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Review of threats to the recovery of NZ sea lions and other otariid species

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*Prepared for the Department of Conservation
& Ministry for Primary Industries*

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Executive summary

- A literature review of population threats for global otariid species (fur seals and sea lions) was conducted, with the aim of identifying probable threats to the population recovery of New Zealand (NZ) sea lions;
- As with NZ sea lions, other extant otariid species have recovered from very low population size following the cessation of commercial sealing, with extremely rapid recovery in species despite low genetic diversity. Anthropogenic threats, including the indirect/direct effects of fishing, persecution/harassment at terrestrial sites and alteration of habitat may have hindered the recovery of some species;
- Climate-mediated changes in prey abundance have a major effect on key demographic rates, particularly pup survival and pupping rates, of an array of otariid species. Suboptimal conditions may persist for a single year (e.g., during El Niño events in the East Pacific) or decades (following a shift in climate regime);
- Disease affects a number of otariid species and has been linked to low genetic diversity, poor nutritional status and transfer from terrestrial mammals. Disease-related mortality of NZ sea lions pups has compromised pup survival at the Auckland Islands with very high rates of pup/yearling mortality in recent years;
- Aspects of otariid behaviour including male harassment of mothers and pups and strong philopatry (the tendency to return to breed at natal site) may slow recovery at very low population size and limit the rate of breeding range expansion;
- Due consideration of natural threats to population recovery and relevant aspect of otariid behaviour may improve the efficacy of measures for mitigating anthropogenic threats to NZ sea lion populations;
- The more frequently forwarded threats to the recovery of NZ sea lions (incidental mortality relating to commercial fishing, disease related mortality of pups and climate/fishery mediated nutritional stress) are commonly some of the main perceived threats for other otariid species. As such, the development of measures for mitigation anthropogenic threats should be informed by experiences gained from other otariids and like species.

1 Introduction

The New Zealand (NZ) sea lion is endemic to NZ and is classified as “Vulnerable” by the International Union for Conservation of Nature IUCN due to a protracted decrease of the main breeding population at the Auckland Islands (IUCN 2014). The breeding range of NZ sea lions was dramatically reduced by subsistence hunting and commercial sealing (Childerhouse & Gales 1998; Collins et al. 2014; Smith 1985) and currently has an extremely concentrated breeding distribution with ~99% of pups born at the Auckland Islands and Campbell Island in the Subantarctic region to the south of the NZ mainland (Childerhouse et al. 2014; DOC unpublished data; Maloney et al. 2012).

The two main Subantarctic island populations have contrasting population trajectories with a decreasing pup production trend at the Auckland Islands and an increasing trend at Campbell Island (Childerhouse et al. 2014; Maloney et al. 2012). Stewart Island and the Otago coast have also been recolonised in recent years and currently support minor populations (DOC unpublished data). The causes of population change in NZ sea lions are not well-understood, though a number of potential drivers of population decline at the Auckland Islands have been identified including (though not limited to): the direct/indirect effects of commercial fishing; predation by great white sharks (*Carcharodon carcharias*); climate variation driven nutritional stress; disease-related mortality of pups; and the effects of low genetic diversity (DOC 2009; Roberts & Doonan 2014; Robertson & Chilvers 2011; also see Appendix A).

Recent pup census estimates at the Auckland Islands are the lowest recorded since at least the early-1970s. These very low pup counts triggered the development of a Threat Management Plan (TMP) for the species. Briefly, the TMP project will:

- Review and assess (qualitatively and quantitatively) all potential threats to NZ sea lions, including natural & anthropogenic threats;
- Identify management options for minimising threats;
- Develop a Threat Management Plan for the species.

This review addresses the first of these goals: the identification of potential threats to NZ sea lion populations. It commences with a review of threats identified for other otariid species (sea lions and fur seals; see Appendix B) and then focusses on potential threats to NZ sea lion populations.

2 Threats to sea lion and fur seal species

The eared seals (family *Otariidae*) include 9 fur seal and 6 sea lion species. Otariids differ from true seals (family *Phocidae*) in their physiology, locomotion, lactation strategy and seasonal foraging strategy. Subsistence hunting and commercial sealing operations greatly reduced the population size and breeding distribution of most if not all otariid species. However, with the exception of the now extinct Japanese sea lion (*Zalophus japonicus*), all are thought to have recovered to some extent following the cessation of commercial sealing (see Gerber & Hilborn 2001). For some otariid species, slow recovery or periods of population decline have been observed in recent years, e.g., Galapagos fur seal (*Arctocephalus galapagoensis*), Australian sea lion (*Neophoca cinerea*), New Zealand sea lion (*Phocarcos hookeri*) and Steller sea lion (*Eumetopias jubatus*) (see Appendix B) and the primary causes are typically uncertain.

Otariids primarily forage in the marine environment and breed on land so that barriers to recovery may constitute a mix of marine and terrestrial factors. They may also be categorised into natural or anthropogenic threats, though some threats, such as changes in prey abundance or ocean climate, could be attributed to either/both. In addition there are likely to be interactions between many of the different threat types listed below.

2.1 Anthropogenic threats

2.1.1 Incidental mortality in fishing gear

The direct effects of fishing arise from the usage of fishing gear that has the potential to kill or injure individuals that become entangled or hooked in trawls, longlines, set or drift gillnets and other gear types (note that entanglements with lost fishing gear are addressed in another section, below).

Direct fishery-related mortality is often called “incidental mortality” on the basis that it is an unintended consequence of fishing. The probability of incidental mortality may be increased where there is spatial and temporal overlap between fishing operations and the foraging effort of otariids, where fisheries target prey species, or where otariids learn to depredate prey from fishing gear (NMFS 2001; Read 2008). The primary gear types implicated in incidental mortality of pinniped species include gillnets and trawls (Read et al. 2005).

Otariids and other pinnipeds tend to be more resilient to incidental mortality than cetaceans due to relatively high population growth potential (Read 2008). Incidental mortality in fishing gear has historically occurred in all otariids and has been identified as a potential population threat to an array of species including the Australian sea lion, Northern fur seal, NZ sea lion and South American sea lion (*Otaria flavescens*) (Chilvers 2008; Goldsworthy & Page 2007; NMFS 2007; Reyes et al. 2013). It was argued that large numbers of incidental mortalities in high seas drift net fisheries were not sufficient to contribute to the decline of the Pribolof Islands population of northern fur seal (*Callorhinus ursinus*) as these were low relative to total population size (Hobbs & Jones 1993). Conversely, incidental fishery mortality was identified as one of the main threats to Australian sea lion populations despite low numbers of mortalities, which were found to be sufficient to drive population decline due to low population size and productivity (Goldsworthy & Page 2007). As such, the population threat posed by direct fishery effects will depend on the extent of mortality relative to population size and on other factors that can affect survival and natality, including natural threats.

2.1.2 Indirect effects of fishing

Commercial fisheries may indirectly affect otariid-prey interactions across ecosystem-wide scales. Indirect fisheries effects could include: changes in the spatial distribution and density of prey aggregations; disruption of otariid foraging patterns; and reduction in prey abundance resulting directly from exploitation or indirectly via alteration of trophic relationships (NMFS, 2001).

There are a number of examples for which commercial catches are comparable to or exceed consumption rates of key prey species by otariids, highlighting potential resource competition, e.g. walleye Pollock (*Theragra chalcogramma*) catches and Steller sea lion consumption in the North Pacific (Lowry et al. 1989; NMFS 2008). Typically, ecosystem complexity, data, model limitations, and indirect linkages are confounded in the quantification of interactions between otariids, their prey and commercial fisheries (NMFS, 2001). However, an ecosystem modelling assessment found that more than one commercial fishery had the potential to indirectly affect Steller sea lion population size in the North Pacific (Guenette et al. 2006).

2.1.3 Subsistence hunting, poaching, persecution and harassment

Historical commercial sealing drove many otariid species to the brink of extinction and dramatically reduced breeding range of some species. Most otariid species are now protected from commercial exploitation, though subsistence hunting is still permitted for northern fur seals (NMFS 2007) and the Namibian Government authorises the killing of ~80 thousand brown fur seal pups annually for the sale of meat and fur and to reduce competition with fisheries (Hofmeyr & Gales 2008). Poaching of South American fur seals is known to occur for bait. Persecution by fishermen and hunting is thought to have been main drivers of extinction of Japanese sea lion (*Zalophus japonicus*) (Aurioles & Trillmich 2008^b).

Activities constituting harassment include: physical disturbance by members of the public and scientific research teams, disturbance from domesticated pets, vehicle-related deaths, noise disturbance and other factors (cited examples in Appendix B). Harassment may cause mortality or injury, dispersal of individuals away from optimal habitat and changes in behaviour.

2.1.4 Pollution & marine debris

The thick pelage of otariid species renders them particularly sensitive to oil pollution. Oil spill is perceived as a major threat to Galapagos fur seals, northern fur seals and South American fur seals due to the limited number of breeding grounds and proximity of breeding grounds to oil fields or oil transportation routes (Alava & Salazar 2006; NMFS 2007).

Chemical pollutants known to bioaccumulate in otariids include polychlorinated biphenyl (PCB) and dichlorodiphenyltrichloroethane (DDT). PCBs and DDT have both found in high concentrations in California sea lions (Debier et al. 2005; Le Boeuf & Bonnell 1971).

Mortality and injury relating to entanglement in lost fishing gear and marine debris is likely to affect all otariid species to some extent and is considered a key threat to populations of Australian sea lions (Australian Department of the Environment 2013). High rates of entanglement in fishing gear have also been observed in Galapagos sea lions, South American fur seals and other species (Alava & Salazar 2006).

2.1.5 Alteration of habitat

Spatial scales of habitat alteration can be: local, e.g., alteration of terrestrial habitat at locations used for breeding or hauling out; regional, e.g., mechanical disturbance of sea floor communities by commercial fishing or introduction of invasive species; or global, e.g., arising from the effects of climate change caused by burning of fossil fuels. The effects of habitat alteration are difficult to quantify, particularly in the marine environment, though it is known to be a key factor regulating the distribution and population size of terrestrial mammals.

Habitat degradation is considered a threat to Australian sea lions (Australian Department of the Environment 2013). The introduction of rabbits to the Auckland Islands is thought to have led to high pup mortality of NZ sea lions in burrows, prior to their eradication in 1993 (Martin Cawthorn, pers. comm.; Torr 2002). Global climate change caused by the burning of fossil fuels will cause widespread alteration of marine and terrestrial habitat and is likely to have wide-reaching effects on otariids and other marine mammal species (Learmonth et al. 2006).

The potential indirect effects of fishing may also be considered as alteration of habitat, where this is deemed to include predator/prey species and this is addressed in sections on the indirect effects of fishing.

2.2 Natural threats

2.2.1 Climate variation

Climate variation can affect otariid populations directly through modification of the marine/atmospheric physical environment and indirectly through changes in predator/prey distribution or abundance. Changes in ocean climate can be abrupt and new states may persist for months or years (e.g., El Niño Southern Oscillation (ENSO) timescales), or decades (climate regime shifts). Climate variation is categorised here as a “natural” threat, though can also be anthropogenic in origin where it is driven by increased atmospheric CO₂ resulting from the burning of fossil fuels (much longer timescale of effects).

Because climate variation and resource competition affect otariid species through alteration of prey abundance, the biological and demographic response of otariid populations may be similar (e.g., reduced nutritional status and reduced survival/pupping rate). However, climate variation effects may be discerned from other potential drivers where climate perturbations are large, such as during the major El Niño events of 1982/83 and 1997/98. The demographic response to El Niño events was most severe in otariid populations of the Eastern Pacific region, particularly with respect to pup survival and natality (pupping rate):

- ~100% pup mortality of South American sea lion populations in 1997/98 compared with 13% in previous years (Soto et al. 2004);
- ~100 pup mortality, disease epidemics in both Galapagos sea lions and Galapagos fur seals during El Niño events and abnormally low natality in the next year (Alava & Salazar 2006);
- 24% natality of California sea lions in El Niño years compared with 77% averaged across all years (Melin 2012);
- Very low natality of South American sea lions populations in 1997/98 (~5% of expected pup production) (Soto et al. 2004).

With all of these examples, abnormally poor survival and natality was linked to abrupt changes in prey distribution or abundance. Note that El Niño events are typically associated with warming in the Eastern Pacific and oceanic cooling around NZ. Climate-mediated variation in prey abundance has also been implicated in: very low pup survival of California sea lion during years when oceanic warming appeared to affect prey abundance (Melin 2010; NOAA 2015); and poor early survival of Northern fur seal populations (NMFS 2007).

Climate regime shift has been implicated in periods of protracted population decline of otariid species, most notably western Alaska populations of Steller sea lion (Trites et al. 2007). As with the ENSO examples given above, climate variation (in this case a prolonged period of oceanic warming in the North Pacific beginning in the late 1970s and continuing for approx. 30 years) was thought to adversely affect the nutritional status of sea lion populations via alteration of the quantity, quality and accessibility of prey (Trites et al. 2007).

The predicted direct effects of anthropogenic global climate change include increased oceanic temperature, decreased sea-ice cover and rising sea levels. In addition to changes in physical habitat, predicted indirect effects include changes in predator/prey abundance and distribution, and alteration of trophic relationships. This is likely to have major consequences for otariid species that

have limited capacity for range expansion or limited habitat availability (Learmonth et al. 2006). Studies have highlighted the potential negative effects of climate change on prey abundance of Subantarctic fur seals (Lavigne & Schmitz 1990) and Australian sea lions for which low pup survival occurred during years of warm ocean climate (McIntosh et al. 2013).

2.2.2 Predation

Predation may constitute a threat to otariid populations where there is a temporal shift in predator abundance, in distribution or diet. However, while the main predators of a particular otariid species are typically known, predation rates (and thus the relative importance of predation to otariid populations) may be poorly described due to a lack of dietary information for the predator (e.g. NMFS 2007).

An ecosystem modelling assessment indicated that predation of Steller sea lions by orcas (*Orcinus orca*) may have had a greater effect on demographic rates when the population size of Steller sea lions was small (in the 1990s in the Aleutians and in the 1960s in Southeast Alaska), though had minimal effect when the population was large (Guénette et al. 2006). Predation of Antarctic fur seal pups by a few individual leopard seals (*Hydrurga leptonyx*) may be a threat to some populations (Hiruki et al. 1999). Predation of otariids by terrestrial species can also occur, e.g. predation of Galapagos fur seal pups by feral dogs (Alava & Salazar 2006).

2.2.3 Disease & parasites

Disease-related mortality has been recorded in most pinniped species, including viral/bacterial infection. The demographic effects of infection may include mortality of pups and adults, though negative effects on the later reproductive success of cohorts affected by disease as pups have also been suggested by an assessment of NZ sea lion demographic rates using mark resighting data (Gilbert & Chilvers 2008).

Disease may be considered a constant threat for otariid species given the aggregated nature of pups and adults at breeding sites (NMFS 2007), and may be exacerbated by the comparatively low genetic diversity of many species following depletion by commercial sealing to very low population size (e.g. Weber et al. 2004).

High rates of bacterial disease-related mortality have been observed in pups of the Galapagos sea lion (Alava & Salazar 2006), NZ sea lion (Roe 2011, discussed in more detail later) and other otariid species. The source of infection is usually unknown, though bacterial infection of California sea lions and viral infection (Canine Distemper Virus or CDV) of Galapagos fur seals/sea lions may occur as a result of exposure to terrestrial animals, particularly feral and domesticated dogs (Alava & Salazar 2006; Norman et al. 2008). Disease prevalence may also be exacerbated by poor nutritional status – e.g. a temporal correlation between *Streptococcus phocae* infection rates of seal pups and starvation/natality rates of brown fur seals (Henton 1999).

Disease is not thought to be a factor affecting pup survival of northern fur seals despite high mortality rates up to age 2, though hookworm prevalence was high in years with low survival and might have contributed to high pup mortality (NMFS 2007).

2.2.4 Toxic bloom events

Toxic phytoplankton bloom events occur naturally though may be more frequent where there is anthropogenic eutrophication of coastal waters. Toxins are accumulated in bodily tissues following ingestion of prey.

The main phytoplankton toxin implicated in marine mammal mortality is domoic acid, which causes Amnaesic shellfish poisoning (ASP). A number of adult California sea lions found dead in a single year were diagnosed with ASP and anchovies were identified as the main vector of toxin transfer (Scholin et al 2000; Lefebvre et al. 1999).

2.2.5 Genetic diversity

The deleterious effects of subsistence hunting and commercial sealing are thought to have greatly reduced the genetic variability of some otariid species, e.g., Guadalupe fur seal (Weber et al. 2004), though not all, e.g. California sea lion (Gonzalez-Suarez et al. 2010). A summary of microsatellite genetic diversity for different otariid species is given in Robertson & Chilvers (2011). Fur seals tended to have greater genetic diversity than sea lions and this was attributed to a greater rate of population increase for a number of fur seals species after the cessation of commercial sealing (Robertson & Chilvers 2011).

Theoretically, low genetic diversity may greatly increase the probability of species extinction. However, rapid recovery Guadalupe fur seals was observed from very low population size despite low genetic diversity (Weber et al. 2004). This study concluded that non-genetic factors such as food resources and direct mortality caused by humans may be of greater importance to population growth of this species (Weber et al. 2004), though low genetic diversity may cause recovering populations to be more susceptible to disease.

2.2.6 Behavioural

Behavioural traits are innate characteristics of otariid species and so cannot be considered as “external” threats, though can have profound effects on the rate of population and breeding range recovery. Key aspects of otariid behaviour include reproductive behaviour at population size (Cassini 1999) and dispersal behaviour (Grandi et al. 2008).

A particular feature of otariid breeding behaviour is that isolated, non-colonial pupping is favoured at small population size and social, colonial pupping is favoured by large populations. This may be driven, in part, by the requirement to find a mate and to avoid predators. In addition, male harassment is likely to be a key factor regulating this behaviour and may potentially be the primary factor (Cassini 1999), due to an increased probability of harassment and pup/mother mortality at low population size (Cassini 1999). However, a study on South American sea lions showed that pup mortality rates will be far greater in non-colonial puppers (60% compared with 0.7% for pups born in colonies), also due to male aggression and starvation caused by an increased probability of mother-pup separation (Campagna et al. 1992). As such, male aggression may be a major barrier to recovery when still at small population size.

Dispersal behaviour will limit the rate of breeding range expansion. Population growth rates will tend to be greatest in new colonies where resources are plentiful (Dans et al. 2004), though strong philopatry and breeding site fidelity limit the speed at which new colonies become established. Also, new colonies tend to form at haul out sites near to existing colonies, so that a rapid expansion of breeding range will be unlikely (Grandi et al. 2008).

3 Threats to NZ sea lion populations

A summary of key threats to NZ sea lion populations is given in a species management plan for the period 2009-2014 and is divided into anthropogenic and natural threats (DOC 2009). MPI and DOC have also drawn up a preliminary list of threats for the current Threat Management Plan project, based on known threats to NZ sea lions and other marine mammals (Appendix A). A review of threats to NZ sea lions was also considered by Robertson & Chilvers (2011). This section briefly summarises the literature regarding potentially key threats to NZ sea lion populations from these studies and also includes consideration of factors known to be threats to recovery for other otariid species, documented in the previous sections and Appendix B.

3.1 Anthropogenic threats

3.1.1 Incidental mortality in fishing gear

Incidental captures of NZ sea lions have historically occurred in the commercial southern arrow squid (*Nototodarus sloanii*) trawl fishery surrounding the Auckland Islands and the Campbell Rise southern blue whiting (*Micromesistius australis*) trawl fishery. Observed deaths were primarily caused by capture and drowning in trawl nets. The observed and estimated number of deaths greatly decreased after the deployment of Sea Lion Excluder Devices (SLEDs) became standard practise in the Auckland Islands squid trawl fishery in 2004/05 (Thompson et al 2013). Prior to the deployment of SLEDs in this fishery, there was considerable inter-annual variation in estimated captures, which exceeded 100 individuals per annum in a number of fishing years prior to 1997/98, though has remained below 100 in all subsequent years and has not exceeded 20 individuals since 2006/07 (DOC 2002; Thompson et al 2013). However, there is uncertainty as to the total mortality given a lack of information regarding the number of individuals that pass through SLEDs and of post-SLED survival rates (Robertson & Chilvers 2011), though a recent review found that the available evidence suggests that SLEDs are effective in reducing NZ sea lion bycatch in trawl nets (Hamilton & Baker 2015). Small numbers of incidental mortalities also occur in other trawl fisheries around the Auckland Islands (Thompson et al. 2013).

Incidental mortalities in the Campbell Rise southern blue whiting trawl fishery were historically lower than at the Auckland Islands, though have increased since 2006, with a strong male bias in captures (Thompson et al. 2013). SLEDs were deployed in this fishery for the first time in 2013, in response to anomalously high captures of sea lions in that year (MPI 2013).

3.1.2 Indirect effects of fishing

A comparative assessment of the Otago Peninsula and Auckland Islands populations and a correlative assessment of demographic rates and biological measurements of the Auckland Islands population indicated that the Auckland Islands population is likely to have been suffering from compromised nutritional status and that this may be a key driver of population decline (Augé 2010; Roberts & Doonan 2014). It is currently not known if this relates to climate or fishery-mediated changes in prey abundance or a combination of drivers.

The diet of NZ sea lions varies by location and includes a number of species targeted by commercial fisheries in NZ waters, including: baracoutta (*Thyrstites atun*), hoki (*Macruronus novaezelandiae*), jack mackerel (*Trachurus* spp.), red cod (*Pseudophycis bachus*) and southern arrow squid in the diet of Auckland Islands and/or Otago Peninsula populations (Augé et al. 2012; Childerhouse et al. 2001; Meynier et al. 2009; Stewart-Sinclair 2013). Also, species not targeted by fisheries, including the large

octopus species *Enteroctopus zealandicus* at the Auckland Islands/Campbell Island and *Octopus maorum* at the Otago Peninsula (Augé et al. 2012; Childerhouse et al. 2001; Meynier et al. 2009; Roberts & Lalas unpublished data; Stewart-Sinclair 2013). A long-term study of scats and regurgitates at the Auckland Islands indicated that changes in diet composition have occurred through time, with an increase in the frequency of occurrence of small-bodied prey during the period of population decline (Childerhouse et al. 2001; Stewart-Sinclair 2013).

Reviews of the potential indirect effects of the squid fishery fishing on the Auckland Islands population have reached opposing conclusions as to the potential for resource competition to negatively affect the NZ sea lion population, though it was acknowledged that a better understanding of diet and foraging distribution was necessary to conduct a robust assessment (Bowen 2011; Robertson & Chilvers 2011). A study estimating consumption rates of NZ sea lions indicated that annual squid consumption of southern arrow squid may be similar to annual catches by the commercial fishery (Meynier 2009). However, comparison of commercial catch rates of southern arrow squid with Auckland Islands NZ sea lion demographic rates indicated that reduced survival rates do not occur when this species is less abundant (Roberts & Doonan 2014). The potential for hoki and red cod fisheries to affect NZ sea lion populations via resource competition has not yet been assessed.

3.1.3 Other anthropogenic threats

Incidents of human disturbance of NZ sea lions include shootings, harassment, clubbing and vehicle related deaths and disturbance from domestic dogs, and have been recorded on the NZ mainland (Catlins, Blenheim and Otago Peninsula) and Stewart Island (DOC 2009). Concern has also been raised regarding the handling/tagging of all pups born at Sandy Bay, Auckland Islands each year by field scientists, especially relating to the potential transmission of bacterial disease (Childerhouse et al. 2014).

Introductions of invasive species may also have an effect, one example being the high incidence of pup mortality in rabbit holes at the Enderby Island, Auckland Islands, prior to their eradication by tracking dogs and a widespread poison campaign in 1993 (Martin Cawthorn, pers. comm.; Torr 2002).

A concentrated breeding range renders Subantarctic populations highly susceptible to pollution events, particularly major oil spills. The effects of coastal zone development, agroforestry and farming on mainland populations of NZ sea lion via habitat alteration have not been explored in detail.

3.2 Natural threats

Changes in ocean climate and oceanography are suspected to have occurred around NZ and the subantarctic region to the south and have been described in some studies (e.g. Forcén-Vázquez et al. 2013). Poor somatic condition of NZ fur seal pups was observed around the NZ South Island coincident with oceanic cooling during the major El Niño event in 1997/98 (Bradshaw 1999). Also, high disease-related pup mortality of NZ sea lion pups was observed at Auckland Islands rookeries in 1998 (Baker 1999), suggesting that extreme climate variation can negatively affect otariid species in New Zealand waters.

Potential climate effects on the abundance or distribution of NZ sea lion prey species include:

- SST and recruitment of red cod (Beentjes & Renwick 2000);
- Surface chlorophyll a concentration (from satellite derived data) and squid catch rates in commercial fisheries (Hurst et al. 2012);
- ENSO and Chilean jack mackerel (*Trachurus murphyi*) abundance (Arcos et al. 2001).

Also, significant correlations were found between the occurrence of key prey species in NZ sea lion scats at the Auckland Islands (including arrow squid, red cod and yellow octopus (*Enteroctopus zealandicus*) and Sea Surface Height (SSH) and Inter-decadal Pacific Oscillation (IPO), which might indicate climate mediation of prey availability to NZ sea lions (Childerhouse et al. 2001; Roberts & Doonan 2014; Stewart-Sinclair 2013). However, it was acknowledged that a longer time series of observations would be needed to identify a causative relationship (Roberts & Doonan 2014).

3.2.1 Disease

Outbreaks of bacterial epizootics have been implicated in high mortality rates of NZ sea lion pups at the Auckland Islands, e.g., >50% of pup production in 1997/98 (at least 74 adult females also died in that season) and *Klebsiella pneumoniae*-related mortality of > 30% and >20% of pups born at the Auckland Islands in 2001/02 and 2002/03, respectively (Baker 1999; Castinel et al 2007). A sticky strain of *K. pneumoniae* was isolated from a number of pups that died in field seasons 2005/06 to 2009/10 (Roe 2011). In this period, disease-related mortalities occurred late in the field season relative to previous years and were still occurring up to the end of sampling (Castinel et al. 2007; Roe 2011). Very low pup/yearling survival estimates were also obtained for cohorts born at the Auckland Islands after 2003/04 from a demographic assessment using mark-recapture observations (Roberts et al. 2014).

3.2.2 Other natural threats

Great white sharks are thought to be the only natural predator of NZ sea lions. This is based on the presence of wounds and scars consistent with great white shark anatomy (DOC 2009). A general lack of information on the diet of this predator in NZ water currently precludes a meaningful assessment of the importance of changes in predation rates in regulating NZ sea lion populations. However, a low temporal variation in the frequency of occurrence of shark bites scars on NZ sea lions at the Auckland Islands over an eight year period suggests that there is minimal inter-annual variation in predation rates (Amelie Augé unpublished data; Robertson & Chilvers 2011).

The genetic diversity of NZ sea lions is considered to be comparable to that of other sea lion species (Robertson & Chilvers 2011), despite the extirpation of genetically distinct mainland populations of NZ sea lions by subsistence hunting prior to the 19th Century (Collins et al. 2014; Smith 1985). However, genetic diversity is low relative to an array of fur seal species (Robertson & Chilvers 2011) and this may increase susceptibility to diseases and other threats.

As discussed in relation to pollution events, the extremely concentrated breeding distribution of the species increases its susceptibility to natural catastrophic events including climatic and seismic events. Tsunami is a particular concern for NZ sea lion populations given very high levels of tectonic activity around New Zealand (DOC 2009).

Aspects of the behaviour of NZ sea lions that may limit recovery of NZ sea lion populations and breeding range expansion include: strong philopatry and breeding site fidelity of females (Chilvers &

Wilkinson 2008); and the effects of male harassment on pup-rearing strategy (isolated versus colonial) and female/pup survival. Male harassment is a well-established cause of pup and female mortality in NZ sea lions (Castinel et al. 2007; Chilvers et al. 2005; Wilkinson et al. 2000) and is likely to be a factor regulating female pupping and pup-rearing strategy (Chilvers 2005), as it is in South American sea lions (Cassini 1999). A recent intensification of male harassment may also have led to an increase in isolated pup-rearing around the Otago Peninsula region (Shaun McConky pers. comm.) with at least one female now using forested areas to rear pups (DOC pers. comm.). Male harassment may be more of a threat to the growth of populations that are currently too small for colonial breeding to be advantageous, such as on the NZ mainland and at Stewart Island. Cannibalism of pups by males has also been observed, though the scale and relative importance of cannibalism are not known (Wilkinson et al. 2000).

4 Discussion

The history of NZ sea lions is very similar to that of other otariid species with some recovery of population size and breeding range expansion following the cessation of commercial sealing. However, as with other otariid species, natural and/or anthropogenic factors may have hindered the rate of recovery and even led to periods of protracted population decline.

Climate-mediated changes in prey abundance have a major effect on key demographic rates of an array of otariid species, particularly pup survival and natality (see Appendix B). Suboptimal conditions may persist for a single year (e.g., during a warm year) or decades (following a shift in climate regime). No specific climatic drivers of population change in NZ sea lions have been identified, though broad-scale shifts in diet composition including an apparent increased reliance on small-bodied prey species, indicate that the relative prey mix available to the Auckland Islands populations has altered through time (Stewart-Sinclair 2013). The extent to which these changes relate to climate variation, resource competition with commercial fisheries or even changes in NZ sea lion behaviour has not yet been resolved.

Incidental fishery mortality has been identified as a key threat to a number of otariid species, with gillnet and trawl fisheries the main implicated gear types. For some species, it has been suggested that direct fishery mortality has been sufficient to drive changes in population trajectory (e.g., Goldsworthy & Page 2007; Robertson & Chilvers). For NZ sea lions, estimated incidental fishery mortalities were lower during the post-2000 period of population decline at the Auckland Islands than in preceding years when the population was thought to be increasing in size (Childerhouse et al. 2014; Thompson et al. 2013), so direct fishery effects alone do not appear to be sufficient for explaining population change. However, studies have suggested that low rates of mortality can affect population trajectory during periods of low productivity (e.g. Goldsworthy & Page 2007), such as during periods of adverse prey availability, and research has found strong evidence for nutritional stress affecting the Auckland Islands population during the period of decline (Augé 2010; Roberts & Doonan 2014). As such, the assessment of population consequences of incidental fishery mortality should give due consideration of other factors that can affect population growth potential.

Anthropogenic harassment and mortality also occurs at terrestrial sites, caused by members of the public at mainland sites and scientific teams at Subantarctic breeding rookeries. The potential indirect effects of coastal zone development include habitat alteration and pollution and there is minimal information available for assessing their relative threat to NZ sea lion populations.

Disease commonly affects a number of otariid species and has been linked to low genetic diversity, poor nutritional status, and transfer from terrestrial mammals. Disease-related mortality of pups has compromised pup survival at the Auckland Islands with very high rates of pup/yearling mortality since 2004/05 (Castinel et al. 2007; Roberts & Doonan 2014; Roe 2011). The various options for assessing/mitigating disease and other causes of pups mortality are currently being considered (Childerhouse et al. 2014; Roberts & Doonan 2014, Roe 2011).

The relative importance of great white shark predation as a threat to NZ sea lion populations is unknown, though modelling studies from other species have suggested that predation may be more of a threat to small populations (Guenette et al. 2006), such as at Stewart Island—where great white sharks are known to be abundant (Malcolm Francis pers. comm.)—and the NZ mainland population.

The concentrated breeding distribution of NZ sea lions increases the susceptibility of the species to catastrophic events, e.g., due to oil spill, disease (exacerbated by low genetic diversity), climate perturbations and tsunamis. The current breeding range (and genetic diversity associated with breeding populations) is greatly reduced from the pre-historic (pre-13th Century) distribution (Childerhouse & Gales 1999; Collins et al. 2014; Smith 1985). Recovery of ancient breeding grounds around the NZ mainland should reduce susceptibility of the species to catastrophic events that occur across regional scales. As such, the conservation of mainland populations and of breeding populations located nearby may be of particular importance.

The more frequently forwarded threats to the recovery of NZ sea lions (incidental mortality relating to commercial fishing, disease related mortality of pups and climate/fishery mediated nutritional stress) are commonly the main perceived threats for other otariid species. As such, the development of measures for mitigation of anthropogenic threats should be informed by experiences with other otariids and like species. In addition, aspects of otariid behaviour including male harassment of mothers with pups and strong philopatry may slow recovery at very low population size and limit the rate of breeding range expansion. Due consideration of relevant aspect of otariid behaviour and other natural threats to population recovery including climate variation is likely to improve the efficacy of measures for mitigating anthropogenic threats to NZ sea lion populations.

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6 Glossary of abbreviations and terms

CDV	Canine Distemper Virus
DDT	Dichlorodiphenyltrichloroethane
ENSO	El Niño Southern Oscillation
IPO	Inter-decadal Pacific Oscillation
IUCN	International Union for Conservation of Nature
NZ	New Zealand
PCB	Polychlorinated biphenyl
SLED	Sea Lion Excluder Device
SSH	Sea Surface Height
TMP	Threat Management Plan (for NZ sea lions)

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Appendix A List of potential threats to New Zealand sea lions based on known threats and threats to other marine mammals

Extract from DOC/MPI (2014) *New Zealand sea lion interim research priorities Sept 2014 – April 2016*.



Department of Conservation
Te Papa Atawhai

Ministry for Primary Industries
Manatū Ahu Matua



Appendix 2 Table 2: A characterisation of threats to New Zealand sea lions which were considered to be relevant within the five year time span.

Threat Class	Threat	Mechanism	Type	Population component(s) affected
Fishing	Commercial trawl	Incidental capture, cryptic mortality	Direct	Juvenile or adult survival
	Any other fisheries/recreational etc			
	Trophic effects			
	Vessel noise; displacement			
Tourism	Boat strike			
	Vehicles			
	Noise			
	Disturbance			
	Displacement			
Other human impacts	Dogs			
	Shooting			
	Deliberate harassment			
Vessel traffic	Boat strike			
	Disturbance			
Pollution	Agricultural run off			
	Industrial run off			
	Oil spill			
	Plastics			
	Marine debris/entanglements			
	Trophic effects			
Coastal development	Marinas / Ports			
	Displacement, noise, pollution, sedimentation			
	Wave power generation			
	Tidal power generation			
Mining and oil activities	Noise (non-trauma)			
	Noise (trauma)			
	Pollution (discharge)			
	Habitat degradation			
Research	Physical			
	Disturbance			
Disease	Klebsiella			
	Hookworm			
	Stress induced			
	Domestic animal vectors			
Climate change	Temperature			
	Prey Availability			
	Displacement			
Small population effects	Stochastic and Allee effects			
Predation	Sharks			
Tsunami???? (from the SMP)				

Appendix B Key threats to the recovery of otariid species

Table 7-1: Summary of species population, distribution and key threats to otariid species. IUCN status: “LC”= Least Concern; “NT”= Near-Threatened; “VU”= Vulnerable; “EN”= Endangered; “EX”= Extinct.

Species	Population (IUCN status)	Distribution	Key threats	References
Sea lion species				
Australian sea lion (<i>Neophoca cinerea</i>)	~14,000; stable or slightly declining (EN)	Southern and Southwestern Australia; not recovered former breeding locations in Tasmania and Bass Strait, extirpated by commercial sealing in 18 th /19 th C	Threats include incidental mortality relating to fisheries and entanglement in fishing gear and other marine debris. Minor threats include habitat degradation, human disturbance at colonies including deliberate killings, disease, pollution, prey depletion and climate change.	Australian Department of the Environment (2013); Goldsworthy et al. (2003); Goldsworthy & Page (2007); McIntosh et al (2013)
California sea lion (<i>Zalophus californianus</i>)	~350,000; different population trajectory comparing populations (LC)	Eastern North Pacific; recent recolonization of historical breeding sites in Northern California	Pup mortality and low natality rates during El Niño events and periods of warm climate affecting prey abundance; changes in carrying capacity; direct fishery interactions; entanglement in marine debris; bioaccumulation of chemical pollutants (e.g., DDT and PCBs); disease from exposure to terrestrial animals; toxic bloom related mortality.	Carretta et al. (2007); Francis & Heath (1991); Lowry & Maravilla (2005); Mellin (2012); NOAA (2015); Silvagni et al. (2005); Szteren et al. (2006)
Galapagos sea lion (<i>Zalophus wollebaeki</i>)	~20,000; decreasing from 40,000 in 1978 (evidence for fluctuation between these population levels) (EN)	Nearly all pups born at the Galapagos; occasional on islands close to the coast of Ecuador	Mortality, low pupping rates and disease epidemics during El Niño events, which affect prey abundance/availability; entanglement in fishing gear; predation and disease transmission (Canine Distemper Virus) from feral dogs	Alava & Salazar (2006); Trillmich & Dellinger (1991)
Japanese sea lion <i>Zalophus japonicas</i> ; considered by some a sub-species of California sea lion)	0 (extinct; estimated population size of 30-50,000 in mid-19th C; proposed relocation of California sea lions) (EX)	Formerly Northwest Pacific	Thought to have been driven to extinction by hunting and persecution by fishermen	Aurioles & Trillmich (2008 ^b); Sakahira & Niimi (2007)

Species	Population (IUCN status)	Distribution	Key threats	References
New Zealand sea lion (<i>Phocarcctos hookeri</i>)	~10,000; declining at Auckland Islands, increasing at Campbell Island (VU)	~99% pups born at Subantarctic Islands; small populations in corner of prehistoric breeding range on NZ mainland	Incidental mortality in commercial trawl gear, disease in pups, nutritional stress (potential drivers are climate/indirect effects of fishing), small population effects (mainland population)	Augé (2010); Shaun McConky pers comms.; Roberts & Doonan (2014); Robertson & Chilvers (2011); Roe (2011)
South American sea lion (<i>Otaria flavescens</i>)	~265,000; stable; increasing around Argentina, declining around southern Patagonia, Chile & Uruguay (LC)	South America (Atlantic & Pacific Coasts)	Very high mortality rates of Pacific populations during strong El Niño events; mortality relating to direct interaction with fishing gear; resource competition with fisheries	Crespo <i>et al.</i> (1997); Koen Alonso & Yodzis (2005); Soto <i>et al.</i> (2004)
Steller sea lion (<i>Eumetopias jubatus</i>)	~140,000 in US; increasing at ~4% per annum; ~69% decline of Western stock from 1977 to 2007 (NT)	North Pacific from California to the Sea of Japan	Threats considered to be high include: climate variability & fishery effects on prey availability; predation by orcas. Other threats include disease, entanglement in fishing gear and deliberate killing by fishermen.	Lowry <i>et al.</i> (1989); NMFS (2001); NMFS (2008)
Fur seal species				
Antarctic fur seal (<i>Arctocephalus gazella</i>)	>4,000,000; all sub-populations increasing or stable; likely to have recovered from single small colony since the early 20th C (LC)	Breeding on Islands of the Southern Ocean; 95% breeding at South Georgia	Entanglement in fishing gear and marine debris; predation by leopard seals at some sites; susceptibility to disease epidemics given concentrated breeding distribution and lack of genetic diversity.	Croxall <i>et al.</i> (1990); Hiruki <i>et al.</i> (1989); Lavigne & Schmitz (1990)
Brown fur seal (<i>Arctocephalus pusillus</i>)	~2,000,000 (Southern Africa); ~90,000 (Australia), both populations increasing (LC)	Southern Africa & Australia	Resource competition with commercial fisheries; Persecution by fishermen; hunting; high mortality of pups relating to temporal changes in prey abundance	Goldsworthy <i>et al.</i> (2003); Goldsworthy & Page (2007); Kirkman <i>et al.</i> (2007); Kirkwood (2005); Roux (1998); Shaughnessy (1980)
Galapagos fur seal (<i>Arctocephalus galapagoensis</i>)	10-15,000; decreased from ~40,000 in late-1970s (EN)	Almost all pups born at Galapagos. One breeding rookery on Peru mainland.	El Niño events affecting prey availability, oil spill, disease (Canine Distemper Virus), predation by feral dogs.	Alava & Salazar (2006)

Species	Population (IUCN status)	Distribution	Key threats	References
Guadalupe fur seal (<i>Arctocephalus townsendi</i>)	~10,000; recovered from ~15 individuals in 1950s (presumed extinct prior to this) (NT)	Guadalupe; California breeding rookeries not recolonized post-extirpation by commercial sealing.	Low pup survival during El Niño events; entanglement in fishing gear and marine debris; lack of genetic diversity	Gallo-Reynoso (1994); Weber et al. (2004)
Juan Fernández fur seal (<i>Arctocephalus philippii</i>)	~10,000; increasing; thought to have been made extinct by commercial sealing, then rediscovered 1965 (NT)	Juan Fernández Archipelago	Entanglement in commercial fishing gear and marine debris; resource competition with commercial fisheries and factors arising from low genetic diversity, including disease outbreaks	Aurioles & Trillmich (2008 ^a); Wickens & Yorke (2006)
New Zealand fur seal (<i>Arctocephalus forsteri</i>)	~200,000; increasing population trajectory (LC)	NZ and Australian populations each comprise ~50% of total species population; expanding breeding distribution	High pup mortality rates in some years relating to starvation, disease and other; predation by orcas, sharks and sea lions; direct fishing-related mortality; entanglement in fishing gear and marine debris; vehicle-related deaths	Baird (2011); Page et al. (2004)
Northern fur seal (<i>Callorhinus ursinus</i>)	~1,100,000; declining (VU)	North Pacific	Potentially important threats include environmental change affecting prey abundance and early survival; predation by orcas; poaching and subsistence hunting; incidental mortality & resource competition with fisheries; entanglement in fishing gear & marine debris; human disturbance at breeding sites; oil pollution events.	NMFS (2007)
South American fur seal (<i>Arctocephalus australis</i>)	>200,000; increasing	South America (Atlantic & Pacific Coasts)	Up to 100% pup mortality during El Niño years of some populations, relating to low marine productivity; direct/indirect fishery mortality & entanglements in fishing gear; illegal exploitation for bait; susceptibility to oil spills and disease epidemics	Campagna (2008)

Species	Population (IUCN status)	Distribution	Key threats	References
Subantarctic fur seal (<i>Arctocephalus tropicalis</i>)	>300,000; all populations stable or increasing (LC)	Temperate islands in the South Atlantic & Indian Ocean; recolonized much of historical breeding range	Climate change effects on prey abundance; low genetic diversity; disease related mortality	Lavigne & Schmitz (1990); Learmonth <i>et al.</i> 2006); SCAR EGS (2004)

Appendix C Distribution of otariid species



Figure C-1: Approximate breeding distribution of sea lion species. *Japanese sea lion likely became extinct in the 1950s.

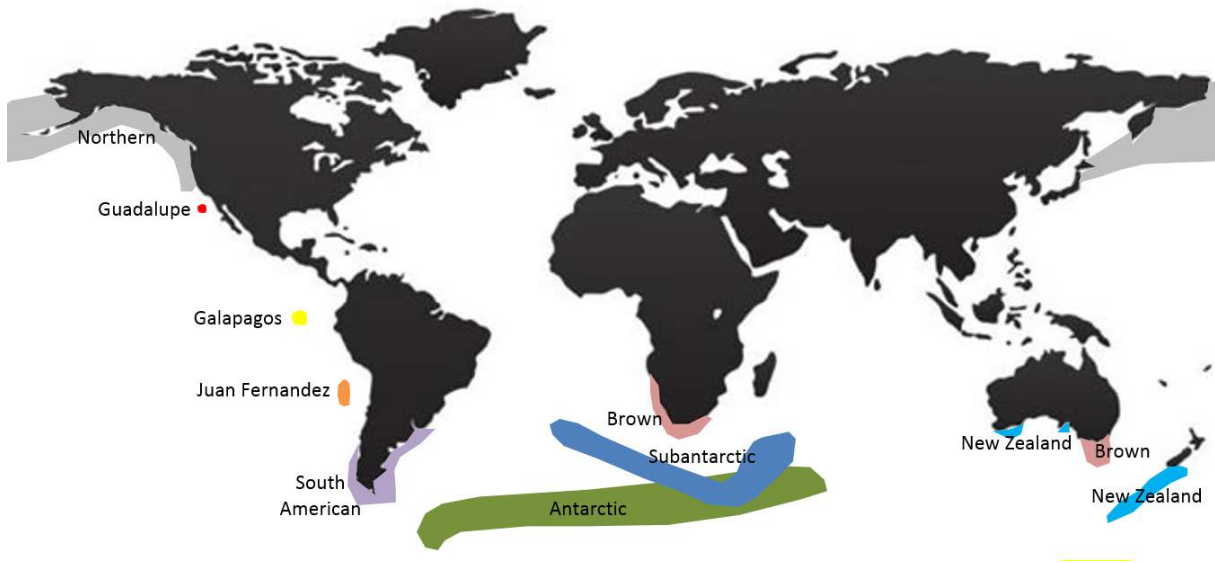


Figure C-2: Approximate breeding distribution of fur seal species. Modified from Wickens & York (2006).