APPENDIX 16

EFFECTS ON MARINE MAMMALS

Marine Mammals and the Port Lyttelton Development

An Environmental Impact Assessment

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For

Lyttelton Port of Christchurch, October 2014.

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Executive Summary

1. The Port of Lyttelton was significantly damaged by the Canterbury earthquakes and requires repair. Marine mammals are iconic and important features of the Lyttelton coastal environment. This report is part of the Environmental Impact Assessments focused on investigating and minimising the environmental effects of rebuilding and extending port infrastructure.

2. Development activities that have the potential to adversely affect marine mammals at Lyttelton include: Pile driving, land reclamation, dredging, marine pollution and increased vessel traffic (e.g. increase in the number and/or size of vessels visiting Lyttelton).

3. Two species of marine mammal are regularly found in and around Lyttelton Harbour; Hector's dolphin and the New Zealand fur seal. Hector's dolphin is listed as Endangered. High and unsustainable levels of bycatch in fishing have depleted the local population. Population viability analyses indicate that the species is declining in most areas, including Canterbury. The NZ fur seal is much more abundant, and is recovering strongly from near extinction in the early 1800s. Both species are vulnerable to the impacts of coastal development. These impacts may include risks to individual animal health, habitat degradation and behavioural impacts including avoidance of the area where the port development is taking place. In combination with other, existing impacts, Port development activities have the potential to cause population level effects.

4. Hector's dolphins use the area in and around Lyttelton Harbour year round, although sightings in winter are less frequent. Some overlap with the area under development has been observed, particularly in summer. Hector's dolphins are routinely seen very close to the shore, and have been seen within the area proposed for reclamation. Groups with calves are regularly found inside Lyttelton Harbour during summer and autumn and have been observed close to the port itself.

5. Pile driving noise can cause physical injury to marine mammals if they are within 2km (for dolphins) and 700m (for seals) of the activity. Pile driving may also cause masking of important sounds used for communication and echolocation. Behavioural modification and changes in habitat use are a likely effect of pile driving noise and can be expected to occur up to at least 20km from the pile driving site. Land reclamation will influence marine mammals due to the removal and disturbance of marine habitat and may expose them to contaminants from disturbed seabed material and fill used for reclamation, however the use of appropriate fill will significantly reduce this risk. Dredging activity will create noise, and may result in significant sediment resuspension causing marine mammals to be exposed to elevated levels of contaminants within the sediment. However sediment plumes from dredging fade rapidly by merging with the high background turbidity. Marine pollution may also be an issue throughout the development due to increased terrestrial contaminant runoff and oil/fuel spills, yet an extensive construction management plan negates this risk. Any increase in vessel traffic associated with the development will increase the risk of 'ship strike' and may cause behavioural changes (including movements, acoustic behaviour and other behaviours). Population-level effects may include a reduction in abundance of Hector's dolphins and NZ fur seals in the Lyttelton area due to displacement from disturbance and potential mortality from effects such as noise injury and ship strike. Whilst population-level effects are possible it can be difficult to identify and describe these effects due to a lack of location and risk specific data.

6. Mitigation methods include: Carrying out pile driving during winter, using marine mammal observers to halt piling activity when animals are nearby and using bubble curtains to reduce sound levels. Using clean uncontaminated fill and ensuring spoil from dredging has acceptable levels of contaminants would help prevent the exposure of these compounds to marine mammals and their prey.

7. Assessing the long-term effects of the development on marine mammals will require acoustic monitoring of marine mammals and human made noise, visual surveys and photographic identification. The lack of detailed "before" data will be a challenge.

Contents

1.1 Background

The 2010 and 2011 Canterbury earthquakes caused serious damage to commercial and private property throughout the region. Port Lyttelton, the port of the city of Christchurch and the largest port in the South Island, suffered significant damage from the earthquakes. Even after temporary, emergency repairs, the damage to infrastructure significantly reduced the port's ability to operate efficiently (LPC 2014). Over 75% of the port's wharves were damaged, and the majority of the remaining infrastructure requires repair for the port to be at full operating capacity. Additionally, trade forecasts predict up to a 400% increase in container cargo over the next 30 years, which puts pressure on Port Lyttelton to increase the size of the port. Thus a significant portion of the development aims to extend port infrastructure to increase its ability to handle higher volumes of trade (LPC 2014).

The development proposed by the Port Lyttelton Plan (LPC 2014), states a desire to maintain a 'healthy harbour' by investigating and mitigating the effects of the development across a range of environmental categories. Also, there is an expressed commitment to engage in ecological monitoring and restoration of the Lyttelton area to enhance the local environment. Marine flora and fauna are among those aspects of the environment considered to be vulnerable to the effects of the development. Lyttelton and the Banks Peninsula area in general, retain high abundance and diversity of marine wildlife that will be considered as the port redevelops.

Marine mammals are of particular interest in terms of understanding the impacts of coastal development, as iconic species in the coastal marine environment. Marine mammal species are often particularly vulnerable to changes in their habitat, and their generally low reproductive rates make recovery from population level impacts slow. Hence carrying out thorough environmental impact assessments (EIA) for these taxa is vital. As part of the EIA procedure for the Port Lyttelton Plan, this report will identify and discuss ways to avoid, mitigate and/or remediate impacts on marine mammals.

The Port Lyttelton Plan sets out LPC's 30 year vision for the repair, rebuild, enhancement and reconfiguration of the port. A large number of construction projects are required as part of the vision, and these are expected to occur over a period of approximately 12-15 years. These construction projects will enable the port to continue to reconfigure to meet the growing freight demands for the next 30 years as well as providing community access to the waterfront.

1.2 Introduction

Development in the coastal zone can result in impacts on the marine environment. Consequently it is important to carry out a scientifically robust appraisal of the potential environmental effects of coastal development. Marine mammals are particularly sensitive to changes in their habitat and so are vulnerable to the effects of coastal development (Harwood 2001; Jefferson et al. 2009). As top-predators, changes in abundance and/or distribution of lower trophic levels can impact marine mammals via changing prey availability (Tynan & DeMaster, 1997). In this manner, factors such as eutrophication, sedimentation and changes to local oceanography can affect marine mammals indirectly. Their high trophic level also makes marine mammals vulnerable to bio-accumulation of pollutants (Tanabe et al. 1983). Due to the variety of potential effects, thorough research programmes are important to ensure effective mitigation, to help minimise the effects of the development on marine mammals.

In terms of direct effects, increased noise pollution can have significant impacts on marine mammals. Anthropogenic noise can mask sounds produced by marine mammals that rely on sound to navigate, communicate and forage (Madsen et al. 2006). Additionally, noise can cause significant alteration of normal behaviours and cause physical damage to the sensitive aural structures which can result in injury or death (Southall et al. 2007). Research has revealed a range of responses associated with anthropogenic noise, including short and long-term behavioural changes (e.g. Southall et al. 2007), avoidance of areas (e.g. Brandt et al. 2011) and strandings (Fernandez et al. 2005; Parsons et al. 2008). Elevated noise from coastal development may originate from activities such as pile driving, dredging and dumping, use of construction equipment and shipping traffic (Jefferson et al. 2009). Following the development, there may be an increase in the size and/or number of ship visits to Lyttelton. High shipping volumes could pose a risk to marine mammals due to ship strike, which is a well-documented cause of injury and fatality of cetaceans in coastal areas (Laist et al. 2001, Behrens and Constantine 2008), and which has been observed for Hector's dolphin in Akaroa Harbour (Stone et al. 2000). Given the nature of the injuries the dolphin sustained in Akaroa Harbour, it is likely that the incident involved a small, planing vessel. Research throughout a development process like this makes it possible to assess the range of potential impacts on marine mammals.

The predominant marine mammal species found in and around Lyttelton Harbour is New Zealand's endemic Hector's dolphin (*Cephalorhyncus hectorii*). Hector's dolphin has declined to about 27% of its 1970 population (Slooten & Dawson 2009), and is listed as Endangered by both the IUCN (Reeves et al., 2013) and DOC (Baker et al 2009). Bycatch in commercial and amateur gillnet fisheries has been the key component of this decline, with other impacts such as bycatch in trawl fisheries contributing (Dawson 1991; Slooten et al. 2000). Hector's dolphins have a fragmented distribution around the South Island of New Zealand (Dawson & Slooten 1988). The Banks Peninsula population is the largest on the east coast of the South Island with about 1,100 Hector's dolphins (CV = 28%; Gormley et al. 2005) resident year round.

The importance of Banks Peninsula to Hector's dolphins was recognised by the implementation of the Banks Peninsula Marine Mammal Sanctuary (BPMMS) in 1988 (Dawson & Slooten 1993). The BPMMS aimed to protect Hector's dolphins from bycatch in commercial and the majority of amateur gillnet fisheries out to 4 nautical miles (Dawson & Slooten 1993). The level of bycatch from trawl and gillnet fisheries has been reduced by regulations implemented by the Ministry of Primary Industries, but is still unsustainable (Slooten 2013). The fisheries regulations have increased the survival rate of Hector's dolphins at Banks Peninsula but as yet survival rates are still too low to ensure a stable, let alone recovering population (Gormley et al. 2012). Gillnets are currently banned out to 4 nautical miles from shore, and trawling is banned to 2 nautical miles offshore. However, Hector's dolphins range to at least 20 nautical miles offshore. Therefore, bycatch still occurs beyond the boundaries of fisheries restrictions. This means that other threats such as habitat modification and shipping may impact upon an already declining population. Under current management, Hector's dolphins are projected to continue to decline (Slooten & Dawson 2009). Coastal development has been identified as a threat to Hector's dolphins in the species' Threat Management Plan (MPI 2007). The endangered status of the species, and the likelihood of continuing population decline, underscores the importance of thorough investigations of any potential impacts from development at Lyttelton Port to ensure adverse effects are avoided or minimised.

Understanding the level of exposure of Hector's dolphins to the development at Lyttelton is crucial to establish the extent of population level effects. Exposure to development activities may occur at a variety of temporal and spatial scales, and may be different for particular demographics (e.g. mothers with calves). A database administered by the Marine Mammal Research Group at the University of Otago, contains sightings and survey information for Hector's dolphins at Banks Peninsula from 1984 until the present. This information can be used to document the 'use' of Lyttelton Harbour and surrounding areas by Hector's dolphins, and so provide a means to assess exposure of the dolphins to the development activities. Sightings information will also be useful to guide recommendations for avoiding and mitigating any adverse effects of the development.

1.3 Objectives

The objectives of this report are:

1. Identify potential impacts to marine mammals from the Port Lyttelton Plan (PLP) by reviewing the relevant scientific literature and technical reports, in the light of the development plan.

2. Identify the species and populations of marine mammals in the area.

3. Use data from the long-term photo-identification database of the Banks Peninsula Hector's dolphin project to assess the extent to which dolphins may be exposed to adverse effects from the development.

4. Via a thorough review of published, peer-reviewed literature, the report will assess the potential impacts identified in (1) in terms of their known effects on marine mammals. This will include an assessment of the likelihood of impairment, injury or other health related effects upon individuals as well as the effects upon the wider populations.

5. Assess the likely effectiveness of strategies for avoiding, mitigating and/or remedying the effects of the development activities on marine mammals.

6. Identify topic areas that require more research in order to understand the effects of development activities on marine mammals at Lyttelton.

2.1 Source information

Information specific to the development is available from the Port Lyttelton Plan (PLP), produced by the Lyttelton Port Company (LPC). The plan provides the overall details of the development, including the spatial extent of the proposed construction work. Technical details concerning each stage of the development along with a development timeline have been made available in a 'project descriptions' document provided by LPC. Technical information concerning the extent of particular impacts (i.e. oceanographic changes) has be made available by LPC.

Data on the use of Lyttelton Harbour by Hector's dolphins are available from a database administered by the Marine Mammal Research Group at the University of Otago. Data come from systematic surveys, conducted in small (4-6.6 m) outboard-powered boats following standardised routes at constant speed (c.15 knots). On encountering dolphins, the boat is stopped or slowed to idle to allow individually distinctive dolphins to be photographed. Survey procedures are more fully described in Slooten et al. (1992). Standardised GPS – based recording of survey effort was incorporated in this study in 1990. Data collected from each encounter include date/time, location, number of individuals, presence of calves, and behavioural state). Detailed logging of survey effort allows calculation of sightings per unit of effort, which is commonly used to illustrate habitat use in a way that allows unbiased comparison between locations and seasons. This allows an assessment of the extent of exposure of Hector's dolphins to the development activities.

The potential impacts of the development on marine mammals is assessed via an extensive review of peer-reviewed literature, focusing on literature specific to the species concerned and other, similar species. A bibliography of cited literature is provided.

The effectiveness of potential mitigation methods is partly based on published accounts of the success of the same, or similar measures in other locations. The success of mitigation measures should be monitored in situ, given the likelihood of differences between Lyttelton and the locations where similar measures have been used previously.

3. Impact Identification

Based on the Port Lyttelton Plan and project description documents, potential impacts upon marine mammals have been identified under the categories below:

3.1 Pile driving

The most severe noise pollution is expected to result from pile-driving. The pile-driver currently used in Lyttelton (Cashin Quay 3 rebuild) uses a 9 or 14 tonne steel drop weight which freefalls from a set height to provide impact force. The weight is lifted by hydraulics. The piles themselves are steel tubes, one metre in diameter, which are hammered approximately 40m into the sediment. The pile driving operation is restricted to daylight hours, 5.5 days per week, and is expected to continue until 2017 (Peterson, pers comm.). We found no published data on the characteristics of underwater sounds generated by this type of pile-driver. Some other pile drivers use a steel piling hammer that falls approximately 2m by gravity and detonates a fuel-air mixture to drive a pile into the seafloor with significant force (Jefferson et al. 2009). This system results in the transmission of between 90-1000kJ of energy per blow, depending upon hammer weight and fuel charge.

Pile-driving is expected during several phases of the development and is most closely associated with the replacement, improvement and/or extension of wharves and jetties (see Table 1 for a list). The specific projects that contain pile-driving as part of their description are: A08 Terminal Development-Wharf, B01, 02 & 03 Cashin Quay development, C01 No1 Breastwork and C06 Oil Terminal development. Additional projects may require pile-driving as the extent of repairs or replacement needed to infrastructure becomes apparent. These projects are all included in the inner harbour development group (C08, 09, 10 & 11). Pile driving to construct a typical wharf will take between six and twelve months to undertake assuming a five and half day working week.

3.2 Land Reclamation

Significant land reclamation is proposed as part of the PLP. Each reclamation project is associated with the development of trades serviced by LPC, in particular container terminal activities. The three major reclamation projects are: A01- 10ha Reclamation, A02- 8Ha Reclamation & A03- 19Ha Reclamation. Project A01 has been previously consented (CRC111659) and began in March 2011.

3.3 Dredging/dumping

Dredging and subsequent dumping of spoil are expected to be carried out mainly during the Cashin Quay development (Group B). The particular projects are: B01- Cashin Quay 2, B02- Cashin Quay 3 & B03- Cashin Quay 4. The purpose of these projects is to rebuild earthquake damaged infrastructure at Cashin Quay to support the ongoing container trade. Additional dredging will also take place during the construction of the container terminal, outer cruise berth and inner oil terminal berth.

It is expected that long-term maintenance dredging of the main harbour channel will be continued.

3.4 Marine Pollution

Coastal development can result in increased marine pollution in local areas. Contaminants can be sourced from activities such as the dumping of fill for reclamation projects and suspension of marine sediments during dredging. Additionally, construction activity may increase runoff of terrestrial pollutants and the risk associated with incidents such as oil or fuel spills may be increased during development. Marine mammals are particularly sensitive to marine contaminants. Therefore, any increased risk of marine pollution from the PLP should be given thorough consideration. The potential for marine pollution from the PLP has been assessed by Sneddon (2014) who concludes that contaminant loads at Lyttelton are unlikely be significantly increased due to the PLP activities.

3.5 Vessel traffic

A general increase in vessel traffic is likely as shipping trade increases as a result of the development. Future projects within the development, such as the provision of a 500 berth marina at Dampier Bay could increase small vessel traffic.

Project Group	Code	Name	Category	Potential Effects
Group A	A01	10ha Reclamation	Reclamation	Habitat removal
Group A	A02	8ha Reclamation	Reclamation	Habitat removal
Group A	A03	19ha Reclamation	Reclamation	Habitat removal
Group A	A08	Terminal development	Pile driving	Injury, masking, behavioural change
Group B	B01	Cashin Quay 2	Pile driving	Injury, masking, behavioural change
Group B	B01	Cashin Quay 2	Dredging	Pollution, habitat modification
Group B	B02	Cashin Quay 3	Pile driving	Injury, masking, behavioural change
Group B	B02	Cashin Quay 3	Dredging	Pollution, habitat modification
Group B	B03	Cashin Quay 4	Pile driving	Injury, masking, behavioural change
Group B	B03	Cashin Quay 4	Dredging	Pollution, habitat modification
Group C	C01	Breastwork	Pile driving	Injury, masking, behavioural change
Group C	C06	Oil berth	Pile driving	Injury, masking, behavioural change
Group C	C09	Jetty	Pile driving	Injury, masking, behavioural change
Group C	C08	Marina	Pile driving	Injury, masking, behavioural change
Group C	C10	Jetty	Pile driving	Injury, masking, behavioural change
Group C	C11	Jetty 3	Pile driving	Injury, masking, behavioural change

Table 1: A summary of the projects in the Port Lyttelton Plan and potential effects upon marine mammals. The threat category and potential effects for each project is given.

4. Marine Mammal Species

4.1 Hectors Dolphin

The endangered Hector's Dolphin has a resident population of approximately 1100 at Banks Peninsula (Gormley et al. 2005). The dolphins have seasonal habitat use patterns, preferring inshore habitat during the summer whilst being more spread out in their offshore distribution during the winter (Rayment et al 2010). Hector's dolphins have been found in and around Lyttelton Harbour at all times of the year (Figure 4) and will therefore be exposed to the development activities. Individual home ranges for Hector's dolphins are small (average alongshore home range is approximately 50km, Rayment et al. 2009). Therefore, dolphins that have home ranges that include Lyttelton may be disproportionately affected by the development.

As mentioned above, many marine mammal species are sensitive to changes in their environment due to their coastal distributions and high trophic level. Therefore, any changes to the marine environment caused, or exacerbated by the development may pose a threat to Hector's dolphins. In particular, noise pollution can result in significant impacts on individual marine mammals and their populations. Hector's dolphins are a highly valued species due being one of only two marine mammals endemic to New Zealand, due to their importance as top-predators in the coastal ecosystem, as taonga species to tangata whenua and commercially - as the basis of marine mammal tourism at Banks Peninsula and beyond.

4.2 New Zealand fur seal

The New Zealand fur seal is native to New Zealand. Once wide-spread around the North and South Islands, the species was hunted by early Maori and European settlers to very low levels (Lalas et al. 2001). From the remaining breeding colonies in the south of the South Island, the species has begun to colonise its former range, including the establishment of colonies at Banks Peninsula. Currently, the majority of seal breeding colonies occur on the south side of the peninsula where the breeding habitat is more suitable. There is, however, a breeding colony located at Long Lookout point, approximately 20 km from the entrance to Lyttelton Harbour (Ryan et al. 1997). Also, non-breeding haulouts may occur along the coast around Lyttelton Harbour and foraging seals have been found inside the Harbour itself.

Like Hector's dolphins, fur seals can be vulnerable to changes in their habitat. Seals at Banks Peninsula feed mostly on arrow squid, lanternfish, and barracouta, which are found around and beyond the continental shelf edge (Allum and Maddigan 2012). Hence they are unlikely to be as sensitive to changes to foraging habitat inshore (Harcourt et al. 2002). Juvenile seals may be more sensitive, as they are known to forage inshore (Page et al. 2006) and so may be impacted by development activities, particularly if degradation of important foraging habitat occurs. Degradation of breeding or haulout habitat for seal populations is unlikely due to the absence of seal colonies within Lyttelton Harbour. Seals can be sensitive to impacts from noise pollution (e.g. Edren et al 2004).

4.3 Other marine mammal species

No other marine mammal species are resident at Banks Peninsula. However there are regular sightings of other species including right whales, humpback whales, dusky dolphins and killer whales. Whale species such as humpback whales (*Megaptera novaeangliae)* are sighted from time to time, as Banks Peninsula is on their migration route. As their populations recover, southern right whales *(Eubalaena australis)* are increasingly seen in mainland coastal areas, including Banks Peninsula and Pegasus Bay. Although whales are currently sighted only a few times each year, the potential for disturbance due to noise pollution is high given the overlap in frequency between whale vocalisations and noise generated by pile driving. Southern right whales once utilised harbours such as Lyttelton as breeding grounds before they were extirpated from mainland NZ. As their populations gradually recover they may be particularly vulnerable to port development. Noise and other disturbance in a particular area may make the habitat less likely to be recolonised.

Delphinid species such as dusky dolphins *(Ladenorhynchus obscurus)* and killer whales *(Orcinus orca)* are also seen at Banks Peninsula from time to time (pers obs). Large populations of dusky dolphins are found offshore and further north at Kaikoura and Admirality Bay (Benoit-Bird et al. 2004). Dusky dolphins have also been sighted off the Otago coastline. The home range of the NZ killer whale populations encompasses Banks Peninsula. These species could be impacted by development activities, most likely from noise pollution, should their occurrence overlap with piling activity. However the likelihood of this is low and any exposure to high noise pollution is likely to be brief for these species.

5. Hector's dolphins and Lyttelton Harbour

Data from the Hector's dolphin photo-identification database were used to assess the extent to which Hector's dolphins use habitat in and around Lyttelton Harbour. The dataset provided information from 302 sightings of Hector's dolphin groups both within Lyttelton Harbour and off the nearby coastline. The distance over which sightings were included on the nearby coast was dictated by what was considered to be a reasonable estimate of the potential range of pile driving noise. The sightings spanned the period 1991 to 2014. The database also provided values for survey effort which enables the sightings information to be standardised by the time spent looking for dolphins or "on effort". This allows comparisons to be made between seasons to assess any seasonal use of Lyttelton Harbour by the dolphins. Using visual plots of sightings, it is possible to determine how Hector's dolphins may be exposed to varying degrees of risk from different impacts.

It is important to note, however, that these surveys were designed as photo-ID surveys, not as representative surveys of the entire habitat provided by Lyttelton Harbour. Because we expected dolphins to redistribute themselves between surveys, we surveyed the same route each time. Hence there are areas of Lyttelton Harbour that did not receive any survey effort. For example, while we have seen Hector's dolphins inside the port itself, this area has never been formally surveyed by us, so there are no sightings from within the port in the database. A typical survey path is shown in figure 1. Lack of sightings in areas well beyond this path should not be interpreted as representing an absence of dolphins.

5.1 Distribution of sightings

Hector's dolphins have been encountered regularly within and nearby Lyttelton Harbour (Figure 2). Of the sightings made inside the harbour itself most (47%) of the sightings have occurred at the heads of the harbour but many have been made in the inner harbour - as far up as Quail Island. There are also regular sightings off Port Levy. Group sizes ranged from 1 to 50 individuals with an average group size of 8. Calves (young of the year) were observed in 65 of the 302 groups (21.5%).

There is some overlap between dolphin sightings and areas under development (Figure 2). Dolphins in these locations would likely be disproportionately impacted by activities associated with the development due to their close proximity to the port. All of the sightings plotted on figure 1 are within at least one of the estimated'zones of impact' in terms of pile driving noise (see discussion of impact zones below).

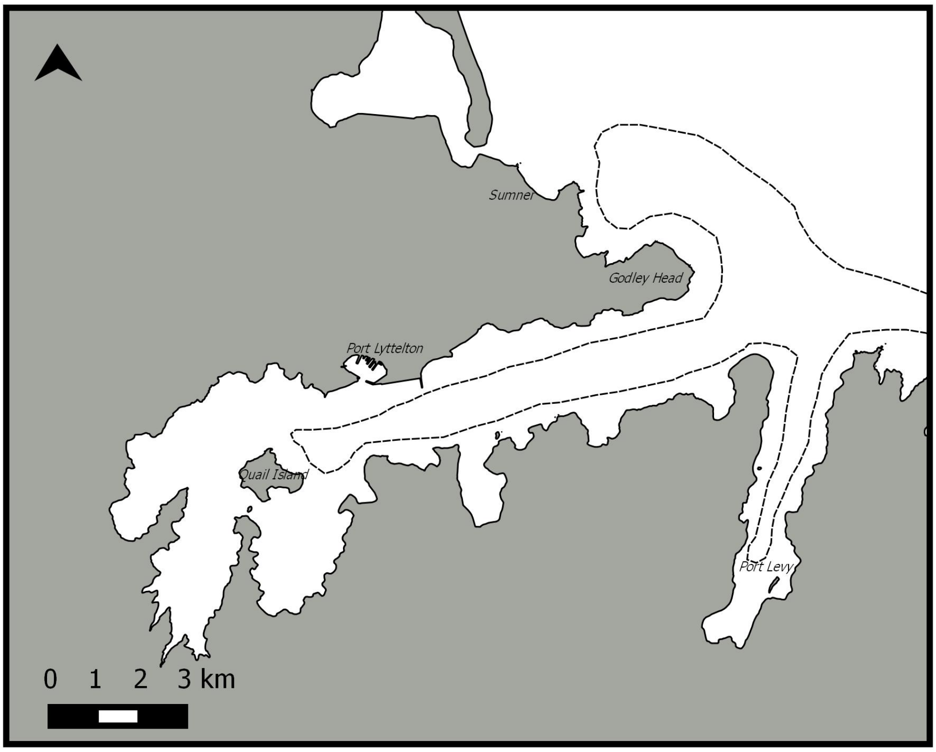

Figure 1: The standard survey route for searching for Hector's dolphins in and around Lyttelton Harbour

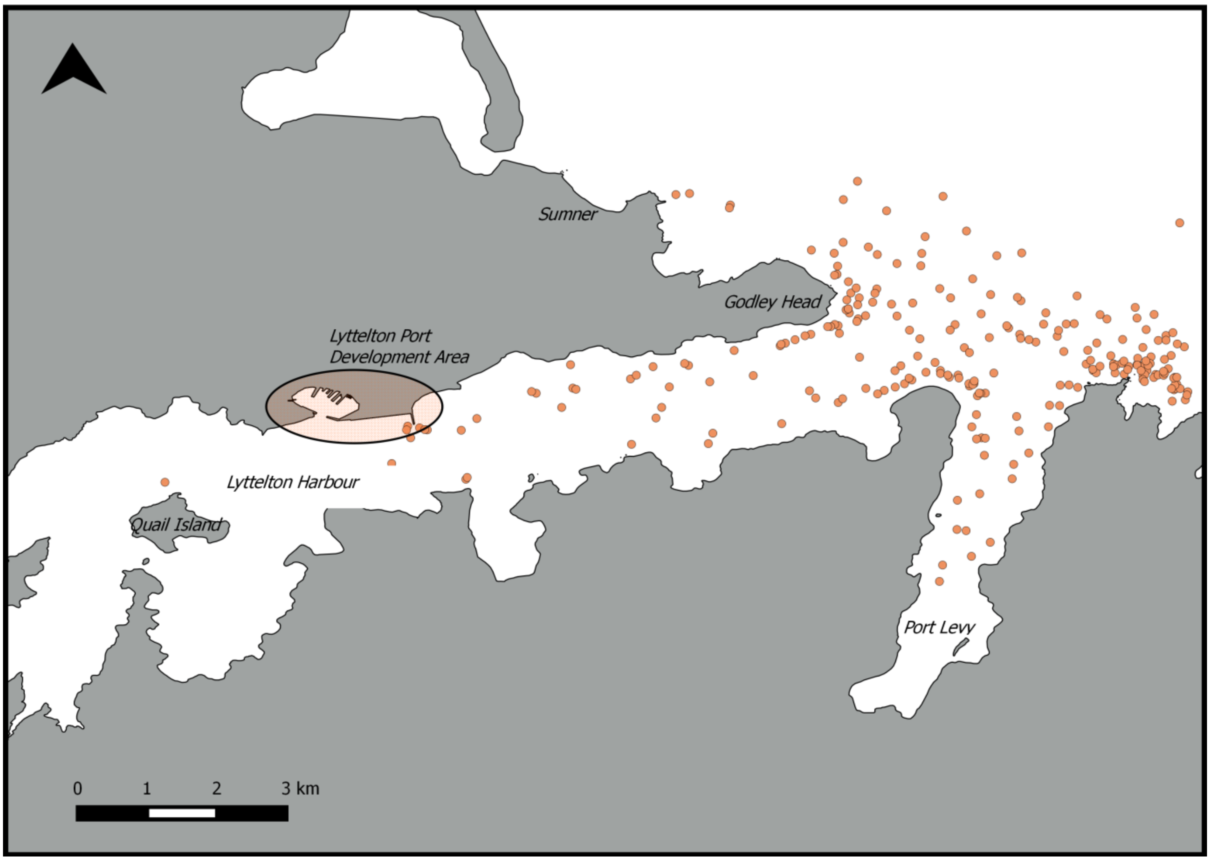

Figure 2: Distribution of Hector's Dolphin sightings in and around Lyttelton Harbour from 1991 to 2014. The shaded area denotes the Port Lyttelton, the location of the development activities discussed in this report.

It is also important to consider the distribution of groups with calves. Some species show a clear preference for particular habitat type as 'nursery habitat'. Younger, smaller individuals may be more vulnerable to development activities due to potentially higher hearing sensitivity, lack of experience and poorer ability to escape. At Lyttelton, groups with calves seem to be distributed in a similar fashion as groups without calves without clear preference for particular areas (Figure 3). However it is notable that many groups with calves can be found inside the harbour and two groups have been observed within the development area (Figure 3). This indicates that groups with calves are likely to be exposed to development activities and adds to the risk of adverse effects on Hector's dolphins.

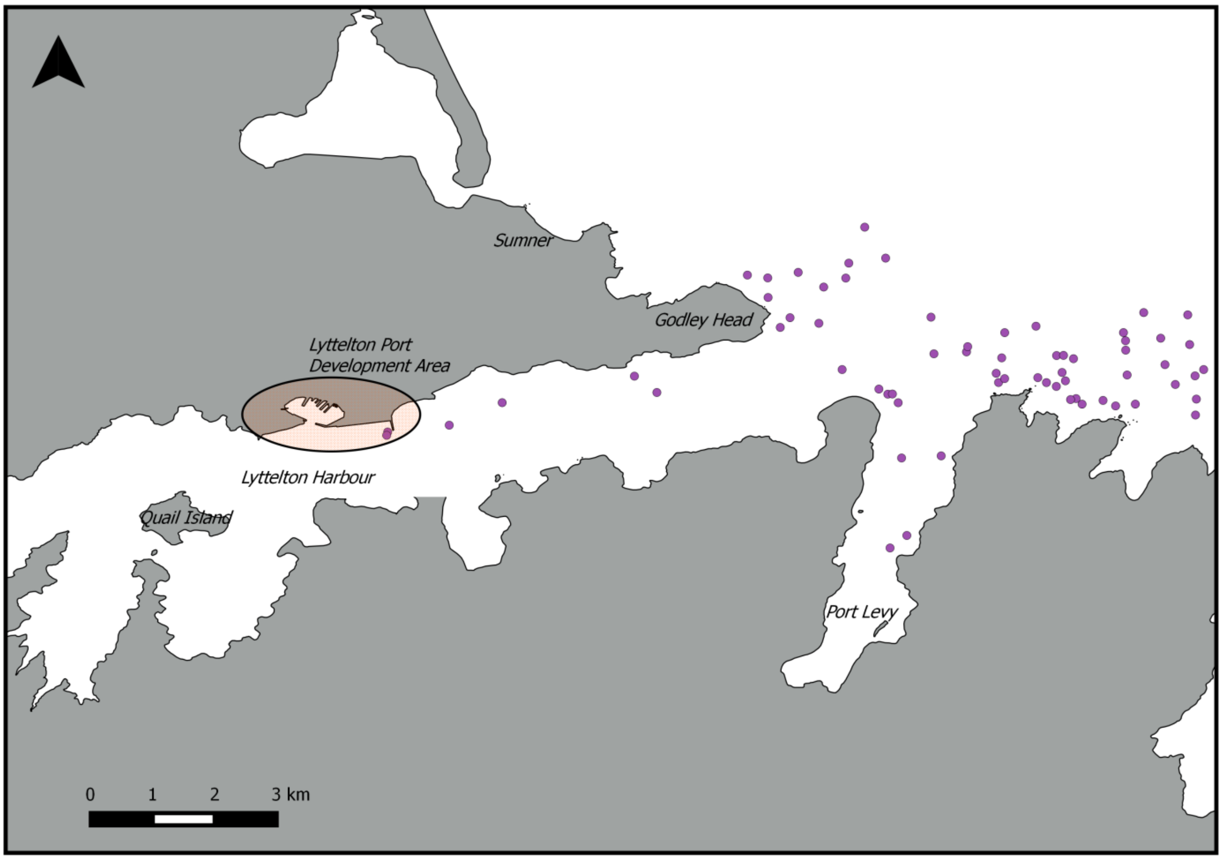

Figure 3: Distribution of sightings of Hector's dolphin groups with calves less than one year old at Lyttelton Harbour between 1991 and 2014. The shaded area denotes the Port Lyttelton, the location of the development activities discussed in this report.

5.2 Seasonal sightings

There have been far more sightings in the Lyttelton area during summer than any other time of the year (Figure 4-a), even after correcting for the larger amount of survey effort during summer. Increased use of inshore waters during summer by Hector's dolphins is also seen in other parts of Banks Peninsula (Rayment et al. 2010). There are fewer sightings in autumn (Figure 4-b). During winter (Figure 4-c), there has been only a small number of sightings made within the greater Lyttelton area, only one of these being made within the harbour itself, and none in the upper harbour. In spring (d) sightings begin to increase again, with a high number of sightings being made in the general Lyttelton area and ten within the harbour itself. For a true comparison between the seasons it is important to view encounters adjusted for effort below.

The maps plot sightings only, and do not take into account survey effort – that is, time spent searching for dolphin groups. This study has far more survey effort in the summer months when dolphin groups are closer to shore and calves are present; this is the most important time for photo-identification surveys. The seasonal differences in dolphin distribution are less pronounced, when the number of sightings is corrected for sighting effort (see below).

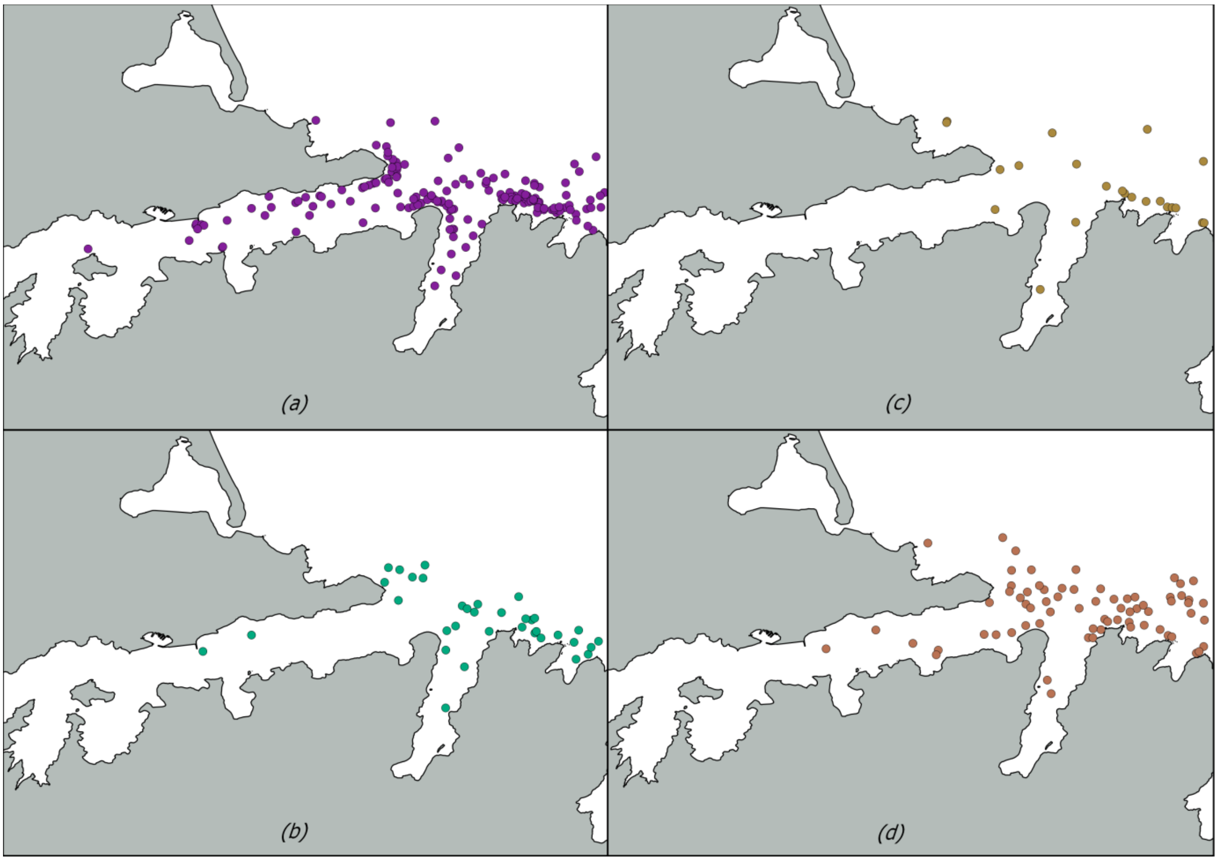

Figure 4: Seasonal distribution of Hector's dolphin sightings at Lyttelton between 1991 and 2014. The summer period is indicated by (a), autumn (b), winter (c) and spring (d).

5.3 Sightings per unit effort

There has been a total of 3558km of survey effort for Hector's dolphins at Lyttelton. This effort is unequal among the seasons, with the majority of effort (58%) taking place in summer (Table 2).

	Total # encounters	Total # dolphins	Total # Calves	Effort (Km)	Effort (% of total)
Autumn	35	201	12	423	12%
Winter	22	124	7	376	11%
Spring	70	735	11	694	20%
Summer	174	1402	68	2065	58%
Total	301	2462	98	3558	100%

Table 2: A seasonal breakdown of Hector's dolphin group encounter information and survey effort for the Lyttelton area.

The number of encounters (groups seen) per unit effort is similar throughout the year (Figure 5). The number of individual dolphins seen, however, shows a very different pattern, with substantially higher levels in spring and summer. This is driven by the fact that group sizes are larger at these times. The peak of calf sightings in summer is explicable by the fact that calves are born at this time.

These data show that in winter much lower numbers of Hector's dolphins are seen in Lyttelton Harbour than at other times of year, with the highest numbers seen in spring and summer. Summer also had the highest number of calves seen per km of effort. Autumn numbers were intermediate between summer and winter. Not surprisingly, there were still relatively high numbers of calves observed per km of effort in autumn. Winter was shown to be the least important season for Hector's at Lyttelton with the lowest values for groups, number of dolphins and low numbers of calves seen per km of effort (Figure 5). These seasonal distribution patterns are important in terms of mitigation options (see below).

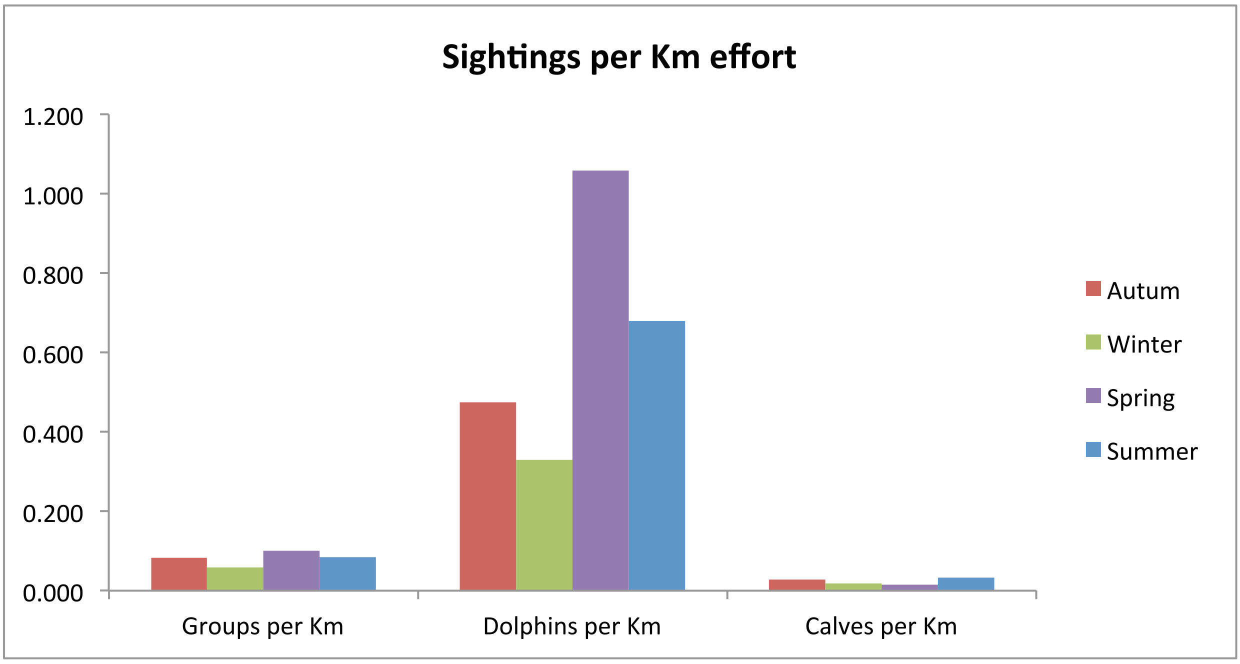

Figure 5: Number of groups, dolphins and calves seen per kilometre of survey effort at Lyttelton. Values are given for each season and represent sightings and effort over the period 1991 to 2014.

Overall, patterns of habitat use by Hector's dolphins in Lyttelton Harbour are similar to those observed in Akaroa Harbour via year-round continuous acoustic monitoring (Dawson et al 2013). Likewise, around the rest of Banks Peninsula higher numbers of dolphins are found inshore in summer than in winter (Dawson & Slooten 1988, Rayment et al. 2010). Therefore the data from Lyttelton and the more extensive peninsula-wide studies show that Hector's dolphins would be least exposed to potentially impacts associated with the construction activities in the port in winter.

6. Impacts of pile driving

Pile-driving is one of the most intense sources of anthropogenic noise in the ocean (Richardson et al. 1995). Noise pollution from pile-driving activity has been established as a serious threat to the health of individuals and populations of marine mammals (Thompson et al. 2013). The extent of risk to marine mammals is dependent on a number of factors including: the characteristics of the sound produced by pile-driving, environmental characteristics of the area, and the acoustic sensitivity, behavioural responses and habitat use characteristics of the species concerned (Richardson et al. 1995). The number of factors involved in determining the influence of pile-driving noise upon marine mammals, complicates the comparison of results among locations and species.

The responses of marine mammals to anthropogenic noise can be described by four zones that identify the likely spatial extent of four 'types' of reaction to noise (Richardson et al. 1995). The first of these zones is the 'zone of audibility' which is simply the range over which a particular species can detect the emitted noise. This range depends on the characteristics of the noise, the animal's hearing sensitivity at the relevant frequencies, sound propagation parameters and ambient noise levels. None of this information is available for species at Lyttelton. Our assessment of the potential impacts of pile driving in Lyttelton is based on comparisons with similar species. For a large pile driving system with a received sound pressure (at 100m distance) of 200 dB re 1 μPa (RMS), and measured values for transmission loss with range, Madsen et al. (2006) calculated the zone of audibility for harbour porpoise, bottlenose dolphins, North Atlantic right whales and harbour seals. For these species, and this source, the estimated zone of audibility was thousands of kilometres. This calculation represents likely maximum ranges. In any particular environment there are sources of sound attenuation and amplification depending on the characteristics of the underwater environment (including depth, substrate type, open water vs enclosed harbour habitats, etc). Taking these factors into account, Madsen et al. concluded that these "pile-driving sounds are audible to all the marine mammals treated here at very long ranges of more than 100 km, and possibly up to more than a thousand kilometres" (Madsen et al 2006, p. 289).

Harbour porpoise is anatomically similar to Hector's dolphin, and produces almost identical narrow-band sonar clicks. Therefore, the hearing sensitivities of the two species are likely to be similar. Likewise, the hearing sensitivities of harbour seals and NZ fur seals are likely to be broadly similar. Therefore, the zone of audibility for the common species at Lyttelton is likely to be extended much further than the extent of the harbour itself.

The remaining three zones are: The zone of responsiveness, the zone of masking and the zone of injury and will be discussed in detail in the relevant sections below.

6.1 Sound characteristics

A number of metrics that measure sound wave pressure and energy are used to assess the potential impact of piling on marine mammals. The first of these, peak pressure, is the instantaneous maximum of the absolute sound pressure (Blackwell et al. 2004). Sound pressure level (SPL) is the average pressure of a sound wave averaged over the duration of the pulse and calculated at particular distance from the source. Sound exposure level (SEL) is the squared instantaneous pressure of a sound wave over the pulse duration, which serves to measure the energy in the pulse (Blackwell et al 2004). The impact on marine mammals is heightened with increasing sound pressures. Thus measures of sound pressure are used to define the various zones of response and predict impacts upon species.

Sound pressure levels themselves are dependent upon several, additional factors. As would be expected, blow energy significantly influences the level of sound pressure produced by a piling event

(Brandt et al. 2011). Brandt et al (2011) calculated a maximum SEL at high blow energy (850KJ), whilst at low energy (<200KJ), SEL was significantly lower. Sound pressure is also influenced by the type of pile used (wood, steel etc), the pile's diameter and the characteristics of the seafloor sediment (Richardson et al. 1995). The piles being driven in Lyttelton are steel, one metre in diameter, and are driven approximately 40m into the sediment. In pile driving, initial strike generates a shock wave, which, over distance, becomes a pressure/sound wave. Sound is radiated into the water column from the pile itself, and from the sediment, which liquifies as the pile is driven. Hence sound radiation from a pile-strike event is complex, and cannot be modeled accurately without extensive measrement data.

The duration of the impulsive sound is an important characteristic to consider when identifying pile driving effects. Increases in duration may lead to impacts that are not initially observed with activity that is similar in frequency and sound pressure (Bailey et al. 2010). Experimental evidence indicates a linear relationship between temporary hearing threshold shifts (see below) and exposure duration. This indicates that the longer animals are exposed to high sound levels, the lower the sound pressure required to induce a negative response.

The sound pressure density spectrum is a measure of sound pressure versus frequency, and shows which frequencies have the most sound energy. These measures are often variable both between and within pile driving sites. In general, sound energy from pile driving starts below 100Hz and extends up to 150kHz (Table 3). Sound pressure levels usually peak between 100 and 1500Hz, although significant energy is often present above 25 kHz (Würsig et al. 2000). Partly because the piles are steel, significant high-frequency content is expected. Sound attenuation is frequency dependent; low frequencies propagate further in water (and in air) than high frequencies. This effect is dramatic. Sounds below 1 kHz suffer almost no absorption (<0.04 dB/km) while at high frequency absorption is much higher (e.g. 120 kHz = 47 dB/km; Richardson et al. 1995). Sound pressure levels and dominant frequencies depend on the distance from the sound source, which has important implications for impacts on marine mammals. Animals that are closer to the source are exposed to higher levels of sound with higher peak frequencies. Würsig et al. (2000) measured sound characteristics at three locations from a pile driver installing piles for a pier in Hong Kong. The piles installed were 1m in diameter and the activity took place in waters 6-8m in depth, so the method is comparable to what is likely to occur at Lyttelton. At 250m they recorded peak sound levels of 160-170dB re 1µPa with a dominant frequency between 400-800Hz, at 500m peak sound levels were 150-160 dB re 1µPa with a dominant frequency between 200-600Hz and at 1000m peak sound levels were 140-150dB re 1µPa, with a dominant frequency 200-300Hz.

Currently, there is no information concerning the likely sound characteristics of pile driving in Lyttelton Harbour. Without this information it is not possible to predict confidently what impacts might be on marine mammals in the area. The characteristics of pile driving for port development are usually different from the installation of piles for offshore wind-farms (where the majority of published measurements of pile driving noise have been made) with lower blast energy, sound pressure levels and peak frequencies (Table 3). However the values provided by Würsig et al. (2000) and Blackwell et al. (2005) are significant and are likely to result in impacts upon marine mammals. In fact, Würsig et al. (2000) documented area avoidance by indo-pacific humpback dolphins during the onset of pile driving for port facilities. Advice we have received from international acouticians with experience in measuring pile driving sounds is that we could expect source levels in excess of 230 dB re 1 µPa @ 1m (Tougaard, pers. comm).

Type	Energy	Peak SPL (re 1µPa) [range at which recorded]	Approximate source level (re 1µPa)	Frequency range	Dominant (peak) frequency	Reference
Wind-farm. 4m steel monopile	360-450 kJ	235 dB [1 m]	235 dB	?-100kHz+	160Hz	Tougaard et al. 2009
Wind-farm. 4m steel monopile	526-965 kJ	196 dB [50m]	213 dB	.05-1kHz	100-200Hz	Norro et al. 2010
Wind-farm. 2.4m steel shell pile.	500 kJ	212 dB [10m]	222 dB	.03-50kHz+	150-200Hz	Rodkin & Reyff 2008
Wind-farm 4m steel shell pile	334 kJ	203 dB [500m]	229 dB	.0.1-100Khz+	200Hz	Nedwell et al. 2007
Port 1m steel shell pile	90 kJ	170 dB [250m]	194 dB	Up to 25kHz	400-800Hz	Würsig et al. 2000
Port 1m steel shell pile	223 kJ	189 dB [62m]	206 dB	100–2000 Hz	350–450 Hz	Blackwell et al. 2005

Table 3: A comparison of pile driving sound characteristics of six projects, four from offshore wind-farm construction and two from port/coastal development. To ease comparisons we have calculated likely source levels, making the conservative assumption of cylindrical spreading. Pile driving sound characteristics at Lyttelton are likely to be most similar to the last two 'Port' examples listed here.

6.2 Species considerations

A simple comparison of sound pressure levels when assessing impacts upon marine mammals, does not take into account the critical bandwidth of the species concerned. The critical bandwidth is a range of frequencies over which a particular species' hearing is highly sensitive. In dolphins this is usually assumed to be the range of frequencies over which the species produces echolocation sounds (Au 1993; Richardson et al. 1995). In order to make a meaningful assessment of the effects of pile driving on a particular species, it would be necessary to know both the species' critical bandwidth and the pile driving noise pressure within this bandwidth (Madsen et al. 2006). Due to the broadband spectrum of pile-driving noise, this is particularly important.

Measuring the underwater hearing sensitivity of marine mammals can be done only with trained animals in captivity. For this reason, audiograms are available for only a few species. In those species, the range of most sensitive hearing closely matches their own sounds (Au et al. 2000). Baleen whales produce sounds used for communication in the frequency range 10Hz to 10kHz, while toothed whales and dolphins produce sounds for echolocation and communication between the frequencies 1 to 150kHz (Au et al. 2000). Pinnipeds communicate with vocalisation in frequencies between 50Hz and 60kHz (Richardson et al. 1995).

The vocal characteristics of species that may be impacted by the Port Lyttelton Plan are listed in table 4. The largest overlap between the range of best hearing and pile driving sounds occurs for species that are low frequency specialists, such as southern right whales, humpback whales and NZ fur seals. These species, if present, are likely to be affected at the greatest ranges. However, some piling driving noise (with lower energy) can be found up into the frequencies where many smaller, high-frequency specialists such as dolphins vocalise (Würsig et al. 2000; Thompson et al. 2010). Additionally, Richards et al's (1995) suggestion that the range of best hearing does not always correspond to the range over which a species produces sounds is now proven to be correct, at least for harbour porpoises. These animals produce narrow band high frequency clicks centred on 130 kHz, but have one of the widest auditory bandwidths of any animal (Miller and Wahlberg 2013). Hearing sensitivity at 2 kHz is only 25dB less than the very high sensitivity they show at 120-140kHz (Kastelein et al 2010). They are significantly more sensitive to low frequencies than bottlenose dolphins, for example (Au et al 2000). We should note also that the auditory system of dolphins appears to be more sensitive to brief broadband pulses (such as produced in pile driving) than to the pure-tone signals typically used studies of hearing (Au et al 2002). On the basis of this research, the pile driving sound is likely to have an impact on a wide range of species, including higher-frequency producing species, such as Hector's dolphin. The likelihood of impacts on these species is substantiated by the significant amount of research demonstrating responses of harbour porpoise to pile driving (see Table 5)

Impacts associated with pile driving are also dependent on habitat use patterns of the species concerned. In the current context, species that are coastal, shallow water specialists are likely to be more impacted than offshore species. Many of the marine mammal species found at Lyttelton are coastal species. Hector's dolphins, have a strong coastal distribution, being rarely found in water that is over 70m deep (Rayment et al. 2010). In summer Hector's show a preference for shallow water in harbours and bays and so are likely to be particularly susceptible to the impacts of pile driving at this time. Likewise, NZ fur seals rarely venture further than the continental shelf margin and rely on the coastal zone for haul out and breeding locations.

It is also important to consider the behavioural characteristics of species. Many marine mammal species are naturally curious and may be initially attracted to novel features in the environment. Hector's dolphins are known for being very boat positive. If Hector's were to be initially attracted to construction activity this may increase the risk of entering one of the higher zones of impact (i.e. injury) at the onset of pile driving.

Species	**Type**	**Frequency range**	**Dominant frequencies**	**Echolocation frequency range (kHz)**	**References**
Killer whale	Whistles, pulsed calls	1.5-18kHz, 0.5-25kHz	6-12kHz, 1-6kHz	12-25kHz	Richardson et al. 1995
Dusky dolphin	Whistles, burst pulses	1.0-27.3kHz	7-16 kHz	Bimodal clicks 40-50kHz, 80-110kHz	Au et al. 2004, 2010
Harbour Porpoise	Clicks	120-140kHz	127.5kHz	120-140kHz	Au et al. 1999
Hector's dolphin	Clicks	112-135kHz	125kHz	112-135kHz	Dawson & Thorpe 1990
Southern right	Tonal, Pulsive	30-1250Hz, 30-	160-500Hz, 50-		Cummings

whale		2200Hz	500Hz	n/a	et al. 1972, Clark 1982.
Humpback whale	Numerous	25-8200Hz	25-4000Hz	n/a	Richardson et al. 1995
Fur seal*	Clicks	100-200Hz	100-200Hz	n/a	Norris & Watkins 1971

Table 4: The characteristics of underwater vocalisations of species that may be impacted by pile driving at Port Lyttelton. Also given for comparison are the characteristics of harbour porpoise vocalisations. *note the values given here for Fur seal are for the Juan Fernandez fur seal, not the NZ fur seal, for which there are no analysis of underwater vocalisations.

6.3 Environmental considerations

The way in which sound propagates is influenced by the characteristics of the environment. Factors such as frequency dependent absorption, refraction and reflection alter the way in which sound waves are received by animals and so can influence the overall impact on species.

Sound propagates differently at different water depths due to the way sound waves interact with the acoustic channel boundaries (the sea surface and the sea floor), which results in absorption and reflection (Bailey et al. 2010). Because of these factors, shallow water depths (<20m) cause significant transmission loss, particularly in the lower frequencies where a cut-off effect can result in reduced propagation of certain low frequencies (Brandt et al. 2011). The removal of these low frequency spectra from the noise causes a decrease in energy. This cut-off effect is also influenced by the impedance of the lower boundary layer which will depend on the characteristics of the seafloor sediment (Jensen et al. 2000). The response of marine mammals to pile driving sound is likely to depend on the sound propagation characteristics of the area due to variation in received levels and frequency. Therefore it is very important to obtain detailed local acoustic data, in addition to data from other research (e.g. Brandt et al 2011).

Variable seafloor topography may result in significant differences in received sound levels among dolphins that are in different directions from the sound source. For example, the occurrence of a sandbank, dredged channel or similar underwater feature can change propagation resulting in high levels of sound absorption, or indeed channelling, which will alter levels received by animals beyond the underwater feature (Richardson et al. 1995; Edren et al. 2004).

The potential impact on marine mammals from piling sounds depends on the level of background noise in the area. Sources such as wave exposure and shipping significantly raise background noise levels. Amoser et al. (2004) demonstrated that background noise in shallow water can be raised by up to 40dB by ships smaller than 60m. According to Bailey et al (2010), impulsive sound from pile driving needs to be detectable above the level of background noise in order to be considered detrimental. While this seems logical, bottlenose dolphins can detect sounds *below* ambient levels, as humans can (see Richardson et al. 1995, for review). Lyttelton Harbour is likely to have high levels of ambient noise due to the ongoing operation of the port, large ship visits, maintenance and recreational boating. The additional repair work will add to the noise levels in the harbour. Based on averaging sound pressures of port noise over 30 minute windows, Dahl et al (2007) suggest peak pressures can reach 120 dB re 1 μPa at peak frequency in a typical port environment. Sounds from pile driving generally exceed this level of ambient noise (Table 3). Based on sound pressures that are likely to exceed ambient noise levels and the fact that impulsive sounds a generally more detectable than constant background sound (Richardson et al. 1995) pile driving is likely to be detectable well above the background noise anywhere within Lyttelton Harbour, and potentially beyond.

To our knowledge there have been no trials measuring sound propagation in Lyttelton harbour. This would be needed to make accurate estimates of how received sound pressure levels change with distance to piling activity. Blackwell et al. 2005 calculated sound propagation loss during piling for wharf construction at Port MacKenzie, Alaska; a site similar to Lyttelton in terms of depth, geography and piling method. A sound propagation loss constant of 16-18 dB/decade (per tenfold increase in distance) was calculated, which is in line with other estimates of propagation loss in the coastal zone (Richardson et al. 1995).

6.4 Masking:

The detection of a sound is limited by the hearing threshold of the ear and the ambient noise at a particular frequency. Pure-tone hearing thresholds are usually below ambient noise levels for a given frequency, meaning increased noise will interfere with the detection of sounds (Madsen et al 2006). This interference is known as 'masking' and is discussed extensively by Richardson et al (1995) in a review of the impacts of anthropogenic sound on marine mammals. The authors describe that the 'zone of masking' is defined as "the range at which the anthropogenic noise adds significant energy to ambient noise in frequency bands that overlap with signals of interest" (Madsen et al. 2006). When loud ambient noise overlaps with signals of interest the probability of detection is decreased due to a lowering in the signal to noise ratio (Madsen et al. 2006).

Based on the characteristics of their vocal repertoire, baleen whales are assumed to be low frequency hearing specialists (Madsen et al 2006). Also, anatomical investigations of the hearing apparatus of these species suggest a range of best hearing below 1 kHz (Ketten 2000). Sounds produced by southern right whales generally fall between 30 – 2200 Hz, with a dominant frequency band between 50-500Hz (Table 4) The spectral peaks for most piling activity also fall within this frequency range, suggesting there may be considerable masking of southern right whale vocalisations by pile driving. Although humpback whales can produce sounds up to 8200 Hz, the dominant frequency band for this species is between 25-4000 Hz (Table 4; Richardson et al. 1995). Consequently, it would be expected for pile driving noise to significantly mask humpback whale vocalisations.

Species that do not produce sounds at low frequencies are likely to have less sensitive hearing below 1 kHz. This means the detection of sounds in the low spectrum may be limited by the species hearing threshold rather than ambient noise (Madsen et al. 2006). Species such as harbour porpoise and Hector's dolphin produce no sounds below 1 kHz (Table 4), thus increased ambient noise in the low spectra may not interfere significantly with their sonar. In contrast, fur seals produce sounds as low as 100Hz and so the detection of sounds may be impacted by increased low spectrum noise (Table 4).

David (2006) modelled observed sound pressure levels and dominant frequencies of pile driving noise in terms of its capacity to mask bottlenose dolphin vocalisations. The modelling assumed a homogenous environment and a source level of 150 dB re 1 μPa. The likelihood of masking from piling a 6t piling hammer upon 9kHz vocalisations and echolocation clicks at 50 and 115kHz was assessed. It was found that pile driving could mask loud vocalisations at 9kHz out to 15km distant and echolocation clicks of 50 and 115kHz to 6 and 1.2km respectively. Weak vocalisations were likely to be masked out to a distance of 40 km (David 2006). However it should be noted that these results were not based on empirical observations, and were a product of modelling only. This study should be considered an indication that masking can occur. Detailed information on the acoustic characteristics of Lyttelton Harbour, and the characteristics of the noise generated by the proposed pile driving and other repairs, would be needed to estimate zones of masking for Lyttelton.

Madsen et al. (2006) used information about pile driving noise characteristics (sound levels, duration, frequency spectrum and propagation likelihoods) and the acoustic characteristics of four species to assess the degree of potential masking attributable to pile driving noise. The authors suggested that significant masking problems were unlikely for the four species assessed (harbour porpoise, bottlenose dolphin, harbour seal and North Atlantic right whale). It was suggested that because of the short duration and low duty cycle of pile driving sounds there would not be significant interference with the detection of other important sounds. However, because of high received levels, it is possible that pile driving may impair the ability for animals to detect or notice sounds via other means such as neural or muscular contraction or distraction by high pressure levels (Madsen et al. 2006). Dolphins, can "turn down" the sensitivity of their hearing system to avoid damage by loud sounds (e.g. Nachtigall and Supin 2013). During these periods of reduced sensitivity they are less likely to detect the sounds of conspecifics.

Pile driving noise can (in addition to masking dolphin vocalisations) mask environmental noise that marine mammals use as passive cues to provide information about their environment i.e. - prey detection, predator avoidance (David 2006). Wood and Evans (1980) demonstrated that a blindfolded, captive dolphin could repeatedly chase and catch free swimming fish without using its own "active" sonar – by listening to the sounds of the fish swimming. This indicates that dolphins can gain a great deal of sophisticated, precise information from listening alone. "Passive" sonar, as this has been called, would readily be masked by pile driving noise. Prediction of this type of masking would be difficult as it would require information about the important acoustic cues particular species respond to and the characteristics of these cues. Hector's dolphins often forage in areas where water clarity is very low and so may rely almost entirely on acoustics (echolocation or prey cues) to detect prey. Thus masking of any of these signals by pile driving may be particularly disadvantageous for Hector's.

6.5 Behavioural responses

Increased noise has the capacity to significantly alter the way marine mammals behave and use their environment. The area in which this occurs is called the zone of responsiveness; defined as the area over which an animal responds to a sound behaviourally or physiologically (Richardson et al. 1995). This zone is usually substantially smaller than the zone of audibility but can be very difficult to estimate (Madsen et al. 2006). This is due to the difficulty of defining and detecting behavioural responses, the temporal and spatial scale over which they occur and the variability of responses among individuals.

The disturbance of normal behaviours can have negative repercussions for individuals and populations. For example, disturbance from tour vessels frequently acts to decrease the time dolphins spend engaged in resting and foraging (e.g. Lusseau 2003). This behavioural disturbance has been implicated in the decrease in relative abundance of populations at Shark Bay, Western Australia (Bejder et al. 2006) and in the Bay of Islands, New Zealand (Tezanos-Pinto et al. 2013). Disturbance of important behaviours appears to cause individuals to leave the area in which the disturbance is occurring, thus decreasing population abundance.

In the context of pile driving, numerous studies have documented behavioural change (usually in acoustic behaviour, as that is easier to quantify) due to the noise emitted by the activity (Table 5). Most of these studies have been undertaken on harbour porpoise, a species that, as stated before, is similar to Hector's dolphin in their habitat use and vocal characteristics, and have used arrays of echolocation detectors (e.g. Tougaard et al. 2009). The common feature of these studies is an observed decrease in acoustic activity. Studies have found that porpoise acoustic activity strongly correlates with porpoise abundance estimates sourced from visual sightings (Tougaard et al. 2009).

Brandt et al (2011) found a clear relationship between decreasing harbour porpoise acoustic activity and the onset of pile driving. This study was carried out at Horns Rev, a reef system located 40km west of the Danish west coast. The area is comprised of an inner and outer reef with a water depth between 4 and 14m with medium-coarse grained sediment. This effect was observable to a distance of 17.8 km. Interestingly this effect was instantaneous with the onset of pile driving, which was also observed by Tougaard et al. (2009). At the closest acoustic monitoring location to pile driving, porpoise activity was reduced between 24 and 78 hrs after the cessation of pile driving. The duration of this effect decreased with distance from the piling location. At the monitored location furthest from pile driving (21 km), acoustic activity increased. This suggests that porpoises may have moved away from piling, increasing abundance at more distant locations. The median time between pile driving events was 16 hrs, during which there was no recovery of porpoise activity was seen within 4.8 km from the piling site. In this study, there were no occasions where piling occurred more than 16 hrs apart, thus porpoise abundance was reduced during the entire 5 month construction period.

The impact of pile driving upon harbour porpoise during the construction of the Horns Reef (I) wind-farm in the North Sea was assessed by Tougaard et al. (2009). The study site was the same as that mentioned above in Brandt et al. (2011). It was found that impulsive sounds with peak levels of 235 dB re 1 µPa at 1 m caused porpoises to move away from the sound source. The average interval between acoustic encounters significantly increased from 5.9 hr during construction to 7.5 hr after construction. No grading in this response was observed with distance from the piling site so the zone of responsiveness could not be accurately determined. However as the response was observed out to the most distant monitoring device, the zone of responsiveness would have exceeded 21km.

Porpoise activity was monitored during the construction of the Nysted offshore wind farm at a coastal location in the western part of the Baltic Sea. Water depth between 6 and 9.5m and the seafloor sediment consisted of sand/silt glacial deposits. Cartensen et al (2006) found that construction activities in general had a substantial effect on harbour porpoise echolocation activity This was considered to be a medium-term response, as porpoises tended to avoid the construction area for the duration of construction. Ramming and vibration activity from pile driving resulted in substantial short-term changes in harbour porpoise activity. This behavioural change was observed out to 15km from the piling site.

After modelling of the characteristics of pile driving sound and the acoustic abilities of a number of species (whales, dolphins and seals), Madsen et al. (2006) concluded that noise from pile driving is likely to impact the behaviour of these species over very large areas. This study was based on high source levels (200 dB re 1 µPa) and conservative transmission loss values. A more detailed assessment of the potential for behavioural reactions to piling sound in Lyttelton Harbour would require more data on the underwater noise produced by pile driving in Lyttelton. Despite apparently low auditory sensitivity to low-frequency sound, bottlenose dolphins reacted to pile driving sounds up to 50km away, at a received level of 140 dB re 1 µPa (source 226 dB re 1 µPa; Bailey et al. 2010). Also, Würsig et al. (2000) identified behavioural impacts on indo-pacific humpbacked dolphins from pile driving for a pier in Hong Kong. In this study the dolphins remained in the vicinity of piling activity before and during the operation, but were found to be lower in abundance afterwards. The dolphins also exhibited higher travelling speeds during pile driving activity (Würsig et al. 2000).

Most of the research discussed above (with the exception of Würsig et al. 2000) has been undertaken in the North Sea, assessing pile driving for the installation of wind-farm turbines. As mentioned previously, pile driving for wind farm construction is generally louder than for port development and differences between coastal/open ocean environments and Lyttelton Harbour may mean received sound pressure levels are different at given distances from the activity. A more detailed assessment of the potential impacts of pile driving in Lyttelton Harbour would require much more information about the local acoustic environment, including pile driving and other human-made noise. Meanwhile, the studies discussed above provide a meaningful assessment of the potential behavioural effects at Lyttelton.

There have been relatively few studies of the behavioural responses of seals to pile driving. Edren et al. (2004) showed that during the construction and piling stage of building the Nysted offshore wind-farm, there was a 20-60% reduction in the number of seals hauling out at a sandbank 4 km distant. It is likely these seals moved to an adjacent area where the noise from pile driving was less intense. However as the study did not observe the seals' in-water behaviour it was not possible to determine this conclusively. The effect was apparently short-term; seal haul-out behaviour returned to normal after the cessation of pile driving activity (Edren et al. 2004). In a separate study Blackwell et al. 2004 detected no changes in behaviour from ringed seals when exposed to pile driving noise from development at Northstar Island, Alaska. The authors attributed the lack of response to the likelihood of these seals being habituated to high noise levels. Northstar Island is an oil port and so substantial sources of noise have been present historically due to the ongoing operation of the port.

There have been no published studies assessing the effects of pile driving noise on the behaviour of baleen whales. Due to the impracticality of keeping them in captivity for experiments, little is known about the hearing or behavioural thresholds of these species. On anatomical grounds it is expected that they are more sensitive to the low-frequency sound, such as those produced by pile driving, than any of the dolphin species (Nowacek et al. 2007). Baleen whales have shown substantial reactions to airgun noise with broadly similar sounds characteristics to piling. Richardson et al (1986) showed that bowhead whales (*Balaena mysticetus)* avoided areas where airgun sounds were above 160 dB re 1 μPa (source level 222 dB re 1 μPa). Further area avoidance was shown in a subsequent study which demonstrated that migrating bowhead whales avoided airguns that were operating up to 20km distant, at which range airgun pulses were 178 dB re 1 μPa (Source levels >220 dB re 1 μPa; Richardson et al. 1999). In a study on the behavioural responses of fin whales (*Balaenoptera physalus*) to airguns used in a seismic survey, Castellote et al. (2012) demonstrated that whales avoid areas where airguns are in use and appear to modify their vocal behaviour to minimise masking. These effects were observed beyond the initial exposure period and were thus considered medium-term effects. These studies indicate that intense sounds such as those from pile driving can cause significant behavioural change in baleen whales over a large range.

At Lyttelton it is likely that pile driving noise will result in behavioural responses in local marine mammals. Hector's dolphins will be the most exposed to the noise, but fur seals are also likely to be impacted. Marine mammals exhibit a behavioural response to pile driving noise out to at least 20km for pile driving with source levels of around 200 dB re 1 μPa (Madsen et al. 2006; Tougaard et al. 2009). The zone of responsiveness for pile driving in Lyttelton Harbour could extend to 20km. A more precise estimate would require thorough investigation into the responses of Hector's dolphins and fur seals to piling noise and estimates of the underwater sound levels of piling at Lyttelton.

Research has demonstrated behavioural responses of marine mammals to pile driving noise. There is currently very little information about the potential long-term impacts of this type of disturbance on populations. How populations respond to this disturbance is a crucial facet of understanding how development may affect the long-term viability of marine mammal populations. Potential population level effects are discussed below.

Paper	Project	Species	Responses observed
Brandt et al. 2011	Horns Reef II offshore wind-farm.	Harbour porpoise	Strong decrease in acoustic activity/abundance,

			lasting effects up to 5 months.
Tougaard et al. 2009	Horns Reef I offshore wind-farm	Harbour porpoise	Decrease in acoustic activity/abundance to 20km.
Carstensen et al. 2006	Nysted offshore wind-farm	Harbour porpoise	Decrease in acoustic activity/abundance, out to 15km.
Thompson et al. 2010	Pile driving for wind turbines NE Scotland	Harbour porpoise	Decreased use of area.
Würsig et al. 2000	Coastal development Hong Kong	Indo-Pacific Humpbacked Dolphin	Area avoidance
Edren et al. 2004	Danish North Sea	Harbour and Gray Seal	Short term behavioural change
Blackwell et al. 2004	Pier development, Alaska	Ringed seals.	No effect

Table 5: Published accounts of marine mammal reactions to pile driving noise from offshore wind-farm construction and coastal development.

6.6 Injury:

The high pressure of the impulsive sounds originating from pile driving activity can cause physical damage to marine organisms that are close to the origin of the sound. The zone for this type of impact is called the zone of injury, and is defined as the range over which received sound pressures may cause an animal to suffer from physical injury or loss of sensitivity in its auditory system (Madsen et al. 2006). Short duration sounds with very high peak pressure can cause blast injury in mammals and fish, which typically affects the organs and sensitive aural structures (Richardson et al. 1995). The likelihood of severe blast injury increases with decreasing body size; the peak sound levels required to cause injury are lower in small animals. Noise from pile driving has been demonstrated to result in physical trauma to fish, in particular for sound-producing fish that have sensitive hearing (Anderson 1990; Popper et al. 2006). For marine mammals, damage to aural structures is the primary concern due to their high sensitivity. The zone of injury is distinguished by the range at which hearing sensitivity is lost, ether temporarily or permanently (Richardson et al. 1995). These effects are called temporary threshold shift (TTS) and permanent threshold shift (PTS). There is no empirical evidence of physical damage to marine mammals exposed to pile driving sounds. This is not surprising: it would be unethical to conduct such experiments, and outside of an experimental setting, the likelihood of being able to examine a victim in sufficient detail to fully document the injuries is exceptionally low. Because of this, there is no firm agreement for the level of sound pressure required to induce TTS or PTS from pile driving noise. However, based on information about species' hearing thresholds and experimental evidence concerning the onset of TTS and PTS from other noise sources it is possible to model the likely extent of the zone of injury.

Hearing impairment, whether temporary or permanent, is complex, depending on several factors including the hearing sensitivity of the species of concern, the received level of the sound, its spectrum, and, importantly, its duration or rate of repetition. Continuous or repeated exposure causes injury at much lower levels than exposure to a single high-level pulse. This is one reason why estimates from the literature differ widely. In general, it has been suggested that most marine mammal species would experience TTS at received levels of non-repeated stimuli at 200 dB and above (David 2006). A study by Southall et al (2007) suggests that high frequency specialists such as the harbour porpoise and Hector's dolphin would experience TTS at 183 dB re 1 μPa and PTS at 198 dB re 1 μPa from non-repetitive sounds (Southall et al. 2007). In an experimental approach, Lucke et al (2009) determined that TTS from a single airgun stimulus would occur at 164.3 dB re 1 μPa in harbour porpoise. Average sound pressure levels and normal repetition from pile driving would cause harbour porpoise to experience TTS immediately at 720m or after 2 minutes duration at 2300m (Brandt et al. 2011). It should be noted that this pile driving method is different to that which will occur at Lyttelton in that the piles are larger (3.9m diameter), shorter (30 to 40m) and were driven by a larger piling hammer (900kJ per strike).

Using much higher estimates of the onset of TTS for non-repeated stimuli (224 dB re 1 μPa and 212 dB re 1 μPa respectively) for cetaceans and pinnipeds, Bailey et al. (2010) found that PTS would have occurred within 5m and 20m for cetaceans and pinnipeds respectively when considering the peak source levels of the piling activity. TTS would have occurred at 10m for cetaceans and 40m for pinnipeds. The authors determined that no form of injury or hearing impairment would have been likely to have occurred beyond 100m, based on a SEL of 166dB re1 μPa^2-S recorded at this distance. In our opinion the assumptions underlying this study are questionable, and the estimates of zone of injury, unreliable.

Madsen et al (2006) defines the zone of injury from repetitive pile driving noise to extend to a range where the sound level has dropped to 180 dB re 1 μPa (RMS) for whales and dolphins and 190 dB re 1 μPa (RMS) for seals. For a pile driver generating 200 dB re 1 μPa (RMS) this equates to a zone of injury of 2km for cetaceans and 700m for seals using the most conservative model of transmission loss (Madsen et al. 2006). Nachtigall et al (2004) suggest that the received level required to induce TTS may be even lower, at 160 dB re 1 μPa (RMS) for dolphins exposed to a 30 minute cycle of noise between 4 and 11 kHz. No estimation for the zone of impact for pile driving noise was given (Nachtigall et al 2004).

At the onset of TTS it is expected that animals would move away from the source of the injuring sound. Yet when taking into account the swimming speed of a harbour porpoise (4.3m s-1) Brandt et al. (2011) considered it unlikely that an animal would be able to move beyond the zone of injury before TTS occurred. Additionally, it is possible that animals may endure harmful sound if important resources are available in the zone of injury (Brandt et al. 2011). Experience with high-level acoustic harassment devices used to deter seals at aquaculture sites indicates that individuals will tolerate high levels of sound if the rewards for doing so are sufficiently great (e.g. Quick et al 2004).

There is little information on the pile driving sound pressure levels that cause TTS and PTS in whale species. However, exposure to high intensity, mid-frequency sonar sounds has been shown to result in injury and death in a number of whale species (Fernandez et al. 2005; Parsons et al. 2008). The susceptibility of whales to acoustically derived trauma from sonar suggests that pile driving sound may also impact these taxa and caution should be applied when carrying out pile driving in whale habitat.

The most common species at Lyttelton, Hector's dolphins and NZ fur seals would be susceptible to physical injury from pile driving sound if they are nearby when the activity starts. It is important to calculate the likely extent of this zone, in order to minimise the animals' exposure to harmful sound. As mentioned above, this would require monitoring of pile driving sound and sound propagation modelling at Lyttelton as well as information about the received pressure levels required to induce TTS in these species. Unfortunately, this information is not currently available. The only option therefore seems to recommend a zone of injury range from the literature yet this is complicated by the lack of agreement between studies. A precautionary approach would use the 2km and 700m range for cetaceans and pinnpeds identified by Madsen et al. (2006). Given the lack of information concerning the true extent of the zone of injury at Lyttelton, it seems prudent to use these values. When further information is available concerning the characteristics of pile driving at Lyttelton these conservative ranges can be amended accordingly.

7. Impact of land reclamation

The major impact of land reclamation upon populations of marine mammals is permanent elimination of habitat. Typically, this impact is irreversible and there is no mitigation that can conceivably replace habitat that is lost to marine mammals. Other impacts from land reclamation may include pollution and sedimentation from the dumping of fill, changes to oceanographic and sedimentation processes and noise pollution.

7.1 Habitat loss

The extent of the impact of total habitat loss depends on two factors; 1)- the size of the area to be reclaimed 2)- the importance of the habitat to the marine mammals. Obviously, the larger the area to be reclaimed the larger area of habitat that will be unavailable for marine mammals. If the reclamation area is favoured by some individuals, the removal of the habitat may force them into more marginal areas. The use of marginal habitat has been linked to population vulnerability and ultimately decline (Tynan & DeMaster, 1997). Empirical evidence of this relationship is very difficult to obtain. In some cases marine mammal species depend on certain types of rare habitat for particular functions i.e. - breeding habitat for seals. If land reclamation reduced the availability of rare but important habitat by a significant amount, impacts could be severe.

The importance of habitat for particular functions is a worthy consideration for land reclamation. Some species of dolphin use shallow water as nursery habitat to decrease risk of predation to smaller, vulnerable calves (Weir et al. 2008). Other marine mammals have particular requirements for foraging habitat based on the availability and distribution of prey resources (Harwood 2001). Additionally, some habitat may be important for marine mammals indirectly, via the contribution of energy to the marine food web. Food webs, particularly in areas that are already highly modified, can be fragile, with small increases in disturbance having the potential to be compounded with previous impacts to result in substantial ecological changes (Thrush and Dayton 2010). Whether habitat is important for particular marine mammal functions or ecologically, there should be due consideration of marine mammal habitat requirements before land reclamation takes place.

The Lyttelton development plan includes a maximum reclaimed area of 37 Ha, including Hector's dolphin habitat (see Figure 1). Despite relatively low survey effort, five sightings of Hector's dolphin groups have been made on the margin of the reclamation area since 1991. Two of these groups contained calves. If these more vulnerable demographics regularly use the reclamation area the potential for adverse effects would be increased. However, the reclamation area is a small percentage of the total harbour area and so the magnitude of the effect of removing this habitat may be small, especially given that the habitat is not unique in the harbour (Sneddon 2014).

It is likely that NZ fur seals use the area occasionally. Most of the fur seals' foraging habitats are towards the continental shelf margin, while breeding and haul out habitat is typically located on the open coast. Thus it is unlikely fur seals would be significantly impacted by the removal of habitat at the reclamation site.

7.2 Pollution from fill:

Depending on its origin, fill may include a range of contaminants that are harmful to marine life. Marine mammals are especially susceptible to the effects of pollutants due to their high trophic level. Further, the close inshore distribution of Hector's dolphins is an exacerbating factor, and it should be noted that this species shows a relatively high pollutant burden (Jones et al 1999; Stockin et al 2010). Hector's dolphins have been shown to use the area around the reclamation site and thus may have heightened risk to the effects of pollution if it was present in fill materials. New reclamation will use Quarry sources for fill (i.e. clean) or marine sediments (from within the harbour). The sediment will be thoroughly analysed before deposition, reducing the likelihood of marine mammals being exposed to high levels of contaminants. Resupension of sediment could be an issue with land reclamation, and other port development processes.

7.3 Oceanographic & sedimentation processes

Land reclamation can cause changes to the oceanographic and sedimentation processes of the area. Reclamation can disrupt or interfere with coastal and tidal currents by changing their velocity, direction or blocking them entirely. Large reclamation projects can also limit the amount of mixing between water bodies in estuarine or wind driven circulation (Li et al. 2007; Wang et al. 2012). As oceanographic processes are explicitly linked with primary productivity, alteration of these processes can have significant biological consequences.

The potential for changes from land reclamation to the oceanographic and sedimentation processes in Lyttelton has been assessed by Goring (2014). Reclamation will result in a change of up to 30% in mean wave heights at particular locations throughout the harbour. Wave heights will decrease in areas close to the reclamation site and will increase in bays on both sides of the harbour to the east of the site. Increased wave height can cause sediments to be suspended more readily; however given the overall small size of the increase this is likely to be minimal. The main change to the harbour wave climate from reclamation is likely to originate from decreasing swell wave height at areas close to the reclamation sites. This will reduce the amount of time sediment is disturbed by waves. Tidal currents will also be influence by the reclamation activities at Lyttelton. The most extreme change will be at Diamond Harbour where there will be a 15% decrease in current velocity. Goring concludes that the changes in wave height and current velocity due to reclamation are unlikely to result in changes to the harbour's sedimentation processes.

7.4 Noise pollution

Noise pollution could be increased by the physical dumping of large loads of fill into the marine environment. The noise is likely to originate from cavitation as the fill enters the water. The sound levels and frequency spectrum of the dumping of fill are unknown, however for large loads, the levels may be significant, and broadband. Increased ambient noise can effect marine mammals in a number of ways (see pile driving above), so it is important to take into account any addition to ambient noise from dumping of fill. This is particularly important at the proposed reclamation site where dolphin groups have been observed. It should be noted that dumping of fill has been carried out for many years at Lyttelton and as such, the PLP itself may not result in a novel effect in terms of noise pollution.

8. Impacts of Dredging

The main impacts of dredging on marine mammals are likely to originate from the resuspension of sediment both during the dredging and dumping of spoil. As mentioned above, the resuspension of marine sediments can cause marine mammals to become exposed to high levels of pollutants- particularly heavy metals, organochlorides and PAHs if they are present in the dredge spoil (Jefferson et al. 2009). Marine mammals are likely to be impacted by pollutants from physical exposure to the chemicals and due to bioaccumulation through their prey species. Their coastal distribution, and high trophic level, means that dolphin and seal species have some of the highest concentrations of organochlorides for any marine animal (Tanabe et al. 1983; Aquilar et al. 2002; Jones et al. 1996,1999; Buckland et al. 1990). Due to these factors marine mammals are particularly vulnerable to marine pollution; it has been suggested that some mass strandings, unusual mortality events and reproductive failure may be attributed to high pollutant concentrations which have severe population level effects (Reijnders, 1986; Tanabe et al. 2002).

Resuspension of sediments may impact marine mammals indirectly, through their prey (Jefferson et al. 2009). Many fish species have been shown to be negatively impacted by high sediment loads and contaminants from resuspended sediments (e.g. Newcombe et al. 2010). Marine mammals have high energetic requirements; if prey becomes scarce, the inability to meet these requirements is reduced which may led to population level consequences. However Lyttelton Harbour is a highly turbid environment and so it is likely that the species present in the harbour are somewhat tolerant of high suspended sediment loads. Dredging is part of the descriptions for three projects in the development plan; the Cashin Quay, the oil terminal and cruise berth developments. Additionally, as part of the ongoing use of the port and predicted increase in shipping, the current maintenance dredging of the main channel and berths will continue long-term. The dredging projects at Cashin Quay will take place in an area that has been dredged historically, to improve access for larger vessels to the quay and inner port. According to Sneddon (2014), trace metals, low levels of PAHs, and organic compound enrichment is present at Cashin Quay. Maintenance dredging of the main channel has been ongoing for many years, thus the habitat in this location is probably already in a degraded state but contaminant levels should be relatively low.

A major issue with dredging is the location for the disposal of spoil. The dumping of large quantities of dredge spoil can be harmful to marine life via increasing the local concentration of contaminants and sediment. The location of the disposal site must be carefully considered so as not to impact habitat that is important for marine mammals and other taxa. The current spoil disposal ground is on the north side of the harbour, between the inner port and Godley Head. There have been numerous sightings of Hector's dolphin groups in this area (Figure 1). This site has been used for spoil disposal for around a century and so can be considered a highly modified site. Yet typical spoil disposal assessment criteria should be used to ascertain the risks to marine mammals and their prey.

9. Impacts of marine pollution

As discussed above, marine pollution could potentially be an issue for the development at Port Lyttelton. In other developments pollution is frequently a product of land reclamation and dredging activities. According to the PLP, pollution from these activities will be managed by using clean fill and contaminant bunds. There is however, potential for pollution from additional sources such as changes in land use practises, terrestrial runoff and from general construction activities. Pollution can impact both the health of individual marine mammals or have longer lasting, population level impacts by causing reproductive failure, strandings and other mortality events (Tanabe et al. 1994; Tanabe, 2002). Industrialisation of catchments often causes an increase in contaminants in the local marine environment (Sherman & Duda, 1999). Ports in particular are a high source of contaminants due to their strong industrial nature. Storm-water runoff, particularly during the construction phase of the development may cause an increase in contaminants if adequate storm-water treatment systems are not established. General constructions activities also have the potential to increase contaminants due to inadequate disposal of construction materials, rubbish generation and the risk of accidents such as oil spills (Jefferson et al. 2009).

These effects can be significant if not properly managed during the development. LPC has developed and implemented a construction environmental management plan to ensure that stormwater and contaminant treatment is upheld to a standard of modern "best practise". The CEMP also prescribes guidelines for the minimisation of contaminants from construction activities and accidents. Additionally, new port infrastructure is proposed to include an upgraded stormwater treatment facility which should improve the quality of discharged stormwater (Sneddon 2014).

10. Impacts of vessel traffic

High levels of shipping and vessel traffic have been shown to impact marine mammals in two ways: 1) Increasing the incidence of ship strike and 2) Causing behavioural and acoustic disturbance from vessel presence and noise.

Ship strike has been reported as a significant problem, particularly in areas where high volumes of shipping and high marine mammal densities coincide (Knowlton & Kraus 2001). Ship strike is usually an issue for whale species such as right whales, humpback whales and gray whales and can result in significant injury and mortality (Laist et al. 2011). However, ship strike can also be a problem for smaller marine mammals such as dolphins and seals. Jefferson et al. (2009) found that in busy areas with substantial coastal development, many dolphins were found with wounds typical of vessel impact. Smaller, planing hulled vessel are usually responsible for ship strikes involving dolphins and seals. Apart from the resultant injury and mortality of the animals hit by vessels, there can be population level effects if ship strike removes a large number of animals from the population (Panigada et al. 2006). The incidence of ship strikes increases with both the number of vessels operating in an area and the speed at which they travel (Laist et al. 2011). Documentation of two fatal boat strikes involving Hector's dolphin calves in Akaroa Harbour, which has lower levels of boating traffic than Lyttelton, indicates that these risks are real and need to be managed (Stone et al. 2000). Thus to minimise ship strike, systems need to be developed to limit either vessel speeds and/or numbers..

Disturbance to marine mammal behaviour is a well noted feature of areas with high vessel traffic. When disturbance repeatedly changes the behaviour of an animal, it can result in deleterious stress and avoidance of important areas (Bejder et al. 2006). In the context of marine mammals and vessels, the typical behavioural change is an abandonment of resting and foraging behaviour at the onset of a vessel encounter (Lusseau 2003). If a high level of this type of disturbance is sustained it can result in a decline in abundance in the areas where disturbance is high (Bejder et al. 2006).

Acoustic disturbance from vessels is also a potential impact from increased vessel traffic (Guerra et al. 2014). The noise that vessels emit underwater can be significant, especially when multiple, large vessels are operating at the same time (Richardson et al. 1995). The increase in ambient noise from vessels can impact marine mammals in the same ways noise from pile driving may, with the exception of physical injury. Masking of marine mammal sounds and behavioural disturbance has been proposed as effects of high vessel noise (Richardson et al. 1995). Guerra et al. (2014) demonstrated that bottlenose dolphins change the way they vocalise when in the presence of tour vessels, which suggests masking may occur and that dolphins change their acoustic behaviour in response to vessel presence to adapt to the masking.

Any increase in vessel operations is likely to be around the port itself. In particular when vessels are operating around Cashin Quay, or at the reclamation sites, both dolphins and seals may be encountered. Due to maritime speed restrictions within the port it is unlikely vessels will be regularly travelling at a speed sufficient to cause injury from ship strike. However skippers of vessels should remain vigilant for the occurrence of marine mammals in the vessels course. Much of the development of the port is to increase its operating capacity and so it is expected that, higher numbers of large ships will visit the port. These ships will be using the main shipping channel, where marine mammals are regularly found. Generally, dolphins and seals will be agile enough to avoid ship strikes with large ships, however species such as southern right whales may be at risk from increased shipping. Ship strike is a significant problem for north Atlantic right whales in and around busy harbours (Knowlton & Kraus 2001) and in northern New Zealand a ship strike issue has immerged with Bryde's whales in the busy Hauraki Gulf (Behrens & Constantine 2008). Although large whales are not currently common at Lyttelton, as southern right and humpback whale numbers increase, ship strike at busy ports such as Lyttelton may become an issue.

Behavioural and acoustic disturbance of marine mammals at Lyttelton from vessel numbers may be an issue if vessel numbers increase. Although most vessels are likely to be operating in areas were marine mammal numbers are relatively low, vessels do not necessarily have to be close to the animals to elicit a behavioural or acoustic response. Larger, noisier vessels that are more often operating outside the inner port where marine mammal densities are higher may pose the highest risk of causing disturbance. Also, the provision of marine recreational facilities such as a new marina is likely to result in future increases in small vessel traffic. Smaller vessels have been implicated in both ship-strike (Jones et al. 2004) and acoustic disturbance (Guerra-Bobo et al. 2014) effects upon marine mammals. There is an established code for minimising the disturbance of vessels upon marine mammals (see mitigation), it is important that these are adhered to whenever groups of dolphins, seals or whales are observed.

11. Long-term impacts

Whilst there have been many studies of short term changes to surface and acoustic behaviour, habitat use and distribution, it is much more difficult to predict longer, population level responses to disturbance. This is due to a number of reasons: 1)- The necessity of long-term baseline data to which post disturbance data can be compared 2)- The difficulty of isolating the effect of a particular impact from a range of potentially important factors 3)- Variability in responses among individuals of the same species.

The difficulty in attributing population level changes to a particular factor is represented by a scarcity of publications on the topic. In the context of marine mammals only two studies demonstrate how human induced disturbance can result in population level effects. Bejder et al. (2006) carried out a study on a population of bottlenose dolphins in Shark Bay, Australia that is subject to a large tourism industry. It was found that after years of disturbance from tourism vessels, a substantial number of dolphins left the study area, decreasing local population abundance. A similar scenario has been observed in the Bay of Islands, New Zealand (Tezanos-Pinto et al. 2013). In these two cases, the animals are unlikely to have died, but no longer contribute to the local population, causing the populations to become more fragile. In both cases the ongoing behavioural modification and acoustic disturbance from tour vessels is likely to have caused more sensitive individuals to migrate, whilst habituated dolphins remain in the area. This highlights the difficulty in accounting for variability among individuals (3) mentioned above.

There have been no published accounts of the long-term effects of coastal development upon marine mammal populations. Jefferson et al. 2009 discussed a range of expected and observed short-term impacts on Indo-Pacific humpback dolphins and finless porpoise from coastal development in Hong Kong, yet no long-term effects were reported. The authors discussed the need for long-term monitoring datasets to attempt to identify the long-term impacts of coastal development on marine mammals (Jefferson et al. 2009).

If marine mammals are repeatedly exposed to the impacts of development activities we would expect to see decreases in local abundance at Lyttelton for both Hector's dolphin and NZ fur seal. It may not be possible to distinguish which of the impacts was the most significant in causing such a decline in abundance, as the impacts are likely to occur in unison. The biological consequences of a decrease in abundance at Lyttelton are worthy of consideration. If Lyttelton is an important area, which a high number of sightings suggest, the exclusion of marine mammals from the area will put extra pressure on resources elsewhere, reducing the overall carrying capacity of the area. Also, for Hector's dolphins, Lyttelton is a relative safe haven, as gillnetting and trawling are not currently carried out in the area. If dolphins are excluded from Lyttetlon by coastal development their use of other areas may increase, increasing the risk of fisheries bycatch. Both of these consequences could have population level effects.

There may also be more serious long-term impacts due to the development activities at Lyttelton. Injury associated with pile driving, mortality from pollution and ship strike all have the capacity to reduce the number of animals in the population. In terms of Hector's dolphins, the Banks Peninsula population is vulnerable to low levels of adult survival, meaning any factor that removes adult dolphins from the population will have significant repercussions for the population as a whole.

To result in population level impacts, a factor must influence one of the main population vital rates: reproductive rate, juvenile survival, adult survival, migration etc. For Hector's dolphins, modelling of these crucial population rates has taken place at Banks Peninsula for decades (e.g. Gormley et al. 2005, 2012), thus the necessary baseline data is available to attempt to detect changes in vital rates from development activities at Lyttelton. However establishing that a change in vital rates has occurred can be complicated by the statistical power required to detect such a trend.

12 Potential methods for avoiding, mitigating and remedying adverse effects

12.1 Pile driving

The most common techniques to reduce the effects of pile driving noise upon marine mammals are:

- Timing the onset of pile driving activity to avoid times when marine mammals are most likely to be in the area. At Lyttelton, Hector's dolphins and possibly NZ fur seals are present in lower numbers during winter. Also, young calves are present during spring, summer and autumn. Therefore pile driving during this time may have particularly negative effects on the smaller, vulnerable calves at this time of year. The most effective way to reduce adverse effects of pile driving would be for this work to be carried out in winter.

- Experienced marine mammal observers are the only effective way of searching for marine mammals in the area before, during and after pile driving. They should be experienced in searching for and identifying the marine mammal species of concern, and be independent of the construction activity. Even with professional observers, some marine mammal sightings will be missed. Inexperienced observers further reduce the sighting probability, and therefore the risk to marine mammals in the area (e.g. Barlow and Gisiner 2006). The use of observers will not eliminate the potential for marine mammals to be exposured to the high sound levels in the zone of injury, but using professional observers can decrease the risk of hearing impairment and mortality. For example, even well trained observers will only be able to detect marine mammals in close vicinity (approx 400m). The effects of pile driving will range far beyond this.

- Bubble curtains have been demonstrated to significantly lower both pile driving sound pressure levels and peak frequencies (Würsig et al. 2000; Jefferson et al. 2009). Typically a bubble curtain consists of a perforated hose that is anchored to the sea floor around the area where piling is taking place. Compressed air is pumped through the hose and a 'curtain' of bubbles produced. Bubble screens can reduce the sound pressure levels up to a biologically significant 25dB in the frequency range of concern for marine mammals (Jefferson et al. 2009). Other variations of bubble curtains such as screens and jackets are commonly used to reduce pile driving noise at offshore wind-farms (Evans 2008) and are worth considering.

- The use of a 'soft start' or 'ramping up' process, in which pile driving energy is gradually increased to normal operating levels, gives nearby animals an opportunity to vacate the area before sound levels increase to an extent that may cause injury. There is some concern that this technique may actually attract animals, and so should be used with this is mind and always with trained marine mammal observers present (Jefferson et al. 2009). Also, it is likely that behavioural changes and possibly masking will still occur for nearby animals (Madsen et al. 2006).

12.2 Land reclamation

The main techniques to reduce the effects of land reclamation on marine mammals are concerned with managing the loss of habitat, sediment resuspension and the associated pollution:

- The most obvious way of avoiding impacts from land reclamation is to avoid removal of marine mammal habitat. It is important to consider the habitat use of the area to be reclaimed, the conservation status of the species involved (e.g. Endangered, Threatened), the ecosystem services the area provides and the component of the dolphin population that most commonly use the area (e.g. mothers and calves). The impact on marine mammals could be reduced by using alternative sites for port structures, on already existing land. Based on discussions with LPC, the authors understand that space on existing land for new structures is unavailable.

- Clean fill should be used for reclamation at all times, however if contaminants are present the risks associated to marine mammals should be assessed before dumping commences.

- Other mitigation methods such as a silt curtain erected around the dumping site, should be considered. This would limit the dispersal of silt that potentially harbours contaminants, and reduce sedimentation and so decrease the risk of harming marine life.

12.3 Dredging
Similar to land reclamation, to minimise effects on marine mammals dredging should be limited and avoided if possible. Mitigation of dredging activities usually focus on limiting the impacts of sediment resuspension and environmental contaminants:

- The level of contaminants in the sediment to be dredged should be tested to determine the likely concentration marine mammals, and other wildlife, will be exposed to during dredging and dumping. This can be assessed by taking samples of the sediment to be dredged and having the appropriate tests for contaminants carried out. If contaminant levels are high, any increases in dredging should be avoided or methods should be implemented to prevent contaminants being discharged during dredging.

- The selection of spoil disposal grounds should consider the effects on marine mammals and be sited in locations where the effects can be avoided.

12.4 Marine pollution
Pollution from sources other than reclamation and dredging can be reduced by:

- Introducing appropriate systems to eliminate or minimise contamination of runoff and storm-water, and by introducing and enforcing no dumping policies for construction material and rubbish.

- Adhering to policies covered in the CEMP that reduce the risk of an oil/fuel spill or related event and having appropriate systems in place to deal with such an event.

12.5 Vessel traffic
- The port should be mindful of the potential for ship strike with whale species such as southern right whales as the population begins to increase. Should whales begin frequenting the harbour again, policies should be developed to reduce ship strike risk by limiting large vessel speeds.

- For vessels involved in construction activities, skippers should remain vigilant for marine mammals in the area. If marine mammals are sighted the guidelines for approaching marine mammals provided in the marine mammal protection regulations (1992) should be followed at all times.

- The port should implement educational programmes for recreational boat users to increase awareness of marine mammal and vessel related issues. This could be incorporated into the new marina development.

13 Recommendations for further research

Substantial gaps in our knowledge exist that reduce our capacity to predict how coastal development at Port Lyttelton would impact marine mammals. However there are ways we can address these gaps by targeting research into the right areas.

- The Hector's dolphin long-term monitoring program should be continued, with a stronger emphasis on Lyttelton Harbour. This will enable quantification of habitat use, generation of local abundance estimates, and the estimation of survival rates that will help to determine population level responses to the development activities.

- Noise pollution from pile driving is the most significant impact from the Port Lyttelton development. In order to study the impacts of piling upon Hector's dolphins a thorough investigation of pile driving and the dolphins' response to the activity would be beneficial. This would include: analysis of pile driving sound at Lyttelton Harbour to determine the acoustic characteristics of the noise, sound propagation measurement and modelling and an assessment of the behavioural responses of dolphins to the noise. Acoustic monitoring using an array of passive acoustic monitoring devices would provide the best assessment of the effects of pile driving noise on Hector's dolphins and is consistent with previous studies. Visual surveys can be easily coupled with acoustic monitoring to provide a thorough assessment of pile driving effects. Any study would need to cover periods well before, during and after any port repairs and additional development takes place. Indeed, piling should not take place before such research is in place.

- Any beach cast or otherwise deceased marine mammal in or around Lyttelton should be retrieved and the cause of death established via necropsy. Specifically, the carcass should be examined for signs of damage from pile driving noise, ship strike and high contaminant levels.

14. Conclusions:

This report outlines the main impacts on marine mammals from the development proposed at Port Lyttelton. Pile driving is likely to have the greatest impact on Hector's dolphins and NZ fur seals, although other marine mammal species may also be affected. Noise from pile driving can cause physical injury, mask vocalisations and cause behavioural changes that could result in declines in relative population abundance. Impacts of other activities such as land reclamation and dredging may also be biologically significan. Icreased marine pollution and vessel traffic also have the capacity to adversely affect marine mammals in the area.

There is the potential for significant impacts. This report outlines methods for avoiding, mitigating and remedying environmental effects to reduce the impacts of port repair and development activities on marine mammals. For example, undertaking pile driving during the winter and using marine mammal observers and bubble curtains would reduce the exposure of marine mammals to potentially harmful noise. Consideration of sediment resuspension and the associated exposure to contaminants during land reclamation and dredging would also reduce the impact of these activities on marine mammals. Given the protected and endangered status of resident marine mammal species, mitigation, monitoring and continued research is critical, to allow Port Lyttelton to meet its goals in terms of retaining a healthy harbour for future generations.

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