Background Document

New Zealand sea lion/rāpoka Threat Management Plan

Ministry for Primary Industries
Manatū Ahu Matua

Department of Conservation
Te Papa Atawhai

NEW ZEALAND SEA LION/RĀPOKA
THREAT MANAGEMENT PLAN

BACKGROUND DOCUMENT

Department of Conservation and Ministry for Primary Industries

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Cover image: New Zealand sea lion pup. *Photo: Laura Boren*

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Purpose

This document is intended to provide more detailed information on the natural history and biology of the New Zealand sea lion/rāpoka (*Phocarctos hookeri*), as well as a summary of the key threats the species is exposed to at its range of breeding locations. This document forms the background information that supports the draft New Zealand sea lion Threat Management Plan.

Sea lion abundance

A population estimate of all sea lions was generated for the year 2015. This was based on estimates of population size for the four known breeding populations at the Auckland Islands, Campbell Island/Motu Ihupuku, the Otago coast, and Stewart Island/Rakiura (see Appendix 11 in Roberts and Doonan 2016). A total species population estimate of 11,800 including pups (immediately after pupping) and 9,400 excluding pups (immediately prior to pupping) was obtained.

The overall size of the sea lion population is monitored using estimates of sea lion pup production (the number of pups that are born each year). This is consistent with international best practice for estimating population sizes for seals and sea lions (Chilvers et al 2007). While the Auckland Islands and Otago breeding sites have been monitored annually since 1995, pup production at the other breeding sites has been monitored less frequently.

Breeding on the Auckland Islands represents approximately 68% of the total pup production for the species. Estimates of pup production for the Auckland Islands show a decline from a peak of 3021 pups in 1998 to a low of 1501 pups in 2009, with the largest single-year decline (31%) occurring between the 2008 and 2009 counts (Robertson and Chilvers 2011). The most recent estimate of pup production for the Auckland Islands population was 1,727 pups in 2016 (Childerhouse et al 2016).

Sea lion distribution

Pre-European remains of sea lions have been identified from at least 47 middens (archaeological food waste sites), ranging from Stewart Island/Rakiura to North Cape, with most occurring in the southern half of the South Island (Gill 1998). Based on the analysis of DNA from the bones found at middens, it was discovered that prehistoric mainland colonies were genetically distinct from the current sea lion population, and became extinct shortly after the arrival of Polynesian settlers (Collins et al 2014a; 2014b). The hunting of sea lions for food on the North and South Island (AD 1280–1450) followed by commercial harvest of sea lions from outlying islands by sealers in the 1800s for skins, meat and oil, resulted in a considerable population decline at these locations and contraction of their range (Childerhouse and Gales 1998). Currently, sea lion breeding populations are only found in the subantarctic islands, Stewart Island/Rakiura, and the Otago coast (Figure 1) with haul-out sites on the Snares Islands and Macquarie Island.

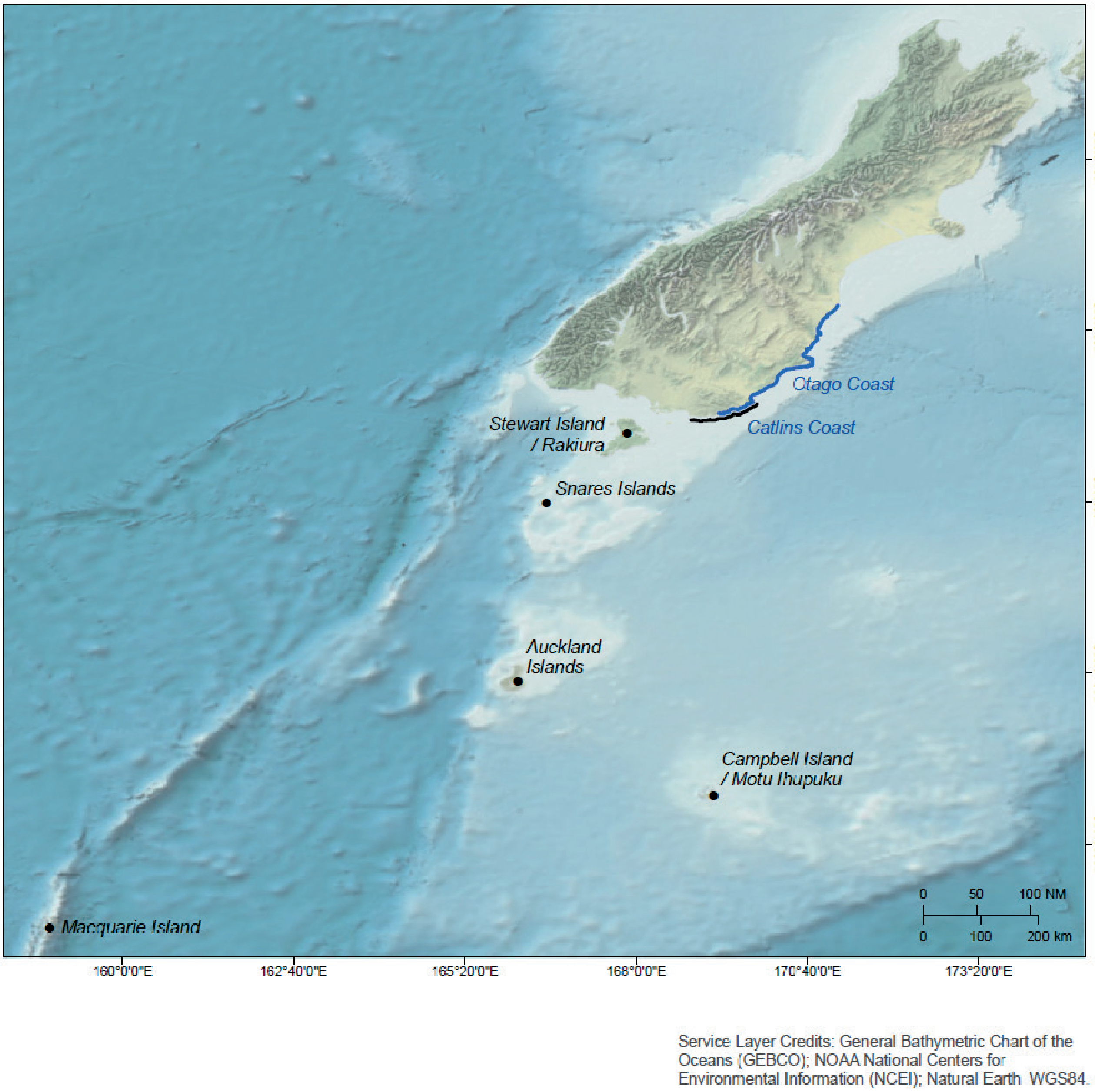

Figure 1: Current New Zealand sea lion haul-out and breeding sites.

Auckland Islands

There are currently three breeding colonies at the Auckland Islands (Figure 2): Sandy Bay on Enderby Island, Dundas Island, and Figure of Eight Island (Childerhouse et al 2015a). Pebble Point (South East Point) on Enderby Island used to be a breeding site and continues to be monitored, but no pups have been observed at this site since 2011 (Childerhouse et al 2015a), with breeding having shifted to Sandy Bay (Roberts and Doonan 2016).

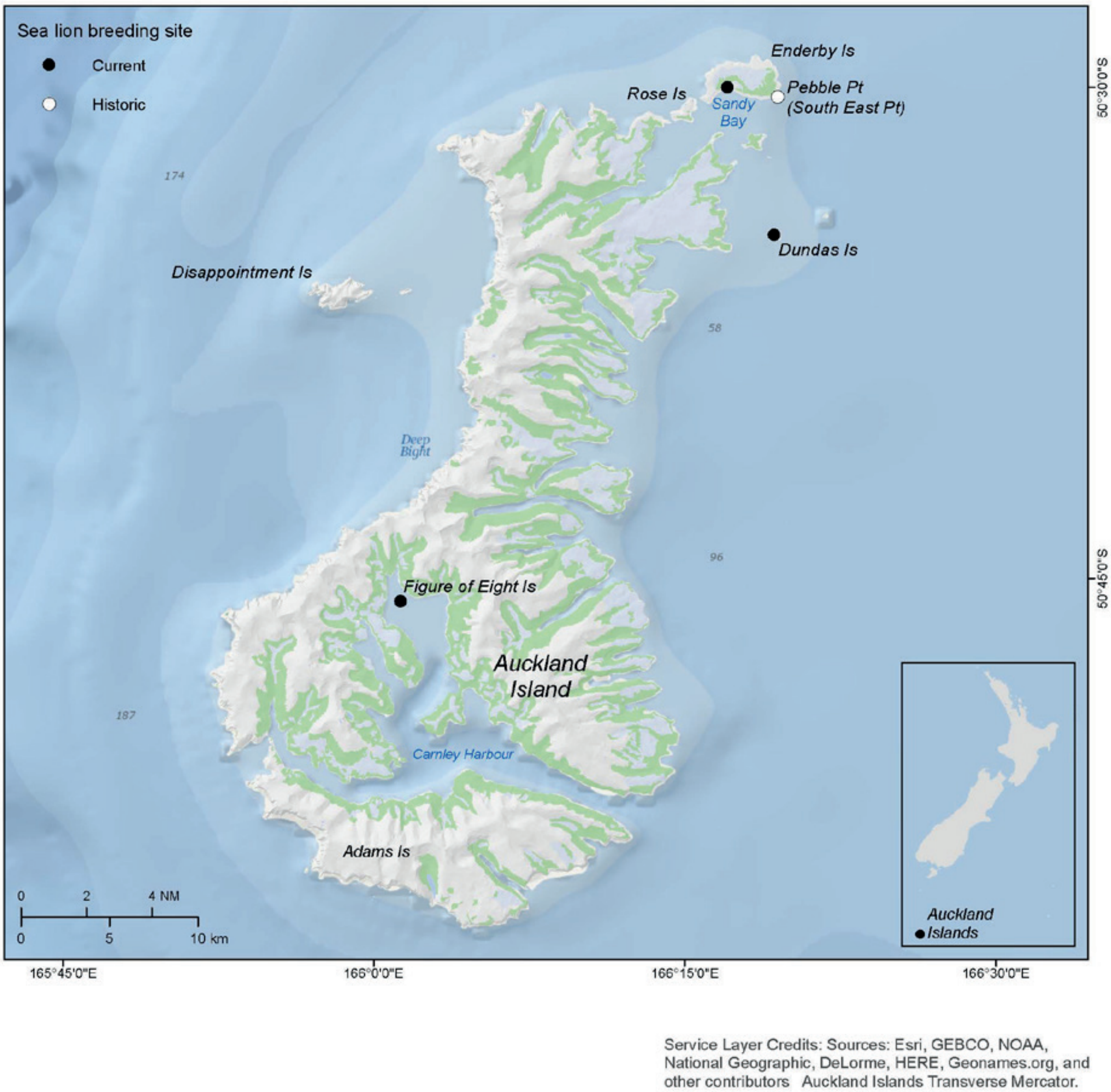

Figure 2: Map of the Auckland Islands showing the location of three current and one historical breeding sites; inset map of New Zealand showing the location of the Auckland Islands in relation to New Zealand.

Campbell Island/Motu Ihupuku

Campbell Island/Motu Ihupuku is the second largest sea lion breeding area, with approximately 30% of pup production. There are breeding colonies at Davis Point and Paradise Point, plus a small number of non-colonial breeders (Maloney et al 2012) (Figure 3).

Historically, estimates of sea lion pup production on Campbell Island have used a variety of methodologies, resulting in estimates that are not comparable. These estimates have ranged from 150 in 1993 (Cawthorn 1993) to 583 in 2008 (Maloney et al 2009). Comparable methods were used in 2010 and 2015 resulting in estimates of 681 and 696 pups respectively (Maloney et al 2012 and Childerhouse et al 2015b). Pup mortality at Campbell Island (refer to section IV Pups falling into holes), is the highest recorded for any sea lion breeding site (40% in 2008, 55% in 2010, and 58% in 2015).

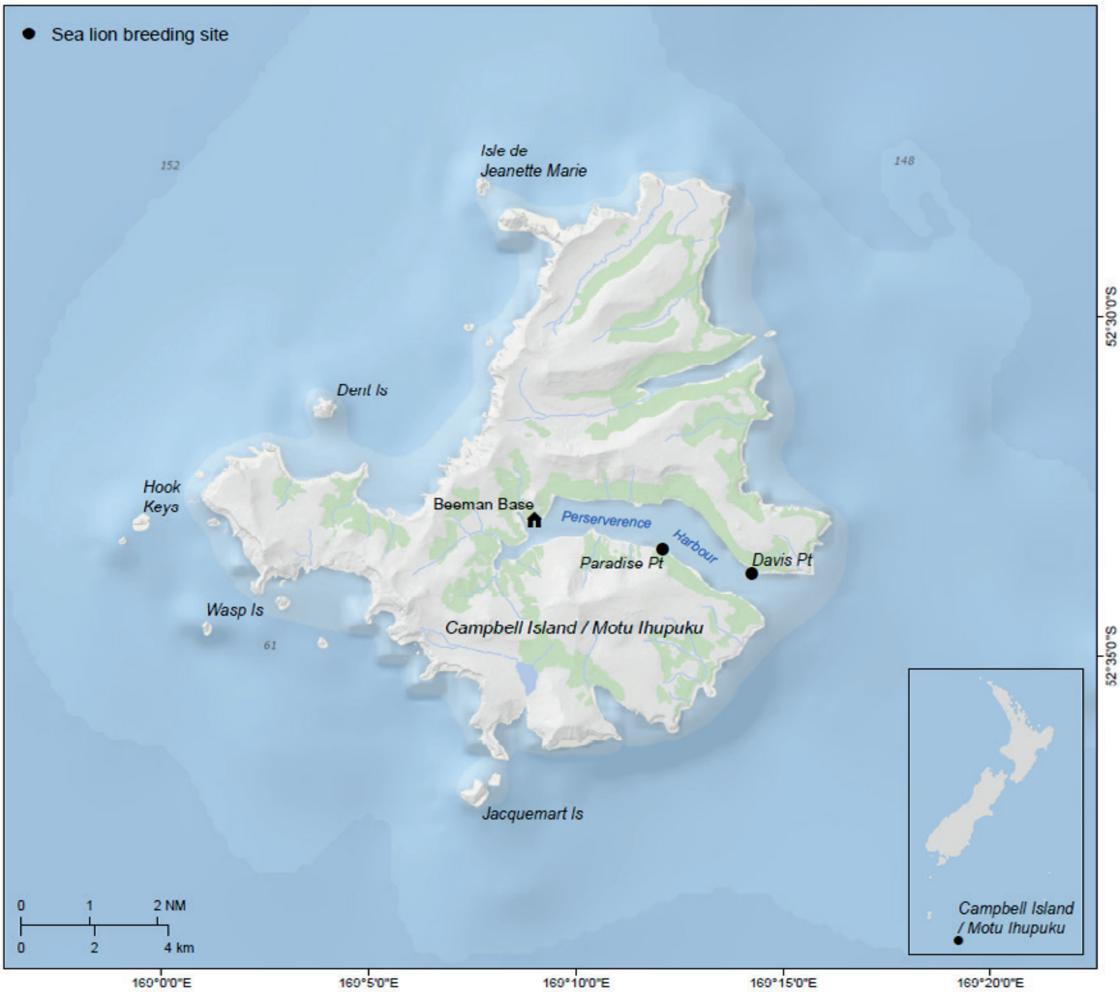

Figure 3: Map of Campbell Island/Motu Ihupuku showing the location of Davis Point and Paradise Point breeding sites; inset map of New Zealand showing the location of Campbell Island in relation to New Zealand.

Stewart Island/Rakiura

Sea lion pups have been counted on Stewart Island/Rakiura in Port Pegasus annually since 2011, with counts ranging from 16 pups in the first year, to 36 pups in 2015. It is likely the increase in number is due to increased search effort and the earlier counts are underestimates rather than measuring population growth. Port Pegasus is a very large area and mothers and pups can be very hard to locate in the dense bush.

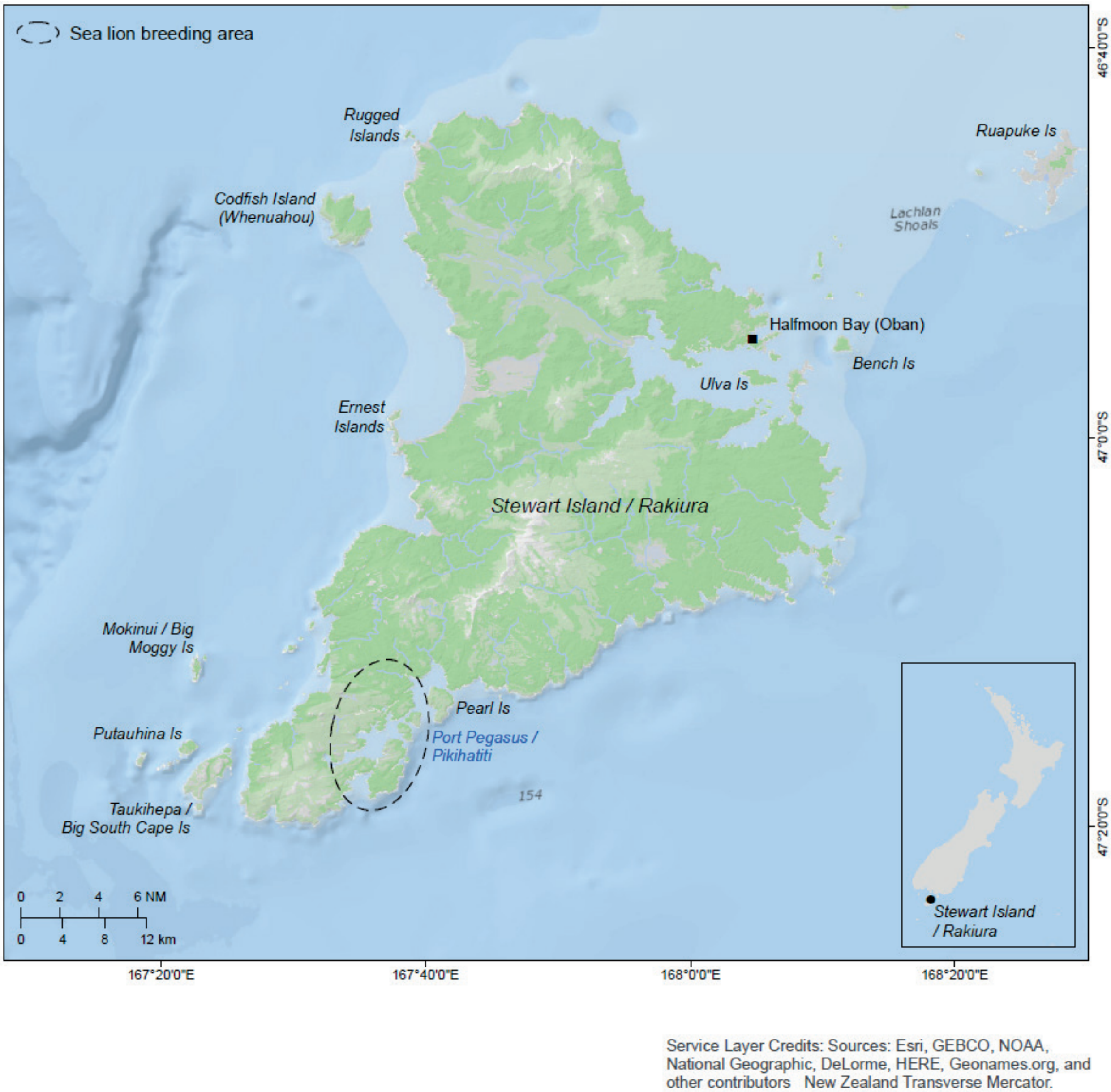

Figure 4: Map of Stewart Island/Rakiura showing the location of Port Pegasus; inset map of New Zealand showing the location of Stewart Island/Rakiura in relation to the rest of New Zealand.

Otago coast (includes the Catlins)

Sea lion breeding on the Otago coast of the South Island of New Zealand (Figure 5), began on the Otago Peninsula, following the arrival of a single female from the Auckland Islands in 1992 (McConkey et al 2002). Annual pup production on the Otago Peninsula has ranged from 0 to 8 pups since the 1995 breeding season when monitoring officially began. In 2015, 8 pups were born on the Otago coast, and in 2016, 11 pups were born on the Otago Peninsula, and 4 in the Catlins area.

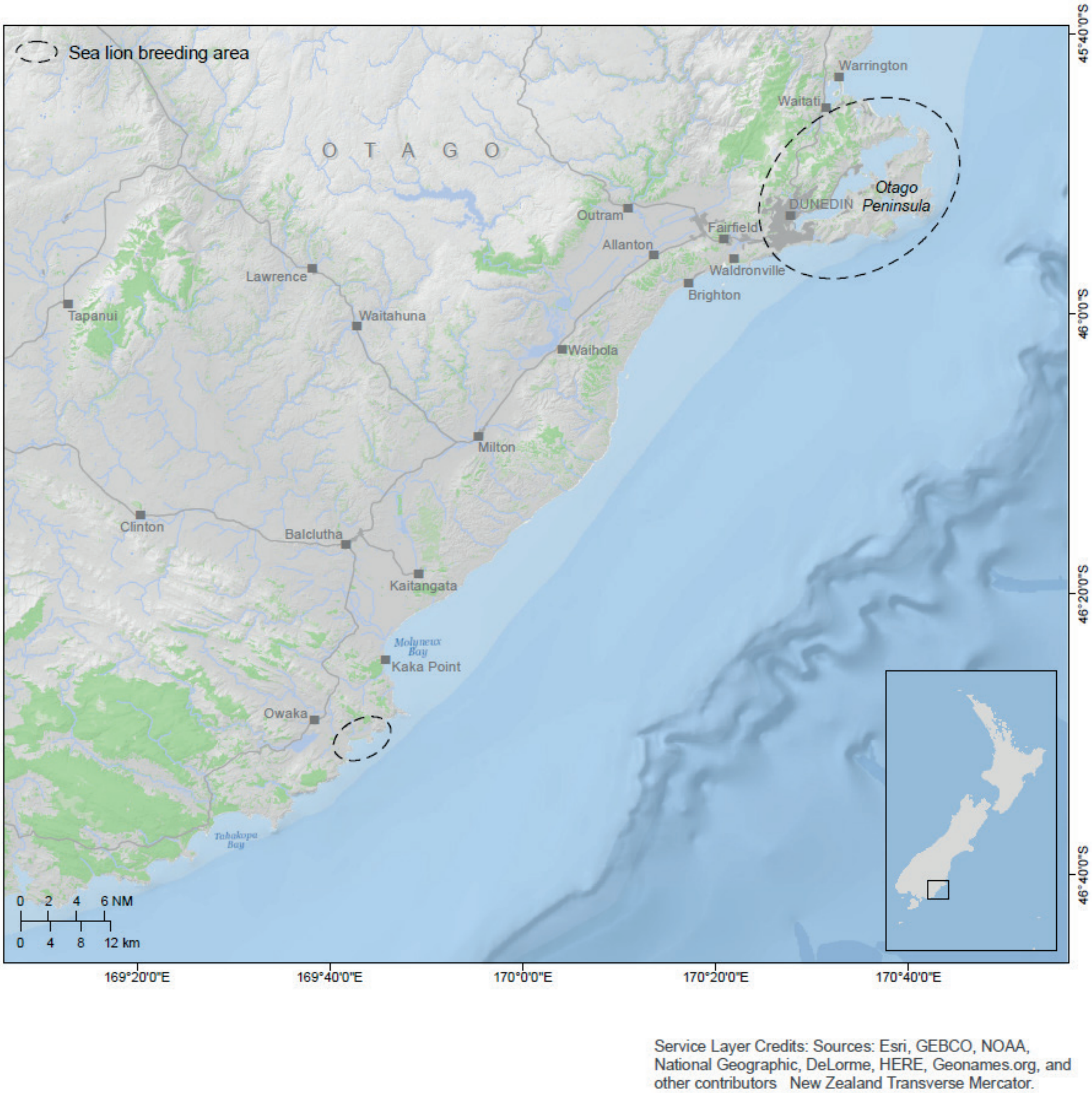

Figure 5: Map of the coast of Otago and Southland, showing the location of Otago Peninsula, and the Catlins breeding sites (Surat and Cannibal bays are circled); inset map of the South Island of New Zealand showing the location of Otago and the Catlins area.

Sea lion breeding biology

There are marked differences between male and female sea lions, with adult males being larger and darker than adult females. Breeding is highly synchronised and starts in late November when adult males establish territories. Males generally reach sexual maturity at 4 years old, but because of their polygynous colonial breeding strategy (i.e., males actively defend territories and mate with multiple females within a harem) they are only able to successfully breed at 7–9 years old, once they have attained sufficient physical size to compete for and control a harem (Cawthorn et al 1985).

Females appear at the breeding colonies in December and early January, with pregnant females giving birth to a single pup in late December. Females mate 7 to 10 days after giving birth, although the egg does not implant until a few months later. The gestation period is approximately 9 months (Marlow 1975). Twin births and the fostering of pups are rare events (Childerhouse and Gales 2001). Sea lions are site-faithful, returning to breed at the location where they were born. Most females do not breed until they are 6 years old. They then breed each year until about the age of 15, when the likelihood of breeding decreases (Chilvers et al 2010). The maximum recorded age for reproduction is 26 years, and the oldest female that has been aged was 28 years (Childerhouse et al 2010b).

Pups typically weigh 8–12 kg at birth (Walker and Ling 1981). Females remain with the pup for about 10 days before alternating between foraging trips at sea and nursing the pups on land (Chilvers et al 2005a). Shortly after the breeding season ends in mid-January, the harems break up with the males dispersing offshore and females often moving away from the rookeries with their pups (Cawthorn et al 1985). Pups are weaned after about 10–12 months (Marlow 1975).

Sea lion foraging

The majority of foraging studies have been conducted on lactating female sea lions from the Auckland Islands and the Otago Peninsula (Chilvers et al 2011; Augè et al 2011a; Leung et al 2013) . These studies show that females from Enderby Island forage primarily within the Auckland Islands continental shelf and its northern edge, and that individuals return to the same foraging sites, both within and across years. Females from Otago forage within 40 km of their breeding sites, typically on the continental shelf (< 200 m deep) (Augè et al 2011a). More recently there have been some tracking studies of winter foraging of sea lions from Campbell Island and from Stewart Island. The data for these studies are currently in press, however, early indications suggest that for Stewart Island, foraging grounds are close to shore, within 40 km (Chilvers, unpub data).

In addition to variation in foraging location, it is apparent that female sea lions have variable foraging strategies. From studies conducted at the Auckland Islands, benthic (bottom) divers consistently dive to near the bottom in relatively shallow water (120 m). They feed further from their breeding colonies, making their way to the north-eastern limits of Auckland Islands' shelf. In contrast the meso-pelagic (mid-water) divers exhibit more varied dive profiles, undertaking both deep (> 200 m) and shallow (< 50 m) dives over deeper water. They tend to forage along the north-western edge of the shelf over depths of approximately 3000 m (Chilvers and Wilkinson 2009). The meso-pelagic diving strategy requires less energy and these sea lions tend to be in better condition than those that are consistently diving deep (Figure 6).

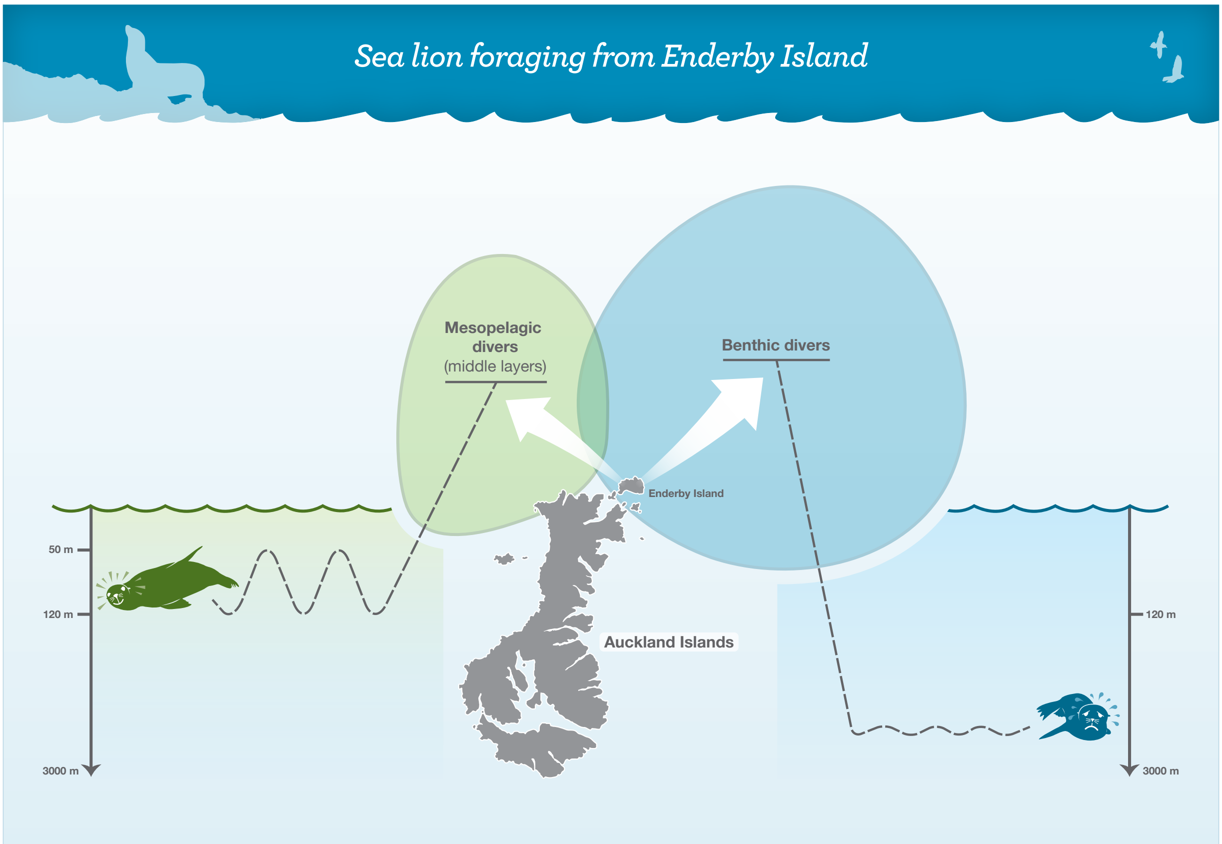

Figure 6: Diagram illustrating the differences between the two distinct foraging strategies of female New Zealand sea lions observed from Enderby Island.

Diet

New Zealand sea lions are generalist predators with a varied diet that includes teleost fish (e.g. opalfish, hoki, red cod, jack mackerel, barracouta), elasmobranchs (e.g. rough skate), cephalopods (e.g. octopus, squid), crustaceans (e.g. lobster krill, scampi) and other invertebrates such as salps and occasionally New Zealand fur seals and some seabirds (e.g. yellow-eyed penguin, blue penguin, southern royal albatross) (Childerhouse et al 2001; Lalas 1997; Meynier et al 2009; Stewart-Sinclair 2013). The most important prey species that make up their diet are arrow squid, hoki, red cod and scampi. There is considerable variation in diet between the sexes, between colonies, and within years and seasons. The diet of female sea lions at the Auckland Islands tends to include more arrow squid and hoki and fewer red cod and scampi than male sea lions (Meynier et al 2008; Meynier 2010). Jack mackerel and barracouta were identified as the main prey species of sea lions in Otago in summer and autumn. In winter and spring, inshore fish species dominated the diet (Augè et al 2011b).

When comparing female sea lions based at Otago Peninsula and the Auckland Islands for factors that may indicate the nutritional stress the animals are experiencing (e.g. foraging behaviour, diet, weight, breeding age and success), sea lions tagged at the Auckland Islands appear to be foraging in less optimal habitat than those tagged at Otago. Female sea lions from Otago are generally heavier for a given age, breed earlier, undertake shorter foraging trips, and have shallower dive profiles than females from the Auckland Islands.

TMP legislation and policy framework

The Department of Conservation (DOC) is the leading central government agency responsible for the conservation of New Zealand's natural and historic heritage, including sea lions. The Ministry for Primary Industries (MPI) is responsible for managing fisheries and their impacts on protected species. There are a number of key policies and pieces of legislation that guide agencies' responsibilities:

- Wildlife Act 1953
- Marine Mammals Protection Act 1978
- Conservation Act 1987
- Resource Management Act 1991
- Marine Mammals Protection Regulations 1992
- Fisheries Act 1996
- Ngāi Tahu Claims Settlement Act 1998
- Fisheries (Commercial Fishing) Regulations 2001
- Conservation General Policy 2005
- New Zealand Biodiversity Strategy 2000
- Department of Conservation Marine Mammal Action Plan 2005–2010
- New Zealand Sea lion Species Management Plan 2009–2014
- Subantarctic Islands Marine Reserves Act 2014
- The SQU6T Fisheries Operational Plan

A proposed Marine Protected Areas Act is currently being consulted on for territorial water out to 12 nautical miles offshore. DOC is responsible for the conservation of sea lions in line with the Conservation General Policy and legislation listed above. Area based protection for sea lions is provided through marine mammal sanctuaries established under the Marine Mammals Protection Act 1978. DOC also engages with stakeholders and encourages protective actions through non-regulatory means.

Under section 9 of the Fisheries Act 1996, MPI, in relation to the utilisation of fisheries resources and ensuring sustainability, must take into account the following environmental principles:

a) associated or dependent species should be maintained above a level that ensures their long-term viability:
b) biological diversity of the aquatic environment should be maintained:
c) habitats of particular significance for fisheries management should be protected.

Additionally, under section 15 of the Fisheries Act, in the absence of a sea lion Population Management Plan, the Minister for Primary Industries may, after consultation with the Minister of Conservation, take such measures as he or she considers are necessary to avoid, remedy, or mitigate the effect of fishing-related mortality on any protected species, and such measures may include setting a limit on fishing-related mortality.

In addition to DOC and MPI, local government (territorial authorities and regional councils) manage coastal and marine development (out to 12 nautical miles), and land use and marine activities that may impact on the habitat of sea lions.

History of fishing mitigation measures

A number of management strategies have aimed at reducing the capture of sea lions in commercial fisheries over time. Around 15 years ago, commercial trawlers were estimated to be incidentally catching around 100 sea lions per year. This number has declined significantly because of area-based measures, codes of best practice, individual vessel management plans that are carefully monitored, and fishery related mortality limits (FRML).

The most important mitigation initiative developed and used by the fishing industry is called the sea lion exclusion device (SLED). The SLED was originally called a 'marine mammal exclusion device' (MMED) and was based on an initial design by the Ministry Agriculture and Forestry (MAF) Fisheries Research Unit in 1992. The design began as an adaptation of a turtle exclusion device that had been used in Australian prawn fisheries. It was designed to allow small species, like squid, to become trapped in the net, but prevent sea lions from entering the end of the trawl net by allowing them to exit through an escape hole. In 2000, SLEDs were trialled by the industry to establish whether sea lions could swim out of the escape holes and what their survival likelihood would be.

The SLED is a mid-section of netting fitted to the trawl net that includes a metal grid with an opening (escape hole) above it (Figure 7). The grid guides sea lions to the escape hole, enabling them to exit the net. A forward-facing hood above the escape hole is held open by floats and a strip of material known as a kite. It is designed so that only actively swimming sea lions can escape the trawl net. Since their introduction in 2000, the design of SLEDs has been regularly adjusted to improve performance. In 2005 the 'Mark 3/13' became the approved SLED standard for SQU6T and is employed by all vessels in this fishery. Each SLED is manufactured by approved net makers to exact technical specifications. The SLED has a unique serial number for compliance checks and must be audited and approved by MPI. Modelling of actual captures suggests that 85% of sea lions exit a trawl net with a SLED. Modelling of collisions with SLEDs suggests the risk of trauma or concussion is around 3%. On this basis, MPI considers that approximately 82% of sea lions probably survive their interactions with fishing gear. Since 2013, SLEDs have also been voluntarily deployed by all vessels in the Campbell Island southern blue whiting fishery (fishery area SBW6I).

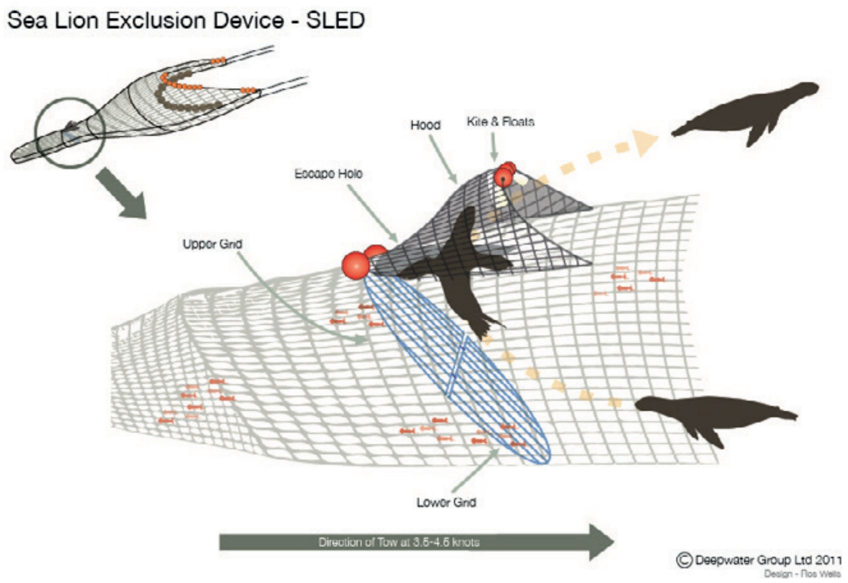

Figure 7. Diagram of a SLED (courtesy of Deepwater Group Ltd).

TMP development process

The process to develop the draft TMP comprised three concurrent work streams:

I. **Monitoring and active management** – activities and projects that contribute directly to understanding and managing the sea lion population, (including data collection during field seasons on the Auckland Islands, Campbell Island/Motu Ihupuku and Stewart Island/Rakiura) and ongoing implementation of threat mitigation measures.
II. **Science and risk assessment** – work that requires technical analysis and expert involvement, including the identification and quantification of threats to the sea lion population.
III. **Policy and engagement** – development of the Threat Management Plan, including the formation of management goals and options, development and implementation of policy amendments, engagement with stakeholders, and publication of relevant reports.

The three coordinated work streams ensured that monitoring and active management could be undertaken to inform the assessment of risk to the sea lions as the TMP was developed. Figure 8 shows a timeline of research and management activities prior to the development of the TMP. The multi-work stream approach enabled the ongoing management of risks; rigorous analysis of existing and emerging data; identification of threats and quantification of the risk posed by each threat; and contributions from experts across the full range of threats and opportunities for stakeholder input, including public consultation on proposed management options.

In June 2014, a workshop focused on identifying causes of sea lion pup mortality at the Auckland Islands, and provided advice on potential actions that could be taken to remedy the issues identified. The advice focused on the impacts of disease and also deaths by pups falling into muddy holes and drowning or starving.

A sea lion demographic model was finalised and formed the basis of the risk assessment model development. This integrated sea lion demographic (population) model was fitted to available data from 1960 onwards, including sea lion tag data, pup census data, sea lion age structure, and data on sea lion deaths resulting from known threats. A qualitative risk assessment was held at the first expert workshop in Wellington between 28 April and 1 May 2015 to identify and characterise the threats to the sea lion population, as well as review the proposed sea lion demographic model. An independent expert panel was convened for this workshop to evaluate the effects of all the sea lion threats and assist with understanding the overall risk to sea lions. The expert panel provided a technical review of the proposed demographic modelling framework and made a number of recommendations to ensure the modelling approach was robust. In collaboration with advisors (researchers with relevant expertise), the panel provided an initial characterisation of all possible threats to the sea lion population and their potential impacts and made recommendations on the key threats that should be included in the model.

Following the conclusion of the workshop, the recommendations on the modelling approach were incorporated and the model and preliminary outputs were presented to three meetings of MPI’s Aquatic Environment Working Group and DOC’s Conservation Services Programme Technical Working Group. These working groups provided additional review and refinements to the model.

A second expert panel workshop was held from 1 to 3 September 2015. The panel comprised the same experts as the first workshop and focused on further review of the demographic model developed at the first workshop, including a review of the preliminary outputs of the model. The panel also critiqued the draft TMP goals and provided recommendations on the treatment of threats in the model, future research priorities, and potential management actions. The expert panel made some minor technical recommendations to improve the demographic modelling. As with all modelling there was some uncertainty or assumptions made over some parameters that were taken into the modelling. The expert panel concluded that the modelling approach was robust and appropriate to underpin the development of the TMP.

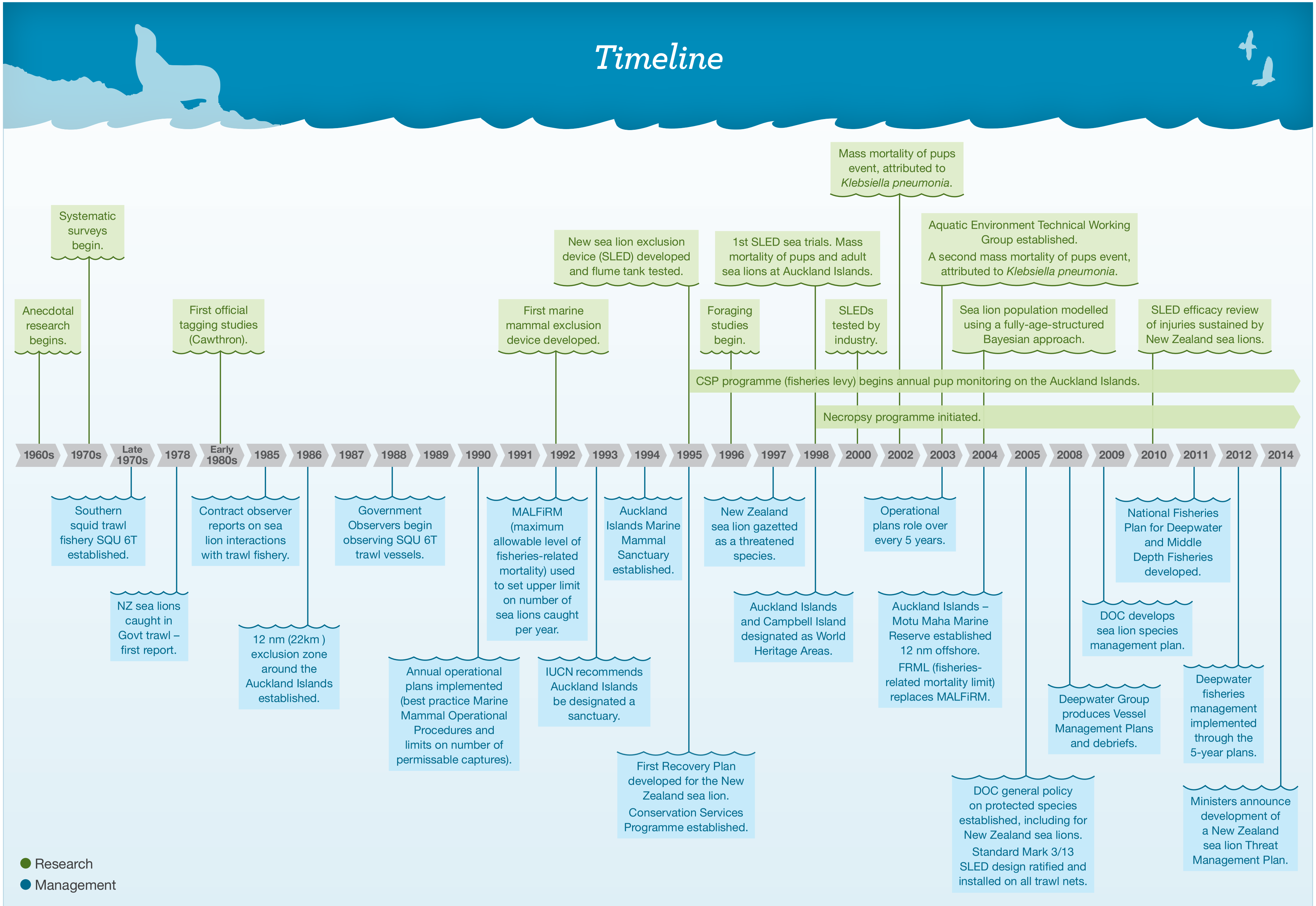

Figure 8: Timeline of New Zealand sea lion research and management actions

Research undertaken during the development of the TMP

In the two years since the TMP development began, a number of research programmes have been initiated or maintained; some of these were included as part of the TMP process and others were additional to the process but provided new information.

I. An expert workshop in 2014 identified causes of sea lion pup mortality at the Auckland Islands, and provided advice on management actions.

II. An integrated sea lion demographic (population) model was developed and finalised and formed the basis of the risk assessment model development.

III. A qualitative risk assessment workshop was held in 2015 to identify and characterise the threats to the sea lion population, as well as contribute to the final sea lion demographic model. The workshop also convened an independent expert panel to evaluate the effects of all the sea lion threats and assist with understanding the overall risk to sea lions.

IV. The model and preliminary outputs were presented at three meetings of MPI's Aquatic Environment Working Group and DOC's Conservation Services Programme Technical Working Group.

V. A second expert panel workshop was held in 2015. The panel critiqued the draft TMP goals and provided recommendations on the treatment of threats in the risk assessment model, future research priorities, and potential management actions.

VI. A sea lion quantitative risk assessment was finalised.

VII. A literature review of threats to the recovery of New Zealand sea lions and species of fur seals and sea lions worldwide was produced.

VIII. Annual sea lion pup monitoring counts were carried out in 2015 and 2016 at the Auckland Islands, Stewart Island/Rakiura, the South Island's Otago coast, and in addition, in 2015 counts were done on Campbell Island/Motu Ihupuku.

IX. The field season on the Auckland Islands in 2015 was extended to monitor the impact of the disease *Klebsiella pneumoniae* on sea lion pups later in the breeding season. A vet was part of the team in both 2015 and 2016 to ensure data was collected on pup mortality and to monitor the impact of *Klebsiella pneumoniae*.

X. The 'Planks for Pups' initiative with WWF was implemented on Enderby and Dundas Islands. It involved installing wooden ramps to enable sea lion pups to climb out of holes. In 2015 and 2016 it included monitoring the success of the ramps with 'GoPro' cameras.

XI. In early 2016, a field trip to Stewart Island/Rakiura investigated the potential for undertaking the sea lion pup counts and disease investigation earlier in the season to be consistent with the other sea lion monitoring trips on the subantarctic islands.

XII. In early 2016, a research voyage investigated the marine habitat and sea lion prey species around Stewart Island/Rakiura and the Auckland Islands. Work was focused on the foraging areas and depths used by lactating female sea lions.

TMP quantitative risk assessment of threats

A major part of developing the TMP has been the production of a quantitative risk assessment of threats to sea lions (Roberts and Doonan 2016). For a summary of all the threats that sea lions face, please refer to the 'Threat Characterisation Spreadsheet' (in Appendix 5 of the TMP Workshop 1 Progress Report). For a summary of the overall Risk Assessment process please refer to Debski and Walker (2016).

The risk assessment process used aimed to quantify which threats pose most risk to the sea lion population to help prioritise management actions that would meet the management goals of the TMP. This was done by developing demographic models, compiling data on threats, a risk ordering process (or 'risk triage') and detailed modelling of key threats where sufficient data was available. A panel of national and international experts was convened to guide and review the process and provide opinion-based input where the availability of data was poor.

The quantitative components of the risk assessment focussed on the Auckland Islands sub-population, where the greatest declines have been observed, and the Otago coast breeding area. These are the two most studied areas and therefore the areas with the most data available.

Auckland Islands

For the major sea lion breeding sites on the Auckland Islands, the key risks identified from the risk triage process were in order of importance from highest to lowest modelled threat: *Klebsiella* disease, commercial trawl fishing, male sea lion aggression, trophic effects/prey availability, hookworm disease, and sea lion pups drowning or starving in holes (Table 1).

Otago coast

For sea lions breeding on the Otago coast, the key risks identified from the risk assessment process were: setnet fishing, deliberate human mortality, entanglement and male sea lion aggression (Table 1). The Otago coast breeding area contains small numbers of breeding females, making it susceptible to occasional or sporadic risks, even if the average level of risk is small. The risk assessment has identified that deliberate human impacts should be managed to maximise future population growth. A more qualitative process of data collation and expert review identified key threats for the Campbell Island/Motu Ihupuku subpopulation and Stewart Island/Rakiura breeding area, where insufficient data was available to build adequate population models.

Table 1: Risks to sea lions identified through the quantitative risk assessment process in descending order from highest to lowest modelled threat, for the Auckland Islands and Otago coast.

Auckland Islands subpopulation	Otago coast breeding population
1. *Klebsiella pneumoniae* disease	1. Direct effects of commercial setnet fishing
2. Direct effects of commercial trawl fishing	2. Deliberate human mortality
3. Male sea lion aggression	3. Entanglement
4. Trophic effects/prey availability	4. Male sea lion aggression
5. Hookworm disease	
6. Sea lion pups drowning or starving in holes	

Overview of key threats

I. Disease

The average mortality rate of sea lion pups in a breeding season at the Auckland Islands is around 9%. This has been observed by researchers during field work from December to March since 1995. Disease outbreaks caused by bacterial infections are significant sources of mortality for sea lion pups, in particular the outbreak in 1998 (the year with the highest pup count on record) that killed at least 1,600 pups (53% of pups born that season) and at least 74 adult females on the Auckland Islands. The bacterium *Klebsiella pneumoniae* (*Klebsiella*) killed at least 33% of pups during disease outbreaks on the Auckland Islands in 2002 and 21% of pups in 2003 (Wilkinson et al 2006). Because only a proportion of adult sea lions are onshore at the time researchers are present, the full impact on adult sea lions during these disease outbreak events is unknown.

Investigation of disease-related mortality of sea lion pups since 2010 indicates that infection from *Klebsiella* has become an increasingly significant cause of pup mortality. However, the lasting effect of disease on the population is not known. There are currently no methods for treating *Klebsiella* in sea lions. Research also indicates that the majority of deaths due to *Klebsiella* now occur late in the breeding season (from mid-February onwards) from a highly virulent strain of the bacteria. Pup deaths are continuing to occur up until the end of the research observation period and perhaps beyond, meaning that the full impact of this infection on the sea lion population may be larger than results from previous studies suggest. In addition, the highly virulent strain is present on the South Island and was responsible for the death of an Otago-born pup in early 2013.

II. Commercial fishing

There are a number of important commercial fisheries around the subantarctic islands. Trawling is the predominant fishing method and the main target fisheries are squid, southern blue whiting, and scampi.

Squid (SQU6T)

The southern squid trawl fishery started in the late 1970s. The first report of sea lion captures was made in 1978 (10 sea lions were caught on a government research trip). Sea lions forage in the same area of ocean and at the same time as these fisheries, which leads to incidental captures in trawl nets. Interactions occur when sea lions are foraging for food and enter the trawl net to catch fish.

Thompson et al (2015) noted that, in the 22-year period between 1992 and 2013, there were 388 sea lion captures in commercial trawl fisheries, with around 7% of sea lions being released alive. 62% of captures were in the arrow squid trawl fishery (SQU6T), which operates around the Auckland Islands from late January to June each year. Observed captures of sea lions declined markedly in the three most recent fishing years examined by the report (2011 to 2013), when only 2 sea lion captures were reported in the Auckland Islands SQU6T fishery. This number of captures was well below the average of 11 captures per year in this fishery over the 22 years reported. Note that sea lion exclusion devices (SLEDs) which allow sea lions to escape from the net have been used in this fishery since 2003. Observer coverage has increased over time, and since 2013 has been high at around 85% of tows observed.

Roberts and Doonan (2016) estimated that incidental mortalities in the SQU6T squid fishery were lower during the post-2000 period of decline in numbers of sea lion pups born at the Auckland Islands than in preceding years when the sea lion population was increasing in size. The risk assessment modelling concluded that direct fishery effects alone do not explain the decline in the sea lion population.

Southern blue whiting (SBW6I)

The southern blue whiting trawl fishery (SBW6I), operates near Campbell Island/Motu Ihupuku from August to September each year. In contrast to the Auckland Islands squid fishery, Thompson et al (2015) found that sea lion captures increased in the Campbell Island southern blue whiting fishery in the 22-year study period between 1992 and 2013. A total of 55 sea lions were observed captured during this period (14% of total reported captures). All animals caught were males, except for one female sea lion, released alive in 2010. In 2014, industry voluntarily agreed that all vessels would use approved SLEDs in the Campbell Island fishery and a trigger point was agreed by industry where all fishing would stop if 25 sea lions (or 12 females) were caught in a season. In addition, any individual vessel capturing 5 sea lions would have to leave the fishery. The introduction of these measures – particularly the use of SLEDs, saw a reduction in captures to 2 sea lions in 2014 and 6 captures in 2015 (with 100% observer coverage in both years).

Scampi (SCI6A)

Thompson et al (2015) found that in the 22-year study period between 1992 and 2013, there were 23 sea lion captures in commercial scampi trawl fisheries around the Auckland Islands (SCI6A), around 5% of total reported captures. On average, 8% of tows have been observed over the last decade in the SCI6A fishery.

Other fisheries

Thompson (et al 2015) found that trawlers targeting other species including scampi, hoki, jack mackerel, orange roughy, and warehou accounted for 24% of sea lion captures around the Auckland Islands and on the Stewart-Snares shelf.

Value

Commercial trawl fisheries in the southern ocean for the main target fisheries of squid, southern blue whiting, scampi and hoki generate around $100 million in export earnings per annum.

III. Changes in food resources

Sea lions are one of the main predator species in the subantarctic region, and therefore are affected by changes in the food web below them. This can be influenced by climate change causing fluctuations in the availability of food for sea lions near their breeding sites and the extraction of biomass by commercial fishing in the foraging areas of adults. If female sea lions are not in good condition, the quality of their milk may not adequately support the health of their pups. Nutritional stress is driven by changes in prey availability and how hard it is for female sea lions to find enough food. As well as potentially leading to starvation (particularly for pups), nutritional stress may increase the susceptibility of sea lions to other threats such as disease.

A number of potential indicators of nutritional stress have been identified during the period of pup numbers declining at the Auckland Islands, including:

I. sea lion diet changing over time to small-sized prey coinciding with a reduced pupping rate
II. delayed age for mothers to have their first pup, and
III. low pup survival rates and reduced condition for lactating females (Roberts et al 2014).

Changes in sea lion diet can have a major effect on key population rates, particularly sea lion pup survival and pupping rates. These changes have also been observed in other sea lion populations world-wide. Large-scale global processes like the El Niño Southern Oscillation can alter ecosystem dynamics. New Zealand sea lion diet assessments have indicated strong seasonal and locational differences that are likely to relate to variation in food abundance and availability across their range (Roberts and Lalas 2015). A comparative assessment with the Otago Peninsula sea lion population indicated that the Auckland Islands sea lion population is likely to have been suffering from less nutritional food which may be a key driver of the population decline (Augé 2010).

IV. Pups falling into holes

Locations where sea lions breed can be dangerous for pups. Some of the breeding sites at the Auckland Islands are peppered with holes that can be deep and contain water or mud. Sea lion pups can fall or climb into these holes and sometimes cannot get out again, so either drown or die of starvation. The nature of these holes varies between the islands. Dundas Island has a series of large holes that form a small moat in some years. On Enderby Island there are numerous small holes formed from undercut streams with steep sides. These small holes are more changeable over time owing to the peat environment, and pup mortality varies annually depending on where the sea lions go when the breeding harems break up. In some years sea lions move to other parts of the island where there are fewer steep holes. Unfortunately in the last 2 years (2014 and 2015), sea lion mothers and pups have moved to areas with many dangerous holes and the mortality rate has been high (Childerhouse et al 2015a).

On Campbell Island, the largest breeding site at Davis Point consists of a rock platform and a bog area. Two-thirds of the breeding at Davis Point occurs on a large rock platform located next to several large rock pools. Pups often fall into one of several steep rock pools and drown. The bog area at Davis Point is where the remaining one-third of the breeding occurs. Pups can also fall off the waterfall or the edge of the cliff or ridge into pools that they cannot climb out of. The second main breeding colony at Paradise Point is located on the steep side of a hill.

Sea lion pup mortality from drowning or starving in holes can be considerable. In the 2015 season, 696 pups were counted by researchers at Campbell Island. However there was a 58% pup mortality rate, two-thirds of which was attributed to starvation and one-third to trauma. Both these causes of death may be the end result of pups falling into holes (Childerhouse et al 2015b).

V. Male sea lion aggression

Male sea lion aggression can cause harassment, injury, and death of both sea lion pups and adult females. Aggressive behaviour can be exhibited by immature, sub-adult, and adult male sea lions. Male sea lions can deliberately kill pups or they can accidentally cause trauma when fighting other males or when breeding.

Male aggression and harassment can also alter adult female sea lion behaviour. When females depart or arrive at the colony they usually do so in groups or when male numbers are low, to avoid aggressive mating behaviour. This avoidance behaviour is energetically costly for female sea lions and also increases the amount of time pups are on their own. This can have long-term negative flow-on effects for both adult female sea lions and their pups.

VI. Hookworm disease

Hookworm is a parasite that is common in sea lion populations around the world. The definitive host is the pup. Adults can carry the parasite but it becomes dormant in their abdomen. It is typically passed to a pup through the milk of lactating females and completes its life cycle in the pup. Depending on the hookworm burden, the effect on pups can range from reduced growth rate through to mortality in severe cases. Previous work on Enderby Island showed that up to 100% of pups examined had hookworms present by late January and that between 1998 and 2005, approximately 13% of dead pups had a significant hookworm burden, although it may not have been the primary cause of death (Castinel et al 2007). Trials have been undertaken to see if treatment of sea lion pups with drugs could improve both pup growth rate and short-term survival (Chilvers et al 2009). Although the study had a small sample size, it suggested that pups treated with drugs that kill hookworms were more likely to survive. However, given that the bacterial disease *Klebsiella* is also present in the same breeding sites (and responsible for pup mortality in the same time frame as hookworm infections), it is difficult to know the true impact of hookworms on pup mortality or whether hookworm infection makes sea lion pups more susceptible to *Klebsiella*.

VII. Other human interactions (disturbance, shootings, tourists, researcher effects, and pollution)

Humans can have a range of other impacts on sea lions. Disturbance can take a number of forms, from unintentional to deliberate. For sea lions, this can result in injury or death. Disturbance can come from:

i. tourists
ii. boating or coastal activities
iii. harassment by dogs
iv. motor bikes or vehicles on beaches and
v. scientists conducting invasive research on sea lions.

These sorts of occurrences are more common at Stewart Island or the South Island breeding locations, for example in Otago one adult female sea lion was killed by a car in 2007 and a juvenile female was killed by a train in 2011. Incidents such as these may not always be discovered or reported. Deliberate human harassment ranges from people throwing rocks or sticks at sea lions (Jackson 2007) through to deliberate shooting. Since 2001, at least 12 sea lions on Stewart Island and the South Island have been shot and killed.

Visits to the Auckland Islands and Campbell Island/Motu Ihupuku by tourists, research scientists, and fishers can disturb sea lions and can potentially introduce or spread disease. However, dogs and vehicles are not allowed in these locations.

The New Zealand sea lion Threat Management Plan

The authors of the risk assessment note that it is likely to be the combination of low pup survival and low adult survival that has caused the observed decline at the Auckland Islands (Roberts and Doonan 2016). A single threat cannot adequately explain the estimated decline in the different survival parameters over different years – there may be multiple drivers of sea lion population change. For this reason, the 20 year TMP goal will be difficult to achieve by removing a single threat to sea lions. Natural processes affecting sea lion habitat, such as food availability, may also make the goal difficult to attain. The authors suggest that the most effective approach to meeting the goals of the TMP would be to spread the management effort across the suite of key threats identified in the risk assessment. This would be complemented by the development of tools for monitoring the effects of management interventions on threat-specific mortality.

DOC and MPI have worked together to develop the proposals in the TMP, which acknowledge that the recovery of the sea lion population is not likely to happen by addressing one threat in isolation. The agencies propose a programme of work to address the range of key threats, while gaining more information about the lesser understood threats. The programme involves monitoring and active management to allow for incorporation of new information on the sea lion population as it becomes available. To view and comment on the proposed work plan, see the New Zealand sea lion Threat Management Plan Consultation Document.

Further reading

SLEDs

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