsula nor Pegasus Bay region is known for being an important breeding ground for most marine mammal species (e.g. Dawbin 1956; Patenaude 2003; Berkenbusch et al. 2013), cow/calf pairs of dusky, common and bottlenose dolphins, orca, southern right and humpback whales have all been sighted within these waters. Other than Hector's dolphins or New Zealand fur seals, no specific feeding grounds for any other marine mammals species are currently associated with Lyttelton Harbour/Whakaraupō or Pegasus Bay waters (see Appendix 1).

2.2.1. Hector's dolphin

Hector's dolphin is the only dolphin endemic to New Zealand waters. Of the estimated 14,849 Hector's dolphins (CV: 11%; 95% CI: 11,923–18,492) known to occur around the South Island, approximately 2,000–4,000 dolphins are found in Pegasus Bay waters throughout the year (MacKenzie & Clement 2016). A significant portion of the east coast population occurs around Banks Peninsula with relatively high densities also present north around the Waipara River and south along the coast to the Waitaki River (Figure 3; MacKenzie & Clement 2016). However, smaller groups are regularly observed off the Otago and Kaikoura coastline (Turek et al. 2013; Weir & Sagnol 2015; Hamner et al. 2016).

The Banks Peninsula animals are considered to be part of a semi-residential community that has limited mixing with other regional communities (Hamner et al. 2012, Appendix 1). During the warmer summer and autumn months, dolphins move close to the shore and spread into most bays and harbours, including Lyttelton Harbour/Whakaraupō (e.g. Clement 2005; MacKenzie & Clement 2014; Brough et al. 2014). It is over this time period that most Hector's dolphin calves are born. While calves are regularly sighted within Akaroa and Lyttelton Harbour/Whakaraupō each summer (Brough et al. 2014), no distinct calving and/or nursery areas have been identified. Over the colder months animals generally move further offshore and mainly out of inner- and mid-harbour regions.

These dolphins are generalist feeders, taking a wide range of prey throughout the water column with the majority of the diet being made up of juvenile demersal and benthopelagic fishes (Miller et al. 2013). Important prey species along the Canterbury coastal region include red cod (*Pseudophycis bachus*), ahuru (*Auchenoceros punctatus*), arrow squid (*Nototodarus* spp.), sprat (*Sprattus* sp.), sole (*Peltorhamphus* sp.), and stargazer (*Crapatalus* sp.; Miller et al. 2013).

Hector's dolphins are listed in New Zealand as a nationally endangered species due to their regional distribution, small home ranges (< 106 km) and fairly low total abundance (Baker et al. 2016). The main threat to this species is entanglement in gillnets (commercial and recreational), and to a lesser extent the trawling fisheries, but also includes increased eco-tourism and boat strikes on newborn calves. As noted in section 2.1, Lyttelton Harbour/Whakaraupō and both of the proposed spoil disposal sites lie within the BPMMS and the fisheries restriction zones set up to protect this species (see Figure 1).

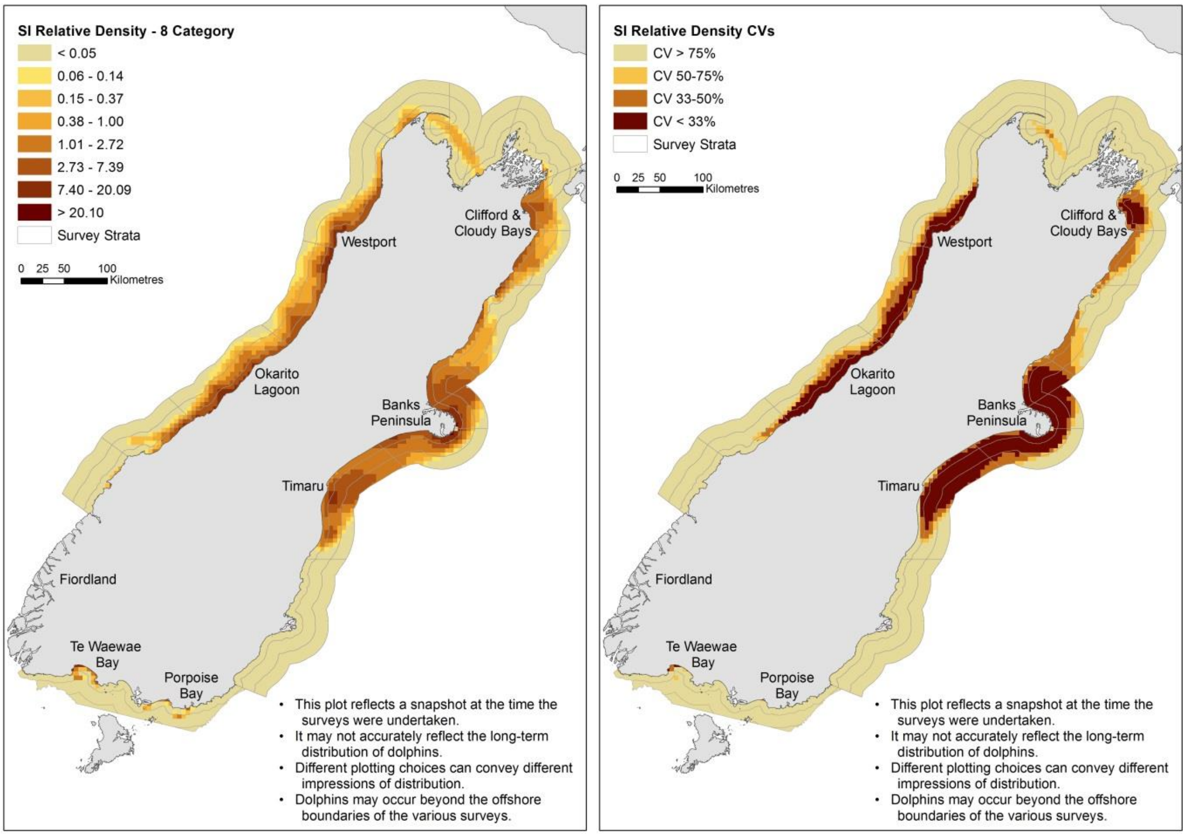

Figure 3. The relative density of Hector's dolphins around the South Island within 5 km × 5 km grid cells generated from density surface models (left panel) with the precision of estimated relative density (right panel) where darker colours indicate greater precision (from MacKenzie & Clement 2016).

2.2.2. New Zealand fur seal

Banks Peninsula is one of many high density areas for New Zealand fur seals around the South Island, mainly associated with breeding rookeries. The closest breeding colonies to the proposal sites are over 20 km away, with several spread throughout the more eastern and southern bays of the Peninsula (Figure 4). Although these colonies are not located at or next to the proposal sites, New Zealand fur seals easily and repeatedly cover large distances, rarely remaining at any one location year-round. Seals are more densely clumped within the colonies around summer periods, with pups generally leaving in winter/spring months. Haul-out sites along rocky shore regions are more regularly used throughout the year, when seals come ashore to rest.

Fur seals in Canterbury waters feed on a large variety of prey items that includes arrow squid, several species of lanternfish, barracoota (*Thyrsites atun*), octopus, ahuru and red cod. Nursing females will often travel further out into open water over winter to forage while juveniles feed on vertically migrating myctophid fish over shelf waters (Goldsworthy & Gales 2008).

Actual sighting data show a low occurrence of sightings of New Zealand fur seals in the inner Pegasus Bay coastal area relative to more offshore regions (see Figure 2). However, these are public sightings only, and as such, do not necessarily reflect a low occurrence of species in these waters (Appendix 1). Fur seals are considered abundant throughout most of New Zealand and not currently threatened; therefore their current conservation status is of 'least concern'.

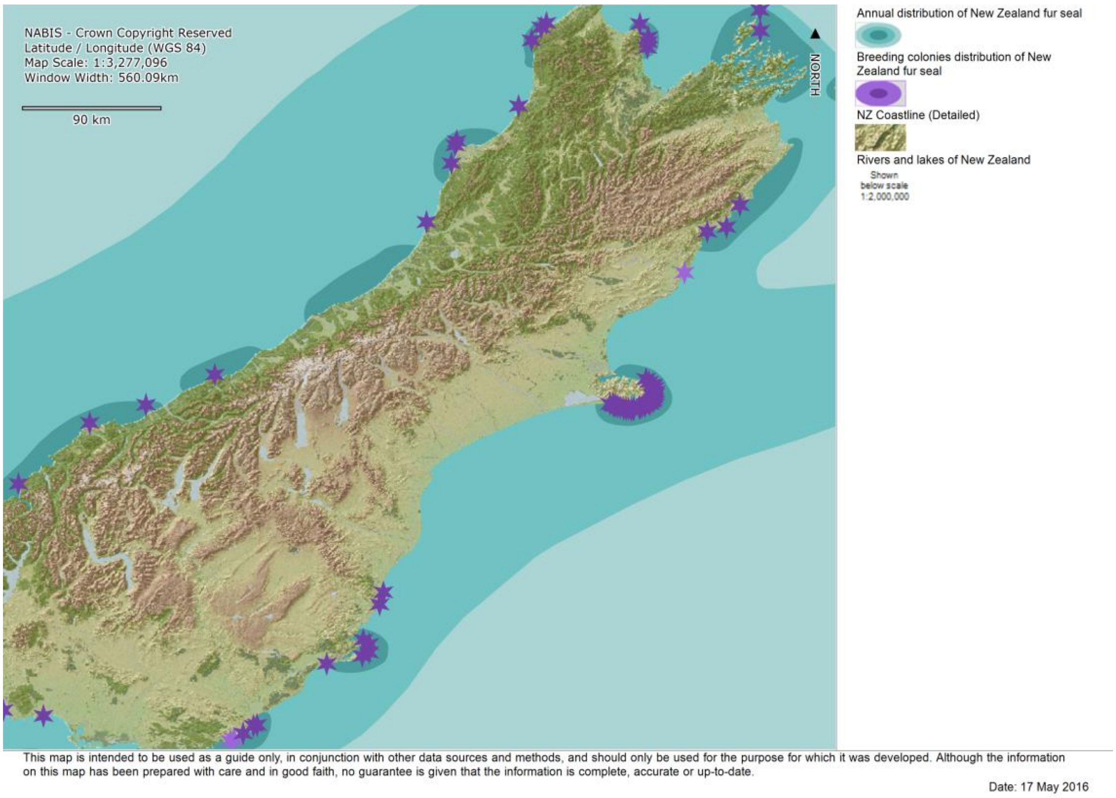

Figure 4. The estimated distribution of New Zealand fur seals around the South Island with darker blue indicating 'hotspots'. Purple stars denote known breeding colonies. Downloaded from the NABIS website May 2016.

2.2.3. Southern right whales

Regular sightings of southern right whales occur off Banks Peninsula, in particular the northern bays and Lyttelton Harbour/Whakaraupō coastline, each year as whales migrate back to their traditional wintering and calving grounds around New Zealand. The majority of whales are sighted along New Zealand's South Island coasts. However, based on historical whaling data and a review of sightings, Banks Peninsula does not appear to be a final destination point for wintering or calving right whales (e.g. Patenaude 2003; Carroll et al. 2014).

At the current sighting rate, at least one, and more likely two, right whales are expected to appear within or near Lyttelton Harbour/Whakaraupō each winter where they will remain for a few days up to several weeks. The majority of right whales are sighted within New Zealand waters from June to October, with calves sighted more frequently between July and September (Carroll et al. 2014).

Due to their recently documented recovery around mainland New Zealand (Carroll et al. 2013), southern right whales have been down-listed from *nationally endangered* to *nationally vulnerable* by the New Zealand Threat Classification System (Baker et al. 2016). However, right whales' tendency to remain within shallow, protected bays and coastal waters (particularly for calving), and their natural curiosity, places them more at risk of interacting with anthropogenic activities in New Zealand's waters than other whale species.

2.2.4. Summary

Based on the available data, and in reference to Section 6 (c) of the Resource Management Act which refers to 'significant habitats of indigenous fauna', Lyttelton Harbour/Whakaraupō and nearby Pegasus Bay waters are not currently considered to be ecologically significant in terms of feeding, resting or breeding habitats for marine mammals with the exception of Hector's dolphins. Banks Peninsula as a whole represents important regional habitat for Hector's dolphin as evident through consistently high densities year-round, and given their current endangered status (which led to the establishment of the BPMMS).

However, Lyttelton Harbour/Whakaraupō and its entrance cannot be considered undisturbed habitat as maintenance dredging (in some form) has been ongoing since 1876. The entrance itself experiences heavy vessel traffic year-round by a variety of commercial and recreational vessels, and until 2008, was regularly exposed to fishing pressure (e.g. trawling). The benthic habitats and fish communities associated with the proposed Lyttelton Harbour/Whakaraupō and disposal sites do not represent any unique or rare habitats or assemblages in relation to the greater regional ecosystem as a whole.

Regardless of these ongoing disturbances, Hector's dolphin and several other marine mammals still remain and/or regularly visit Lyttelton Harbour/Whakaraupō and its surrounding waters. As such, Lyttelton Harbour/Whakaraupō and Pegasus Bay coastal waters represent a small (and conceivably less pristine) fraction of similar habitats available to support those marine mammal species utilising this larger coastal region.

3. ASSESSMENT OF ACTUAL AND POTENTIAL EFFECTS

Despite the frequent use of dredges in most ports, harbours and coastal development projects, little research has focused specifically on the effects of dredging operations on marine mammals (see review by Todd et al. 2015 and references therein). Interactions between marine mammals and coastal development usually result from an overlap between the spatial location of the development and important habitats of the species. The direct effects of such overlap range from physical interactions with the animals (e.g. vessel strikes or entanglements) to avoidance or even abandonment of the area by the species due to the general increase in activity (e.g. noise or traffic). Indirect effects may result from physical changes to the habitat itself that adversely affect the health of the local ecosystem and / or impinge on important prey resources. The following section describes the direct and indirect effects that dredging can have on marine mammals based on available (predominantly overseas) studies while relying on a wider range of research focused on coastal development and marine mammals in general.

3.1. Direct effects

The act of breaking and/or removing bottom substrate in itself is not expected to directly affect any marine mammals known to frequent Lyttelton Harbour/Whakaraupō. Instead, the associated increase in vessel activity, resulting production of underwater sound and physical activities within the harbour are the more likely circumstances in which marine mammals will be affected.

3.1.1. Vessel strikes

The proposed CDP of Lyttelton Harbour/Whakaraupō's channel will involve the removal of dredge spoil to the proposed offshore disposal site in inner Pegasus Bay. Depending on the type of dredge vessel, this removal will involve approximately 2,100 return trips within the general vicinity of the harbour entrance over a minimum 9 to 14 month period (possibly longer depending on available equipment).

A recent worldwide review of dredging effects by Todd et al. (2015) suggests that the risk of collision between dredges and marine mammals will be minimal if the activity avoids critical habitats and seasons when the species of concern may be distracted (e.g. feeding or resting) or have calves present. To date, most reported incidences of vessel strikes have been with mysticete (baleen) whales.

Baleen whales

Vessel strikes are a well-known source of injury and mortality for several species of baleen whales around the world (Laist et al. 2001). A review of vessel strikes worldwide by Laist et al. (2001) found that the whales more commonly struck by vessels were: fin whales (*Balaenoptera physalus*), right whales (*Eubalaena glacialis* and *E. australis*), humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and gray whales (*Eschrichtius robustus*). In New Zealand waters, at least four baleen whale species have been found wrapped around the bows of container ships entering Ports of Auckland (Stone & Yoshinaga 2000; Constantine et al. 2015) and one species across the bow of a car carrier entering Lyttelton Harbour/Whakaraupō (L Allum, Department of Conservation, pers. comm. 2009). These species include; Bryde's whale (*Balaenoptera edeni*), blue whale (*Balaenoptera musculus*), sei whale (*Balaenoptera borealis*), minke whale (*Balaenoptera acutorostrata*) and fin whale (*B. physalus*).

The likelihood of vessel strike depends on a number of factors including vessel type, speed, location and the species and behaviour of marine mammals (Van Waerebeek et al. 2007). While all types and sizes of vessels have hit whales, the most severe collisions (e.g. fatal injury or mortality) occurred with large (*i.e.* > 80 m) and fast moving ships (*i.e.* > 14 knots or > 26 km/h; Laist et al. 2001; Jensen & Silber 2004). However, the size of the vessel appears to be less significant than its speed. The risk of collision and the likelihood that it will result in severe injury or death both increase above speeds of 10–14 knots (Todd et al. 2015). This might explain why dredges, which generally have maximum transit speeds of 12–16 knots (Brunn et al. 2005), have only been involved in one out of the 134 worldwide collision cases (in which the vessel type was known) reported between 1975 and 2002. A 110 m dredge operating in South Africa struck a southern right whale cow / calf pair that surfaced directly in front of it while underway, and the calf was subsequently killed (Jensen & Silber 2004).

Based on this evidence, the likelihood of a vessel strike (injury or mortality) associated with the capital or maintenance dredging of Lyttelton Harbour/Whakaraupō is low for migrating baleen whale species (see Table 2). This conclusion is based on:

- low probability of the dredging vessel encountering a migrating whale as currently only 1-3 individual whales are sighted within or near Lyttelton Harbour/Whakaraupō each year,
- whales occur seasonally with most sightings restricted mainly to winter months and remain only for a few days up to a few weeks,
- Pegasus Bay (and Lyttelton Harbour/Whakaraupō) are not significant or critical habitat for migrating whales in terms of feeding, resting or breeding[1],
- low probability of dredge vessel striking a migrating whale as the dredging vessel will be relatively stationary while dredging and when travelling to the disposal site, normal operating speed of the dredging vessel should be slow enough for any whales to be detected and avoided if needed,
- no reported incidences of whale strike by a dredge vessel within Lyttelton Harbour/Whakaraupō despite over 100 years of on-going dredging activity, and

[1] Accepting the occasional whale may transit through the area with a calf

- the dredging would represent only a temporary increase in vessel traffic within a fairly localised spatial area relative to the rest of Pegasus Bay waters.

Odontocetes and pinnipeds

In general, most odontocete ('toothed' whales or dolphins) and pinniped (seals or sea lions) species demonstrate few avoidance behaviours around most ships and boats. In fact some species regularly tolerate heavy vessel traffic while others often approach the vessels themselves (Richardson 1995). However, Todd et al. (2015) noted that certain age groups (i.e. calves and juveniles) and individuals engaged in particular behaviours (i.e. feeding or resting), and therefore less focussed on vessel movements, may be more susceptible to vessel strike. For instance, in Akaroa Harbour (Banks Peninsula) newborn Hector's dolphin calves are thought to be potentially vulnerable to small, high-speed vessels (Stone & Yoshinaga 2000). Recent reports documented lethal injuries on both common and bottlenose dolphins in the Hauraki Gulf consistent with vessel strike (Martinez & Stockin 2013; Dwyer et al. 2014), despite these species regularly interacting with vessels. Regardless, it should be noted that odontocete and pinniped reactions to vessels can vary greatly between species, populations and even individual animals.

Based on the research to date, the likelihood for any vessel strikes (i.e. injury or mortality) due to an increase in dredging traffic in Lyttelton Harbour/Whakaraupō is also considered low for any resident or visiting odontocete or pinniped species (see Table 2). This conclusion is based on:

- these species exhibit a general attraction or curiosity towards boats and most dolphin species safely approach and/or bowride with numerous vessels while fur seals often respond neutrally to boats when in the water (although they may bowride occasionally),
- Lyttelton Harbour/Whakaraupō is not considered important feeding, resting or nursery habitats for Hector's dolphins or fur seals relative to other sheltered bays found throughout the Peninsula [2],
- the low probability of dredge vessel striking an individual odontocete or pinniped given the vessel will be relatively stationary while dredging and when travelling to the disposal site, normal operating speed of the dredging vessel should be slow enough for any marine mammals to be detected and avoided if needed,
- the species known to frequent Lyttelton Harbour/Whakaraupō have a general nearshore distribution and are in regular contact with all types and speeds of commercial (including tourism and ferry services) and recreational vessels,
- no reported incidences of dolphin or seal strike by a dredge vessel within Lyttelton Harbour/Whakaraupō despite over 100 years of on-going dredging activity, and
- relatively temporary increase in dredge vessel traffic within a fairly localised spatial area relatively to the rest of Pegasus Bay waters.

[2] Accepting newborn calves will be present within these waters over summer and autumn months

Despite a low probability of the dredge vessel both encountering and striking a marine mammal within the Lyttelton Harbour/Whakaraupō region, the likelihood is not zero and the resulting consequences could be major (*i.e*. death of an endangered species; Table 2). However, researchers have found that, when given a chance, most marine mammal species will exhibit avoidance behaviours when approached by vessels moving at speed, a vessel producing rapidly changing noises and/or when a vessel directly approached the animal (Richardson 1995). Simple and commonsense boating behaviour around marine mammals by the dredge vessel, particularly around baleen whales and any calves, are expected to further reduce any overall risk of collision to near zero (see Table 2, Section 4.1.1 and Appendix 2 for further details).

Table 2. Summary of actual and potential effects on marine mammal species from the dredging and disposal of Lyttelton Harbour/Whakaraupō and entrance.

Potential environmental effects	Spatial scale of effect	Persistence / duration of effect	Consequence	Likelihood of effect	Overall risk level
Marine mammal / vessel strike due to increased vessel activity	**Large** Limited to vessel movements between the harbour and disposal site	**Moderate to Persistent** A risk only while dredge vessel is operating; each stage expected to last 9–14 months	**Major Effect:** death or injury of critically endangered species **Minor Effect:** death or injury of pinniped	**Low**	**Tolerable to Acceptable**
Increase in underwater sound from dredge vessel and dredging/disposal activities	**Small to Large** dependent on types of noise produced and frequencies (i.e. lower frequencies travel several km but noise levels generally attenuate within 10s of m)	**Short:** Whales will only be present in area for a few days to weeks **Persistent:** for resident dolphins and pinnipeds, annual maintenance dredging will continue for years to come.	**Minor Effect:** local avoidance by migrating whales **Less than Minor Effect:** pinnipeds and some dolphins may actually approach or be attracted to vessels/site	**Moderate**	**Acceptable**
Marine mammal entanglement in operational gear and / or debris	**Small to Medium** Limited to immediate waters around operating dredge vessels	**Moderate to Persistent** A risk only while dredge vessel is operating; each stage expected to last 9-14 months	**Major Effect:** death or injury of critically endangered species **Minor Effect:** death or injury of pinniped	**Low**	**Acceptable**
Contaminant effects on marine mammals from dredge sediments and/or spoil	**Medium to Large** Limited to immediate waters and habitats adjacent to dredge and disposal sites	**Short to Persistent** dependent on level of contaminations in sediments	**Less than Minor Effect:** Given tested contaminant levels in sediments	**Low**	**Acceptable**
Marine mammal habitat / prey disturbance from dredging/disposal activities	**Medium to Large** Limited to immediate waters and habitats adjacent to dredge and disposal sites	**Moderate to Persistent** Re-colonisation will begin during on-going activities and recovery within disposal site only after disturbance has ceased	**None to Less than Minor Effect:** Pinnipeds and some dolphins may even target site(s) for foraging	**Not Applicable to Low**	**Negligible to Acceptable**

The definitions used in the table are:

- Spatial scale of effect: Small (tens of metres), Medium (hundreds of metres), Large (> 1 km)
- Duration of effect: Short (days to weeks), Moderate (weeks to months), Persistent (years or more)
- Consequence: None, Less than Minor, Minor, Major
- Likelihood of effect: Not Applicable (NA), Low (< 25%), Moderate (25–75%), High (> 75%)
- Risk level: Not Applicable (NA), Acceptable, Tolerable, Unacceptable.

3.1.2. Underwater noise

The CDP will involve an increase in vessel traffic and mechanical activities that will generally increase the amount of anthropogenic (human-made) underwater sound produced in the area (e.g. CEDA 2011; WODA 2013). Increasing underwater noise is always a concern in regards to marine mammals. Noise has the potential to negatively affect both cetacean and pinniped species since they heavily rely on underwater sounds for communication, orientation, predator avoidance and foraging. However, only a few studies have specifically examined the effects of dredging noise on marine mammals or attempted to tease apart these effects from other, often coincident, construction sources. Potential effects associated with underwater noise from dredging activities will be dependent on the types and levels of noise produced, with possible impacts ranging from short-term avoidance, behavioural changes and acoustic masking to physical injury resulting for auditory damage (see Todd et al. 2015 and references therein).

Dredge noise

Generally, the noises produced from dredging activities are continuous, broad-band sounds mostly below 1 kHz (Todd et al. 2015). Dredges produce relatively lower sound levels than a powerful ship; 124–188 dB *re*1 µPa rms @ 1 m[3] versus 180-190 dB *re*1 µPa rms @ 1 m, respectively (OSPAR 2009; Todd et al. 2015). However, the two differ in that a dredge may be actively operating within one general area (<10 km) for longer periods of time (weeks or months) while a ship rarely remains in the same area for long (minutes or hours). The associated noise characteristics of dredging activities can also vary depending on the type of dredge, operational stage, and ambient (environmental background) conditions.

An underwater noise review by CEDA (2011) found that trailer-suction hopper dredges and cutter-suction dredges, the two main types of dredge considered for this proposal, produce mostly low frequency, omni-directional sounds between 100-500 Hz. However, their bandwidths could fluctuate as low as 30 Hz and as high as 20 kHz. The exact ranges are dependent on the sediment extraction process and the types of sediment being extracted, with coarser gravel causing greater sound levels. Hopper dredges were found to be slightly 'noisier' than cutter-suction dredges, although their noise levels fluctuated with operation status (Greene 1987).

Understanding ambient underwater sound levels is important in assessing the potential scale and impact of additional underwater noises as background noise, along with the physical environment, will influence the propagation and detection of these new sounds. The ambient background sound levels for Lyttelton Harbour/Whakaraupō have been estimated at 129 dB (URS 2013; based on calm

[3] The term 'dB *re*1 µPa @ 1 m' represents the sound pressure level at one metre distance from the source. RMS = root mean square or mean squared pressure and rms levels are often used for long duration or continuous noise sources instead of 'peak' levels. The averaged square pressure is measured across some defined time window that encompasses the call signal.

conditions and no shipping in the area) and are similar to other New Zealand ports measured in the relative absence of ships (e.g. Pine et al. 2015). Nearshore coastal environments outside the harbor are expected to be generally lower; 109–118 dB *re*1µPa for frequencies below 10 kHz (Pine et al. 2015).

Environmental factors that may lessen the noise levels produced from dredging, and thus the distances at which it can be detected are; thermo- or haloclines, depth of water, ambient level of suspended sediments and the types of sediment being dredged. For example, shallower depths will attenuate (*i.e*. reduce the strength of a signal) some of the lower frequency sounds created from dredging (e.g. Gerstein & Blue 2006). Richards et al (1996) reported that suspended sediments in concentrations of 20 mg/L can cause an attenuation of 3 dB over 100 m, but only in the higher frequency range (~100 kHz). Gerstein and Blue (2006) found dredging of soft and / or unconsolidated sediment also tends to absorb or dampen lower frequency sounds.

Possible underwater noise impacts

Theoretical 'zones of auditory influence', originally proposed by Richardson et al. (1995), are mainly based around the distance between the source (e.g. dredge) and receiver (e.g. whale), and the idea that underwater sound intensity, and its potential impact, decreases in severity with increasing distance (Figure 5). Once a sound can be detected by a species (zone of audibility), the next zone of influence is one thought to result in a range of behavioural response or avoidance reactions by the animal to a sound (zone of responsiveness). The distance at which such reactions may take place is thought to be highly variable and dependent on the type of sound, species' auditory capabilities and more importantly, an individual's behavioural state at the time (e.g. feeding, resting).

Underwater noises can also 'mask' or obscure the ability of an animal to detect important intra-species communication noises as well as interfere with other acoustic cues from predators or nearby vessels (e.g. Lammers et al. 2013; Erbe 2002; Gerstein & Blue 2006). Recent propagation modelling suggests potential masking of some low-frequency right whale calls can occur at tens of kilometres (Tennessen & Parks 2016). Hence, the distance at which masking may occur is variable depending on the auditory capabilities of the species, but also difficult to accurately predict (WODA 2013). Thought to be more of a chronic rather than acute impact, masking of communicative noises may have implications on longer-term population dynamics (Clark et al 2009).

The zones at which physiological hearing effects can occur is related to a temporary auditory threshold shift (TTS) and/or permanent auditory threshold shift (PTS), the latter of which is considered an auditory tissue injury. As TTS and PTS impacts are related to dose and duration of exposure, sound thresholds are considered more useful criteria for identifying possible impacts than distance alone (see Appendix 3. Theoretical zones of auditory influence and sound threshold criteria. for threshold criteria levels).

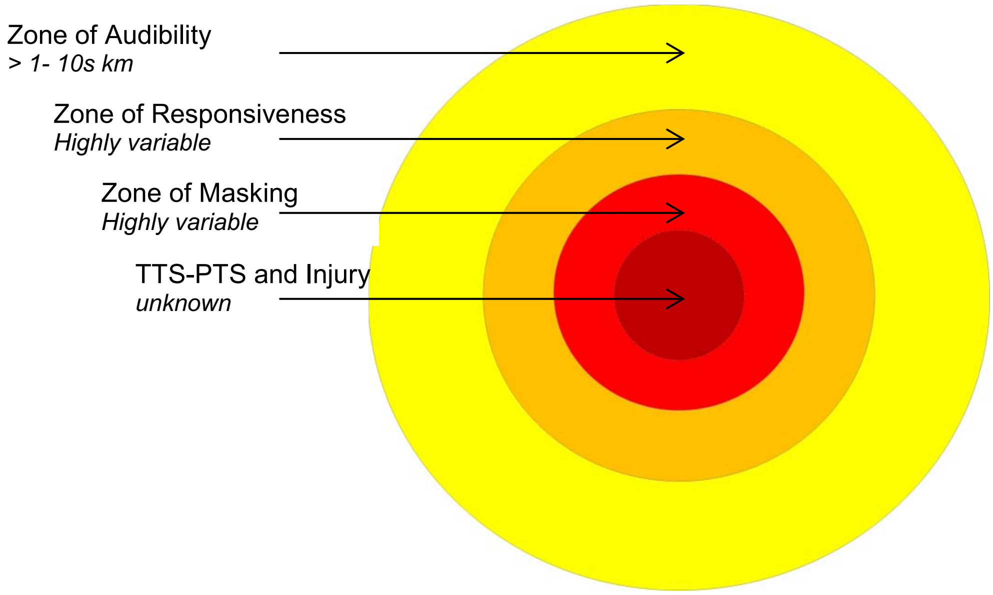

Figure 5 Schematic of the theoretical zones of auditory influence based on Richardson et al (1995).

Baleen whales

The lower vocalisation ranges of southern right whales suggest their best hearing capabilities are at least between 50 Hz and 2 kHz (Parks & Tyack 2005) and 20 Hz to 12 kHz for humpbacks (McCauley & Cato 2003), while the functional hearing of baleen whales in general is thought to be between 7 Hz and 22 kHz (Southall et al. 2007). These frequency ranges directly overlap with most anthropogenic underwater noise, including dredging activities as discussed above, meaning baleen whales are the species most susceptible to any dredge noise effects, in particular acoustic masking (Clark et al. 2009).

As evidenced by overseas studies, the likelihood of any migrating and visiting baleen whales detecting or hearing underwater noise produced by dredging activity is *moderate* (25–75%; Table 2), depending on the dredge's location in the harbour. However, the consequences are expected to be *minor* with the strongest responses resulting in short-term masking of some whales' communication calls to temporary avoidance of the areas by pregnant whales or whales with calves during their migration past the Peninsula (Todd et al 2015). This conclusion is based on:

- mainly lower-frequency noise expected to be generated by dredging vessels and activities that would be detectable by whales up to at least several kilometres, if not more, once outside of harbour (see Figure 5),

- dredge sound level ranges are not expected to exceed any injury threshold criteria, while whales' short-term (i.e. days to weeks) visits ensure that any exposure effects (i.e. TTS) will be negligible to non-existent (for more details see Appendix 3),
- relevant environmental factors (i.e. shallow depths, high sediment load, soft sediments; Sneddon et al. 2016) may help dampen underwater noise production in the lower, and some higher, frequencies,
- a seasonal presence of only 1-3 individual whales within or near Lyttelton Harbour/Whakaraupō each year with sightings restricted to winter months and occasionally spring (see Appendix 1 for more detail), and
- previous and current exposure to similar types and levels of dredging noise within the Harbour has not resulted in any lasting avoidance behaviours (i.e. whales continue to return to area each winter) and/or led to any known vessel strike through acoustic masking.

Odontocetes and pinnipeds

Odontocetes (e.g. orca and dolphins) generally communicate at higher frequency ranges than baleen whales and have the capability to echolocate (produce biological sonar for navigation and hunting). While most dolphin functional hearing is estimated to be quite large and they can likely detect low-frequency sounds, their sensitivity significantly decreases at frequencies below 1–2 kHz (Au 2000; Southall et al. 2007). Pinnipeds' hearing ranges are thought to vary more widely, including some ultrasonic frequencies, and are quite sensitive to frequencies below 1 kHz (based on grey and harbour seals; Thomsen et al. 2009). However, a study of New Zealand fur seals in Western Australia reported no disturbance reactions to dredging taking place close to haul-out sites (Todd et al. 2015 and references therein).

While more detailed research is needed in terms of individual species' sensitivity to low-frequency sound, the physiological differences in these species' hearing (relative to baleen whales) may help minimise any direct hearing effects caused by a general increase in lower frequency noise production. It also may explain the continued presence of several dolphin (e.g. Hector's, common, bottlenose) and pinniped species in harbour and coastal regions with extremely high shipping and development activities.

The noise from dredging and disposal operations is expected to have a *less than minor effect* on local or visiting odontocete and pinniped species (Table 2). If any effects do occur, they are expected to result from the increase in activity as much as underwater noise, which may led to temporary avoidance or even possible attraction to the activity area. This conclusion is based on:

- relevant environmental factors, such as soft mud substrates, may help ensure underwater noise production from dredge activities remains below 1 kHz,

- differences in functional frequencies ranges between species' hearing sensitivities and the lower frequency sounds produced by dredge activities,
- Hector's dolphins' and New Zealand fur seals' continued year-round occupancy of Lyttelton Harbour/Whakaraupō and / or nearby Pegasus Bay waters despite on-going maintenance dredging taking place over the last 100 years or more, and
- previous and current exposure to similar types and levels of dredging noise within the Harbour has not resulted in any lasting avoidance behaviours and/or led to any known vessel strike through acoustic masking.

3.1.3. Operational loss and possible entanglements

Potentially harmful operational by-products of any type of coastal development can include such items as lost ropes, support buoys, bags and plastics (Weeber & Gibbs 1998), items often collectively known as marine debris (Laist et al. 1999). As most marine materials are now manufactured from a range of plastics, they often tend to float and persist rather than degrading quickly as is generally the case with more natural, fibre materials (Laist et al. 1999).

The major hazard associated with marine debris from coastal development projects to whales and dolphins is the possibility of entanglement (Laist et al. 1999). Whales and dolphins are often attracted to floating debris, with a potential risk of becoming entangled in floating lines and netting (e.g. Suisted & Neale 2004; Groom & Coughran 2012). Loose, thin lines pose the greatest entanglement risk (e.g. lines used to tie up boats, floats and other equipment, and especially lost ropes and lines). However, the nature of dredge operating activities and equipment involved makes the risk of entanglement in marine debris from capital and/or maintenance dredging and disposal extremely low. Any subsequent effects on marine mammals will be non-existent in well-maintained coastal development projects with proper waste management programmes in place.

3.2. Indirect effects

Coastal dredging and the associated spoil disposal within any established ecosystem will result in some change to that system. However, the nature and extent of such change will be dependent on many variables, including the scale of dredging. Currently there is little to no research on how ecosystem changes due to dredging activities might indirectly affect marine mammals. While most cetaceans are generalist feeders and flexible in their habits, some species have been known to dramatically alter their distribution patterns in response to even small changes in prey availability (e.g. bottlenose dolphins: Bearzi et al. 2004) and / or ecosystem dynamics (e.g. North Atlantic right whales: Baumgartner et al. 2007). The following section focuses on potential indirect effects that dredging and / or spoil disposal activities could have on the ecosystem as a whole, and more specifically on the abundance, distribution and/or health of marine mammal prey resources.

3.2.1. Quality of dredge spoil

Despite evidence of detectable concentrations of several known contaminants within a large number of global and New Zealand species (e.g. Evans 2003; Fossi & Marsili 2003; Stockin et al. 2007, 2010), to predict the possible consequences of marine mammal exposure to contaminants is difficult due to the lack of available information around most species' distribution ranges, individual sensitivities to pollutants and exposure to non-point sources of pollutants (Jones 1998). However, in this case, contaminants associated with the capital dredge spoil have not been identified as a significant risk for the ecology of Lyttelton Harbour/Whakaraupō or the Pegasus Bay spoil ground (Sneddon et al. 2016). Therefore, risks for bioaccumulation and biomagnification by local marine mammal species from the resuspension and dispersal of contaminants in dredge sediments were also assessed as low, even for those species with the highest potential for exposure, such as Hector's dolphin and New Zealand fur seals.

Contaminants and bacteria adsorb to marine sediments leading to their accumulation and bioturbation over time. Dredging re-suspends these sediments and may result in the contaminants becoming bioavailable to potential prey species. The only health risk to local marine mammals is through direct (floating debris or particulates trapped in surface micro-layers) or indirect consumption of contaminants through exposed prey species. Possible exposure to contaminants by marine mammals will depend on the chemical characteristics of the spoil sediments, the subsequent uptake by relevant prey resources, and the feeding habits and range of local marine mammal species.

Todd et al. (2015) notes that risks are greatest to marine mammals only when dredging *contaminated* sediments (i.e. not all sediments have heavy contaminant loads), and concluded that in even those cases, exposure was still spatially restricted. Hector's dolphins and New Zealand fur seals are generalist feeders that potentially range and forage throughout the entire harbour and bay and, in the case of fur seals, off the continental shelf edge (Goldsworthy & Gales 2008). Hence, individual animals would not be expected to forage regularly or frequently on individual prey fish exposed to any contaminants from the dredging or spoil disposal.

Based on Sneddon et al. (2016) contaminant review and the available contaminant work on marine mammals both within New Zealand and overseas, any potential effects on local marine mammals from spoil contaminants will be less than minor. This conclusion is based on the following:

- expected low contaminant levels in dredged sediments,
- rapid settlement of dredged sediments resulting in limited spatial exposure to individual prey species,

- insolubility of some contaminants and others that are not expected to be bioavailable (i.e. bound in mineral forms with very limited solubility),
- generalist diet and roving nature of local marine mammals is expected to limit contact with any prey species exposed to hazardous materials.

3.2.2. Ecological effects on habitat and prey species

Benthic disturbance and loss

Dredging activities are expected to directly affect local food webs to some degree. However, the duration and extent of such changes will vary temporally and are dependent upon the benthic species impacted and the scale of the dredging activity. As a result, Todd et al.'s (2015) dredging effects review concluded that only minor changes (i.e. positive or negative) in the prey resources of local marine mammal are likely to occur in response to most dredging activities, thus limiting further flow-on effects to marine mammals themselves.

The capital dredging of the new channel extension is expected to cause immediate loss of the existing benthic biota and permanently alter the habitat within the immediate region of activity (Sneddon et al. 2016). However, the author concluded that this habitat loss is unlikely to significantly affect the lower and / or outer harbour ecosystem as it constitutes only 5% of the available benthic habitat at the entrance of the harbour as a whole. Once capital dredging and channel construction is finished, it is likely that a temporary colonisation of some benthic species (Sneddon et al. 2016) along with the re-establishment of soft sediments in the channel itself will occur between periodic maintenance dredging. This situation is similar to the present benthic dynamics in the existing channel.

Sneddon et al. (2016) also concluded that while smothering of benthic communities within the disposal site will initially take place, it will be an incremental build-up of the deposited layer over time with smothering impacts existing in a 'quasi-steady state'. This is because benthic recovery will continue at any single location as soon as a single depositional event take place and will not be interrupted until another deposition happens in that same location. Benthic survival and recovery around the spoil grounds will be meditated by the adopted dump release pattern and rate of spoil deposition, rather than the nominal thickness of the final deposition layer. However unlike the channel extension, the benthic communities within the spoil grounds are expected to have effectively recovered after spoil disposal ceases.

Based on the above ecological effects, Sneddon et al. (2016) suggested that benthic fish (e.g. flatfish such as sole and/or flounder) and demersal fish species (e.g. red cod) found in the dredging and disposal regions are expected to temporarily leave the immediate vicinity due to the physical disturbance and subsequent loss of existing food sources. However, this assessment did not identify these sites as having any special ecological or conservation importance for fish species in the area. As discussed in the section on Hector's dolphin, red cod (*Pseudophycis bachus*) constitutes a major proportion of the dolphins' diet around Banks Peninsula (Miller et al. 2013). This species spawns in deeper, offshore waters along the continental shelf and slope (Habib 1975; Alying & Cox 1982) so it is unlikely that capital dredging or spoil disposal within the limited offshore spoil ground will significantly affect red cod recruitment to the area. As a result, any associated benthic changes at these project sites are expected to affect only individual fish, not any particular species as a population.

Based on the findings of Sneddon et al. (2016), it was concluded that the ecological effects of dredging activities will be limited in their spatial extent, displacing only a small portion of individual fish temporarily from disturbance sites; hence any short- or long-term flow-on effects to local marine mammal will be negligible. This conclusion was based on:

- a relatively small percentage of benthic habitat loss within the harbour entrance and approaches, which is expected to recover after capital dredging and largely recover between annual maintenance dredging,
- benthic smothering effects confined to a limited region around the spoil disposal site, and affected fauna expected to fully recover,
- only temporary and localised avoidance of capital and/or maintenance disposal sites by individual benthic and demersal fish with no effect on species recruitment,
- general lack of evidence that project sites serve as unique and / or rare habitat for any marine mammal species in terms of feeding activities,
- the overall home ranges of local species are large and overlap with similar types of habitats in other regions of the harbour and throughout Pegasus Bay.

Turbidity plumes

Turbidity plumes are generated from the re-suspension of sediments at the dredging site and any marine location where dredged spoil is later deposited. There is potential for such plumes to be additive to existing turbidity levels, or become entrained in local gyres and eddies. High turbidity levels and movements of any concentrated sediment plumes created by dredging and / or disposal activities may be of some concern to fauna within or adjacent to work sites (e.g. Sneddon et al. 2016).

However, marine mammals are known to inhabit fairly turbid environments worldwide and especially within New Zealand. While they have very good vision, it does not appear to be the sense they rely upon most for foraging. Instead, odontocetes mainly depend on echolocation systems for underwater navigation and searching for food. But even baleen whales, which do not have the ability to echolocate, regularly forage in dark, benthic environments stirring up sediments to find prey. Thus, turbidity plumes are more likely to affect marine mammals indirectly via their prey resources rather than directly (Todd et al. 2015). Previous research on plumes suggests that any impacts on local food organisms should be short-term and limited in scale, and therefore, no substantial flow-on effects to local marine mammals are expected (Todd et al. 2015 and references therein).

Overseas research has demonstrated that dredging turbidity plumes generally fade into ambient turbidity levels relatively quickly (i.e. within one hour to 4–5 tidal cycles; Hitchcock & Bell 2004) and are fairly spatially constrained in their impacts (as predicted in this case), with any plumes dissipate towards background levels within less than 1 km of the point of origin (Sneddon et al. 2016, MetOcean 2016). Benthic layers of high turbidity and surficial fluid mud are more likely to be features of the seabed within the spoil ground immediately after deposition. The severity and extent of the turbidity plume has been modelled and assessed by MetOcean Solutions (2016). As such, turbidity plumes are not expected to meander over large distances or into diversity-rich habitats such as nearby rocky shores.

A large portion of the ambient turbidity found in Pegasus Bay waters is tied to the extensive run-off from numerous braided rivers along the east coast of the South Island (Carter & Herzer 1979; Herzer 1981). Most benthic and finfish species in the proposed sites are adapted to the highly dynamic and fairly high levels of turbidity associated with Pegasus Bay inshore waters, and as such, are expected to withstand any resulting turbidity plumes created from spoil disposal. Therefore, any ecological effects of dredging activities will be limited in their spatial extent as to displace only a small portion of individual fish temporarily from proposed sites.

Sneddon et al. (2016) also noted that spoil dumping may indirectly be a food resource for benthic fish species such as flatfish, gurnard and red cod due to the infauna within it. Such fish are all known prey species of Hector's dolphins and occasionally opportunistic fur seals. Any aggregation of fish species due to entrained food or temporary frontal aggregations will attract curious individual dolphins and seals. Hence, any indirect effects of turbidity plumes from dredging activities are not expected to have any detrimental or long-term flow-on effects to local marine mammals in the region. This assessment is based on:

- turbidity plumes resulting from dredging or disposal activities are expected to settle out relatively quickly and are not expected to adversely affect nearby coastal habitats (e.g. rocky shore),
- regular exposure to naturally high turbidity waters by local marine mammal species, and their prey. They may even be attracted to localised and/or temporarily frontal zones created by turbidity plumes to feed.
- low likelihood of whales being affected by any localised turbidity plumes as they regular migrate through Peninsula waters during the potentially more turbid winter months (e.g. Carter & Herzer 1979).

3.3. Ongoing maintenance dredging

The 256 ha area of the proposed offshore maintenance dredge spoil ground (Figure 1) is expected to receive spoil volume from the outer Harbour and approach channel of between 900,000 m^3 and 1.2 million m^3 annually. The available information on marine mammal occurrence does not indicate that the location of the proposed maintenance spoil ground would put any species at greater risk than with capital dredging spoil disposal. The risks to marine mammals from the activity of maintenance dredging and spoil disposal are effectively identical to those from the CDP itself. The main points of difference in maintenance dredging which may have some bearing on overall risk are as follows:

- it is ongoing and periodic (typically annual)
- it is likely to be carried out using a smaller capacity trailer suction hopper dredge (TSHD) (in this case probably 1,840 m^3).

In comparison to the current maintenance dredging program, the increased operating range of a dredge using the proposed offshore maintenance ground undoubtedly represents an incremental increase in the risk of collision with marine mammals. However, these risks from dredging and spoil disposal activities are already assessed as being very low. The increase in vessel activity represented by the post-CDP maintenance dredging program will also remain spatially limited to the Harbour approaches where transit of Port shipping traffic is already concentrated. As stated, commonsense vessel operational procedures around marine mammals should reduce collision risk to near-zero.

Any increase in underwater noise associated with maintenance dredging will also be incremental over that already produced by Port traffic and the current dredging of existing navigation channels.

Indirect effects from use of the proposed offshore maintenance spoil ground are likely to be less than minor. Any effects from spoil deposition on important prey species will be very localised to the spoil ground, which occupies a benthic area representing a very small proportion of similar available habitat in the wider area. The dynamic nature of this habitat also means that recolonisation with similar communities will be rapid following deposition events. In view of these factors, any food web effects on wide-ranging hunters such as dolphins and seals are likely to be negligible.

While the use of the offshore maintenance spoil ground will be ongoing, effects from turbidity and risks from contamination are likely also to be very low. Since the majority of the spoil taken to the offshore ground will come from the outer Harbour channel, its contamination status is likely to be near background levels for inshore Pegasus Bay.

The use of a smaller TSHD for maintenance dredging than that used for the CDP is likely to result in the generation of correspondingly lower levels of both turbidity plumes and underwater noise.

4. MITIGATION AND MONITORING

4.1.1. Mitigation

Overall, the risk of potential impacts on local and visiting marine mammals from dredging activities is assessed as *acceptable to tolerable* when considering the types of effects, their spatial scales and durations, likelihood, and potential consequences. However, given that some of the possible consequences of rare events (i.e. vessel collision or entanglement) could be major (i.e. injury or death of an endangered animal), several best practice standards are recommended as mitigation actions in relation to marine mammals and dredging in Lyttelton Harbour/Whakaraupō (Table 3).

To ensure that the most appropriate measures are in place, it is also suggested that a marine wildlife management plan be completed in consultation with DOC prior to commencing CDP operations. This plan should outline in detail some of the procedures referred to in Table 3 and determine timelines for any on-going monitoring (see Section 4.1.2) and/or any implemented procedures that will need to be reviewed for effectiveness during operations. Note that BMPs are suggested even where the likelihood of effects are low. Together, industry and DOC can use this information to further understand any actual effects on marine mammals due to dredging activities, and if necessary, help reduce the risk of similar incidences in the future.

4.1.2. Monitoring

Despite the lack of data specific to Lyttelton Harbour/Whakaraupō and the Pegasus Bay region for some marine mammal species discussed in this review, no systematic marine mammal surveys are recommended. The problems associated with trying to implement normal monitoring programmes for marine mammals around cause-effect relationships are that even with an established baseline dataset (i.e. Hector's dolphins) and a high level of long-term effort (i.e. greater than five years), it would be highly unlikely that any statistical conclusion could be reached in terms of an impact's effect on the population. This is due to marine mammals' mobile and flexible nature, highly variable population dynamics, low sample sizes, while any impacts of dredging are likely to be very small relative to other stressors (i.e. masked by background variability).

In this case, it would be more realistic (scientifically and economically) for a monitoring programme to gather information focused on simple questions related to specific aspects of the dredging that might help further mitigate any potential effects, particularly given that the expected likelihood of impacts as assessed through the AEE were mostly low to negligible. Such questions might include:

- What are Hector's dolphins (or other marine mammals) behavioural reactions to the presence of dredging vessels during active versus non-active operations? For example, if present prior to dredging start-up, do they immediately leave at start up?
- What are Hector's dolphins (or other marine mammals) behavioural reactions to spoil disposal? For example, if present prior to disposal, do they immediately leave once disposal begins? If so, what is the mean time it takes them to return (if at all)?
- Are Hector's dolphins (or other marine mammals) visiting/passing through the dredge or spoil area in between disposals?
- What are the actual noise levels and frequencies produced from dredging and disposal activities within Lyttelton Harbour/Whakaraupō and at the disposal site?

Hence, a monitoring programme for marine mammals is recommended that would involve a combination of visual sightings from dredging vessels with simultaneous passive underwater acoustic monitoring collected within the proposal area prior to and during dredging and disposal activities, and for a period after all operations have ceased. While this monitoring information will lack some statistical robustness (given limited detection distances), a well-kept database will confirm which species might be expected within the vicinity of proposed works, their potential seasonality and relative frequency as well as monitor for the species' continued presence both during and after activities have ceased.

Another advantage of a monitoring programme is that it will allow for the effectiveness of any mitigation measures put in place to be revisited and amended, if necessary, while dredging operations are underway. Such information is crucial towards continuing to investigate and develop appropriate mitigation measures in the context of this proposal.

4.1.3. Maintenance dredging

The consideration of possible mitigation actions for CDP dredging and spoil disposal apply also to ongoing maintenance dredging, especially those concerning operational practices in proximity to observed marine mammals. The more intensive monitoring aspects suggested for the CDP may be less appropriate for ongoing routine maintenance dredging. However, information compiled via direct observation and passive acoustic monitoring during the CDP may inform aspects of any program for maintenance dredging; especially regarding marine mammal response to dredging and spoil disposal operations and seasonal use of the area by particular species.

Table 3. Proposed mitigation goals and practices to mitigate or minimise the risk of any adverse effects of dredging activities on marine mammals in Lyttelton Harbour/Whakaraupō and Pegasus Bay.

Potential effects	Mitigation goal	Best Management Practice	Reporting / monitoring
Marine mammal / vessel strike due to increased vessel activity	1. Minimise the risk of dredge vessel collisions with any marine mammal and aim for zero mortality	1a. Adoption of best boating guidelines for marine mammals, including speed limits, to further reduce any chances of mortality from vessel strikes. 1b. Consider establishing a designated observer on the vessel and maintain a watch for marine mammals during any dredging and disposal activities over daylight hours. 1c. Liaison with the Department of Conservation over the project period to help anticipate and mitigate potential seasonal interactions with any whale species sighted, particularly southern right whales.	• Record and report the type and frequency of any marine mammal sighted before, during or after transiting to or from the disposal site.
Increase in underwater sound from dredging / disposal activities	2. Minimise the avoidance (or attraction) of marine mammals to dredging activities	2a. Regular maintenance and proper up-keep of all dredging equipment and the vessel (e.g. lubrication and repair of winches, generators) can significantly help lessen some underwater noise production.	• Encourage or support specific research into noise production and / or its effects; e.g. measure underwater noise levels from dredging activities • Passive acoustic monitoring of marine mammals' presence near dredging activities
Marine mammal entangle-ment in operational gear and / or debris	3. Minimise entanglement and aim for zero mortality	3a. Avoid loose rope and / or nets (i.e. keep all ropes and nets taut). 3b. Minimise potential for loss of rubbish and debris from dredging vessels and activities with proper waste management plans in place.	• Record all entanglement incidents or near incidents regardless of outcome (e.g. injury or mortality). • In case of a fatal marine mammal incident, carcass(es) recovered and given to DOC, and further steps taken in consultation with DOC to reduce the risk of future incidences.
Contaminant effects on marine mammals from dredging activities	4. Minimise or lower the risk of exposure to any contaminated sediments	4a. Test spoil sediments prior to dredging 4b. Ensure any significantly contaminated sediments are disposed of properly (i.e. on land, etc.)	• As discussed in Brough et al. (2014)

5. CONCLUSIONS

The purpose of this assessment of effects report was to describe the existing environment in terms of the local and visiting marine mammals that utilise and / or are influenced by the Pegasus Bay ecosystem. In particular, information on the various species were reviewed for any life-history dynamics that make them more vulnerable to dredging activities or where dredging sites may overlap with ecologically significant feeding, resting or breeding habitats (which include prey resources). This in turn, enabled the potential effects associated with the CDP on marine mammals to be assessed in the context of the proposal.

The marine mammals most likely to be affected by the proposed CDP include those species that frequent Lyttelton Harbour/Whakaraupō and Pegasus Bay year-round or on a semi-regular basis: Hector's dolphin and New Zealand fur seals. The only other species of concern is the southern right whale given that is more vulnerable to anthropogenic impacts due to its coastal tendencies, low population numbers and its known collision risks.

In light of the direct and indirect issues highlighted in this report, the overall risk of any effects of the CDP on these species within southern Pegasus Bay and Lyttelton Harbour/Whakaraupō was assessed as acceptable to tolerable. These conclusions were based in part on additional information from other consultant reports on the expected levels of underwater noise due to dredging activities, concentrations of contaminants in dredging materials (Sneddon et al. 2016), expected effects on local benthos and fish communities (Sneddon et al. 2016), and modelled and predicted turbidity plume dynamics (MetOcean 2016).

A monitoring programme for marine mammals is recommended that would involve a combination of visual sightings from dredging vessels with simultaneous passive underwater acoustic monitoring collected within the proposal area prior to and during dredging and disposal activities. Such a programme will also serve the dual purpose of assessing the effectiveness of any mitigation measures put in place that can then be amended, if necessary while dredging operations are underway, and will also provide data on dredging activities for future projects.

6. REFERENCES

Au WWL 2000. Hearing in whales and dolphins: an overview. In: Au WWL, Popper AN, Fay RR (eds). Hearing by whales and dolphins. New York, USA. Springer-Verlag Inc. pp. 1-42.

Ayling T, Cox GJ 1982. Collins guide to the sea fishes of New Zealand. Auckland: Williams Collins Publishers, Ltd.

Baird S 1999. Estimation of nonfish bycatch in commercial fisheries in New Zealand waters, 1997-1998, NIWA Report 23: 58 p.

Baird SJ 2000. Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1998-1999. Wellington, New Zealand Fisheries Assessment Report: 40 p.

Baker AN 1999. Whales and dolphins of New Zealand and Australia; an identification guide. Victoria University Press, Wellington. 133 p.

Baker AN 2001. Status, relationships, and distribution of *Mesoplodon bowdoini* Andrews, 1908 (Cetacea: Ziphiidae). Marine Mammal Science 17(3):473-493.

Baker CS, Clapham PJ 2004. Modelling the past and future of whales and whaling. Trends in Ecology and Evolution 19(7): 365-371.

Baker CS, Chilvers BL, Childerhouse S, Constantine R, Currey R, Mattlin R, van Helden A, Hitchmough R, Rolfe J. 2016. Conservation status of New Zealand marine mammals, 2013. New Zealand Threat Classification Series 14. Department of Conservation, Wellington. 18 p.

Barr K, Slooten E 1999. Effects of tourism on dusky dolphins at Kaikoura. Conservation Advisory Science Notes No. 229. Department of Conservation, Wellington. 28 pp.

Baumgartner MF, Mayo CA, Kenney RD 2007. Enormous carnivores, microscopic food, and a restaurant that's hard to find. In: Kraus SD, Rolland RM (eds).The urban whale – North Atlantic right whales at the crossroads. Cambridge Massachusetts, Harvard University Press. Pp. 138-171.

Bearzi G, Quondam F, Politi E 2004. Bottlenose dolphins foraging alongside fish farm cages in eastern Ionian Sea coastal waters. European Research on Cetaceans 15:292-293.

Berkenbusch K, Abraham ER, Torres LG 2013. New Zealand marine mammals and commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 119. 104 p.

Best PB, Brandao A, Butterworth DS 2001. Demographic parameters of southern right whales off South Africa. Journal of Cetacean Research and Management Special Issue 2:161-169.

Borggaard D, Lien J, Stevick P 1999. Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992–1995). Aquatic Mammals, 25(3): 149-161.

Brabyn MW 1990. An analysis of the New Zealand whale strandings. Master's thesis. University of Canterbury, Christchurch, New Zealand. 85 p.

Brodie JW 1960. Coastal surface currents around New Zealand. New Zealand Journal of Geology and Geophysics 3(2): 235-252.

Brough T, Slooten E, Dawson S 2014. Marine mammals and Port Lyttelton development: An environmental impact assessment. Prepared for Lyttelton Port of Christchurch October 2014. 41 p.

Brunn P, Gayes PT, Schwab WC, Eiser WC. 2005. Dredging and offshore transport of materials. Journal of Coastal Research, Special Issue No. 2: 453–525.

Carroll E, Patenaude N, Childerhouse S, Kraus S, Fewster R, Baker C 2011a. Abundance of the New Zealand subantarctic southern right whale population estimated from photo-identification and genotype mark-recapture. Marine Biology 158(11): 2565-2575.

Carroll E, Patenaude N, Alexander A, Steel D, Harcourt R, Childerhouse S, Smith S, Bannister J, Constantine R, Baker CS 2011b. Population structure and individual movement of southern right whales around New Zealand and Australia. Marine Ecology Progress Series 432: 257-268.

Carroll EL, Childerhouse S, Fewster RM, Patenaude NJ, Steel D, Dunshea G, Boren LJ, Baker CS 2013. Accounting for female reproductive cycles in a superpopulation capture-recapture framework. Ecological Applications 23(7): 1677–1690.

Carroll EL, Rayment WJ, Alexander AM, Baker CS, Patenaude NJ, Steel D, Constantine R, Cole R, Boren LJ, Childerhouse S 2014. Reestablishment of former wintering grounds by New Zealand southern right whales. Marine Mammal Science 30(1): 206-220.

Carter L, Herzer RH 1979. The hydraulic regime and its potential to transport sediment on the Canterbury Continental Shelf. New Zealand Oceanographic Institute Memoir 83: 1-33.

Carwardine M 1995. Whales, dolphins and porpoises. Dorling Kindersley Ltd, London. 256 p.

CEDA. 2011. CEDA Position Paper: Underwater Sound in Relation to Dredging. 6p. www.dredging.org.

Childerhouse S, Gibbs N 2006. Preliminary report for the Cook Strait humpback whale survey 2006. Unpublished report to the Department of Conservation, New Zealand.

Childerhouse S, Jackson J, Baker CS, Gales N, Clapham PJ, Brownell Jr RL 2008. *Megaptera novaeangliae* (Oceania sub-population). In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.1.

Childerhouse S, Double M, Gales N 2010. Satellite tracking of southern right whales (*Eubalaena australis*) at the Auckland Islands, New Zealand. Unpublished report (SC/62/BRG19) presented to the Scientific Committee of the International Whaling Commission, Cambridge, UK.

Chilvers BL, Goldsworthy SD 2015. *Arctocephalus forsteri*. The IUCN Red List of Threatened Species 2015: e.T41664A45230026. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T41664A45230026.en. Downloaded on 23 May 2016.

Cipriano FW 1992. Behaviour and occurrence patterns, feeding ecology and life history of dusky dolphins (*Lagenorhynchus obscurus*) off Kaikoura, New Zealand. PhD thesis. Department of Ecology and Evolutionary Biology, University of Arizona, Tucson.

Clapham P, Mikhalev Y, Franklin W, Paton D, Baker CS, Ivashchenko YV, Brownell RL Jr 2009. Catches of humpback whales, *Megaptera novaeangliae*, by the Soviet Union and other nations in the Southern Ocean, 1947–1973. Marine Fisheries Review 71(1):39-43.

Clark CW, Ellison WT, Southall BL, Hatch L, Van Parijs SM, Frankel A, Ponirakis D. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. Marine Ecology Progress Series 395: 201-222.

Clement DM 2005. Distribution of Hector's dolphin (C*ephalorhynchus hectori*) in relation to oceanographic features. Ph.D thesis. University of Otago, Dunedin, New Zealand, 253p.

Constantine R, Baker CS 1997. Monitoring the commercial swim-with-dolphin operations in the Bay of Islands. Science for Conservation, 56. Department of Conservation, Wellington.

Constantine R, Brunton DH, Baker CS 2003. Effects of tourism on behavioural ecology of bottlenose dolphins of northeastern New Zealand. DOC Science Internal Series 153. Department of Conservation, Wellington. 26 p.

Constantine R, Russell K, Gibbs N, Childerhouse S, Baker CS 2007. Photo-identification of humpback whales (*Megaptera novaeangliae*) in New Zealand waters and their migratory connections to breeding grounds of Oceania. Marine Mammal Science 23(3): 715–720.

Constantine R, Johnson M, Riekkola L, Jervis S, Kozmian-Ledward L, Dennis T, Torres LG, Aguilar de Soto N 2015. Mitigation of vessel-strike mortality of endangered Bryde's whales in the Hauraki Gulf, New Zealand. Biological Conservation 186: 149-157.

Dawbin WH 1956. The migration of humpback whales which pass the New Zealand coast. Transactions of the Royal Society of New Zealand 84(1):147-196.

Dawson SM, Slooten E 1993. Conservation of Hector's dolphins: The case and process which led to establishment of the Banks Peninsula Marine Mammal Sanctuary. Aquatic Conservation: Marine and Freshwater Ecosystems 3: 207-221.

Dawson SM, Slooten E 1988. Hector's dolphin *Cephalorhynchus hectori*: Distribution and abundance. Reports of the International Whaling commission (Special Issue 9): 315-324.

DuFresne S 2005. Survival rates of Hector's dolphins at Banks Peninsula. Ph.D thesis. University of Otago, Dunedin, New Zealand, 152 p.

DuFresne SP, Grant AR, Norden WS, Pierre JP 2007. Factors affecting cetacean bycatch in a New Zealand trawl fishery. DOC Research & Development Series 282, Department of Conservation, Wellington, New Zealand. 18 p.

Dwyer S, Tezanos-Pinto G, Visser I, Pawley M, Meissner A, Berghan J, Stockin K 2014. Overlooking a potential hotspot at Great Barrier Island for the nationally endangered bottlenose dolphin of New Zealand. Endangered Species Research 25: 97-114.

Erbe C 2002. Hearing abilities of baleen whales. ICES Document DRDC Atlantic CR 2002-065. 28 pp.

Evans K 2003. Pollution and marine mammals in the Southern Hemisphere: potential or present threat? In: Gales N, Hindell M, Kirkwood R. (eds). Marine mammals – fisheries, tourism and management issues. Australia, CSIRO Publishing. Pp.1-19.

Fossi MC, Marsili L 2003. Effects of endocrine disruptors in aquatic mammals. Pure Applied Chemistry 75 (11-12): 2235-2247.

Gaborit-Haverkort T 2012. The occurrence and habitat use of common dolphins (*Delphinus* sp.) in the central Bay of Plenty, New Zealand.

Gales NJ 1991. New Zealand fur seals and oil: an overview of assessment, treatment, toxic effects and survivorship. The 1991 Sanko Harvest Oil Spill. West Australian Department of Conservation and Land Management.

Gaskin DE 1964. Return of the southern right whale (*Eubalaena australis* Desm.) to New Zealand waters, 1963. Fisheries Research Bulletin No. 67, Fisheries Research Division, New Zealand Marine Department, Wellington.

Gaskin DE 1968a. Distribution of Delphinidae (Cetacea) in relation to sea surface temperatures off eastern and southern New Zealand. New Zealand Journal of Marine and Freshwater Research 2: 527-534.

Gaskin DE 1968b. The New Zealand cetacea. Fisheries Research Bulletin, no. 1. New Zealand Marine Department, Wellington. 92 pp.

Gaskin DE 1972. Whales, dolphins and seals with special reference to the New Zealand region. Heinemann Educational Books Ltd. 200 pp.

Gaskin DE 1992. Status of the common dolphin, *Delphinus delphis,* in Canada. Canadian Field Naturalist 106: 55-63.

Gerstein ER, Blue JE 2006. Underwater noise from hopper dredging and the zones of masking that impact manatee hearing in the lower St. Johns River, Jacksonville, Florida. The Jacksonville Waterway Commission. Draft Final Report Contract No. 8548. 55p.

Gibbs N, Childerhouse S 2000. Humpback whales around New Zealand. Conservation Advisory Science Notes No. 257, Department of Conservation, Wellington.

Goldsworthy S, Gales N 2008. *Arctocephalus forsteri*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.1. <www.iucnredlist.org>. Downloaded on 28 October 2009.

Greene CRJ 1987. Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea. Journal of the Acoustical Society of America, 82: 1315–1324.

Greig AP, Secchi ER, Zerbini AN, Dalla-Rosa L 2001. Stranding events of southern right whales, *Eubalaena australis*, in southern Brazil. Journal of Cetacean Research and Management Special Issue 2: 157-160.

Groom C, Coughran D 2012. Entanglements of baleen whales off the coast of Western Australia between 1982 and 2010: patterns of occurrence, outcomes and management responses. Pacific Conservation Biology 18(3): 203-214.

Habib G 1975. Aspects of biology of red cod (*Pseudophycis bachus*). Ph.D thesis. University of Canterbury, Christchurch, New Zealand, 203 p.

Hammond PS, Bearzi G, Bjørge A, Forney K, Karczmarski L, Kasuya T, Perrin WF, Scott MD, Wang JY, Wells RS, Wilson B 2008b. *Delphinus delphis*. The IUCN Red List of Threatened Species. Version 2014.3. <www.iucnredlist.org>.

Hammond PS, Bearzi G, Bjørge A, Forney K, Karczmarski L, Kasuya T, Perrin WF, Scott MD, Wang JY, Wells RS, Wilson B 2008a. *Lagenorhynchus obscurus*. The IUCN Red List of Threatened Species 2008: e.T11146A3257285. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T11146A3257285.en. Downloaded on 23 May 2016.

Hammond PS, Bearzi G, Bjørge A, Forney KA, Karkzmarski L, Kasuya T, Perrin WF, Scott MD, Wang JY, Wells RS, Wilson B 2012. *Tursiops truncatus*. The IUCN Red List of Threatened Species 2012: e.T22563A17347397. http://dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T22563A17347397.en. Downloaded on 23 May 2016.

Hamner RM, Pichler FB, Heimeier D, Constantine R, Baker CS 2012. Genetic differentiation and limited gene flow among fragmented populations of New Zealand endemic Hector's and Maui's dolphins. Conservation Genetics 13: 987-1002.

Hamner RM, Steel D, Constantine R, Morrissey M, Ogle M, Weir J, Olavarria C, Baxter A, Arlidge W. Boren L, Baker CS 2016. Local population struture and abundance of Hector's dolphins off Kaikoura – 2014 and 2015. Report to the New Zealand Department of Conservation 6 March 2016. 24 p.

Harlin AD, Markowitz TM, Würsig B 2001. Foraging strategy modifications by dusky dolphins moving between different habitats: effects on group movement, composition, behaviour and association. Proceedings of the 14th Biennial Conference on the Biology of Marine Mammals, Society of Marine Mammalogy, Vancouver.

Herzer RH 1981. Late quaternary stratigraphy and sedimentation of the Canterbury Continental Shelf, New Zealand. New Zealand Oceanographic Institute Memoir 89: 1-71.

Hitchcock DR, Bell S 2004. Physical impact of marine aggregate dredging on seabed resources in coastal deposits. Journal of Coastal Research 20(1):101-114.

Hupman K, Visser IN, Martinez E, Stockin KA 2014. Using platforms of opportunity to determine the occurrence and group characteristics of orca (*Orcinus orca*) in the Hauraki Gulf, New Zealand, New Zealand Journal of Marine and Freshwater Research. DOI: 10.1080/00288330.2014.980278.

Jensen AS, Silber GK 2004. Large whale ship strike database. US Department of Commerce, NOAA Technical Memorandum NMFS-OPR-25. 37 p.

Jones PD 1998. Analysis of organic contaminants in New Zealand marine mammals. Conservation Advisory Science Notes No.184. Department of Conservation, Wellington, New Zealand.

Kraus SD, Rolland RM 2007. Right whales in the urban ocean. In: Kraus SD, Rolland RM (eds). The urban whale – North Atlantic right whales at the crossroads. Cambridge Massachusetts, Harvard University Press. Pp. 1-38.

Laist DW, Coe JM, O'Hara KJ 1999. Marine debris pollution. In: Twiss JR, Reeves RR (eds.). Conservation and management of marine mammals. Smithsonian Institution Press, Washington DC. pp. 342–363

Laist DW, Knowlton AR, Mead JG, Collet AS, Podesta M 2001. Collisions between ships and whales. Marine Mammal Science 17 (1): 35-75.

Lammers MO, Pack AA, Lyman EG, Espiritu L 2013. Trends in collisions between vessels and North Pacific humpback whales (*Megaptera novaeangliae*) in Hawaiian waters (1975–2011). Journal of Cetacean Research and Management 13: 73–80.

Leatherwood S, Reeves RR, Foster L 1983. The Sierra Club handbook of whales and dolphins. Sierra Club Books. San Francisco. 302 pp.

MacKenzie DI, Clement DM 2014. Abundance and distribution of ECSI Hector's dolphin. New Zealand Aquatic Environment and Biodiversity Report No. 123. 79 p + supplemental material.

MacKenzie DI, Clement DM 2016. Abundance and distribution of WCSI Hector's dolphin. New Zealand Aquatic Environment and Biodiversity Report No. 168. 67 p + supplemental material.

Markowitz T 2004. Social organisation of the New Zealand dusky dolphin. Unpublished PhD dissertation, Texas A&M University, Texas, USA. 278 p.

Martinez E, Stockin A 2013. Blunt trauma observed in a common dolphin *Delphinus* sp. likely caused by a vessel collision in the Hauraki Gulf, New Zealand. Pacific Conservation Biology 19(1): 19.

McCauley R, Cato D 2003. Acoustics and marine mammals: Introduction, importance, threats and potential as a research tool. In: Gales N, Hindell M, Kirkwood R (eds.) Marine mammals: fisheries, tourism and management issues. CSIRO Publishing, Australia. 446 pp.

MetOcean Solutions Ltd 2016. Lyttelton Harbour/Whakaraupō Dredging Project: Simulations of suspended sediment plumes and associated deposition from offshore disposal. Prepared for Lyttelton Port of Christchurch P0201-02. 54p.

Meynier L, Stockin KA, Bando MKH, Duignan PJ 2008. Stomach contents of common dolphins (*Delphinus* sp.) from New Zealand waters. New Zealand Journal of Marine and Freshwater Research 42:257-268.

Miller E, Lalas C, Dawson S, Ratz H, Slooten E 2013. Hector's dolphin diet: The species, sizes and relative importance of prey eaten by *Cephalorhynchus hectori*, investigated using stomach content analysis. Marine Mammal Science 29(4): 606-628.

Neumann DR, Leitenberger A, Orams MB 2002. Photo-identification of short-beaked common dolphins (*Delphinus delphis*) in north-east New Zealand: a photo-catalogue of recognisable individuals. New Zealand Journal of Marine and Freshwater Research 36: 593–604.

Nichols C, Stone G, Hutt A, Brown J, Yoshinaga A 2001. Observations of interactions between Hector's dolphins (*Cephalorhynchus hectori*), boats and people at Akaroa Harbour, New Zealand. Science for Conservation Report 178. Wellington: Department of Conservation, 49 pp.

NOAA (National Oceanic and Atmospheric Administration). 1998. Incidental taking of marine mammals; acoustic harassment. Federal Register 63(143): 40103.

Olavarría C, Baker C, Tezanos-Pinto G 2014. Low mtDNA genetic diversity among killer whales around New Zealand. New Zealand Journal of Marine and Freshwater Research 48(1): 147-153.

OSPAR 2009. Assessment of the environmental impact of underwater noise. OSPAR Commission. http://qsr2010.ospar.org/media/assessments/p00436_JAMP_ Assessment_Noise.pdf.

Parks SE, Tyack PL 2005. Sound production by North Atlantic right whales (I) in surface active groups. Journal of the Acoustic Society of America 117: 3297-3306.

Patenaude N 2000. Southern right whales wintering in the Auckland Islands. Conservation Advisory Science Notes No. 321. Department of Conservation, Wellington. 31 pp.

Patenaude N 2003. Sightings of southern right whales around ‘mainland’ New Zealand. Science for Conservation 225. 43 p.

Pichler FB, Baker CS 2000. Genetic variation and population structure of Hector's dolphins along the South Island's west coast. West Coast Conservancy Technical Report Series 4. Wellington: Department of Conservation. 24 p.

Pine MK, Radford CA, Jeffs AG 2015. Eavesdropping on the Kaipara Harbour: characterising underwater soundscapes within a seagrass bed and a subtidal mudflat. New Zealand Journal of Marine and Freshwater Research 49(2): 247-258.

Rayment WJ, Dawson S, Slooten E, Brager S, DuFresne S, Webster T 2009. Kernel density estimates of alongshore home range of Hector’s dolphins at Banks Peninsula, New Zealand. Marine Mammal Science 25(3): 537-556.

Reeves RR, Dawson SM, Jefferson T., Karczmarski, L, Laidre K, O’Corry-Crowe G, Rojas-Bracho L, Secchi ER, Slooten E, Smith BD, Wang JY, Zhou K 2013. *Cephalorhynchus hectori*. The IUCN Red List of Threatened Species 2013: e.T4162A44199757. http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T4162A44199757.en. Downloaded on 23 May 2016.

Reilly SB, Bannister JL, Best PB, Brown M, Brownell RL Jr, Butterworth DS, Clapham PJ, Cooke J, Donovan G., Urbán J, Zerbini AN 2013. *Eubalaena australis*. The IUCN Red List of Threatened Species. Version 2014.3. www.iucnredlist.org.

Richards SD; Heathershaw AD; Thorne PD 1996. The effect of suspended particulate matter on sound attenuation in seawater. Journal of the Acoustical Society of America 100(3): 1447-1450.

Richardson WJ 1995. Documented disturbance reactions. Chapter 9 in: Richardson WJ, Greene CR Jr, Malme CI, Thomson DH eds. Marine mammals and noise. Academic Press, San Diego. Pp 241-324.

Slooten E 1991. Age, growth, and reproduction in Hector's dolphins. Canadian Journal of Zoology 69: 1689-1700.

Slooten E, Lad F 1992. Survival rates of photographically identified Hector's dolphins from 1984-1988. Marine Mammal Science 8(4): 327-343.

Sneddon R, Atalah J, Forrest B, Mackenzie L, Floerl O 2016. Assessment of impacts to benthic ecology and marine ecological resources from proposed Lyttelton Harbour Channel Deepening Project. Prepared for Lyttelton Port Co Ltd. Cawthron Report No. 2860. 190 p. plus appendices.

Southall BL, Bowles AE, Ellison WT, Finneran JJ, Gentry RL, Greene CR Jr, Kastak D, Ketten DR, Miller JH, Nachtigall PE 2008. Marine mammal noise-exposure criteria: initial scientific recommendations. Bioacoustics 17(1-3): 273-275.

Stone GS, Yoshinaga A 2000. Hector's dolphin (*Cephalorhynchus hectori*) calf mortalities may indicate new risks from boat traffic and habituation. Pacific Conservation Biology 6: 162-170.

Stockin KA, Law RJ, Duignan PJ, Jones GW, Porter L, Mirimin L, Meynier L, Orams MB 2007. Trace elements, PCBs and organochlorine pesticides in New Zealand common dolphins (*Delphinus sp*.). Science of the Total Environment 387:333-345.

Stockin KA, Lusseau D, Binedell V, Orams MB 2008b. Tourism affects the behavioural budget of common dolphins (*Delphinus sp*.) in the Hauraki Gulf, New Zealand. Marine Ecology Progress Series, 355: 287-295.

Stockin KA, Pierce GJ, Binedell V, Wiseman N, Orams MB 2008a. Factors affecting the occurrence and demographics of common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand. Aquatic Mammals 34: 200-211.

Stockin KA, Law RJ, Roe WD, Meynier L, Martinez E, Duignan PJ, Bridgen P, Jones B 2010. PCBs and organochlorine pesticides in Hector's (*Cephalorhynchus hectori hectori*) and Maui's (*Cephalorhynchus hectori maui*) dolphins. Marine Pollution Bulletin 60 (6): 834-842.

Suisted R, Neale D 2004. Department of Conservation Marine Mammal Action Plan for 2005–2010. Report by the Marine Conservation Unit, Wellington: Department of Conservation, 89 p.

Taylor BL, Baird R, Barlow J, Dawson SM, Ford J, Mead JG, Notarbartolo di Sciara G, Wade P, Pitman RL 2013. *Orcinus orca*. The IUCN Red List of Threatened Species. Version 2014.3. <www.iucnredlist.org>.

Tennessen JB, Parks SE. 2016. Acoustic propagation modeling indicates vocal compensation in noise improves communication range for North Atlantic right whales. Endangered Species Research 30:225-237.

Tezanos-Pinto G, Constantine R, Mourão F, Berghan J, Scott Baker C 2014. High calf mortality in bottlenose dolphins in the Bay of Islands, New Zealand–a local unit in decline. Marine Mammal Science DOI: 10.1111/mms.12174.

Thompson FN, Abraham ER 2010. Estimation of fur seal (*Arctocephalus forsteri*) bycatch in New Zealand trawl fisheries, 2002–03 to 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 61.

Thomsen F, McCully S, Wood D, Pace F, White P 2009. A generic investigation into noise profiles of marine dredging in relation to the acoustic sensitivity of the marine fauna in UK waters with particular emphasis on aggregate dredging: Phase 1 Scoping and review of key issues. MEPF 08/P21. 49 p.

Todd VL, Todd IB, Gardiner JC, Morrin EC, MacPherson NA, DiMarzio NA, Thomsen F 2015. A review of impacts of marine dredging activities on marine mammals. ICES Journal of Marine Science: Journal du Conseil 72(2): 328-340.

Townsend AJ, de Lange PJ, Duffy CAJ, Miskelly CM, Molloy J, Norton DA 2007. New Zealand threat classification system manual. Department of Conservation, Wellington. 35 p.

Turek J, Slooten E, Dawson S, Rayment W, Turek D 2013. Distribution and abundance of Hector's dolphins off Otago, New Zealand. New Zealand Journal of Marine and Freshwater Research 47: 181–191. DOI:10.1080/00288330.2013.771687.

URS 2013. Technical review of Hegley Acoustic Consultants noise assessment report. Prepared for the New Zealand Environmental Protection Authority (EPA). 14 p. http://www.epa.govt.nz/Publications/Trans-Tasman%20Resources%20Irons%20Sand%20Project_Review%20of%20technical%20reports%20on%20noise.pdf.

Van Waerebeek K, Baker AN, Félix F, Gedamke J, Iñiguez M, Sanino GP, Secchi E, Sutaria D, van Helden A, Wang Y 2007. Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. Latin American Journal of Aquatic Mammals 6 (1): 43-69.

Visser I 1999a. Benthic foraging on stingrays by killer whales in New Zealand (*Orcinus orca*) in New Zealand waters. Marine Mammal Science 15: 220-227.

Visser I 1999b. Summary of interactions between orca (*Orcinus orca*) and other cetaceans in New Zealand waters. New Zealand Natural Sciences 24: 101-112.

Visser I 2000. Orca (*Orcinus orca*) in New Zealand waters. PhD thesis, University of Auckland, New Zealand.

Visser IN 2007. Killer whales in New Zealand waters: status and distribution with comments on foraging. Unpublished report (SC/59/SM19) to the Scientific Committee, International Whaling Commission.

Visser IN, Zaeschmar J, Halliday J, Abraham A, Ball P, Bradley R, Daly S, Hatwell T, Johnson T, Johnson W 2010. First record of predation on false killer whales (*Pseudorca crassidens*) by killer whales (*Orcinus orca*). Aquatic Mammals 36(2): 195-204.

Weeber B, Gibbs M 1998. Marine farming guide, the law, the environment, and how to have your say. Forest and Bird (Wellington, New Zealand). 32 pp.

Weir JS, Sagnol O 2015. Distribution and abundance of Hector's dolphins (*Cephalorhynchus hectori*) off Kaikoura, New Zealand, New Zealand Journal of Marine and Freshwater Research, 49:3, 376-389, DOI: 10.1080/00288330.2015.1020502

Wells RS, Scott MD, Irvine AB 1987. The social structure of free ranging bottlenose dolphins. In: Genoways HH (ed.) Current Mammalogy. Plenum Press, New York. pp. 247-305

WODA 2013. WODA Technical guidance on: underwater sound in relation to dredging. June 2013. 8p. www.dredging.org.

Würsig B, Cipriano F, Slooten E, Constantine R, Barr K, Yin S 1997. Dusky dolphins (*Lagenorhynchus obscurus*) off New Zealand: status of present knowledge. Reports to the International Whaling Commission 47: 715–722.

Würsig B, Duprey N, Weir J 2007. Dusky dolphins (*Lagenorhynchus obscurus*) in New Zealand waters: Present knowledge and research goals. DOC Research & Development Series 270. 28p.

7. APPENDICES

Appendix 1. Marine mammals in Lyttelton Harbour/Whakaraupō and Pegasus Bay waters

A1. 1 Hector's Dolphin (*Cephalorhynchus hectori hectori)*

A1.1.1. Distribution and abundance

Hector's / Maui's dolphin is the only dolphin species endemic to New Zealand (Baker et al. 2016). Hector's dolphin is found around the South Island while Maui's dolphin (*Cephalorhynchus hector maui*) is restricted to the North Island's west coast. The distribution of this species is highly clumped, effectively divided into four genetically distinct regional sub-populations around the South Island—north, west, east, and south coasts.

The east coast sub-population is the largest, with Banks Peninsula sitting at the centre of the main concentration of east coast dolphins. Between 3,000 and 6,000 dolphins out of the estimated total population (c. 14,000–15,000 animals) are found within Banks Peninsula waters year-round (MacKenzie & Clement 2016). However, the Banks Peninsula animals are considered to be part of a semi-residential and fairly isolated community that are thought to intermix rarely with other regional communities to the north or south (Pichler & Baker 2000; Hamner et al. 2012).

Particular regions of the Peninsula also appear to be important to this community (Clement 2005; Rayment et al. 2009). While the highest dolphin concentrations occur around eastern regions, large densities and several individual home ranges are based in northern bays between Baleine Point (eastern most headland of Port Levy) and Stony Beach (west of Okains Bay—Figure 6). DuFresne (2005) found dolphins along the north side of Banks Peninsula are more likely to be re-sighted in eastern bay regions or Akaroa Harbour.

A1.1.2. Life-history dynamics

Newborn Hector's dolphin calves have been observed as early as October and as late as March within Banks Peninsula's nearshore waters. While calves have been regularly sighted within particular areas of Akaroa and Lyttelton Harbour/Whakaraupōs (Brough et al. 2014) and some southern bays, no distinct calving and/or nursery areas for Hector's dolphins have been identified within Banks Peninsula waters.

Hector's dolphins feed on a variety of fish species in the 10-35 cm size range, including mid-water and bottom-dwelling fish. Stomach samples from Banks Peninsula include arrow squid (*Nototodarus sloanii)*, ahuru *(Auchenoceros punctatus),* yellow-eyed mullet (*Aldrichetta forsteri)*, stargazer *(Crapatalus novaezelandiae),* and sole *(Peltorhamphus novaezelandiae),* with red cod *(Pseudophycis bacchus)* being most important (Miller et al. 2013). Larger numbers of sprat and ahuru are taken, but these very small fish are not dominant in terms of weight.

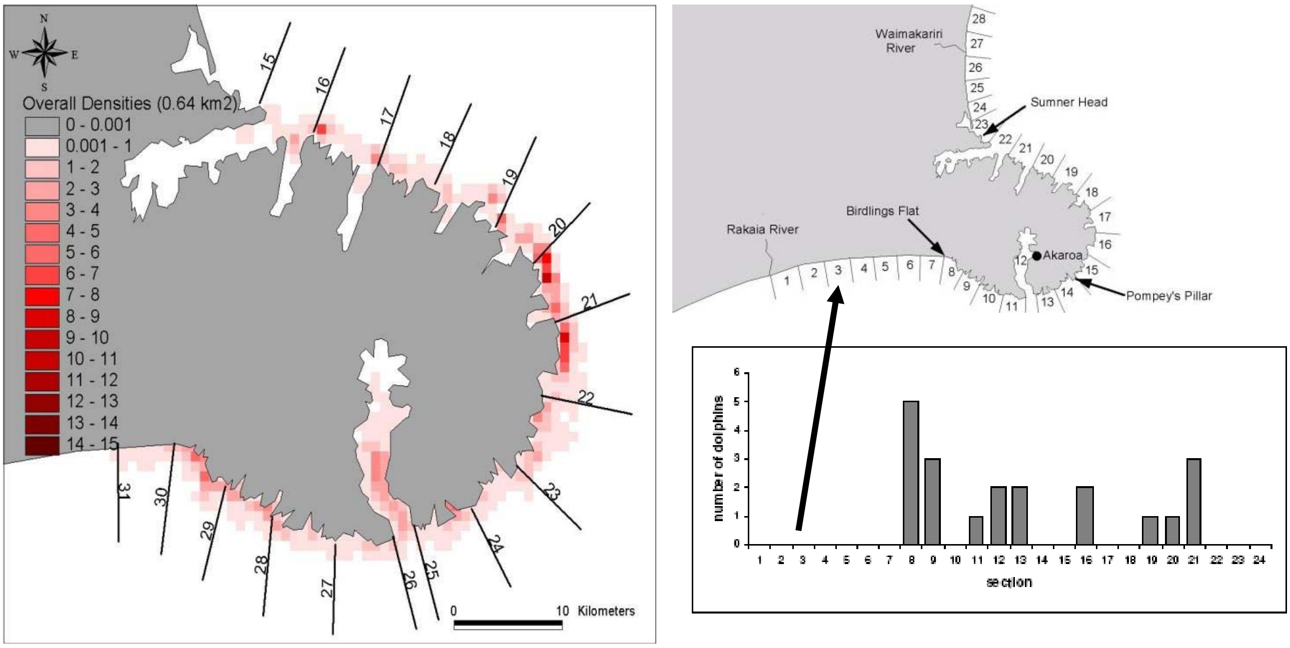

Figure 6. Left panel: Summer density pattern of Hector's dolphins around Banks Peninsula based on sightings between 1988 and 1997 (Clement 2005). Top right panel: the distribution of individual dolphins' home range centres. Section numbers from the map correspond to the x-axis on the graph below (bottom right panel; Rayment et al. 2009).

A1.1.3. Conservation status

The South Island Hector's dolphin has been listed as *nationally endangered* by New Zealand's Threat Classification System (Baker et al. 2016) and as *endangered* by the International Union for Conservation of Nature and Natural Resources (IUCN ver 3.1, Reeves et al. 2013). Hector's dolphins have several natural factors working against their continued existence. Their low reproductive rates (Slooten 1991) and slow population growth (Slooten & Lad 1992) along with highly localised distribution and low total abundance (Dawson & Slooten 1988) make this particular species naturally vulnerable. However, the main threat to this species is entanglement in gillnets (commercial and recreational), and to a lesser extent the trawling fisheries.

Other human activities that have been found or noted to potentially influence this population include increased dolphin-watching and dolphin-swim tourism programmes (Nichols et al. 2001) and boat strikes on newborn calves (Stone & Yoshinaga 2000). Todd et al. (2015) suggested that this species may be sensitive to disturbance from increased shipping traffic and noise levels as well as any destruction or alteration to important habitats.

A1.2 New Zealand Fur Seal (*Arctocephalus forsteri*)

A1.2.1. Distribution and abundance

New Zealand fur seals (kekeno) are one of two native pinniped species found around New Zealand coasts, as well as western and southern Australia and several of the sub-Antarctic islands (Figure 7). They are the most common pinniped species observed within New Zealand waters today, despite being harvested to near extinction by the mid-1800s by European sealers. This species is considered non-migratory but is known to travel large distances within their currently defined range. Tagged pups have been known to disperse throughout New Zealand, even crossing over to Australia (Goldsworthy & Gales 2008). They regularly travel out to the continental shelf and more open-ocean waters to feed.

In New Zealand, current estimates of fur seals number around 100,000 with some local populations increasing between 12% and 25% a year (Goldsworthy & Gales 2008). As the population has recovered and spread north into former territories, they have re-established breeding colonies/rookeries throughout most of the South Island and many parts of the North Island. Their preferred habitat includes rocky shoreline with some shelter, although they are known to use area with thick coastal vegetation (Chilvers & Goldsworthy 2015). Along the Canterbury coastline, fur seals breed where they find suitable habitat. Known breeding colonies along Banks Peninsula include Horseshoe Bay, Island Bay, Whakamoa Bay and Te Oka Bay to the south around eastern bays such as Goat Point and East Head to approximately Long Lookout Point (off Paupo Bay; DOC database).

The Department of Conservation keeps records of pinniped sightings reported by staff and members of the public. Research sightings of adults and pups are common throughout the Canterbury coastline and offshore regions. However, live sighting reports of pinnipeds by the public are generally sparse compared to other marine mammal species (i.e. dolphins and whales).

A1.2.2. Life-history dynamics

Females generally give birth every year once they have reached sexual maturity. Males generally defend and breed with a harem of up to 5–8 females in their territory. The breeding season lasts from mid-November to mid-January (Goldsworthy & Gales 2008). By January most males are returning to sea. However, pups will remain within the colony, nursing from the female until they are weaned around late winter or spring. After that they disperse and are generally thought to return to the same breeding colony once they are sexually mature.

Fur seals feed on a large variety of prey items that can include mainly squid and small mid-water fish (i.e. several species of lanternfish) but also eels, cephalopods and even birds. Nursing females will often travel further out into open water over winter to forage while juveniles feed on vertically migrating myctophid fish over shelf waters (Goldsworthy & Gales 2008).

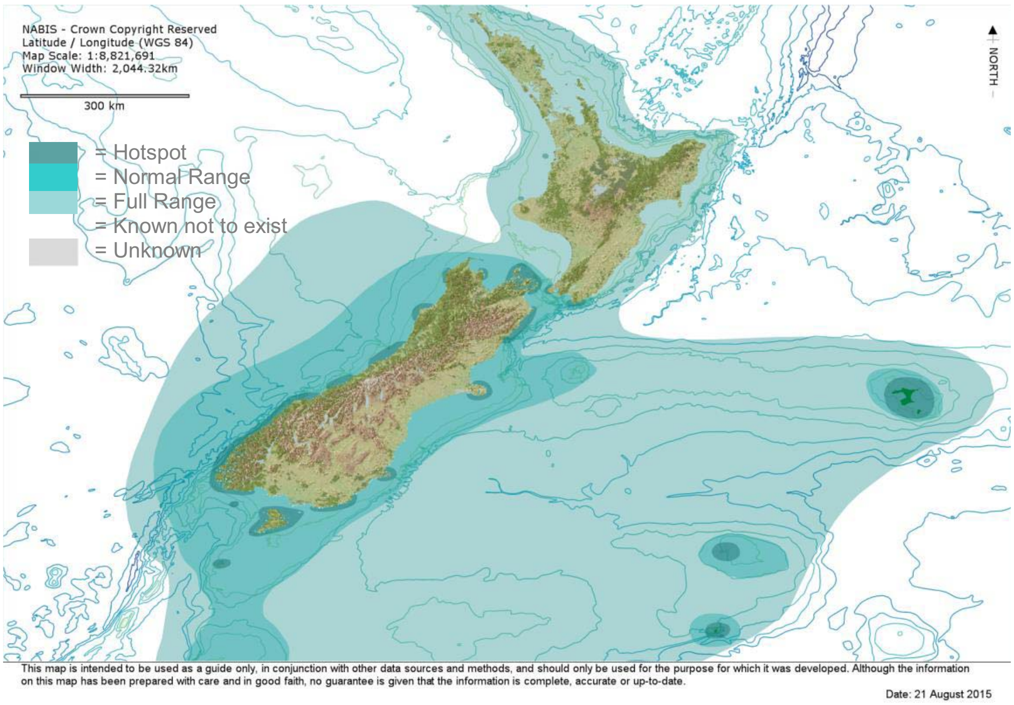

Figure 7. The general distribution pattern of New Zealand fur seals in New Zealand coastal waters based on New Zealand's National Aquatic Biodiversity Information System (NABIS) sighting database (modified from https://www.nabis.govt.nz/nabis_prd/map.jsp accessed August 2015).

A1.2.3. Conservation status

Due to their general abundance and sustained growth, New Zealand fur seals have been listed as *least concern* by IUCN (Chilvers & Goldsworthy 2015; IUCN ver 3.1) and *not threatened* by the New Zealand Threat Classification System (Baker et al. 2016). Current threats at sea include entanglement in trawl fisheries, particularly squid, and pollution such as oil spills (Thompson & Abraham 2010; Gales 1991). On land, fur seals are susceptible to disturbance within their breeding colonies from humans and domestic animals, such as dogs, causing disruption in breeding and even site abandonment. Todd et al. (2015) suggested that fur seals may be sensitive to any habitat alterations, increased turbidity or changes to prey availability due to dredging activities. Such impacts may result in auditory masking, incidental capture or injury, or avoidance to increased shipping traffic.

A1.3 Southern Right Whale (*Eubalaena australis*)

A1.3.1. Distribution and abundance

Today, the overall abundance of right whales in the Southern Hemisphere (also known as southern right whales) is estimated between 7,000–8,000 animals; only 10% of pre-whaling numbers (Baker & Clapham 2004). Present populations of southern right whales continue to follow a seasonal north-south migration pattern. They spend the warmer summer months feeding in unknown locations within the Southern Ocean (Patenaude 2000). During autumn, whales migrate back to warmer, temperate waters north of 50°S and winter breeding / calving grounds (Carwardine 1995; Patenaude 2000).

Within New Zealand, a recovery in population numbers has been observed within the traditional breeding grounds of the sub-Antarctic islands, with researchers estimating a sub-Antarctic super-population for 1995-2009 to be around 2169 whales (95% CL= 1,836-2,563 animals; Carroll et al. 2013). While this remnant population was known to exist off Campbell Island and the Auckland Islands since the 1940s, the first re-sighting of a right whale off the New Zealand mainland did not occur until 1963 (Gaskin 1964). More recent research has shown mounting evidence that the sub-Antarctic population is slowly re-colonising mainland New Zealand and becoming re-established as a secondary wintering ground (Figure 8; Childerhouse et al. 2010; Carroll et al. 2011a; Carroll et al. 2014).

Carroll et al. (2014) noted that the highest concentrations of southern right whale sightings, between 2003 and 2010, was Foveaux Strait, the Otago Peninsula and the Northland coast, in which 38% of these sightings were cow / calf pairs (Figure 9). Based on historical whaling data and a review of sightings, Banks Peninsula does not appear to be a final destination point for right whales although it has been noted as preferred habitat (e.g. Patenaude 2003; Carroll et al. 2014). Right whale sightings along the Canterbury coastline have been reported within Lyttelton Harbour/Whakaraupō, near the harbour entrance and/or along the northern Banks Peninsula bays (DoC sighting database), with most occurring during June, July, August and occasionally October with some cow/calf pairs reported.

Southern right whales can be slow migrators, especially cow / calf pairs, with a tendency to remain near continental and island masses. Migrating individuals have been noted remaining in the same area for days and / or weeks. Single whales were rarely sighted more than once a week, generally averaging 2.5 days while cow / calf pairs averaged 11.5 days and up to four weeks (Patenaude 2003).

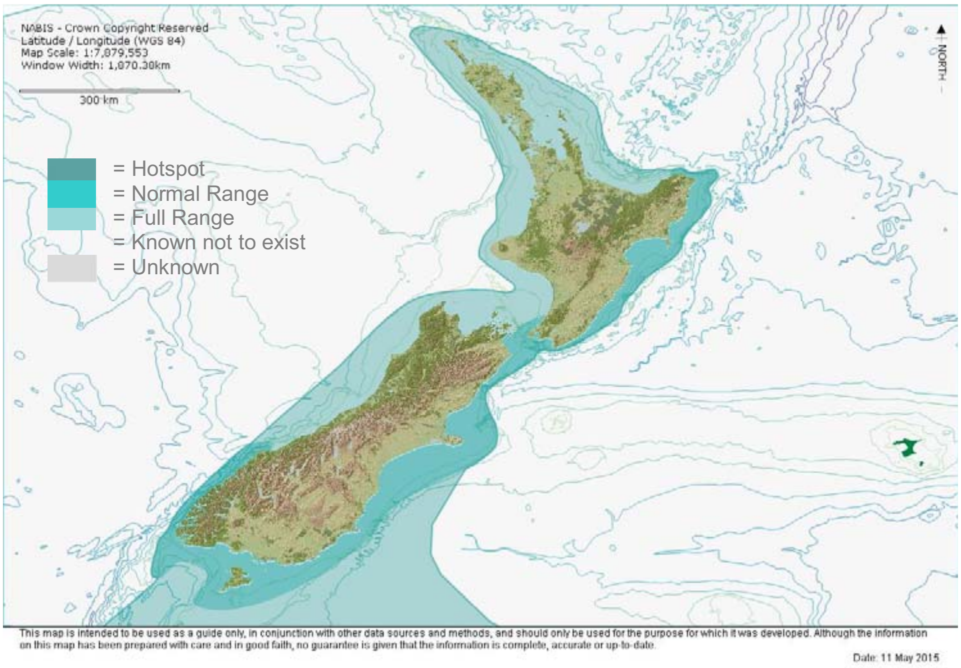

Figure 8. The general distribution pattern of southern right whales in New Zealand coastal waters based on New Zealand's National Aquatic Biodiversity Information System (NABIS) sighting database (modified from https://www.nabis.govt.nz/nabis_prd/map.jsp accessed May 2015).

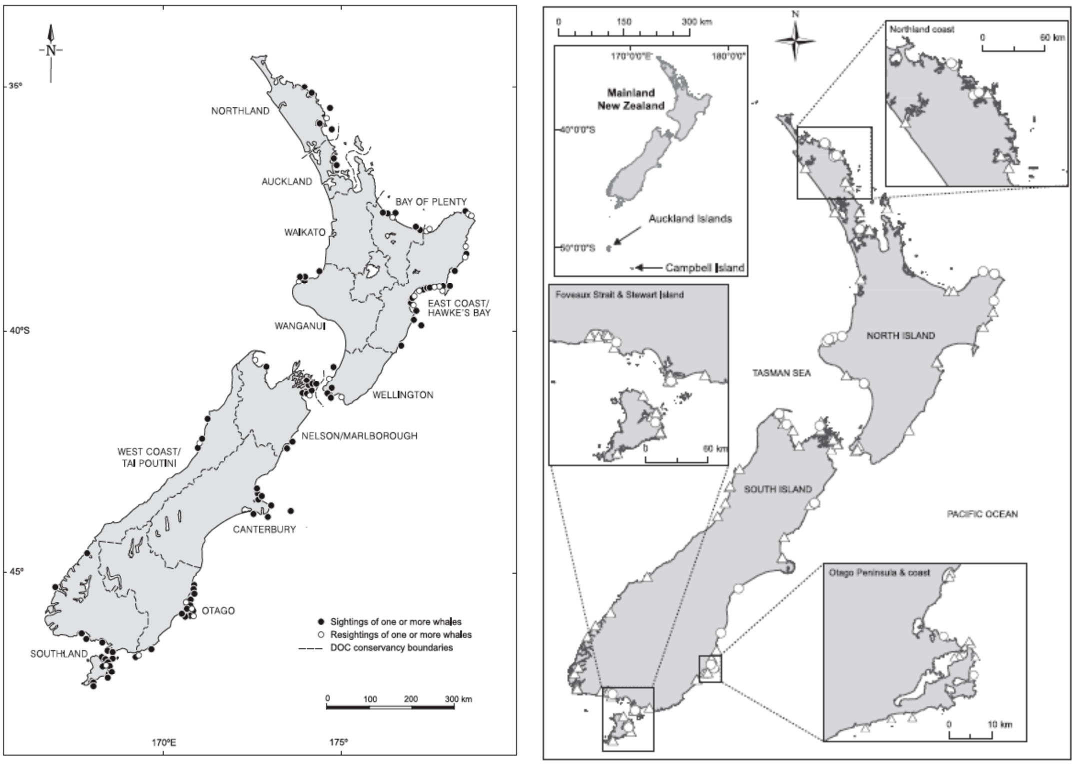

Figure 9. The locations of confirmed southern right whale sightings around mainland New Zealand; left—between 1976 and 2002 (Patenaude 2003) and right—from 2003-2010 (Carroll et al. 2014). In right panel, circles show sightings of groups containing cow-calf pairs and triangles show sightings of other whales.

A1.3.2. Life-history dynamics

As with most large mammals, southern right whales are slow breeders. Females usually mature between 5 and 10 years of age and then only give birth at 3–4 year intervals (Carwardine 1995). New Zealand right whales are fairly solitary animals that usually travel alone or in small groups of 2–3 individuals. However, breeding aggregations wintering off the Auckland Islands have been reported as large as 70 whales (Patenaude 2000).

Right whales feed mainly on krill, specialising on copepods and euphausiids. Due to their prey location, right whales spend the majority of their time at the surface. When feeding, they are most often seen skimming the water surface with their mouths open (Carwardine 1995).

A1.3.3. Conservation status

Southern right whales are considered a species of *least concern* as most southern populations are demonstrating large rates of increase (Reilly et al. 2013, IUCN ver 3.1). This classification recognises the species is well below historical numbers, but considers most populations are exposed to low level threats at present. Under the New Zealand Threat Classification System, southern right whales have recently been down-listed to *nationally vulnerable* from nationally endangered due to their strong recovering trend (Baker et al. 2016).

Right whales' tendency to remain within coastal surface waters while feeding and migrating, and their natural curiosity places them at greater risk from some human impacts. Currently, the most significant threat to right whale populations worldwide is habitat change due to coastal development. These changes include anthropogenic activities such as increased vessel traffic, aquaculture, oil / gas exploration, fishing and general pollution (Kraus & Rolland 2007). The southern right whale's vulnerability to ship strikes and entanglements with fishing gear has also been reported along the South African (Best et al. 2001) and Brazilian coastlines (Greig et al. 2001). Todd et al (2015) suggests that dredging activity may lead to habitat avoidance and / or behavioural changes in this species, while highlighting that the only reported marine mammal collision with a dredge vessel was a southern right whale calf struck off the South African coast (Best et al. 2001).

A1.4 Humpback Whale (*Megaptera novaeangliae*)

A1.4.1. Distribution and abundance

Similarly to right whales, humpback whales in the Southern Hemisphere numbered around 100,000 in the pre-whaling era (Leatherwood et al. 1983). Within the Southern Hemisphere, six distinct and isolated stocks are recognised. The humpback whales around New Zealand (Oceania Area V subpopulation–breeding stock E) are thought to winter off Tonga, Samoa and Fiji, visiting New Zealand's coastal waters while migrating to and from summer feeding grounds in the Antarctic (Constantine et al. 2007).

Humpbacks travel up along the east and west coasts of New Zealand during the autumn and back to Antarctic waters along the west and east coast again in the spring. Humpbacks are thought to travel in relatively straight lines from headland to headland, only occasionally passing inshore to bays, bights, and / or harbours. Dawbin (1956) noted from detailed whaling logs that humpbacks travelled outside the Canterbury Bight and were seldom seen inshore along the Canterbury coast. While a manned lighthouse was operating off Godley Head at the entrance of Lyttelton Harbour/Whakaraupō during the whaling period, no humpbacks were recorded in the area. However, fishing vessels reported daily sightings of humpbacks within 100 yards and as far as 10 miles from the Peninsula while travelling north during the months of June, July and August. Whales returning on their southbound migrations (peak return from October and November) also pass along the same coastline, some venturing inshore to feed while others stay further offshore (Dawbin 1956).

The Oceania subpopulation is thought to number between 2,361-3,520 animals, while the New Zealand portion of this stock is only thought to number between 250–500 animals as only 157 sightings have been made between 1970 and 1999 (Gibbs & Childerhouse 2000). Recent and ongoing studies have noted an apparent increase in humpback numbers around New Zealand (Gibbs & Childerhouse 2000).

A1.4.2. Life-history dynamics

Both female and male humpbacks mature around five years of age. Females, once reproductively active, give birth every two years. As with the other marine mammals, a slow reproductive rate has slowed this species' population recovery. Humpback whales are found in groups of 2–3, though are often observed alone. As they migrate north past New Zealand, most humpbacks traditionally travelled singly or in pairs (Dawbin 1956). On their south-bound return, they tended to occur more in groups, most often with calves.

Southern hemisphere humpbacks feed mainly in Antarctic water on krill and maybe some schooling fish (Leatherwood et al. 1983). Like right whales, humpbacks are often seen feeding along or just below the surface, although they are known for their innovative feeding techniques (Carwardine 1995). Their most well-known technique involves driving schools of fish to the surface using a cooperative feeding behaviour known as 'bubble netting'.

A1.4.3. Conservation status

Due to the recent revelation of illegal commercial whaling in the 1960s and 1970s by the Soviets within Southern Ocean waters (Clapham et al. 2009), and the slow population recovery (Childerhouse & Gibbs 2006), the Oceania stock of humpback whales is considered *endangered* by the IUCN (Childerhouse et al. 2008, IUCN ver 3.1). This species is classified as a *migrant* under the New Zealand Threat Classification System (Baker et al. 2016) and considered as a *threatened migrant* by DOC's Marine Mammal Action Plan (Suisted & Neale 2004) due to the small number of animals regularly migrating through New Zealand waters.

In the absence of whaling, the greatest impact to this species is habitat competition and / or degradation, entanglements and ship strikes. Due to the overlap in food-rich habitats and their surface and sub-surface behaviours, humpbacks in the Southern Hemisphere are often entangled in fixed fishing gear within inshore waters (Leatherwood et al. 1983). Todd et al (2015) noted that in regards to dredging activities, this species may be susceptible to habitat avoidance (Borggaard et al. 1999), noise pollution, habitat degradation, behavioural alterations, masking of conspecifics at close range (< 1 km), alterations to migration routes and avoidance (Lammers et al. 2001).

A1.5 Dusky Dolphin (*Lagenorhynchus obscurus*)

A1.5.1. Distribution and abundance

Dusky dolphins are widespread across the Southern Hemisphere with a patchy distribution pattern of geographically isolated populations (Würsig et al. 2007). Recent genetic evidence suggests that up to three subspecies exist, one isolated subpopulation is centred around New Zealand (Hammond et al. 2008a). They are generally regarded as a coastal and/or semi-pelagic species, hardly ever being sighted far from shore, shallow shelves and/or slopes (Würsig et al. 1997).

In New Zealand, Markowitz (2004) estimated between 12,000 and 20,000 dusky dolphins occur around most of the South Island and are rarely seen north of East Cape on the North Island (Baker 1999; Figure 10). This species appears to prefer colder temperature waters in New Zealand (Gaskin 1972), in particularly off Kaikoura, Otago Peninsula and the Marlborough Sounds as well as occasional visits to Fiordland and the South Island's west coast. Gaskin (1968a) suggested that these dolphins associate with the Subtropical Convergence, which flows up the South Island's east coast to near Banks Peninsula where it branches east with a weaker branch flowing towards north towards Kaikoura (Brodie 1960).

Some dusky dolphins in New Zealand may be year-round residents (e.g. Cipriano 1992) while others make seasonal migrations, some as far as c. 1000 km (Harlin et al. 2001; Markowitz 2004). Despite Banks Peninsula's location between two areas known for their dusky dolphin residents, these dolphins do not reside within Peninsula waters. Instead, they only occur 'infrequently' within inshore waters of Pegasus Bay, tending to occur in deeper offshore waters (DOC databases, Gaskin 1968a; Clement, pers. obs.) and are more common north of the Waiau River (Würsig et al. 1997).

A1.5.2. Life-history dynamics

Dusky dolphins in New Zealand are known for their gregarious social gatherings, particular in summer. Sightings of this dolphin around Peninsula waters vary from small groups (5–10 animals) to several hundreds. In more open waters, large groups can vary daily from 10s to 100s up to several thousand (Würsig et al. 1997).

Dusky dolphins are thought to follow prey inshore during the spring and early summer and offshore into deeper waters in late summer and autumn. Not known as deep divers, this species seem to feed more at night when their prey vertically migrates to within 50 to 100 m of the surface (Barr & Slooten 1999). There is no current evidence of dusky dolphins feeding off Banks Peninsula or inshore waters of Pegasus Bay.

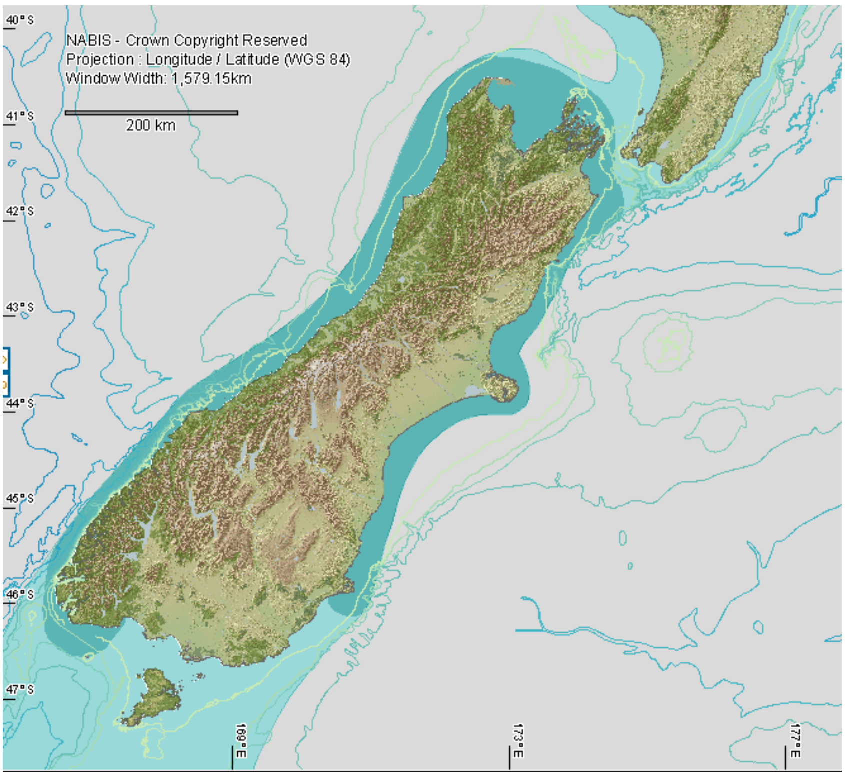

Figure 10. The general distribution patterns of dusky dolphins around the South Island based on New Zealand's National Aquatic Biodiversity Information System (NABIS) sighting database (modified from https://www.nabis.govt.nz/nabis_prd/map.jsp accessed May 2015).

A1.5.3. Conservation status

In New Zealand, dusky dolphins are currently categorised as *not threatened* by the Department of Conservation's threat ranking system (Baker et al. 2016) and as *data deficient* by the IUCN (ver 3.1; Hammond et al. 2008a). Like other small dolphins, dusky dolphins are known to be vulnerable to incidental mortality in fishing gear and nets (Würsig et al. 1997; Baird 1999, 2000). More recently, the large increase in marine aquaculture farms in the Marlborough Sounds has raised concern as they may potentially fragment and / or compete for critical habitat needed by dusky dolphins wintering there (Markowitz 2004). Todd et al. (2015) noted that this species may be sensitive to dredging activities that increased shipping traffic or noise levels as well as any habitat destruction, perhaps resulting in changes to behaviour or avoidance of coastal habitats.

A1.6 Common Dolphin (*Delphinus delphis*)

A1.6.1. Distribution and abundance

While this species is perhaps the most numerous of all the cetaceans inhabiting New Zealand waters, little is known about their total population size or movement patterns except in a few locations around New Zealand (Figure 11). They are particularly prevalent off the east coast of the North Island (Gaskin 1968b) from the Bay of Islands (Constantine & Baker 1997), the Hauraki Gulf (Stockin et al. 2008a) and the southern portion of the Bay of Plenty (Neumann et al. 2002; Gaborit-Haverkort 2012). New Zealand common dolphins are thought to be meso-pelagic and tend to be restricted to waters warmer than 14°C (Gaskin 1972); and as such they appear to be less prevalent from Banks Peninsula south (Gaskin 1968b).

Common dolphins are present in New Zealand coastal waters year-round along the North Island and potentially more seasonally around the South Island. Gaskin (1968a) suggested common dolphins mostly associate with warmer waters (>14°C) of the subtropical East Cape Current and thus may be limited by its southward extent (Banks Peninsula). Occasional sightings and strandings of common dolphins in Pegasus Bay and nearby water have been reported year-round (Brabyn 1990), but tend to be more frequent over winter/spring months and within more offshore waters; coinciding with the seasonal movement of the East Cape subtropical waters to these southern areas (Figure 11; DOC sighting and stranding databases).

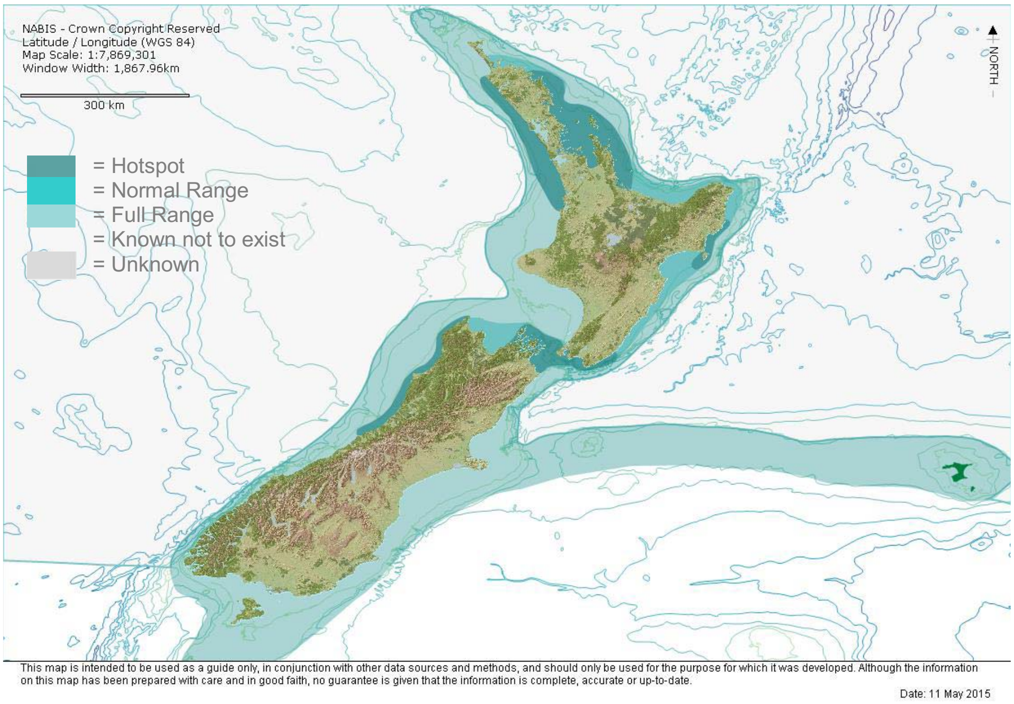

Figure 11. The general distribution pattern of common dolphins in New Zealand coastal waters based on New Zealand's National Aquatic Biodiversity Information System (NABIS) sighting database (modified from https://www.nabis.govt.nz/nabis_prd/map.jsp accessed May 2015).

A1.6.2. Life-history dynamics

Groups of common dolphins can range between two to at least 400 animals in New Zealand. Common dolphins groups sighted around Peninsula waters are often very large (100s) but spread across large areas when not travelling.

Common dolphins in New Zealand are known to feed on both surface and pelagic fish species, and are often seen herding schooling fish at the surface and feeding cooperatively. Common dolphins often occur over continental shelf regions where they feed on the organisms of the deep scattering layer (DSL); groups of relatively small invertebrates and fish that migrate to surface waters at night and return to depths during the day (Gaskin 1992).

A1.6.3. Conservation status

According to the current New Zealand Threat Classification System, common dolphins are considered *not threatened* (Baker et al. 2016) and of *least concern* by the IUCN (ver 3.1, Hammond et al 2008b). However, Meynier et al. (2008) consider this classification as 'ambiguous given that no population estimates exist for this species within New Zealand waters.'

The greatest risk to common dolphins in New Zealand waters appears to be entanglement in mid-water trawl fisheries (DuFresne et al. 2007). However recent findings suggest that Hauraki Gulf populations may also be under additional anthropogenic stress from coastal pollution (Stockin et al. 2007), eco-tourism (Stockin et al. 2008b) and high boating activity due to their proximity to Auckland (Dwyer 2014). Todd et al. (2015) noted that the most likely effects that dredging could have on common dolphin populations would be habitat alterations and/or changes to prey distribution.

A1.7 Orca (*Orcinus orca*)

A1.7.1. Distribution and abundance

Orca occur in all oceans from the equator to polar regions, yet they generally prefer cooler waters (Carwardine 1995). A long-term study of orca sightings around New Zealand estimated an abundance of less than 200 (95% CI=71–167) individuals (Visser 2000). At least three sub-populations of orca are thought to exist; a regional North Island population, a regional South Island population, and a population that travels back and forth between the two islands (Figure 12). There appears to be little to no mixing between the North Island and South Island regional groups (Visser 2000), and genetic studies suggest the population is geographically structured (Olavarría et al. 2014).

Most sightings of orca along the South Island's east coast occurred from late autumn to mid-spring (Visser 2000). At least one group sighting of orca occurs within Banks Peninsula waters each year, more often over autumn or spring months as the group tends to slowly work their way around the different bays, harbours and inshore waters before travelling off again (DOC sighting and stranding databases).

A1.7.2. Life-history dynamics

Orcas are known to live up to 80 or 90 years and are thought to be one of the longest-lived toothed whales. As such, they only mature when between 11 and 21 years old and females give birth over five year intervals.

They are a moderately gregarious species, being found in pods numbering a few to 30 individuals. Their group structure is fairly stable as they usually maintain close family groups (Carwardine 1995). The most common group size of orca in New Zealand is 12 animals, however groups can range from 2 to 22 (Visser 2000). While some New Zealand orca seem to remain within a fairly small home range, other orca have travelled 3,800 km in 34 days, an average of 111 km per day (Visser 1999a).

In New Zealand, orcas most commonly forage on rays (Visser 1999a), which may account for their tendency to frequent fairly shallow waters (Hupman et al. 2014).

They also feed on pelagic and reef fish (Visser 2000) and other cetaceans including common dolphins, dusky dolphins, bottlenose dolphins, humpback whales and sperm whales (Visser 1999b), and more recently, on false killer whales (Visser et al. 2010).

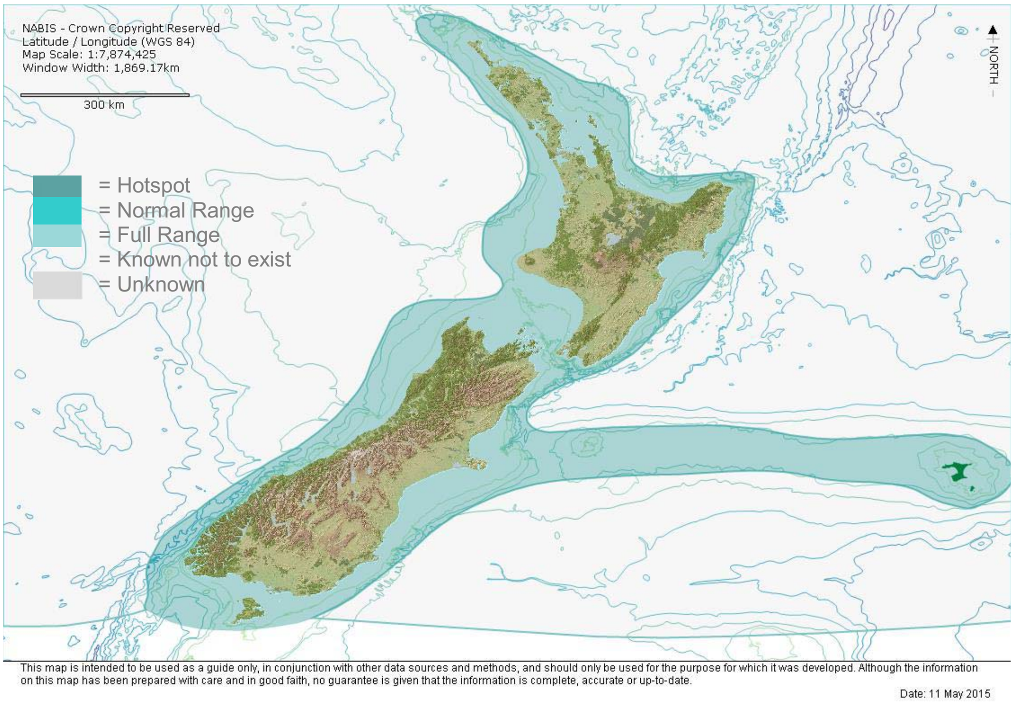

Figure 12. The general distribution pattern of orca in New Zealand coastal waters based on New Zealand's National Aquatic Biodiversity Information System (NABIS) sighting database (modified from https://www.nabis.govt.nz/nabis_prd/map.jsp accessed May 2015).

A1.7.3. Conservation status

The orca is listed as *data deficient* by the IUCN (ver 3.1, Taylor et al. 2013), mainly due to the ambiguity around its current taxonomic units. It is felt that this species will be divided into several smaller new species or sub-species with new research, many of which will warrant higher categories of risk due to localised effects of impacts. According to the New Zealand Threat Classification, this species is listed as *nationally critical* due to lack of data and low abundance (Baker et al 2016).

The main threats facing orca in New Zealand involve fisheries interactions, potentially heavy pollutant loads and the risk of vessel strike near busy ports and harbours (Visser 2000). Incidental mortalities of orca in fisheries are also summarised in Visser (2007) and include interactions with vessels and fishing gear/line entanglements. Visser (2007) suggests that the tendency for orca to forage in enclosed harbours makes this species more susceptible to harbour developments. The author notes that developments, such as dredging, have the potential to affect this species' foraging habitat, expose them to noise population and degrade their water quality. Todd et al. (2015) also suggests that the effects of dredging activities on orca are likely to include any alterations in prey availability, possible habitat avoidance and / or behaviour alterations, increased boat traffic and underwater sound masking (noise pollution).

A1.8 Bottlenose Dolphin (*Tursiops truncatus*)

A1.8.1. Distribution and abundance

In New Zealand waters, bottlenose dolphins are known to inhabit the coastal waters of Northland, the Marlborough Sounds and Fiordland with occasional sightings of animals around most other regions (Figure 13; Tezanos-Pinto et al. 2008). The bottlenose dolphins within the Marlborough Sounds represent the closest of three isolated sub-populations to Bank Peninsula waters.

According to the DoC sighting database, only irregular sightings of bottlenose dolphins have been recorded around Pegasus Bay and other inshore regions of the Peninsula. The national stranding database shows a handful of bottlenose dolphins stranding in Banks Peninsula, all within Lyttelton Harbour/Whakaraupō and northern bays (Brabyn 1990). Little else has been reported about bottlenose dolphin around Banks Peninsula despite their known tendency to visit both Akaroa and Lyttelton Harbour/Whakaraupō and other nearby coastal regions (Clement, pers. obs.).

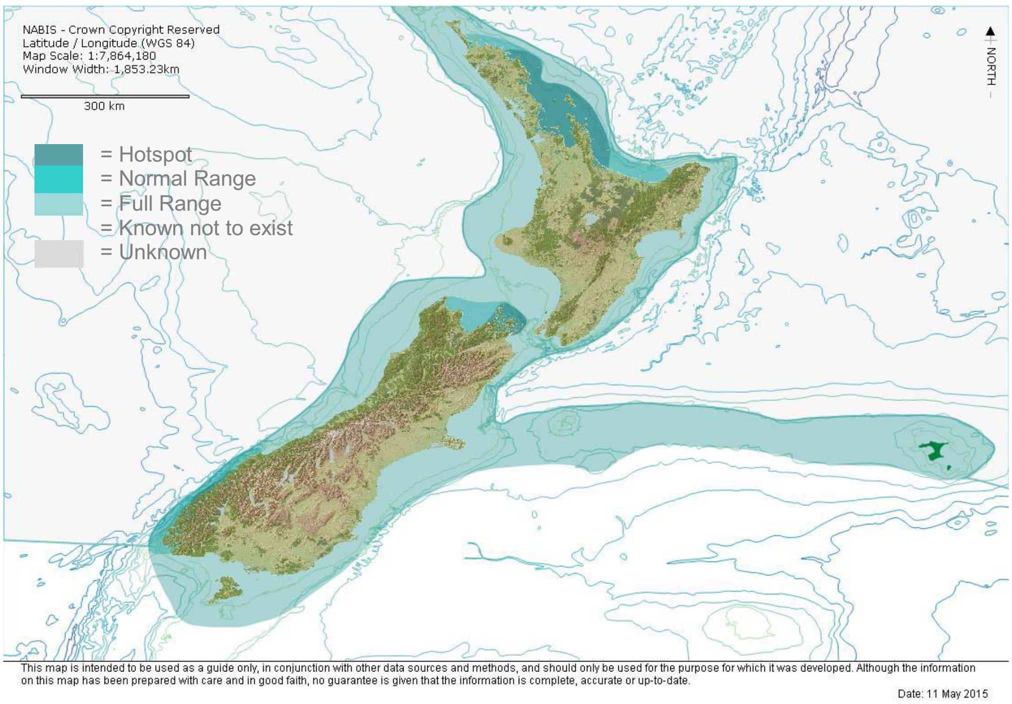

Figure 13. The general distribution pattern of bottlenose dolphins in New Zealand coastal waters based on New Zealand's National Aquatic Biodiversity Information System (NABIS) sighting database (modified from https://www.nabis.govt.nz/nabis_prd/map.jsp accessed May 2015).

A1.8.2. Life-history dynamics

Bottlenose dolphins are fairly long-lived (> 50 years), and individuals usually do not mature until 5–14 years of age (Wells et al. 1987). Young dolphins can remain with their mothers up to two years or more; as a result most females breed at 3–5 year intervals. In New Zealand waters, bottlenose dolphins tend to travel in groups of up to 30 animals (Baker 1999). The median group size in the Bay of Islands population is around 12 animals, but varies from 1 to 60 dolphins (Tezanos-Pinto et al. 2008).

Most bottlenose dolphin groups are generalists in their feeding preferences, and can be quite adaptive in their feeding styles. Constantine & Baker (1997) observed bottlenose dolphins in the Bay of Islands feeding on flounder (*Rhombosolea* spp.), yellow-eyed mullet (*Aldrichetta forsteri*), kahawai (*Arripis trutta*), parore (*Girella tricuspidata*), piper (*Hyporhampbus ihi*), blue maomao (*Scorpis violaceus*) and leatherjacket (*Parika scaber*).

A1.8.3. Conservation status

Due to this species commonality and global distribution, they are listed by the IUCN as *least concern* (ver 3.1, Hammond et al. 2012). However, in New Zealand, bottlenose dolphins are classified as *nationally endangered* (Baker et al. 2016), which means New Zealand populations have demonstrated demographic isolation and appear to be limited in their overall home range (Townsend et al. 2007). Recent research suggests that both the Northland and the Fiordland populations underwent local declines around 2003 (Tezanos-Pinto et al. 2014). This decline may be due to high calf mortality in this population (Tezanos-Pinto et al. 2014) and / or emigration as simultaneous research has suggested that this population may now be using Great Barrier Island (northeast of Hauraki Gulf) as an important hotspot (Dwyer et al. 2014).

Bottlenose dolphin populations in New Zealand are exposed to a growing eco-tourism industry (Constantine et al. 2003). In addition to the increasing risks from eco-tourism, this species is occasionally reported as by-catch in the New Zealand trawl fishery (DuFresne et al. 2007) and other potentially invasive human activities. Based on overseas research, Todd et al. (2015) suggested that dredging activities have the potential to alter bottlenose dolphins' feeding patterns and cause potential disturbance to any nursing areas, depending on the project scale, vessel types and equipment used. In addition, the subsequent increase in shipping traffic can also be considered a possible effect of channel dredging/deepening.

Appendix 2. Guidelines for boating around marine mammals.

The overall risk of a vessel strike between dredging vessels and marine mammals is low. In the unlikely case that a vessel should encounter a marine mammal while working, the following 'best practice' boating behaviours used worldwide around marine mammals should further reduce any chances of collision.

General

If a whale or dolphin is sighted, but not directly in the path of the vessel:

- Keep boat speed constant and / or slow down while maintaining current direction
- Avoid any abrupt or erratic changes in direction
- Maintain or resume normal operating speeds once well way from animals.

Large baleen whales — such as southern right and humpback whales

If a whale is sighted directly in the path of the vessel:

- If the whale is far enough ahead of the vessel (e.g. > 500 m) and can be avoided, slow to 'no-wake' if necessary and maintain a straight course away from the immediate sighting area (where practicable)
- If the whale is too close to the vessel and cannot be avoided, immediately place the engine in neutral and allow the boat to drift to one side of the sighting area where practicable (do not assume the whale will move out of the way)
- Avoid any abrupt or erratic changes in direction while at speed
- Once the whale has been re-sighted away from the vessel, slowly increase speed back to normal operation levels.

If a cow / calf pair is sighted within 500 m of an underway vessel:

- Gradually slow boat while maintaining a course away from the immediate sighting area (where practicable)
- Allow the pair to pass
- Once the pair has been re-sighted away from the vessel (> 500 m), slowly increase speed back to normal operation levels
- Avoid any abrupt or erratic changes in direction while at speed.

If a whale and / or cow / calf pair approaches a stationary vessel:

- Keep the engine in neutral, and allow the animal to pass
- Maintain or resume normal operating speeds once well away from animals.

Small to medium whales and dolphins —– such as common dolphin or orca

If a dolphin(s) is sighted directly in the path of the vessel:

- Keep boat speed constant and / or slow down while maintaining a course slightly to one side of the group, do not drive through the middle of a pod
- Avoid any abrupt or erratic changes in direction
- Maintain or resume normal operating speeds once well way from animals.

If a dolphin(s) approach an underway vessel to bow-ride or ride the stern wave:

- Keep boat speed constant and / or slow down while maintaining course
- Avoid any abrupt or erratic changes in direction
- Do not drive through the middle of a pod
- Maintain or resume normal operating speeds once well way from animals.

Appendix 3. Theoretical zones of auditory influence and sound threshold criteria.

Theoretical 'zones of auditory influence', originally proposed by Richardson et al. (1995), are mainly based around the distance between the source and receiver, and the idea that underwater sound intensity, and its potential impact, decreases in severity with increasing distance (see Figure 5). This type of distance model is a simplistic way of classifying sound impacts. However, it can be misleading in that several of the zones can overlap or impacts can occur at a distance that does not trigger the actual response of the zone in which it is occurring. For example, within the zone of responsiveness some behavioural reactions may occur, such as rapid ascent or stranding due to strong sound sources, which actually lead to direct injury or death. Hence, several overseas regulatory agencies have suggested the use of sound threshold criteria.

Southall et al. (2007) used a number of studies that examined the potential onset of temporary auditory threshold shifts (TTS; in humans this is often described as the muffled effect your hearing might have after a loud concert) and more permanent threshold shifts (PTS) in captive marine mammals, and extrapolated these to initially set some thresholds for assesses effects of potential auditory damage. These levels are summarised in Table 4 below.

The US National Oceanic and Atmospheric Administration (NOAA) has set interim sound thresholds for the sound levels they consider likely to cause injury (Level A harassment) or significant behavioural disturbance (Level B harassment) for marine mammals in the context of the Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA) and other statutes (NOAA 1998). These criteria are described below and summarised in Table 5. Note that these thresholds are currently under review and are expected to be revised by the end of 2016.

The regulatory description for Level A harassment is defined as …*any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild*. Criteria thresholds are set at 180 dB *re*1µPa rms[4] for cetaceans and 190 dB *re*1µPa rms for pinnipeds. Level B thresholds range between 120 and 160 dB *re*1µPa rms (including both non-pulse and pulse noise) and are defined as having …*the potential to disturb a marine mammal or marine mammal stock in the wild by causing meaningful disruption of biologically significant activities, including, but not limited to, migration, breeding, care of young, predator avoidance or defense, and feeding.*

[4] The term 'dB *re*1 µPa @ 1 m' represents the sound pressure level at one metre distance from the source. RMS = root mean square or mean squared pressure and rms levels are often used for long duration or continuous noise sources instead of 'peak' levels. The averaged square pressure is measured across some defined time window that encompasses the call signal.

Table 4. Proposed injury criteria for individual marine mammals exposed to 'discrete' noise events (either single or multiple exposures within a 24-h period) from Southall et al. (2007).

Mammal Group	Effect	Measurement	Threshold
Cetaceans*	PTS onset	Pressure Level^	230 dB re 1 μPa peak
		Exposure Level@	198 dB r e.1μPa^2/s SEL M-Weighted
	TTS onset	Pressure Level	224 dB re 1 μPa peak
		Exposure Level	183 dB re.1μPa^2/s SEL M-Weighted
Pinnipeds (in water)	PTS onset	Pressure Level	218 dB re 1 μPa peak
		Exposure Level	186 dB re 1μPa^2/s SEL M-Weighted
	TTS onset	Pressure Level	212 dB re 1 μPa peak
		Exposure Level	171 dB re 1μPa^2/s SEL M-Weighted

* Applies to low-frequency cetaceans – 7 Hz-22 kHz, all baleen whales; mid-frequency cetaceans – 150 Hz-160 kHz, all toothed cetaceans except those listed in high-frequency category; and high-frequency cetaceans - 200 Hz-180 kHz, true porpoises, *Kogia*, river dolphins, cephalorhynchid (Hector's dolphin), *Lagenorhynchus cruciger, L. australis*.

^ Sound pressure level for single, multiple pulses (e.g. pile driving) and non-pulses (e.g. drilling).

@ Sound exposure level is 198 db re: 1 μPa^2-s (M_{lf}) for single, multiple pulses and 215 db re: 1 μPa^2-s (M_{lf}) for non-pulses

Table 5. NOAA's draft sound threshold criteria for possible auditory injury and behavioural disruption (NOAA 1998). Note these thresholds are expected to change as part of the on-going review process by NOAA.

Criterion	Effect Definition	Threshold
Level A	PTS (injury) conservatively based on TTS	Pinnipeds: 190 dB re 1 μPa rms Cetaceans: 180 dB re 1 μPa rms
Level B	Behavioural disruption for non-pulse noise (e.g. drilling)	120 dB re 1 μPa rms
Level B	Behavioural disruption for impulsive noise (e.g. impact pile driving)	160 dB re 1 μPa rms