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A Summary of the Risk Assessment of Threats to New Zealand Sea lions

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By Igor Debski and Nathan Walker

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1. Summary

This report describes the work undertaken, as part of the development process of a draft Threat Management Plan (TMP), to assess risks to New Zealand sea lions, a nationally critical and endemic species to New Zealand. The TMP assesses all threats on the population, prioritises threats for management and mitigation, and covers all sub-populations and breeding sites.

Risk assessments provide a systematic framework for evaluating the potential implications of different management decisions. The risk assessment process used for the development of the TMP aimed to quantify which threats pose most risk to the population, and inform the prioritisation of management actions that would meet the management goals of the TMP. The approach involved the development of demographic models, compilation of data on threats, a risk triage process 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 data availability 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 were the two areas with most data available.

For the Auckland Islands, the greatest risks identified from the triage were; *Klebsiella* disease, commercial trawl fishing, male aggression, trophic effects/prey availability, hookworm disease and wallows. For the Otago coast, the greatest risks identified from the triage were; setnet fishing, deliberate human mortality, entanglement and male sea lion aggression

Results from the risk assessment at the Auckland Islands indicated alleviation of any one threat will not result in an increasing population. Similarly none of the major threats assessed were sufficient alone to explain the observed decline in pup production at the Auckland Islands. Clearly multiple factors were acting on the population, and for management to recover the species a holistic view must be adopted. Further studies will be needed to fully understand, and development management options for some of the key threats, such as trophic effects and *Klebsiella* disease.

The Otago breeding area contains small numbers of breeding females, making it susceptible to small levels of risks. The risk assessment has identified leading risks, such as deliberate human impacts, which must be managed to maximise future population growth to encourage the establishment of a new sub-population.

A more qualitative process of data collation and expert review identified key threats for the Campbell Island sup-population and Stewart Island breeding area, where insufficient data was available to build adequate population models.

The risk assessment approach developed for New Zealand sea lions will allow for a quantitative assessment of progress towards achieving stated management goals, and some components could readily be applied in other situations.

2. Introduction

The New Zealand sea lion (*Phocarctos hookeri*, Gray, 1844) is New Zealand's only endemic otariid (the family of eared seals, such as fur seals and sea lions) and is listed as Nationally Critical under the New Zealand Threat Classification System (Baker et al 2010). In response to a series of declining pup counts at the Auckland Islands, the most important breeding area, the Department of Conservation (DOC) and the Ministry for Primary Industries (MPI) have developed a draft Threat Management Plan (TMP) for the species. The TMP assesses all threats on the population, prioritises threats for management and mitigation, and covers all sub-populations and breeding sites.

This report describes the work undertaken, as part of the TMP development process, to assess risks to New Zealand sea lions. The report has been produced to complement the TMP consultation paper, part of the public consultation process on the TMP, by providing more detailed information on risks and how they have been prioritised. The consultation paper has appendices providing a wider overview of New Zealand sea lion biology, its status, threats and previous management actions.

Ecological Risk Assessments (ERAs) provide a systematic framework for evaluating the potential implications of different management decisions when information is sparse, incomplete or uncertain (Burgman et al. 1993). Broadly speaking, the challenge of any risk assessment is to assemble whatever relevant knowledge is available—whether quantitative or qualitative, objective or subjective—and devise a means to utilise that knowledge in the most rigorous and objective way possible to estimate the likely consequences of actual or potential actions. It should also maintain transparency about the requisite assumptions and inputs, and associated uncertainty.

Discussion of the risk assessment process is often fraught with confusion arising from vague and inconsistent use of language, and the term 'risk assessment' is commonly applied to a wide range of loosely related analytic approaches. The scoring framework of Hobday et al (2007) describes qualitative, semi-quantitative, quantitative or 'model-based' approaches. The choice of approach and methodology is often driven by the nature and availability of data on both the population and the threats.

The risk assessment process used for the development of the TMP aimed to quantify which threats pose most risk to the population, and inform the prioritisation of management actions that would meet the management goals of the TMP. Threats are defined as any extrinsic factor or activity that may negatively affect the New Zealand sea lion population, either by killing individual animals, i.e. direct threats, or by changing their population characteristics (e.g. resulting in reduced reproductive output), i.e. indirect threats.

New Zealand sea lions are relatively well studied at some breeding areas (e.g. Enderby Island at the Auckland Islands), but not at others (e.g. Campbell Island). Similarly, some threats are data rich and relatively well understood (e.g. commercial trawl fishing) whilst others are not (e.g. indirect trophic effects). Because of this, a process that incorporated both highly quantitative modelling approaches, and more qualitative approaches, was developed, and this is described in more detail in Section 3.

3. Risk assessment approach

The risk assessment process implemented for New Zealand sea lions during 2014-15 involved the development of demographic operating models based on available field data. Threats were identified and characterised based on available data and using expert opinion where data was poor or not available. All of the compiled threats were then included in a risk triage process to prioritise the threats for more detailed modelling. Population projections were developed using a quantitative risk assessment model, based on the demographic operating model, for the threats that were carried through the triage process. The threat characterisation and risk assessment model were reviewed at two stages of development by an expert panel to ensure the final risk assessment results were as robust as possible within the timeframe available. Full details of the methodological approach are provided by Roberts et al (2016).

3.1 Sites

New Zealand sea lions breed in southern and subantarctic New Zealand. The breeding strongholds are in the subantarctic, at the Auckland Islands and Campbell Island, with smaller numbers breeding at Stewart Island and on the Otago coast (including the Catlins) of South Island (Figure 1). New Zealand sea lions are primarily colonial breeders, though scattered births may occur, particularly where population densities are low. What is known of the historic distribution is summarised in the consultation document.

Within the Auckland Islands, where approximately 70% of New Zealand sea lion pups are born, breeding occurs on three smaller islands, Dundas Island, Enderby Island (previously at two areas on the island, but now only at Sandy Bay) and Figure of Eight Island. On Campbell Island, new colonial breeding sites have recently become established and the majority of pups are now born at Davis Point or Paradise Point (Childerhouse et al 2015). Since 1994, small numbers of pups (up to ten) have been born on the Otago coast, and breeding at Stewart Island has been confirmed within the last 5 years, with 36 pups recorded in 2015. There have been occasional, infrequent, breeding records at the Snares Islands (Childerhouse & Gales 1998). Further population information is provided in appendices to the consultation document.

In addition to the number of animals in a population, the population structure is also important in assessing the recovery of a threatened species. Indeed, threat classification schemes consider the number of sub-populations in determining threat status. Definitions for terminology referring to populations for the purposes of the TMP are based on the New Zealand Threat Classification Scheme and the IUCN RedList (Townsend et al 2008, IUCN RedList 2015). The New Zealand sea lion **population** is considered the total number of animals across the range and a **sub-population** is a breeding area with an annual pup production of at least 35 pups born per year for 5 years with an immigration rate of less than one adult female area each year. A **breeding area** is used to describe a geographically defined area where New Zealand sea lions breed, regardless of whether the area is considered a sub-population. Using these definitions, there are currently two sub-populations at the Auckland Islands and Campbell Island. Note, immigration between different breeding areas on the Auckland Islands (i.e. Dundas, Enderby and Figure of Eight Islands) occurs, so these areas together form a single sub-population. The Stewart Island breeding area is approaching the size required for a sub-population, but pup production will need to be sustained at or above current levels for several more years.

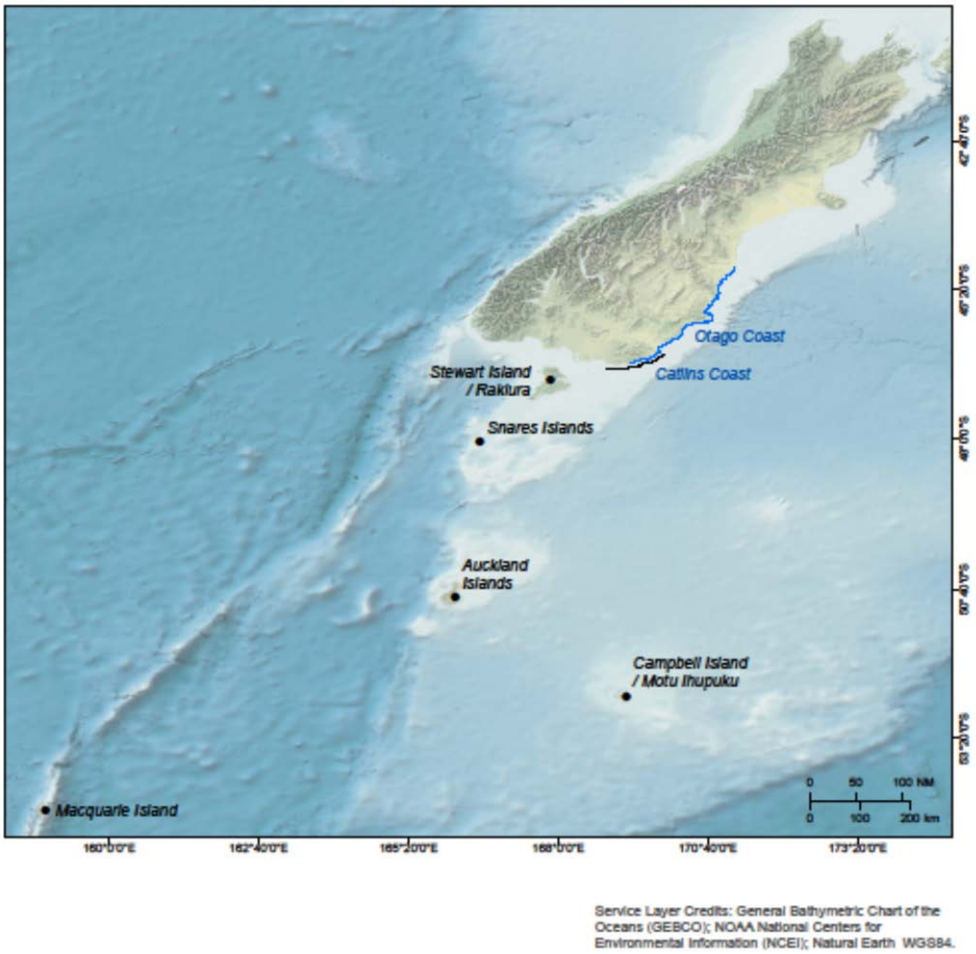

Figure 1. **Overall map of New Zealand sea lion distribution – which includes the Auckland, Campbell, Stewart, Snares Islands, and Macquarie Islands and the Otago/Catlins coasts.**

3.2 Data

There were several sources of available data for the risk assessment modelling.

For the Auckland Islands sub-population, sufficient data were available to develop a demographic model. Pup production estimates were available for breeding areas dating from 1966-2015 for Sandy Bay, and 1995 -2015 for other Auckland Island areas. Mark-resight data of tagged sea lions provided observations of female sea lions marked from 1990-2014 and resighted from 1998-2014. The most common form of marking has been flipper tags using one tag attached to each pectoral flipper when they are pups. A smaller number of sea lions have been marked with micro-chips and even fewer with brands. Behavioural observations of marked female animals at Sandy Bay were also used to determine breeding status during each field season. Each animal was categorised as a confirmed pupper, confirmed non-pupper, unknown or immature. Rates of tag loss were estimated using the field observations of the number of flipper tags seen on each sea lion and compared with observations of those sea lions that were also micro-chipped or branded.

For the sea lions breeding on the New Zealand mainland, the New Zealand Sea Lion Trust has been collecting data based on photographs, from which individual sea lions are identified and tracked over time similar to the marked sea lions on the Auckland Islands.

The population data from Campbell and Stewart Islands were not considered sufficient to develop a demographic model for this risk assessment process. Estimates of pup production for sea lions breeding on Campbell Island have been infrequent, using several different methods. Mark-resight studies have been undertaken more recently, however the number of tags, resightings and the time between studies meant this dataset was insufficient at present for developing a demographic operating model adequate for this risk assessment.

Over the last five years, sea lion pups have been counted and tagged on Stewart Island in late March. Few of these have been resighted. As the survey work has been conducted late in the breeding season, pup mortality may have occurred before the researchers have been present, underestimating the pup production at this breeding area.

3.3 Demographic analysis of available data

The first stage of the analytical process was a demographic assessment made by constructing a population model based on the observed census, mark-resighting and age distribution data from the most well studied breeding areas at Sandy Bay on the Auckland Islands and at Otago. The aim of this demographic modelling was to construct operating models (female only) as a basis for risk assessment and future projections. These models needed to be able to reflect the observed population trends. Full details of the modelling approach is provided by Roberts et al (2016).

A panel of national and international independent experts, supported by relevant subject matter advisors, was convened to provide guidance on the level of threats to New Zealand sea lions and review the demographic assessment. The first of two workshops was held 28 April to 1 May 2015 and built on previous discussions at a pup mortality workshop held in June 2014 (see Appendix 1 for minutes of this workshop), but considered all threats to all sea lion age groups. The initial stage of the risk assessment model – the demographic assessment, was completed in advance of the first workshop, in order for the panel to review and provide recommendations for model improvements. Notes, outcomes and recommendations from this workshop are provided in Appendix 2.

3.4 Threat identification

To ensure the risk assessment process considered the full range of relevant threats, an iterative process was used to identify all known and potential, non-negligible, threats to New Zealand sea lions. First, existing threat information from the previous management framework (DOC 2009), the literature (e.g. Robertson & Chilvers, 2011) and recent experience in threat management for other marine mammals (e.g. Currey et al 2012) were collated and classified by threat type. In November 2014 this list was presented for review to a broad group of stakeholders established as part of the TMP development process. This list, together with input from stakeholders and technical experts, was used to develop a comprehensive list of all threats, and used as the basis of the threat characterisation described below. The list was circulated to the expert panel participants ahead of the first workshop and, during the workshop, the list was reviewed and refined. The resulting list formed the basis of the threat characterisation (included in Appendix 2).

3.5 Threat characterisation

For each threat, or potential threat, the next stage was to identify which population components each threat impacts and the mechanism through with the threat impacts on animals. Characterising threats in this way enables numeric threat scenarios to be modelled and prioritised.

The population components used were: breeding area (Auckland Islands/Campbell Island/Stewart Island/Mainland); life stage (pup/juvenile/adult); and sex (male/female).

The mechanism through which each threat acts on animals was classified by identifying the demographic parameter(s) which would be changed (survival/breeding rate). In most cases this could be estimated as, or translated to, a number of animals removed from a certain component of the population (including indirect mechanisms such as starvation of pups if lactating females are killed). For threats that impact on breeding rate, this was characterised by the proportional reduction in pupping rate amongst mature females in the relevant breeding area. Both removal of animals and reduction in pupping rate are measures readily modelled. Suitably partitioned models were available for the Auckland Islands and Otago breeding areas (see Section 3.3).

Threats were initially characterised by DOC and MPI staff, and provided for review by the expert panel, and relevant expert advisors, at the first workshop in April 2015. Once threats were identified and characterised by population component and mechanism, the next stage was to assign a best estimate and/or credible bound of the extent of each threat to each population component. This was a major focus of the first expert panel workshop.

For some threats extensive data were available, such as estimates of captures in trawl fisheries in the vicinity of the Auckland Islands and Campbell Island. Where the panel considered the existing evidence base adequate, best estimates (with associated uncertainty) were generated for that threat. Expert advisors were able to provide information to the panel at the workshop which allowed estimation of the extent of some threats to be made at the workshop. For some other threats, it was identified that data existed but not immediately available, and the panel tasked DOC/MPI and/or expert advisors to collate information to populate a best estimate and/or credible bound for later review. In other cases, where little or no information was available, the panel either provided estimates based on their own or expert experience, or decided the threat was so small that further consideration was not required. In all cases where the panel assigned a best estimate and/or credible bound, a justification/confidence score was assigned to record the associated level of uncertainty in the estimate.

Because of the large number of threats identified, the panel also prioritised which threats were most important to be included in the more detailed modelling. A complete list of threats identified, their characterisation and estimates of extent is included in Appendix 2. The appended list includes modifications that were made following the first workshop, and reviewed by the panel at the second workshop. From this extensive list of threats, model input matrices of the upper bounds of threat estimates were developed for the Auckland Islands and Otago breeding areas (the two areas to be modelled), often providing year by year animal removal rates (Appendix 3). These formed the basis of the modelling evaluations reported in Section 5.

4. Results Auckland Islands and Otago

As outlined in Section 3.3, sufficient data were available to develop demographic operating models for the Auckland Islands sub-population and Otago breeding area. A summary of the risk triage and more detailed modelling for both areas, as well as a retrospective analysis for the Auckland Islands is provided here. Full details were reported by Roberts et al (2016).

4.1 Risk triage

A triage of the risks posed to New Zealand sea lions was conducted in order to limit the number of risks to be included in the more detailed (Markov chain Monte Carlo, MCMC) modelling. To do this, a simple model was used to assess the upper bound, or worst case scenario, of the threat by predicting the response of the population to that threat being removed. The results of this triage are not considered to be the best estimate of the risks posed to the New Zealand sea lions, but a mechanism to reduce the list of the threats to those that have the largest influence.

4.1.1 Auckland Islands

Triage model run projection outputs for the Auckland Islands using the final model are shown in Table 1 and Figure 2. The black line in Figure 2 indicates the estimated historical trend and population projection based on demographic parameters from the last ten years. The removal of each single threat is plotted separately.

The effects of removing the threats that act on pups (i.e. *Klebsiella*, hookworm, wallows[1]) have a delayed effect on the size of the mature population of sea lions. This is because the pups that will survive still need time to mature before they are included in the modelled mature female population.

Removal of the upper bound of *Klebsiella* risk creates the largest change in population size over the 20 year time period (2017-2037), however the population reacts more quickly to the removal of the upper bound of estimated trawl interactions as this acts directly on the mature females. The ratio of mature female population in 2037 compared with 2017 is 1.30 when *Klebsiella* is removed, and 1.24 when trawl interactions are removed.

The independent panel considered that some of the upper bounds used in the triage process were unlikely to be realistic and should be treated with caution.

[1] While this report refers to this threat as ‘wallows’, this includes all types of hole, drop, barrier, that either causes a sea lion pup to drown or be separated from its mother.

Table 1 Auckland Islands Triage model run estimates of mature female λ_{2037} and N_{2037}/N_{2017} for all threat scenarios, using upper values of threat mortality. *Carried forward to detailed modelling.

Threat scenario	λ_{2037}	N_{2037}/N_{2017}
Klebsiella*	1.02	1.44
Commercial trawl*	1.01	1.36
Male aggression*	0.98	0.63
Trophic – prey*	0.97	0.60
Hookworm*	0.97	0.59
Wallows*	0.97	0.55
Tuberculosis	0.96	0.54
Entanglement	0.96	0.50
Shark predation	0.96	0.50
Base	0.96	0.49

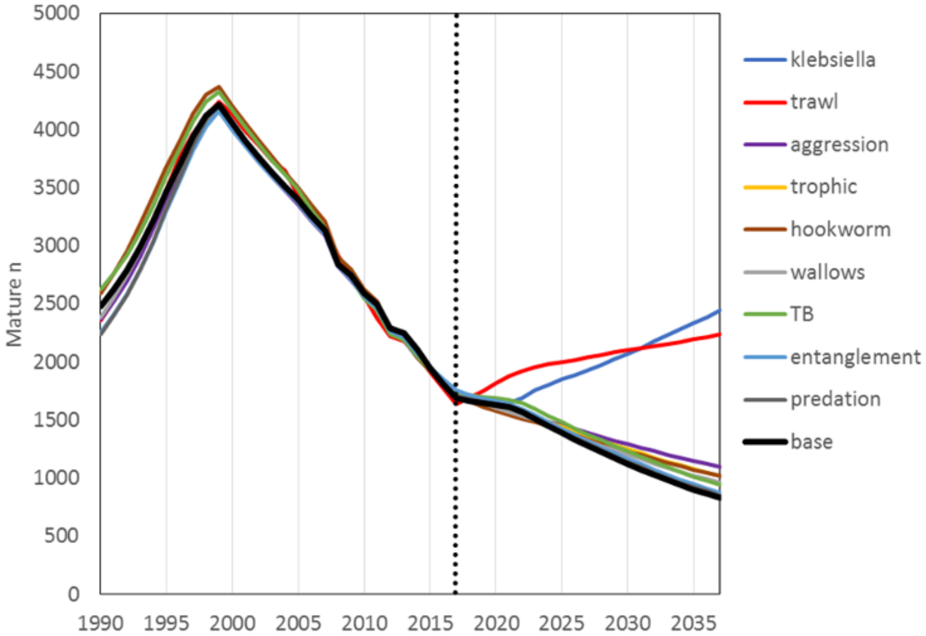

Figure 2: Triage projections of model estimated mature *N* at the Auckland Islands in the period 1990-2037, using upper values of threat mortality. Black lines = with threat (base run); coloured lines = threats alleviated.

4.1.2 Otago Peninsula

Triage model run projection outputs for the Otago Peninsula are shown in Table 2 and Figure 3.

Table 2 Otago Peninsula Triage model run estimates of mature female λ_{2037} and N_{2037}/N_{2017} for all threat scenarios, using upper values of threat mortality. *Carried forward to detailed modelling.

Threat scenario	λ_{2037}	N_{2037}
Set net*	1.15	16.31
Deliberate human mortality*	1.12	9.10
Entanglement*	1.11	7.77
Male aggression*	1.10	6.13
Shark predation	1.10	5.89
Klebsiella	1.09	5.69
Cars & trains	1.09	5.34
Dogs	1.08	4.61
Base	1.07	4.05

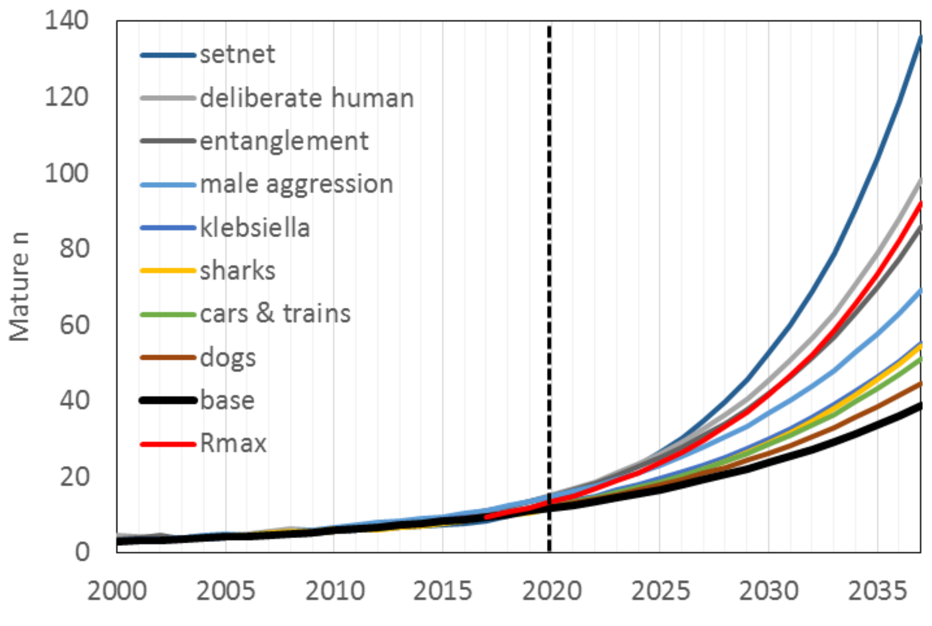

Figure 3: Triage projections of model estimated mature n at the Otago Peninsula in the period 1990-2037, using upper values of threat mortality. Black lines = with threat (base run); coloured lines = threats alleviated, except red for population growth at R_{max} (assumed to be 0.12).

For the Otago peninsula model, the removal of upper bounds of some threats produced a very rapidly growing population, higher than the assumed maximum optimal growth rate (R_{max}). This indicates that the upper bounds used for setnet and deliberate human threats were probably unrealistically high.

For the Auckland Islands, the risks carried forward from the risk triage were:

- *Klebsiella*
- Commercial trawl (with an 82% discount rate as a base case, with other discount rates as sensitivities. The discount rate is the assumed probability that a sea lion will survive an encounter with a trawl fitted with a SLED)[2]
- Male aggression
- Trophic – food limitation
- Hookworm
- Wallows

For the Otago peninsula, the risks carried forward from the risk triage were:

- Setnet
- Deliberate human mortality
- Entanglement
- Male aggression

4.2 Demographic scenario projections

To better understand how much change in demographic parameters was required to lead to recovery of the population (i.e., a positive population growth rate), a range of scenarios were developed and assessed. Scenarios were assessed using simple model projections (MPD, maximum of the posterior density function) to investigate the effect of varying levels of adult survival, pup survival and rate of pupping on the project population growth rate of mature sea lions.

Figure 4 shows the effect of varying demographic parameters on the projected population trend for the Auckland Islands sub-population, compared with the projection based on the mean of the demographic parameters from the last ten years. In order to achieve a stable or increasing population, adult survival would need to increase from 0.88 (the mean over the last ten years) to approximately 0.96, or pup survival would need to increase from 0.38 (the mean over the last ten years) to almost 0.6. Increased pupping rate alone would not result in a stable or increasing population (Figure 4). It is important to note that reducing a risk that acts on any of these demographic parameters is also likely to effect the others as well.

[2] See MPI 2012

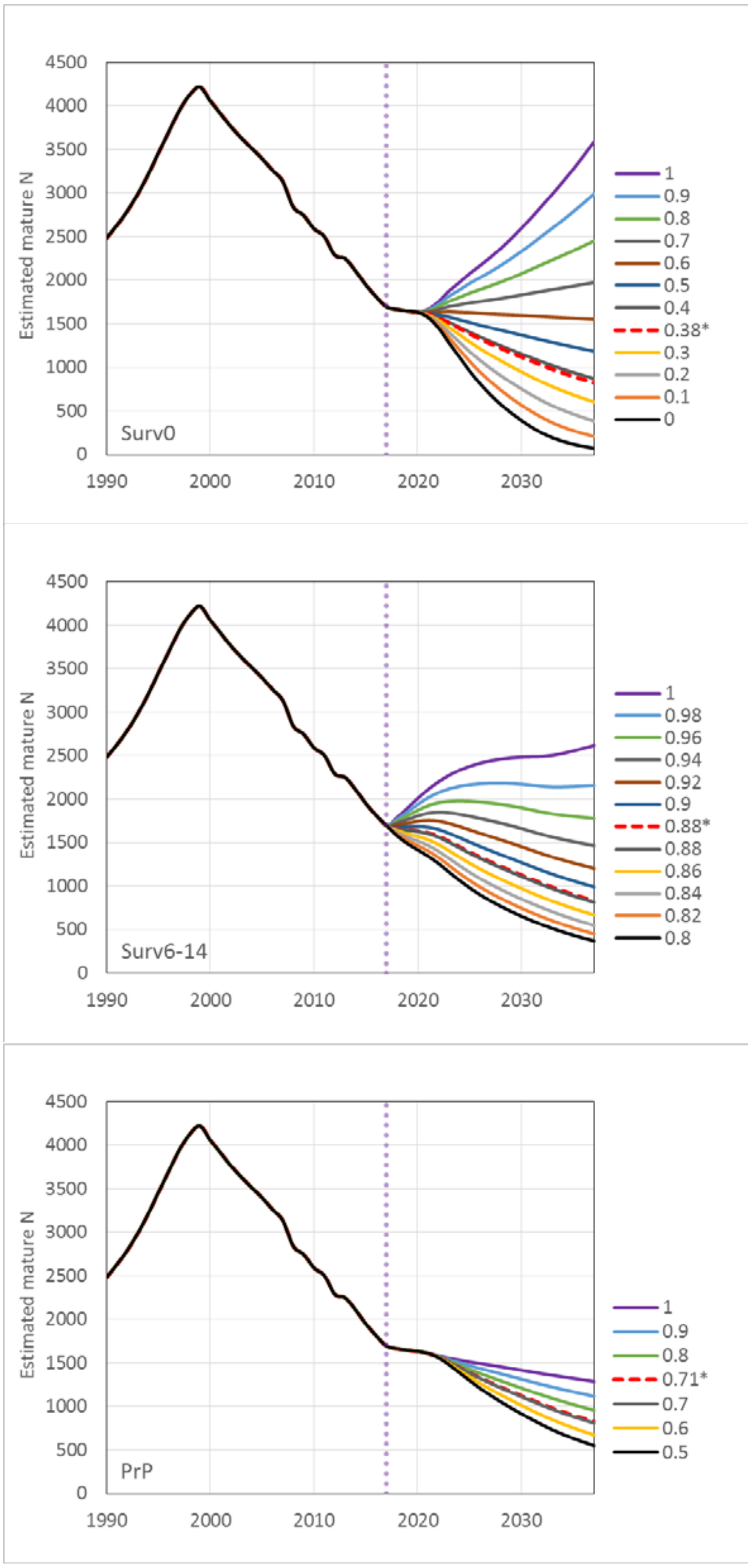

Figure 4 **Demographic rate scenario projections of model estimated mature *N* at the Auckland Islands in the period 1990-2037, with varying $Surv_0$ (top), $Surv_{6\text{-}14}$ (middle), Pr_P (bottom). Dashed red lines are projections using the mean of each respective demographic rate (*=value) from 2005-2012 for $Surv_0$ and 2005-2014 for $Surv_{6\text{-}14}$ and Pr_P.**

4.3 Population projections assessing the effects of threats

Full Bayesian modelling (using Markov chain Monte Carlo methods, known as MCMC) was conducted on all risks carried forward from the risk triage process. This modelling approach is computationally time intensive for complex models such as the population model constructed to reflect the various mark types, ages and maturity stages and this limits the number of runs that can be achieved.

The estimates of impact by each threat were determined by the first expert panel workshop and assessed using the operating models (generated by the demographic assessment). The impact of each threat was removed from the model and the resulting population trajectory compared with the base case (using recent observed demographic parameters).

MCMC runs were conducted based on the best estimates of risk levels, as defined by the threat characterisation process (see Section 4.2, Appendix 3). Model outputs are given in terms of the population growth rate of mature females in 2037 (λ_{2037}) and the relative population of mature females in 2037 compared with 2017 (N_{2037}/N_{2017}). Due to the delay in the effect of alleviating some risks on the mature female population (as some risks act on the pups) it is more appropriate to compare the difference in λ_{2037}.

The independent panel met for a second workshop in September 2015, with relevant modelling advisors, 1-3 September 2015, to consider the methods and results of the qualitative and quantitative risk assessment approaches and provide further advice on improving the modelling. Notes and recommendations from this workshop are provided in Appendix 4.

4.3.1 Auckland Islands

Model outputs using the final model configuration are summarised in Table 3, Figure 5 and Figure 6.

The results in Table 3 show that, if threats are removed individually, only the removal of *Klebsiella* will result in a stable or increasing population, however it is important to note the wide uncertainties as seen in Table 3 and Figure 5. The alleviation of *Klebsiella* produced the projection with the highest λ_{2037}, of 1.002 (0.786-1.276). This is followed by the impact of the trophic risk with a λ_{2037} of 0.974 (0.805-1.175), followed by male aggression with a λ_{2037} of 0.965 (0.749-1.246) and trawl (given an 82% discount rate) with a λ_{2037} of 0.965 (0.749-1.231).

Table 3 Auckland Islands model estimates of mature female λ_{2037} and N_{2037}/N_{2017} for all threat scenarios. Values are median and 95% credible interval. Shading indicates the sensitivities around the base case for trawl risk (82% discount rate).

Threat scenario	λ_{2037}	N_{2037}/N_{2017}
Base	0.961 (0.89 - 1.02)	0.47 (0.32 - 0.67)
Wallows	0.965 (0.891 - 1.027)	0.51 (0.35 - 0.74)
Hookworm	0.967 (0.894 - 1.026)	0.52 (0.36 - 0.75)
Aggression	0.969 (0.895 - 1.029)	0.54 (0.38 - 0.77)
Trophic	0.974 (0.905 - 1.038)	0.59 (0.36 - 0.96)
Klebsiella	1.005 (0.926 - 1.069)	0.93 (0.67 - 1.26)
Trawl captures	0.964 (0.890 - 1.025)	0.49 (0.34 - 0.72)
Trawl 82% discount	0.965 (0.891 - 1.024)	0.5 (0.35 - 0.73)
Trawl 35% discount	0.971 (0.899 - 1.031)	0.58 (0.4 - 0.84)
Trawl 20% discount	0.973 (0.898 - 1.032)	0.6 (0.41 - 0.88)
Trawl interactions	0.977 (0.902 - 1.036)	0.64 (0.44 - 0.92)
Max growth	1.069 (1.051 - 1.084)	3.4 (2.39 – 4.60)

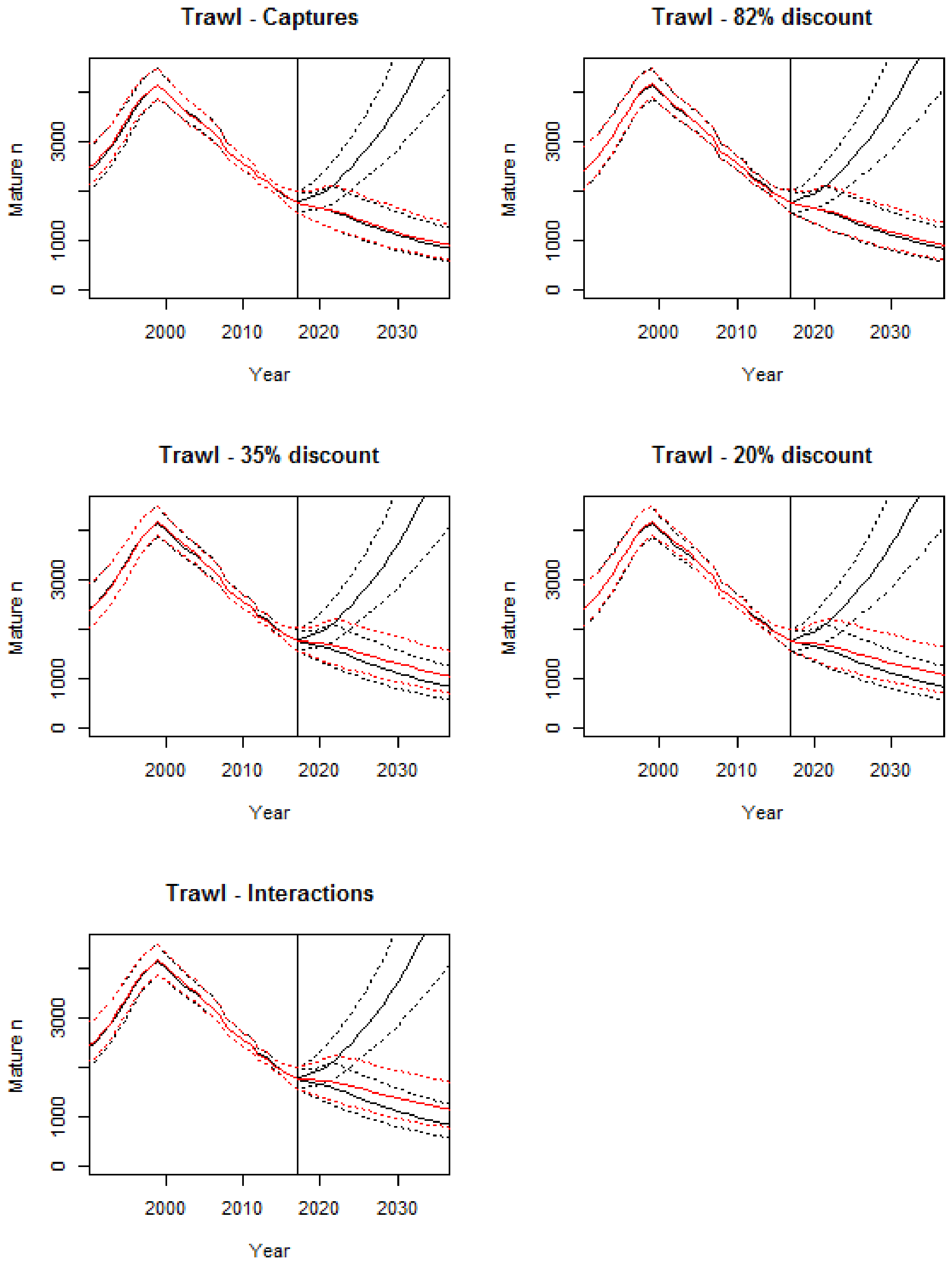

Figure 5: Model estimates of mature n at the Auckland Islands in the period 1990-2037 for trawl fishery mortality scenarios. Black lines = with threat (base run) and max growth; red lines = threat alleviated.

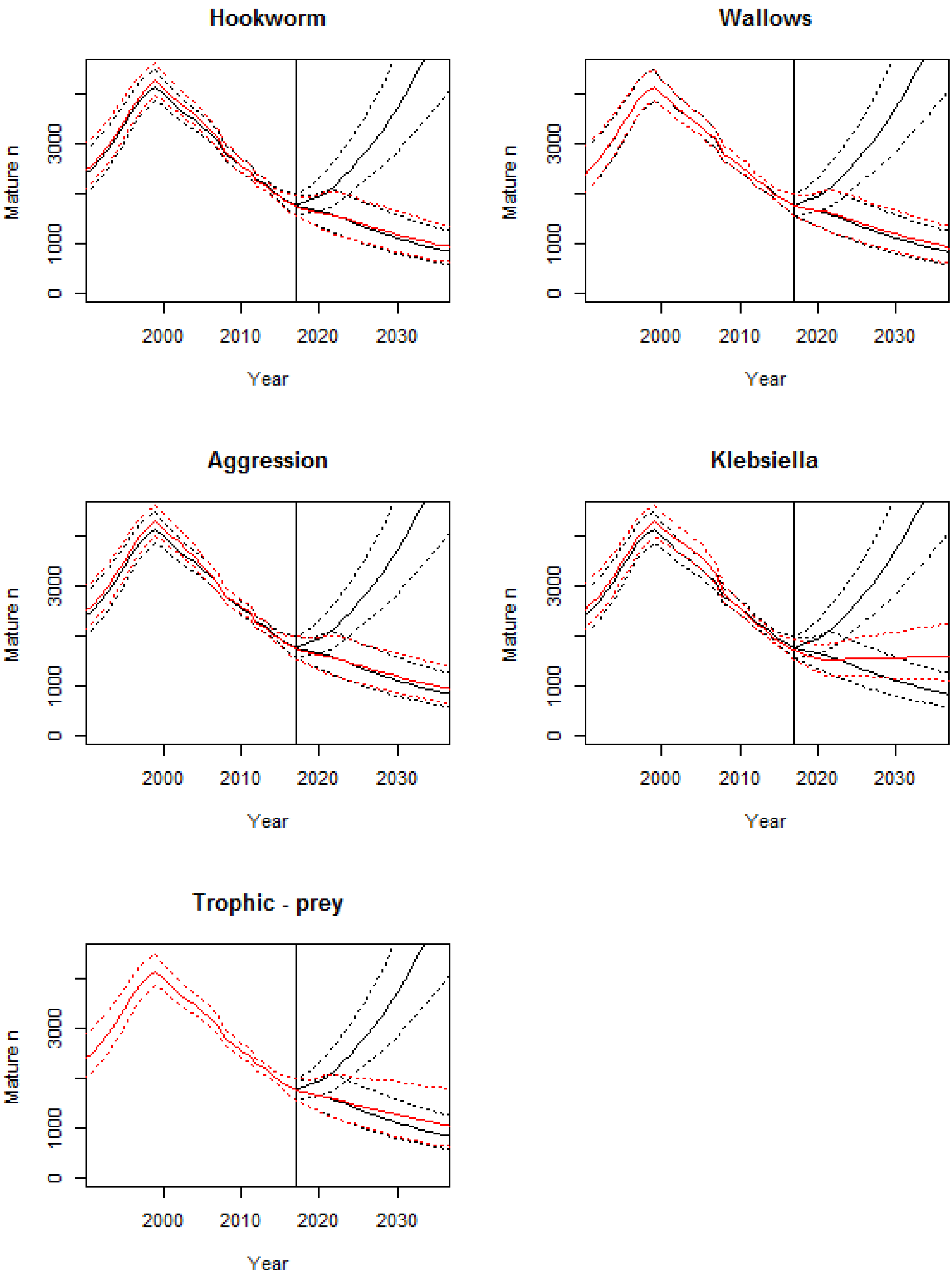

Figure 6: Model estimates of mature n at the Auckland Islands in the period 1990-2037 for all other threat scenarios. Black lines = with threat (base run) and max growth; red lines = threat alleviated.

4.3.2 Otago Peninsula

The MCMC projections for the Otago Peninsula threat scenarios are presented in Table 4 and Figure 7. The alleviation of the best estimate for the risk of deliberate human mortality results in the highest λ_{2037} of 1.093 (1.075-1.112).

Table 4 Otago Peninsula model estimates of mature female λ_{2037} and N_{2037}/N_{2017} for all threat scenarios. Values are median and 95% credible interval.

Threat scenario	λ_{2037}	N_{2037}/N_{2017}
Deliberate mortality	1.093 (1.075-1.112)	5.98 (4.28-8.33)
Entanglement	1.088 (1.070-1.106)	5.41 (3.89-7.49)
Male aggression	1.087 (1.070-1.104)	5.36 (3.88-7.32)
Set net	1.082 (1.065-1.099)	4.83 (3.52-6.59)
Base	1.070 (1.053-1.087)	3.89 (2.82-5.34)

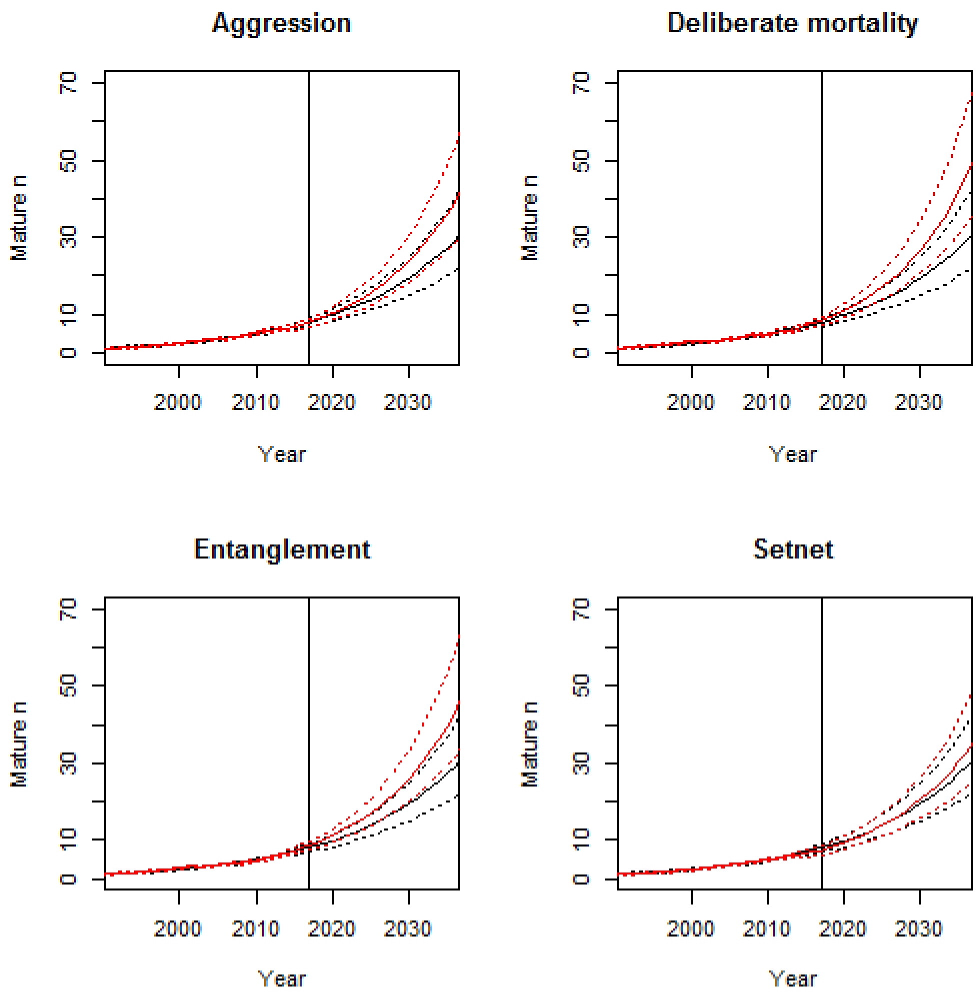

Figure 7: Estimates of mature n at the Otago Peninsula in the period 1990-2037 for all threat scenarios. Black lines = with threat (base run); red lines = threat alleviated.

4.4 Retrospective analysis of Auckland Island decline

Further modelling analyses were undertaken to investigate how much of the observed ~50% decline in pup production at the Auckland Islands since the late 1990s could be explained by the key threats that had passed through the risk triage process. To do this a retrospective analysis was conducted in which demographic rate estimates obtained from the best-estimate MCMC run for each of the key threats were used to project forwards from the year 2000 with removing any mortality associated with each threat (or using optimal demographic rates used in the case of trophic food limitation).

The following threats were assessed:

- Trophic (food limitation)
- Commercial trawl – interactions (i.e., assuming all sea lions exiting through SLEDs die)
- *Klebsiella pneumoniae* mortality of pups
- Hookworm mortality of pups

The timing of the effect of each threat on mature numbers varied because some threats operate on different age groups and the trophic impacts of food limitation were applied only from 2005-2008. As such it was not a fair comparison of the effects of each threat with respect to the mature *N* in 2015, although it does give an indication of the effect on the threat on the population trend.

None of the threats assessed was sufficient alone to explain the observed decline in pup production at the Auckland Islands (see Figure 8 and Table 5). The alleviation of *Klebsiella pneumoniae* mortality of pups had the greatest effect on population growth rate (λ_{2015} = 0.98, 95% CI = 0.94-1.01) relative to the base run (λ_{2015} = 0.94, 95% CI = 0.91-0.98).

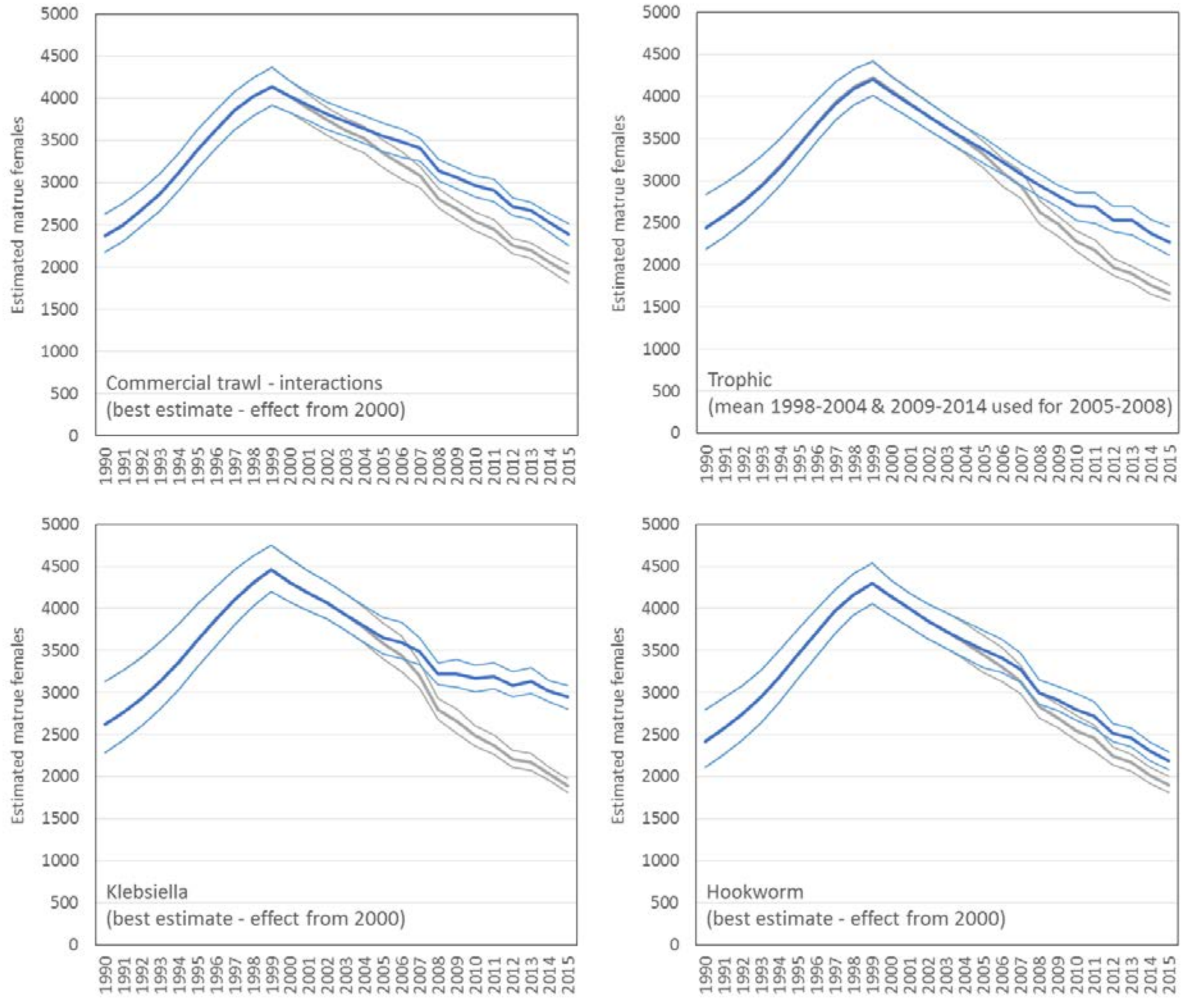

Figure 8 **Predicted mature *N* by year comparing the base run – mature *N* with threat affecting population (grey lines) and run with the threat alleviated (blue lines). Heavy lines are median estimates and light lines are credible intervals.**

Table 5 **Projected growth rate of mature *N* (λ_{2015}) and population status in 2015 N_{2015}/N_{2000} (%)**

Threat	λ_{2015}	N_{2015}/N_{2000} (%)
Klebsiella	0.98 (0.94-1.01)	68 (63-73)
Trophic (prey)	0.96 (0.92-1.00)	56 (52-61)
Hookworm	0.95 (0.92-0.98)	53 (49-57)
Commercial trawl – Interactions	0.94 (0.91-0.97)	59 (55-64)
Base run	0.94 (0.91-0.98)	47 (44-51)

5. Results Campbell and Stewart Islands

As outlined in Section 3.3 there was not sufficient data available to build demographic operating models for the Campbell Island sub-population and Stewart Island breeding area. For these areas, priority threats were identified through the threat characterisation process (see Section 3.5). This process included review and input by the expert panel, primarily during the first workshop (Appendix 3), and was later supplemented by advice during the second workshop (Appendix 4).

5.1 Campbell Island

Priority threats identified to the Campbell Island sub-population were:

- *Klebsiella* disease
- Interactions between trawl gear and sea lions
- Holes at key breeding sites at Campbell Island
- Pups, and occasionally females, injured or killed by aggressive male sea lions

5.2 Stewart Island

Priority threats identified to the Stewart Island breeding area were:

- *Klebsiella* disease
- Climate and environmental change causing depletion of food resources
- Interactions between set nets and sea lions
- Interactions between people and sea lions

6. Discussion

The risk assessment process described in this report identified the most important risks to each New Zealand sea lion sub-population/key breeding area using a variety of methods and allowed appropriate management options to be developed to allow for recovery of the species. In addition, the modelling tools developed allowed an assessment of the degree to which individual threats may have contributed to the observed population decline, and will allow for a quantitative assessment of progress towards achieving stated management goals.

The sub-population with highest conservation concern is that at the Auckland Islands, where the greatest declines have been observed. Results from the risk assessment suggest that alleviation of any one threat will not result in the population increasing. Similarly none of the major threats assessed were sufficient alone to explain the observed decline in pup production at the Auckland Islands. This included commercial trawl-related mortality, even with the most conservative view of cryptic mortality (all sea lions that exit trawl through SLEDs die, i.e. the trawl interactions option modelled) and associated loss of pups. Clearly multiple factors were acting on the population, and for management to recover the species a holistic view must be adopted.

The retrospective modelling also showed that disease-related mortality of pups could have a major effect on population growth rate if the best-estimates of annual mortality are realistic, but it would need to have commenced some years prior to the start of the decline in pup production to be the main cause of decline (given the delay to maturation).

Some threats are relatively well understood, with sufficient data available. However, other threats, such as trophic impacts, are less well known. The expert panel highlighted that the trophic risk was potentially underestimated, as the increase of the Auckland Islands sub-population during the 1990s demonstrates the ability of the population to increase under good conditions. Information on sea lion diet and prey availability is limited and the mechanism of any trophic effects and the underlying drivers (e.g. indirect fisheries effects vs climate/oceanographic changes) were not clear. Understanding the mechanisms of trophic effects will allow a better assessment of risk and assist in identifying the drivers, thus enabling appropriate management options to be developed if required.

Klebsiella disease is another ostensibly important threat where our knowledge is limited. If successful long term management of this threat is to be developed, a full understanding of the nature and transmission of the disease will be required.

The Otago breeding area contains small numbers of breeding females, making it susceptible to small levels of risks. The risk assessment has identified leading risks, such as deliberate human impacts, which must be managed to maximise future population growth to encourage the establishment of a new sub-population.

Although the risk assessment process was thorough and relatively complex, review by the expert panel identified aspects worthy of future exploration. The role and influence of any compensatory effects of the risks assessed was one such area. It is clear that multiple threats are acting on sea lions, and an understanding of how risks factors may interact will aid the prioritisation of management actions.

A structured qualitative process with expert review was used to identify priority to threats to the Campbell Island sub-population and Stewart Island breeding area. This process collated available data on threats and allowed expert opinion to assess and supplement this data in a transparent way.

Considering how the risk assessment approach developed for New Zealand sea lions could be applied in other situations, it is clear that the rapid triage process was adequate to identify key threats, and thus could be relatively easily and quickly be applied in other situations to allow rapid development of management actions. One of the greatest values in the more in depth modelling aspects of the risk assessment was that it allowed for better measurement of progress against management actions, however, developing these models is resource intensive and may not always be necessary.

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9. Appendices

Appendix 1. Threat scenarios

Appendix 2. New Zealand sea lion pup mortality workshop: notes

Appendix 3. Development of the Threat Management Plan for New Zealand sea lions: NZSL Threat workshop 1

Appendix 4. Development of the Threat Management Plan for New Zealand Sea Lions: NZSL Threat Workshop 2

Appendix 1: Threat scenarios

Table 0-1: Summary of threats used in Auckland Islands Triage projection models for all threat scenarios assessed. Threat levels are upper bound values.

																	Numbers killed													
Threat scenario (upper bound)	**Demographic group**	**Threat type**	**Age**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Male aggression	Adult	Numbers killed	5+	0	0	0	0	0	0	0	0	0	9.1	8.7	8.4	8.8	8.1	8.4	7.9	7.6	7.0	6.7	6.6	6.1	5.8	5.4	5.3	5.0	5.0	5.0
	Pup indirect		0	0	0	0	0	0	0	0	0	0	3.2	3.0	3.0	3.1	2.8	2.9	2.8	2.7	2.5	2.4	2.3	2.1	2.0	1.9	1.8	1.8	1.8	1.8
	Pup direct		0	0	0	0	0	0	0	0	0	0	419.6	182.9	314.9	73.8	81.4	81.4	82.5	75.9	81.6	67.9	35.4	52.6	37.4	128.7	62.0	13.4	17.2	17.2
Entanglement	Adult	Numbers killed	5+	1.2	1.2	1.3	1.4	1.5	1.7	1.8	2.0	2.1	2.0	1.9	1.9	2.0	1.8	1.9	1.8	1.7	1.6	1.5	1.5	1.4	1.3	1.2	1.2	1.1	1.1	1.1
	Juvenile		1 to 4	5.2	5.6	6.0	6.4	6.9	7.4	8.2	8.9	9.4	9.1	8.7	8.4	8.8	8.1	8.4	7.9	7.6	7.0	6.7	6.6	6.1	5.8	5.4	5.3	5.0	5.0	5.0
	Pup		0	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Hookworm	Pup	Numbers killed	0	80.0	80.0	80.0	80.0	80.0	80.0	85.0	94.0	96.0	91.0	91.0	91.0	72.0	80.0	80.0	68.0	66.0	71.0	69.0	48.0	58.0	49.0	53.0	61.0	50.0	50.0	50.0
Klebsiella	Pup survival	Demographic rate	0														NA													
Shark predation	Juvenile+	Numbers killed	1+	12.0	12.0	12.0	12.0	12.0	12.0	12.8	14.2	14.4	13.7	13.6	13.6	10.9	12.0	12.0	10.2	9.9	10.6	10.4	7.1	8.6	7.4	8.0	9.2	7.5	7.5	7.5
	Pup		0	4.2	4.2	4.2	4.2	4.2	4.2	4.5	5.0	5.0	4.8	4.8	4.8	3.8	4.2	4.2	3.6	3.5	3.7	3.6	2.5	3.0	2.6	2.8	3.2	2.6	2.6	2.6
Tuberculosis	Adult survival	Demographic rate	6 to 14														NA													
	Pup indirect survival		0																											
Commerical trawl - captures	Adult	Numbers killed	3+	0.0	0.0	0.0	0.0	0.0	0.0	121.0	115.0	62.0	26.0	67.0	59.0	71.0	49.0	194.0	169.0	162.0	113.0	256.0	242.0	274.0	154.0	116.0	138.0	170.0	170.0	170.0
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	42.0	40.0	22.0	9.0	23.0	20.0	25.0	17.0	68.0	59.0	57.0	40.0	90.0	85.0	96.0	54.0	41.0	48.0	60.0	60.0	60.0
Wallows	Pup	Numbers killed	0	111.9	111.9	111.9	111.9	111.9	111.9	119.3	132.2	134.3	127.4	126.9	127.1	101.4	111.8	111.8	95.5	92.9	98.9	96.7	66.7	80.6	68.9	74.9	85.8	70.0	70.0	70.0
Trophic	Pup	Demographic rate	0																											
	Adult survival		6 to 14														NA													
	Adult pupping		4+																											

Table 0-2: Summary of threats used in Auckland Islands MCMC projection models for all threat scenarios assessed. Threat levels are best estimate values.

				Numbers killed																										
Threat scenario	**Demographic group**	**Threat type**	**Age**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Male aggression	Adult	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	8.7	8.4	8.8	8.1	8.4	7.9	7.6	7.0	6.7	6.6	6.1	5.8	5.4	5.3	5.0	5.0	5.0
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.0	3.0	3.1	2.8	2.9	2.8	2.7	2.5	2.4	2.3	2.1	2.0	1.9	1.8	1.8	1.8	1.8
	Pup direct		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	419.6	182.9	314.9	73.8	81.4	81.4	82.5	75.9	81.6	67.9	35.4	52.6	37.4	128.7	62.0	13.4	17.2	17.2
Hookworm	Pup	Numbers killed	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	104.9	182.9	240.8	72.2	73.8	232.2	129.5	87.4	93.9	78.2	47.2	0.0	18.7	51.5	71.4	0.0	8.6	8.6
Klebsiella	Pup survival	Demographic rate	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	315	131	55.6	474	605	359	371	457	491	409	260	431	131	283	373	301	310	310
Commerical trawl - Captures	Adult	Numbers killed	3+	58.5	10.5	40.3	8.8	18.8	55.3	74.0	77.0	38.0	16.0	44.0	31.0	30.0	14.5	27.0	22.5	19.0	13.0	11.5	9.0	9.5	6.0	5.5	6.0	4.0	4.0	4.0
	Pup indirect		0	20.5	3.7	14.1	3.1	6.6	19.3	25.9	27.0	13.1	5.6	15.4	10.7	10.5	5.1	9.5	7.9	6.7	4.6	4.0	3.2	3.3	2.1	1.9	2.1	1.4	1.4	1.4
Commerical trawl - 82% discount	Adult	Numbers killed	3+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	25.8	22.6	19.9	13.7	17.4	15.8	15.5	10.3	8.8	9.2	6.3	6.3	6.3
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	9.0	7.9	7.0	4.8	6.1	5.5	5.4	3.6	3.1	3.2	2.2	2.2	2.2
Commerical trawl - 35% discount	Adult	Numbers killed	3+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.8	73.5	62.1	56.1	35.1	48.4	42.6	46.7	26.8	20.1	22.9	15.0	15.0	15.0
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	25.7	21.7	19.6	12.3	16.9	14.9	16.4	9.4	7.0	8.0	5.3	5.3	5.3
Commerical trawl - 20% discount	Adult	Numbers killed	3+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.3	88.7	74.7	67.6	41.9	58.3	51.1	56.7	32.0	23.7	27.2	17.8	17.8	17.8
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	31.0	26.1	23.7	14.7	20.4	17.9	19.8	11.2	8.3	9.5	6.2	6.2	6.2
Commerical trawl - Interactions	Adult	Numbers killed	3+	58.5	10.5	40.3	8.8	18.8	55.3	74.0	77.0	37.5	16.5	44.0	41.5	45.0	29.0	109.0	91.5	83.0	51.0	71.5	62.5	70.0	39.0	28.5	33.0	21.5	21.5	21.5
	Pup indirect		0	20.5	3.7	14.1	3.1	6.6	19.3	25.9	27.0	13.1	5.8	15.4	14.5	15.8	10.2	38.2	32.0	29.1	17.9	25.0	21.9	24.5	13.7	10.0	11.6	7.5	7.5	7.5
Wallows	Pup	Numbers killed	0	56.0	56.0	56.0	56.0	56.0	56.0	59.7	66.1	67.1	63.7	63.5	63.5	50.7	55.9	55.9	47.7	46.4	49.4	48.3	33.4	40.3	34.4	37.4	42.9	35.0	35.0	35.0
Trophic	Pup	Demographic rate	0																											
	Adult survival		6 to 14														NA													
	Adult pupping		4+																											

Table 0-3: Summary of threats used in Otago Peninsula Triage projection models for all threat scenarios assessed. Threat levels are upper bound values.

Threat scenario (upper bound)	Demographic group	Threat type	Age	Numbers killed																										
				1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Male aggression	Adult	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Juvenile		1 to 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Entanglement	Adult	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Juvenile		1 to 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pup		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dogs	Pup	Numbers killed	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Klebsiella	Adult	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pup direct		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Shark predation	Juvenile+Adult	Numbers killed	1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
	Pup direct		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Deliberate human	Adult survival	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
	Pup indirect survival		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Setnet	Adult	Numbers killed	5+	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0
	Pup indirect	Numbers killed	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Vehicles	Juvenile+Adult	Numbers killed	1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	Pup indirect	Numbers killed	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0

Table 0-4: Summary of threats used in Otago Peninsula MCMC projection models for all threat scenarios assessed. Threat levels are best estimate values.

Threat scenario	Demographic group	Threat type	Age	Numbers killed																										
				1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Male aggression	Adult	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Juvenile		1 to 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0
	Pup indirect		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Entanglement	Adult	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Juvenile		1 to 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pup		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deliberate human	Adult survival	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0
	Pup indirect survival		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Setnet	Adult	Numbers killed	5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
	Pup indirect	Numbers killed	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Department of Conservation
Te Papa Atawbai

Ministry for Primary Industries
Manatū Ahu Matua

New Zealand sea lion pup mortality workshop: notes

Workshop held 10 June 2014
Place: Archibald Centre, Wellington Zoo, Manchester St, Newtown, Wellington

Facilitator: Sarah Wilson (Down 2 Earth Facilitation)

Attendance: Nigel French, David Hayman, Laureline Meynier, Sarah Michael, Wendi Roe (Massey University), Simon Childerhouse (Blue Planet Marine), Rob Mattlin (Marine Wildlife Research), Jim Roberts (NIWA), Katrina Goddard (Forest & Bird), Milena Palka (WWF), Barry Weeber (ECO), David Middleton (Seafood NZ), Richard Wells (DWG & FINZ), Vicky Reeve, Nathan Walker (MPI), Laura Boren, Katie Clemens, Igor Debski, Jim Fyfe, Kate McInnes (DOC)

Apologies: Ian Angus (DOC), Louise Chilvers (Massey University), Bruce Robertson (Otago University), Shaun McConkey (NZ Sea Lion Trust), Michelle Beritzhoff-Law (MPI)

Introductions and Opening

Workshop participants introduced themselves and the agenda was outlined.

A summary paper was pre-circulated, prepared by Simon Childerhouse, Wendi Roe and Jim Roberts. Workshop organisers thanked the authors and welcomed the paper as a useful background report for the workshop (Note: the background paper is available on the CSP website).

A question was raised as to why the pup mortality issue was being progressed ahead of the NZ sea lion Threat Management Plan (TMP) generally. It was clarified that Massey University wrote to Minister of Conservation asking for some tangible research and adaptive management techniques to investigate and address the high pup mortality during the coming field season. Due to time constraints in the development of the TMP and the researchers wanting to take action during the upcoming field season, the organisers saw this workshop as a parallel process running alongside the TMP and a way to potentially improve the situation in the interim.

Note: These notes set out the discussion held at the workshop. For background and context please refer to the pre-workshop report by Childerhouse, Roberts and Roe, 2014.

DOC provided an introduction to the workshop as follows:

- The main purpose of the day is to focus on pup mortality and in particular on what can be done in the next field season on the Auckland Islands to make a difference.

- This workshop has brought together the leading experts to focus on the question of pup mortality so that we can get permits in place in time for the next field season (December 2014 -January 2015). Getting the necessary permits in place and fulfilling our obligations to consult with Ngai Tahu takes approximately 5 months so this workshop has been arranged at this time to enable these timeframes to be met.

- The results of this workshop and any further work will also inform the broader TMP process. We acknowledge that this workshop of pup mortality is occurring ahead of the rest of the TMP process. In simple terms this is because we do not want to miss any opportunity to put in place research and management measures as soon as possible for this Nationally Critical species.

- Along with MPI, DOC is working hard to put together a robust plan for the TMP process. For the purposes of this workshop we are not going to go into much detail about that. Except to say that over the next two years DOC and MPI will be putting a lot of effort into understanding all the threats and acting as fast as possible to reduce and reverse the decline in the sea lion population.

- Where issues come up today that relate to the broader TMP process then we will make sure these are recorded. However, it is vital that in the short time we have that we focus on pup mortality.

Discussion followed about the timeframe for the New Zealand sea lion TMP and ensuring that people are informed and engage with the broader process.

Background and context for pup mortality

1. **Simon Childerhouse's presentation**
   (Note: all presentations are available and will be posted on the DOC website)

   Simon presented his experience with the Auckland Islands field programme. He outlined the background to the work and presented the population data. He also outlined his experience of the pup mortality issues on the Auckland Islands including rescue of pups from holes and terrain traps.

Matters for clarification:

Pups getting caught in holes:

This has always been a problem on Dundas Island, the field team has added ramps in some holes to allow pups to climb out, but never done so on Enderby Island. Louise Chilvers perhaps didn't flag this as an issue in the past as the pups are usually more spread out over Sandy Bay and don't always move into the areas with large holes. This year they spread out over a larger area with more holes. The team built ramps to help some get out. In total 70 pups were removed from holes prior to the ramps being built. However, tag numbers were not recorded so some of these pups may have been removed multiple times. Alternatively, some years no pups fall in holes because they move into different areas of the sward and forest where holes are not so common.

The team came back from the field season impassioned about this issue as it seemed like a tractable issue where we could improve the outcome for some pups. We recognise that pup mortality in holes is unlikely to be the main driver of population decline, but it is an issue that we can do something about in the short term. If this is done, it is unlikely to lead to an increase in the population, but may slow the decline. Anything we can do to improve the situation for this species, regardless of how small the positive benefit may be, should be done.

The workshop participants agreed that it would be useful to know what is happening at Campbell Island and the other colonies with respect to relative pup mortality, including mortality in holes.

2. Wendi Roe's Presentation

Wendi presented the background on causes of NZ sea lion pup mortality. Including preliminary and definitive diagnosis basied on necropsy work on the Auckland Islands. Causes discussed included pup mortality from:

- Bacterial infection (*Klebsiella pneumoniae*)
- Hookworm
- Stillbirth
- Trauma
- Congenital abnormalities
- Starvation.

Matters for clarification:

Klebsiella species are bacteria commonly found in both the sea lion and the human gut, and also in the environment, but not the "sticky" strain that we are currently seeing in NZ sea lions.

We've never seen the "sticky" strain in adult sea lions, but this hasn't yet been fully investigated. We know that the bacterium can survive in the environment, but not for how long and under what conditions.

Were the pup mortalities that were historically attributed to "trauma" actually bacterial infection?

Yes, some of them were likely to be that. Infection and trauma are also likely related – for example, it's easier to pick up a pup that's sick and shake it than to do so to a healthy one.

Klebsiella is now being seen in every breeding season, and is now thought to be the leading cause of pup death.

Are birds possible vectors? That hasn't been a focus of research projects so far, but possibly. Adult sea lions could also be vectors, or other species on the island.

Does *Klebsiella* survive in salt water?

Not as well as it does in fresh water, but yes. may as Again, we'd need to do some experiments to determine how long it could survive in salt water, and whether it was still as virulent after a while under these conditions.

In 2002 and 2003, we felt confident that we were capturing the number of pups dying since the deaths peaked earlier in the season, but since 2007 we aren't, as mortality is potentially occurring after the field team leaves the island.

3. **Sarah Michael's Presentation**
Sarah was the vet on the Auckland Islands during the 2013/14 field season and is an undergraduate student under Wendi Roe at Massey University. She presented the results of her necropsy work and details relating to pup mortality from bacterial infection.

Matters for clarification:

The pups are only dying of infections caused by the "sticky" strain of *Klebsiella*. We don't know if the bacterium has changed since the 2001/02 mortality event, but this is part of an ongoing PhD study. The mortality event that occurred in 1998 was probably caused by a completely different bacterium.

Could *Klebsiella* be getting in through the tag wounds?

Klebsiella is probably infecting pups through multiple sites, and the lesion patterns suggest that it would be from multiple routes of infection (for example inhaled, ingested, through bite wounds). The tag wounds don't look too bad under the microscope, but we would need to do some further studies to see if there is any evidence of *Klebsiella* infection in the wounds.

Were you recording where you were finding the pups?

Not GPS coordinates, but detailed and descriptive locations were recorded.

The problem is that they're moving around and end up clustered anyway. They don't die in the same place as they picked up the infection.

Do a certain proportion of infected pups recover?

No, not once it has reached the brain, then its terminal. Once pups are visibly showing signs of infection, they die within a day or two.

Do they have any natural resistance to the infection?

We're not sure, but it's a highly virulent bacteria which would kill most of them. If it got into the brains of contracted humans who were properly treated in hospital, it would still kill about 80% of people. We don't yet know how (or if) pups mount an immune response to this pathogen.

There was discussion about the fact that we don't know if every pup encounters this strain and whether they all die or if the only ones that encounter it are dying, and we won't know about inherent resistance, any changes in resistance, etc. The chances of a pup getting sick from this bacteria probably depend on the 'dose' of the infection (whether they come into contact with large numbers of bacteria or only a few) as well as the route of infection (wound, inhalation etc) and the response of the pup itself.

What's the antibiotic resistance for this strain?

Massey has a PhD student working on that currently.

There was discussion about whether it was possible that a pup's parasitic burden is affecting and lowering the pup's immune system, and whether gut trauma caused by parasites could be another possible way for the pup to become susceptible to bacterial infection. Aurelie Castinel did some work on this as part of her PhD, and found that it was unlikely that hookworm were transferring bacteria from the gut into the abdominal cavity or blood stream.

4. Jim Robert's Presentation

Jim presented preliminary findings from his population correlation research as they relate to pup mortality.

Matters for clarification:

As with other pinniped species larger pups appear to have a greater probability of survival. Changes in pup mass at 3 weeks appear to relate to the mean age and reproductive history of breeders, i.e. whether the mother concluded energetically-costly lactation in the previous year.

Between 1998 and 2004 the breeding population of females at Sandy Bay appeared to be in synchrony, with a large proportion producing small pups with a low probability of survival in one year (e.g. 1997/98, 1999/00, 2001/02 and 2003/04) and large pups with a high probability of survival in the next (e.g. 1998/99, 2000/01 and 2002/03). This suggests that during this period resources were insufficient for females to produce pups with a high probability of survival in consecutive years and that poor maternal nutritional status may have compromised pup survival.

in addition, it appears that maternal survival was compromised by high pup survival (and completion of lactation) in the previous year. This has lead to alternate years of high and low adult survival related to reproductive status (similar to some albatross species).

The results pre-2004 with regards to female survival (non-breeders vs. breeders), why do you feel that is a trend?

Preliminary results from a demographic assessment indicated very low survival of non-breeders during the period that pup/yearling mortality was high. It is not clear how these are related, though it does suggest that high pup mortality post-2005 is related to processes affecting the survival of breeding-age females.

5. Laureline Meynier's Presentation

Laureline presented her research findings on diet analysis and NZ sea lion nutrition as it relates to pup mortality and breeding success including lactation.

There was discussion about the foraging habits of NZ sea lions, the data Louise Chilvers collected in her diet analysis from January – February, the winter foraging report done by Simon Childerhouse, the switch in behaviour (i.e. deeper diving) in winter foraging and the types of prey that the animals preferentially select.

There was discussion relating to the change between January – February in percentage of milk lipid content which is attributed to the increase of lipid content as lactation continues (i.e. females feed more/produce milk with higher lipid content).

There was a lengthy discussion about the lack of samples from outside the breeding /CSP field work season and the need to gather further samples as well as analyse existing samples to get further information.

6. Rob Mattlin discussion about Campbell Island (no presentation material)

NIWA and MWR are looking at the foraging distribution of females and young males from the Campbell Islands. The females and young males that have been satellite tagged are going across the shelf to other side of the island to feed, but remain on the shelf the whole time. Jim Roberts was there last year, and he did diet research.

Jim clarified that he found small-scaled cod appeared to be the main finfish prey species - these are the most abundant fish species at the Auckland Islands over shallow rocky reefs. The sea lions are foraging right around Campbell Island at 20-30m, but as they get older, are sometimes diving deeper, down to 200-300m.

There was discussion that other marine associated species (i.e. Gibson's albatross) have shown changes, including foraging areas, since 2005.

List of affecting factors

Participants were asked to suggest any factors affecting mortality in addition to those identified in Table 1 of the pre-circulated paper.

There was agreement to add starvation to the table of factors, additional to nutritional stress. Starvation would be attributed to a pup losing its mother (either lost or abandoned), prolonged foraging trips by the mother or poor milk quality/output.

What can we do, and information gaps, as related to the table of affecting factors

1. Historic samples and data:

We have a considerable number of historic samples archived around the country. We should look at tissues from dead pups from previous years and analyse other samples (i.e. milk and serum samples, etc.). We've only partially analysed the old samples, but science has advanced quite far in the last decade so we could get more information out of the samples now.

In short, there was broad support for the analysis of historic samples so as to learn more about such things as: evidence of disease, nutritional status etc

2. Pups falling into holes and dying

This year, it was estimated that as many as 70 of the 400 pups born at Sandy Bay fell into holes and most likely would have died if they had not been rescued. We should mitigate the problem of pups falling into holes, as it would be relatively simple to achieve and could be undertaken during the normal field season. There was discussion about trialling methods to better understand this interaction and also to understand any benefit from actions (e.g. cameras or transponders). There are some simple mitigation measures that could be used to keep pups out of the holes (e.g. stairs, ramps, escalators, rescue, fences etc).

The disease outbreak prompted a longer field season where we observed that the pups moved to the eastern area where the holes are more prevalent. If the season had not been extended we wouldn't have known it was an issue or been there to retrieve them from the holes. It is important to stay on the Auckland Islands longer to understand additional pup mortality caused by pups falling in the holes and disease.

If we can quantify whether the pups which fall into holes also end up infected or were infected with *Klebsiella* then we can look for an association between the two. We need a case control study, to understand more about pups falling into holes as well as infection and transmission of *Klebsiella.*

We collected substrate samples (sand, mud, water), which were show to contain Klebsiella, but only from later in the season (i.e. the pups could already have infected the substratesand). We should test the environment earlier, i.e. before breeding, and in other locations.

3. Hookworm

Hookworm can be treated with Ivomec orally or by injection. The pups or the adult females can be treated, as hookworm is transmitted to pups through the mother's milk. We need a proper study to see if Ivomec actually works including monitoring its effect which will require a control study.

Repeat treatments of Ivomec are required. If all pups were treated, but treatment was not repeated sufficiently to break the cycle, it is possible to create resistance of the hookworm to the drug.

Louise Chilvers' preliminary work showed that treating with Ivomec has no effect in a normal year, but in years where there were increased bacterial deaths, treatment with Ivomec for hookworm improved pup survival. It was noted that longer term survival of the Ivomec treated individuals could be examined, but has not been done to date.

If trialling Ivomec, it would preferable to use bigger sample sizes than were trialed previously, along with a control group.

4. *Klebsiella* infection

There was wide ranging discussion regarding information gaps and actions as summarised below:

- There was discussion about the development of a rapid **PCR test** that could be used *in situ* for detection of *Klebsiella*. Massey University has some research underway, albeit at PhD pace. Although in theory this development can be done more quickly, it is an iterative process. Care would be needed to avoid false positives. There was discussion about the state of technology and the cost involved in determining whether a particular sample of the bacteria is still virulent (currently we need to grow the bacteria to do this).

- Is the same disease in other species (i.e. in NZ fur seals?)

Yes, but not in the same way. It is present in California sea lions, but it affects mature animals and is not as virulent.

- Is Klebsiella an issue on the main breeding areas? (e.g. Mainland NZ, Stewart Island, Campbell Island and the Auckland Islands).

  There was discussion about the relative trends in mortality exhibited at the different sites. Sandy Bay and Dundas, the 2 largest breeding populations on the Auckland Islands, show a similar trend in population but we don't know the reasons for pup deaths on Dundas since no post mortem work has been done there. A very small number of pup post mortems were done on Campbell Island pups in 2007/08, but not enough to be able to work out the major causes of mortality there. It was noted that one pup in Otago has died of Klebsiella infection.

- Can we develop a vaccine?

  Yes it is possible, but could take millions of dollars and at least 5 years of research.

- What about treatment?

  That's technically possible but not recommended. By the time you can see clinical signs, they're more than likely to die anyway. There are disadvantages to treating, such as antibiotic resistance, the fact that you would need a broad spectrum antibiotic to kill only *Klebsiella* but not the animal's natural bacteria. It would also need to reach the brain and the joints, which is difficult and not common in antibiotics.

- We need to determine the bacterial landscape (i.e. is it in other species, accumulation over time, etc.)

- It seems to be present in middle of the islands, and the animals aren't. There was discussion on seabird sampling, whether or not samples have been taken, and that they should be collected in the future. Previously collected samples are suitable enough for historically determined information. There was a discussion about the fact that cattle were present on the island until 1992 and whether *Klebsiella* could have originated from them, although this seems extremely unlikely as sticky Klebsiella has never been isolated from cattle...

- It was suggested that the Sustainable Seas National Science Challenge (or possibly New Zealand's Biological Heritage NSC) could have a role in implementing surveillance programmes on the health of protected species populations.

- There was discussion surrounding the fact that we need to better understand the immune response, and to figure out which antibodies would be present.

- Infected tag wounds – Is that a potential source of infection? Do we need more research on that to see if it is something to consider doing less of? They are a potential site for bacteria to get in, and if our aim is to decrease ways of infection, that might be an idea. There is a risk of infection due to creating an open wound(the tag hole), but not from the process of tagging itself as the tagging instrument doesn't directly contact the skin.

- There was further discussion on the need to examine archived samples, take samples from other species, the potential for the shedding of the bacteria in faeces, and the infectiousness of the bacteria.

- *Klebsiella* is unlikely to have originally been of human origin.

- What about the relocation of sea lions to other areas? Is this a possibility – setting up new colonies? Discussion ensued on the possibilities and inherent difficulties of attempting to establish new colonies through relocating NZ sea lions, and the fact that a successful relocation has never happened with otariids. Overall not a high-ranked option.

- Case control studies (i.e. use a concurrent case control design) were viewed as a priority, to compare pups that have the disease to healthy pups and comparing a whole range of risk factors, including maternal factors as well, to get an idea of risk factors of getting the infection and dying from it. Identify one infected/dying pup, track down its mother, collect all relevant variables, and then select 3 control individuals to get maximum confidence and measure for same variables. This idea was well supported.

- There was discussion about the future necessity to have the capacity to determine and respond to issues like this in the future, such as gaining a general awareness of disease issues to prevent events like this in the future. Discussion then turned to debate the mortality event of 1998 and whether it would be possible to examine samples from that year to better determine the cause of the event.

In summary: Once the infection is in their brain there's nothing practical that we can do to treat it. Once infection is in the bloodstream then there's probably little we can do unless it could be diagnosed early and we had done some studies to determine if a particular antibiotic would be effective. Antibiotics would need to be given over a period of days to weeks to be effective. A vaccine which could be preventative is extremely expensive and years away. There is the possibility that we can do testing for site prevalence and then take extreme care to limit any possibility of exposure.

5. Nutritional stress

There was discussion about needing to collect samples of pup weight over time, looking at milk content as well, the methods for measuring milk production, and the process for catching and anesthetising females to obtain the necessary samples. This information has been collected in the past, but intermittently - Louise Chilvers has information for a few years at Sandy Bay, and Simon Childerhouse has information on pup growth on Campbell Island. Also Martin Cawthorn did work in the 1980s, so we have data to compare with.

It was suggested that we get tracking data about individuals/colonies movements throughout the year. For now we assume that they're foraging in the same place all the time. There's also winter data that suggests that it is the same place but deeper. If we did track the sea lions throughout winter, we could have 8 months of continuous data prior to moulting. We could then collect foraging data through summer, and get scat samples to analyse as well. Regurgitates are also important as they reveal a different species composition.

Research so far has generated time series of diet, pup mass, etc., and the information is pointing to nutritional stress exerting negative effects on the population. There appear to be yearly effects as well as monthly effects. Hiowever, there are gaps in the time series that could be filled by analysis of samples or other methods.

There was discussion of a study being conducted at NIWA involving isotope analysis in sea lions from teeth. Samples (where possible) are to be collected from NZ sea lions to assist with this work.

We need to come up with ways to improve the understanding of the nutritional stress of the population. Are there things we can do with existing samples that will help us see through time if/when they are becoming nutritionally stressed? We also need to look at what happened in 2000 and 2005. Can we look at isotopes in blood serum, vitamin D levels in bone, teeth; look for pathogens in serum?

We should also consider future proofing, i.e. we need to include minimum database of things (i.e. samples) that need to be collected every year. Or maybe re-capture the same individuals every other year.

There was discussion on previous attempts at developing a body condition score, how it is measured (blubber layer size is a good proxy), and why the attempt to do so didn't work (improperly calibrated ultrasound). Most studies show that weight divided by length is just as good a measure.

There was discussion about the possibility of examining body condition in two groups of females (benthic and mesopelagic). Tagging wouldn't be necessary to conduct such a study; it is possible to do stable isotope analysis in this case from skin samples.

6. Injuries

Up until now, the Auckland Islands field team have never treated any animal, as they have always felt that it is a natural system and that these are natural events. However, they now believe that there's no reason not to help some of those that we can. Such actions are unlikely to halt the decline, but it could be done with minimal additional cost and effort. However, it would require specialist veterinary advice.

Massey vets believe that we should at least be euthanising animals that are obviously dying. It was mentuioend that euthanising infected animals may also limit some of the transmission of disease.

A **triage system** needs to be established, detailing whether to save, treat or euthanise. .Such a triage system would need to be very clear and detailed, and written out with examples. There was continued discussion about the level of detail that would need to be involved in the triage system, and the need to properly determine which injuries are commonly seen, and which would be treatable within reason.

7. Pup Starvation

We need to address information gaps in the starvation data.

Should we consider supplemental feeding of pups? For those pups whose mother is absent from the colony – should we keep feeding them in the field? Take them into captivity? It was noted that sometimes the mothers can be away from the colony for some time and return later.

We also have to consider what to do about skinny pups that are simply not getting enough milk and whether giving them a top up will help reduce their sensitivity to adverse effects in the environment.

There are potential issues related to supplementary feeding, such as:

- Breaking the bond with the mother, will she stop feeding it?
- Supplemental feeding will also produce a larger pup, and put more stress on the mother
- It could potentially be high risk and very difficult/impossible to do.
- Most of the starving pups are starving because they simply can't find their mother.
- the animals might imprint on humans and become a nuisance.

What about females with mastitis, and perhaps a link from that to *Klebsiella* infections?

We have milk samples from females that get caught for tagging, and so far haven't seen any really grossly mastitic individuals. But we wouldn't know if it was present if the females with mastitis had already abandoned their pups. We could do somatic cells counts and/or cultures on milk samples to see if it's possible.

8. Impacts of human intervention (tagging and capturing)

Currently, there's increasing levels of scrutiny on all work with animals, and two potentially conflicting views – reducing impacts on endangered species, and the need to get more data. Somehow we must reach a compromise between these two views. These animals have been intensively researched for 20 years, and are among the best researched endangered marine species, yet there are still significant gaps in our information. We've got a team down there for 1-3 months/year, tagging and capturing animals – we need to think really hard about what we're doing and why. We're going to need to better justify not only why we're tagging but also how many we need to tag.

There was discussion on the benefits of running a study (such as PIT tag all individuals and flipper tag half of the group, and compare for effects) to determine the impacts and effects of flipper tagging, and whether one method of tagging or another is exposing pups to infection with *Klebsiella*. It was also noted that PIT tagging has issues, caused by migration of the tag, making it impossible to read. There was also discussion about ways to read PIT tags remotely.

There was discussion on the use of branding as an alternative marking to tagging and chipping. Previous hot branding had produced some undesirable results, however it was noted that other researchers have developed cold branding techniques that could be worth investigating.

The group discussed whether halting tagging at Dundas was an option as there has been no follow up resighting effort there since tagging started 16 years ago. Dundas is the largest population containing about 60-70% of the entire NZ sea lion population. Examining 20% of a large colony might show similar results to examining 100% of a smaller colony. A range of views were discussed.

We need to figure out what questions we have and then work out how best to proceed to answer them including optimal study sites, methods and numbers of animals.

There was discussion about genetic tagging, how it is done, and the feasibility of employing it as an alternative to other tagging methods.

Wrap-up: mitigation methods/ways to increase knowledge base

Following a round of each participant stating their views, there was broad agreement that the following work needs to be further considered for the upcoming field season:

a) Dealing with pups falling in holes should definitely be addressed during the next field season.

b) *Klebsiella* work is a priority (i.e. additional environmental sampling to understand the bacterial landscape, the genotyping and development of PCR and the concurrent case control study)

c) Running case control studies over 2 seasons, including Ivomec and tagging studies, all running concurrently.

d) More work could be done to explore existing data sets and samples – work that needs to be done as a priority before the 2014 field season needs to be identified.

e) A longer field season should be considered to work out the extent of pup mortality later in the season.

f) For animal welfare/logistics – looking at tagging and investigating other tagging techniques that could replace current used ones, not only to mitigate Klebsiella transmission but also other stressors.

g) need to further examine nutritional stress.

Closing remarks

DOC said that the key points and presentations will be circulated – initially to participants and then to a broader audience.

DOC will need to look at achievable options for the next field season, based on what is going to be done as part of the CSP work. Any addition to the programme will be added on the back of the CSP-project, but will need to have its own source of funding. However, it can run concurrently with the CSP-funded project to make best use of time and resources.

MPI noted that the TMP will be focused on next 5 years, and hopefully it will be able to pick up on the longer term work.

Appendix 1: New Zealand sea lion pup mortality workshop: notes

Table 1: DOC and MPI summary of the potential research and management interventions as suggested during the pup mortality workshop, with subjects arranged across time frames with rough cost estimates.

(**Note**: this summary material was prepared after the workshop by DOC and MPI and is appended for information only.)

Short term	**Cost**	**Field season**	**Cost**	**Long term**	**Cost**
Ramps for holes (permissions, build, monitor)	$$	Implement in field			
		Longer field season (disease mortality profile)	$$$		
Develop triage protocols	$	Implement in field (requires vet) Vet present through field season (necropsies, triage etc)	 $?		
Design case control study (Nigel French)	$	Case control study (including pup weights)	$		
Analysis to determine appropriate level of tagging and resighting Review tagging methods Tag injury followup (Massey)	$ $ $				
Develop field protocols for Klebsiella testing and collection of other samples	$	Environment and other potential host sampling Opportunistic sampling (other field trips/reps, other sites) for regurgitate, scat, environment, pup weights (Lab costs)	 $$	Klebsiella vaccine development and implementation Year round (monthly) sampling of regurgitates, scat, pup weights, environment, other potential hosts	$$$$$ $$$

Table 1 [Continued]

Short term	**Cost**	**Field season**	**Cost**	**Long term**	**Cost**
Develop PCR approach to improve sampling for Klebsiella (scoping initially, fast track, field testing possible?)	$$				
		Monitoring at other sites (especially Campbell Islands)	$$$		
Ivomec - initial steps (analyse long term survival from previous study, treatment options/method)	$	Ivomec trial in field (with control)	$$		
Review Baker report re: 97/98 disease outbreak	-			Campylobacter type disease samples (could do short term if priority and funding)	$$

Development of the Threat Management Plan for New Zealand sea lions: NZSL Threat workshop 1

Purpose of Document:

This document provides a process summary on progress in developing a Threat Management Plan (TMP) for New Zealand sea lions (NZSL). It reports at a high-level on Workshop 1 and seeks to provide context around the threat characterisation spreadsheet and expert panel recommendations.

Background:

For further information on the process involved in the development of the New Zealand sea lion TMP, please see http://www.doc.govt.nz/nzsl-tmp.

Risk assessment forms a key work stream in the development of the New Zealand sea lion TMP. The first major milestone of the risk assessment process was a multi-stakeholder workshop held in Wellington between 28 April and 1 May 2015.

The purpose of the workshop was to identify and consistently characterise the threats to the New Zealand sea lion population, as well as review the demographic model's suitability to assess risk. For More detail on the purpose of the workshop see **Appendix 1**.

Invited subject matter experts were present in the capacity of "Advisors" to provide support to an Expert Panel on their particular topic of expertise and to provide feedback to inform the threat characterisation.

The Expert Panel was comprised of four invited national/international persons with expertise relevant to the assessment of risk to the sea lion, who were considered independent of current New Zealand sea lion research or management. A list of participants is included in **Appendix 2**.

The Expert Panel took part in the identification and characterisation of threats, and reviewed the sea lion demographic population model which will be used to assesses key threats and inform latter steps of the TMP process.

Workshop 1 Outputs:

The workshop provided two key outputs,

1. A list of prioritised recommendations from the Expert Panel on: the demographic model, monitoring and research, risk characterisation, mitigation, and the threat assessment modelling process (**Appendix 3**); and
2. A list of threats (**Appendix 5**) which have been characterised by Advisors and confirmed by the Expert Panel. This characterisation will be used to inform the risk assessment model. Where possible the characterisation was based on evidence and plausible estimates of impact were made, however for most threats only upper and lower bounds of the impact were estimated. Impacts of threats considered to be data rich were not characterised at the workshop as they will be more effectively assessed through a quantitative method.

An initial list of threats was populated which outlined all possible pathways through which a threat could impact the population.[3] While DOC and MPI acknowledge all of these potential threats, for many of them there is little to no information, nationally or internationally, on how they impact a pinniped population. It was therefore proposed by the TMP Project Team and agreed on by the Expert Panel that these threats were removed from the list for the time being so that the workshop would focus on threats which could plausibly be characterised within the TMP. Some threats were also aggregated to help improve the characterisation.

Even after refining the list of threats it was not possible to characterise all of the remaining threats within the workshop timeframe. To ensure all direct threats were characterised for the TMP, workshop attendees agreed to a process by which DOC and MPI would contact relevant Advisors after the workshop to help characterise any remaining threats that were not addressed at the workshop. All threat characterisations conducted after the workshop were circulated to all Advisors and Expert Panel members for review and feedback prior to the list of threats being finalised.

Next Steps:

- July/August 2015 – High and medium priority recommendations from the expert panel members that relate to the demographic model will be incorporated and presented at a DOC (CSP)/MPI (AEWG) technical working group to update stakeholders on the progress of the model development. The Panel's recommendations on monitoring and research, risk characterisation, and mitigation will be used to help develop management options for the TMP
- July/August 2015 – A stakeholder meeting will also be held to discuss the draft management objectives and targets for the three high-level goals of the TMP.
- September 2015 – The second TMP workshop will be held where the same Expert Panel will review the outputs of the risk assessment model.
- October/November 2015 – A progress report will be released to stakeholders to update them on the outputs of the second workshop.
- October/November 2015 – The outputs of the second workshop will be used to inform the development of management options that make up the TMP.
- January 2016 – Draft management options will undergo public consultation.
- April 2016 – Final advice presented to Ministers.

For updates on the process moving forward visit the Department of Conservation website: http://www.doc.govt.nz/nzsl-tmp.

[3] There were 137 threats initially listed

APPENDIX 1: Threat Management Plan Workshop Terms of Reference New Zealand sea lion Threat Workshop 1 – Development of the TMP

Introduction

There are concerns for the New Zealand sea lion (NZSL), primarily because pup production at the Auckland Island, the main breeding area, has been in a decline for over a decade. In 2014 the Minister of Conservation and Minister for Primary Industries instructed officials to begin work to develop a Threat Management Plan (TMP) as a means to further the recovery of the species throughout its range.

A number of potential factors are thought to be contributing to the sea lion decline. In developing the NZSL TMP it is envisaged that the Department of Conservation (DOC) and Ministry for Primary Industries (MPI), in consultation with iwi and stakeholders, will look at all potential threats to all breeding sites, and develop management options to minimise or mitigate key threats to the sea lions.

A plan and timeline for developing the NZSL TMP was agreed by Ministers in April 2014. An integral part of developing the NZSL TMP is conducting a comprehensive risk assessment for the whole sea lion population. As the amount of information on each possible threat to sea lions varies it has been decided that two workshops will be needed to inform the risk assessment. This April Workshop is the first of the two.

More details on the April workshop is provided below, but very broadly speaking the first workshop is focused on an initial review of the developing sea lion demographic model and to consistently characterise the threats to the NZ sea lion. The second workshop will be focused on reviewing the outcomes of the risk assessment.

The outputs of the risk assessment will be used to inform management options that might make up the NZSL TMP. Prior to the finalisation of the NZSL TMP and to aid decision-making, a public consultation over the draft NZ TMP will be undertaken. It is expected that Ministers will be presented with the options on the content of the NZSL TMP, as well as all submissions, in April 2016.

Purpose of April Workshop

The purpose of the April workshop is to bring together international and national experts to:

1. Review the New Zealand sea lion demographic model as a potential construct to underpin the risk assessment,
2. Characterise threats to sea lions across all breeding sites, and
3. Discuss the likelihood of certain population trends given different assumptions around carrying capacity and accumulative impacts.

Scope

This workshop will address three topics over four days:

1. A review of the demographic model framework (Day 1)
2. Threat characterisation, highlighting the breeding site and age each threat is likely to impact (Day 2-3)
3. Discussion on the implementation of modelling multiple threats on sea lion populations (Day 4)

The three topics are described in more detail within the Workshop Schedule and Methodologies below.

The focus of the workshop is risk assessment, not risk management. Discussion of alternative options for managing the identified risks will be out of scope for the workshop. Development and evaluation of threat management options will be addressed separately, following the conclusion of the risk assessment.

Conduct of the Workshop

The workshop will be conducted in a professional, collegial and scientifically objective manner. Members of the Advisory Group will have their own views and interpretations of available evidence and are expected to provide these views objectively, explaining how they consider them to be supported by the available evidence. A clear distinction will be made between evidence-based interpretation and personal opinion.

All members of the Scientific Panel will be accorded equal opportunity to express their views, and are required to respect the views of other participants, whether they share those views or not.

All workshop participants will commit to:

- facilitating an atmosphere of honesty, openness and trust;
- having respect for the role of the Chair; and
- listening to the views of others, and treating them with respect.

All Members of the Scientific Panel and Advisory Group will further commit to:

- participating in the discussion in an objective and unbiased manner;
- adopting a constructive approach;

Participants who do not adhere to the above protocols of participation may be excluded by the Chair from a particular part of the workshop or, in more serious instances, from the remainder of the workshop.

Participants

The workshop participants will include:

- An independent workshop Chair;
- A facilitation group of nominated DOC and MPI scientists that will assist the chair;
- A science panel comprising invited national and international experts to address each workshop topic;
- A group of advisors consisting of nominated national experts; and
- Observers.

The workshop is open for observers, however due to limited space being available at the workshop venue, space will be made available first and foremost for the expert panel and invited advisors. Expectations and responsibilities of participants are explained in more detail below.

Chairperson

The Chair of the workshop will be an independent scientist selected by MPI and DOC to be an objective, impartial and respected scientists in their field, able to Chair and actively participate in scientific debates on the research topics to be dealt with by the workshop. The Chair is primarily a facilitator, and is responsible for:

- Ensuring that all participants adhere to the workshop terms of reference and agenda, including adhering to allotted times specified in the agenda.
- implementing the rules of procedure consistent with the workshop's purpose and scope;
- promoting full participation and constructive discussion by all participants;
- working to achieve consensus from the Expert Panel where possible, based on available evidence. Where consensus cannot be reached, the Chair may refer to the facilitation group for support in identifying or clarifying and recording alternative views; and
- identifying and managing conflicts of interest.

Expert Panel

The expert panel will be comprised of invited national/international persons with expertise relevant to the assessment of risk to the sea lion, which are considered not to be directly involved with any NZSL research or management. The expert panel members will be responsible for:

- Familiarising themselves with the material circulated to them prior to the workshop

- Adhering to the workshop code of conduct
- Providing constructive review/input on the review of the demographic model
- Provide constructive review/input into the threat characterisations
- Provide constructive review/input into discussions on modelling population dynamics
- Drawing on the information and experience of the invited advisors

The panel is not required to produce any documents as a result of this workshop. However they are asked to review the workshop meeting notes to ensure their thoughts/ideas have been effectively and accurately communicated.

Advisors

Advisors are national experts that have been invited to attend the workshop by the TMP Project Team to advise the panel on their own specific topic of expertise, provide feedback to inform the threat classification, and to ensure transparency in the scientific process.

Advisors will be invited to attend the workshop on certain days. On those days they may be asked to give a presentation on a relevant topic. Advisors giving presentations will have 15 min to present and five minutes after the presentation to answer any questions from the Expert Panel or Advisors.

Advisors are responsible for:

- Adhering to the workshop code of conduct
- Providing information to the expert panel on the topic which they have been invited to communicate on

Advisors are welcome to attend the workshop on the days they have not specifically been invited to. However they will be attending as an observer and no longer as an advisor

Observers

Those participating as observers are only there to observe the proceedings, to facilitate transparency and understanding of the process. Observers will not be permitted to contribute to workshop discussion unless specifically asked to by the Chair.

Observers will include any persons who are interested in attending the workshop and are not participating as chosen advisors or expert panel members. Observers are responsible for adhering to the workshop terms of reference.

Conflicts of Interest

Participants will be asked to declare any interests that may give rise to actual, perceived or likely conflicts of interest before involvement in the workshop is approved. Expert panel members and advisors will be expected to declare any conflicts of interest that arise during the workshop. These will be clearly documented in the notes of the workshop. Observers will be expected to register on the sign in sheet the group or groups which they represent.

The Chair will be responsible for managing any conflicts of interest that arise during the workshop in consultation with the facilitation group, to ensure that conflicts of interest do not jeopardise the objectivity of the workshop outcomes.

Documents and record-keeping

The workshop will be run formally with an agenda and background documents circulated prior to the workshop and formal records kept of recommendations, conclusions and action items.

Other than publically available published reports, workshop working documents circulated to participants are done so in confidence. Participants may not distribute these to others without the prior agreement of DOC and MPI in writing. Participants who do not maintain the confidentiality of workshop papers will be excluded from the workshop.

Presentations (unless otherwise specified) should be 15 minutes. There will be 5 minutes after a presentation for questions.

The overall responsibility for record-keeping rests with nominated DOC and MPI staff, including:

- Recording the threat classification, including comments and spatial information (e.g. GIS files)
- Recording any recommendations, conclusions or follow-up actions; and
- In cases designated by the Chair or the facilitation group, recording the extent to which agreement or consensus was achieved, and recording any disagreement.

Material provided to the International experts will be circulated prior to the workshop so everyone is aware of the material. Information presented will have been reviewed by both the MPI Aquatic Environment Working Group and the DOC Conservation Services Programme Technical Working Group.

Material provided at the workshop will include:

- Workshop Schedule
- Draft New Zealand sea lion literature review
- Copy of all presentations
- Initial list of threats and draft characterisation
- Map of sea lion distribution and map of fishing effort

Schedule

Day 1: A review of the demographic model framework

- *Scope* - The first day of the workshop will be primarily focused on reviewing the demographic model's suitability as a framework for risk assessment. To facilitate this discussion, brief presentations on sea lion biology, genetics, demographic rates, and population structure will be given.
- *Aim* - The aim of this first day is to provide constructive feedback to NIWA on the models potential as a construct to underpin the risk assessment as well as recommendations on future work for model construction
- *Advisors* - Due to the technical topics being discussed, Advisors invited to participate on day one will have an understanding of population modelling and/or sea lion population demographics.

Day 2 – Day 3: Threat Characterisation

- *Scope* - The second and third day of the workshop will focus on characterising threats to the NZSL population initially identified by DOC and MPI, and subsequently on any new threats identified during the workshop.
- *Aim* - For each potential threat identified, the panel are tasked with:
    - identifying one or more population parameter through which each threat is most likely to impact on the population (e.g. adult survival, pup production).
    - Recommending plausible time bounds of the impact
    - Identifying the geographic range over which the threat is plausible.
- *Advisors* - People invited as Advisors over these two days are considered to have a considerable amount of knowledge about either the specific breeding locations (and possible threats found at these locations), direct impact of fishing, disease, climate change or diet. A series of presentations on both sea lion biology/ecology and known threats will be made to the panel.

- *Process* - At the start of Day 2 DOC and MPI will present the draft list of threats and threat characterisation. Other threats may be added to the list at this point. The rest of Day 2 will comprise a range of presentations from Advisors to provide context before characterising the threats. We will aim to go through one trial characterisation at the close of Day 2 and the bulk of the characterisations on Day 3.

Day 4: Discussion on the implementation of modelling multiple threats on sea lion populations

- *Scope* - Following the identification and characterisation of threats (Days 2 and 3), the final day of the workshop will focus on consideration of how cumulative threats may act on sea lion populations and associated issues with modelling this. The need for density-dependence, and its mechanism, in such modelling will form part of the considerations.
- *Aim* - To provide recommendations to the NIWA modelling team on the most appropriate mechanisms to model multiple threats on multiple population parameters. This will allow NIWA to develop a robust modelling framework for evaluating potential management strategies.
- *Advisors* - Due to the technical topics being discussed, Advisors invited to participate on day four will have an understanding of population modelling and/or sea lion population demographics.

APPENDIX 2: List of Attendees

Chair:
Andrew Penney

TMP Project Team Attendees:
Nathan Walker, Laura Boren, Michelle Beritzhoff-Law, Katie Clemens-Seely,

TMP Project Executive:
Vicky Reeve, Ian Angus

Independent Expert Panel:
- David Hayman
- Jason Baker
- Mark Hindell
- Mike Lonergan

Advisors: [4]

Day 1	Day 2 and Day 3	Day 4
• Ed Abraham	• Louise Chilvers	• Ed Abraham
• Darryl MacKenzie	• Brittany Graham	• Jim Roberts
• Jim Roberts	• Chris Lalas	• Ian Doonan
• Ian Doonan	• Wendi Roe	• Simon Childerhouse
• Simon Childerhouse	• Ros Cole	• Martin Cryer
• Catherine Collins	• Martin Cryer	
• Martin Cryer	• Jim Fyfe	
• Paul Breen	• Shaun McConkey	
	• Brent Beaven	
	• Jim Roberts	
	• Ian Doonan	
	• Richard Wells	
	• Simon Childerhouse	
	• Richard O'Driscoll	

Observers:[1]
- Sarah Michael
- Mark Geytenbeek
- Kyle Morrison
- David Middleton
- Martin Cawthorn
- Annie Galland

[4] Many of the Advisors attended other days of the workshop as Observers, therefore the list of Observers are people that attended who are not already listed as an Advisor

APPENDIX 3: Final Recommendations from the Expert Panel

Expert panel priorities are indicated as **H**igh (important to the current TMP process, or for research in the near future), **M**edium (useful to the current TMP process, or important for medium term research) or **L**ow (potentially interesting for future research).

Demographic Model

- **H** - The workshop noted and supported the recommendations already made by the AEWG for model improvements, revisions and exploratory analyses.
- **H** - Model outputs, such as estimates of demographic parameters and trends should be presented with information on their precision (such as standard errors or confidence intervals) where possible. Use of MCMC for final analyses would allow credible intervals to be provided for all parameter estimates.
- **L** - Use of tag re-sighting data to estimate tag loss rates depends on knowledge about when each tag type (flipper tags, PIT tags or branding) was looked for. It is not clear that this information was recorded for all re-sightings. If a particular tag type was not looked for, then that record cannot be used in estimation of tag loss rates for that tag type. There seems to be a particular need to check this for the PIT tag re-sighting estimates.
- **L** - Questions were raised about the most appropriate way to deal with animals of unknown pupping status in the model. At present, decision rules are used to determine pupping status from observations (observed suckling, at least 3 sightings with a pup or 3 sightings without a pup) to determine pupping status, with the remaining animals classified as unknown and divided in the proportion of known pupping / non-pupping. Exclusion of animals of unknown status results in increased estimates of pupping rate. Alternative approaches should be considered and the sensitivity of pupping rate to relaxing the decision rules should be explored, such as relaxing the decision rules used to determine pupping status to 2 or 1 observations with or without a pup, or use of other information such as females calling to pups.
- **M** - Similar questions were raised about determining pupping status before an animal that has moved between colonies is used to estimate migration(translocation) rates. As an alternative, this requirements could be relaxed to include animals simply observed (but not confirmed to be pupping) at another colony to be included in migration rate estimation.
- **H** - Questions were raised about the fixing of pup survival rates for 1985 - 1989, 1994 - 1997 and 2008 at 0.5. Exploratory analyses presented at the workshop suggested that use of cohort strength from age structure data may provide estimates for the earlier years, but results in a very low survival estimate for 2008. The confounding effect of apparent poor tag retention in that year makes the veracity of this low estimate uncertain. Alternatives should be investigated other than fixing survival for these years at 0.5, including the use of age structure or, for 2008, using the average of previous and next years.
- **M** - The assumption of a CV of 0.06 for pup census indices, as the only way of specifying a relative weighting between census and tag-recapture data, was questioned. Alternative CVs and weighting approaches should be determined using something like standard deviations of Pearson residuals.
- **H** - The use of 0.95 as an upper bound for survival rate for all age classes was questioned. Higher survival rate upper bounds (1.00) are used for other pinnipeds. Some potential alternative explanations for the lower apparent survival after age 6 yr include: 1) adults experience higher tag loss rates but the model is fitting age-invariant tag loss, which would negatively bias adult survival estimates; 2) Low adult survival for a few cohorts in the 2000s might have pulled down the average for all years - this could be investigated by examining lx curves for each cohort to determine whether the depression in adult survival relative to sub-adults is consistent among

cohorts, and 3) the age 6+ group may be made up of quite different age structures over time, including senescent animals.

- **H** - Exploratory analyses presented at the workshop showed that a number of parameters vary by year and age. This was observed for tag loss estimates, at least partially related to different tagging approaches in different years. Using fixed estimates of tag loss contributes to under-estimation of tag loss and resulting effects on survival estimates for older age classes, particularly the 8+ group. This may be a combined effect of different tagging approaches and increasing tag loss rate for older animals. Options for modelling time-varying tag loss (by year and age) should be explored.
- **M** - Incorporation of time-varying re-sighting probability was noted to improve model fits, indicating that that re-sighting probabilities did vary over time. One could explore whether the number of days on which re-sightings were conducted each year are correlated with effort days, in which case effort days could be used to estimate re-sight probabilities for recent years that have not been back-corrected.
- **M** - It was recommended that the effect of incorporation of 'phantom tags' on parameters such as re-sighting probability should be explored. An alternative approach would be to simply multiply the survival rate from tagging to age 1 yr by the directly estimated proportion of pups that die prior to tagging. The latter is, after all, the basis for how many phantom tags are added.
- **H** - The decision to use an area-aggregated model for the Auckland Islands area was supported. However, this raised questions about which census data should be used. Noting that the key tag re-sighting index was for Sandy Bay, it was recommended that the base-case model use the tag re-sighting and census data for Sandy Bay only. A second analysis should use the incorporate the Sandy Bay and Southeast Point census data. A third analysis should use combined census data for the entire Auckland Islands area.
- **H** - Concerns were expressed at restricting analysis to an 8+ group, noting that full maturity is achieved at 6 or 7 years, that older animals show increasing reproductive senility and that much of the available age-composition data is for animals older than 8 years. It was recommended that an older plus group be considered, appropriate to data availability, possibly to 15+. Sensitivity of model estimates to the definition of the plus group, and to possible grouping of some ages below the plus group, should be explored.
- **H** - There were concerns at apparent instability and indications of correlation between some parameter estimates in initial MCMC analyses. These may be resolved by running longer MCMC chains, and there may be a need to investigate reasons for any remaining problems in MCMC chains. It should be attempted to achieve adequate effective sample sizes in these analyses.
- **H** - Questions were raised about the appropriateness of the Seabird demographic model for conducting projections under alternative risk-reduction strategies. The approach used in fisheries assessments would be to develop a base-case demographic model using the current model selection criteria (best AIC) and use this to develop best estimates of demographic rate parameters. A limited number of alternative specifications of this model, exploring key unresolved uncertainties, should be specified and used as robustness trials to explore the effects of these uncertainties on projections and risk reduction strategy evaluations. An alternative approach could be to develop a simpler model for projections and planning conservation strategies. Implementation of conservation strategies should be followed by well-designed data collection to evaluate efficacy.
- **H** - Retrospective analyses could be used to evaluate and correct for the increase in historical pup survival rate estimates as the number of years of re-sighting increase for each estimate.

This would be important for projections. However, this initial downward bias in survival estimates may result from fixing survival for ages 2 - 5. If so, then it would be preferred to estimate survival for each of these age classes separately or fit a trend in survival over these ages. This may not be that important for projections which could draw from a distribution of observed rates excluding recent years. Alternately, one could estimate recent rates by fixing re-sight probabilities based on an observed relationship between field effort and re-sight rates.

- H - Interpretation of the results of modelling and projections incorporating density dependent effects is problematic as results will primarily be driven by assumptions regarding the density-dependence relationships. Projections should focus on the short to medium-term (5 - 10 year) timeframe.
- L - Hierarchical modelling approaches should be considered for future (i.e. beyond the current TMP) demographic modelling work, to provide for the estimation and fixing of certain parameter estimates before moving on to estimation of further parameters.
- H - Subsets of data could be used to explore fitting to part of the data (training data set) and then determining how well the resulting parameter estimates predict the remaining data.

Monitoring& Research

Campbell Island

- H - There are currently irregular census data and limited re-sighting data available for the Campbell Island colony. This limits the capability to conduct demographic modelling of the population there. Efforts to understand the drivers behind population trends should be enhanced by comparing declining (Auckland) and growing (Campbell) sub-populations. The trends (population growth) and demographic rates (apparent high pup mortality) at Campbell Island differ from those at the Auckland Islands, and it would be useful to understand the reasons for these. Options for improving data collection at this site should be investigated.

Mark / Recapture Studies

- M - It is important for all re-sighting records to record which type of marking (flipper tag, PIT or brand) were actually looked for, in addition to recording which were seen / detected.
- H - Mark loss is a challenge for all long-term demographic studies based on tracking individuals. The fact that nearly all pups born at Sandy Bay have been tagged in the past 17 years, yet only some 20-40% of the population is currently marked, is a concern. The field program should investigate methods for maintaining ID's longer, either through active re-tagging of single tagged seals, re-tagging PIT tagged seals, photo ID or perhaps branding at some age prior to significant tag loss.

Dietary Analysis

- M - Stable isotope ratio analysis of historically collected sea lion whiskers should be used to further investigate diet composition and benthic / pelagic prey switching for the Auckland Islands sea lions.
- M - Stable isotope ratio dietary analysis of existing samples should be extended beyond the Auckland Islands to all other colonies. Results from whisker and tooth analyses from the same individuals should be compared to ascertain whether high isotope variability in tooth analyses is a methodological issue.
- L - Sea lion stable isotope ratio diet analyses should be compared with broader data sets and longer time series, including similar analyses for species such as fur seals, to try and detect consistent signals indicating environmentally driven changes in food web isotope ratios.
- L - Future field biological data collection should include collection of sea lion whiskers for use in further dietary studies using isotope ratios.

- **M** - Future dietary studies using scats or casts should attempt to determine whether such samples emanate from male or female sea lions, using genetic analysis of a portion of the sample.
- **H** - Existing information and results of past sea lion dietary studies should be summarised and collated into a single document. This review should evaluate the strengths and weaknesses of alternative approaches and methods used and identify relevant data sources.

Disease Analysis

- **H** - Time series of weekly pup mortalities at the Auckland Islands should be used to develop an epidemiological model to understand the course of annual disease outbreaks, estimate R_0 vales and estimate annual epidemic sizes.
- **H** - Molecular epidemiology (genetic) analyses should be conducted of *Klebsiella* outbreaks to evaluate whether these all emanate from a recent introduction and clonal expansion, or from a wider spread historical background of pathogens that recently started entering the population.
- **H** - There is a gap in information on disease processes at a time of high unobserved mortality in the period after females and pups disperse after the pupping season. Efforts should be made to collect information after the pupping season. This could be achieved by conducting winter surveys to the Auckland Islands.
- **M** - Efforts should be made to collect additional information on predisposing risk factors (such as immuno-competence) for bacterial infection in pups at various sites.
- **M** - A mainland disease surveillance program should be implemented to detect potential sea lion diseases and disease vectors, including fur seals and other potential pathogen reservoirs or vectors (domestic and feral animals, livestock, etc.) This information could be used to develop approaches to reduce disease transmission and facilitate successful mainland re-colonization by sea lions.

Risk Characterisation

- **H** - Initial model evaluations of threats should focus on using their upper bounds to evaluate whether significant effects are expected at this level. If not, then these insignificant threats can be excluded from further analyses. If yes, then further threat analysis should be based on an appropriate probability distribution of the significant threats between the proposed upper and lower bounds.
- **M** - Further correlation/regression analysis is needed to assess the relative effects of fishing and environmental effects on prey availability and nutritional stress, particularly in years of low pupping rate.
- **M** - A central database should be compiled to document all observed impacts (injuries, mortalities, disappearances, entanglements, etc) of sea lions.
- **H** - Efforts should be made to better quantify strike rates in trawl fisheries, such as by use of cameras to detect entry of sea lions into nets.
- **L** - Efforts should be made to model the effect of loss of a breeding site as a result of a catastrophic site-specific event. Consideration of meta-population hypotheses might be useful in this respect.

Mitigation

- **H** - Suitable education programs should be developed and implemented to inform the public regarding protection and conservation of mainland sea lions in the Stewart Island, Otago and Southland areas, to reduce human impacts in these areas.

- **H** - While the long term aim is for the population to exist in as natural a state as possible, with minimal human intervention, the potential for beneficial interventions to improve survival, reproductive success or distribution should be investigated.
- **H** - At sites where significant numbers of pups die due to entrapment or drowning in holes, proven methods (such as escape ramps for pups) or other promising tools should be tested and evaluated for their efficacy.
- **M** - The recent re-colonization by monk seals of the Main Hawaiian Islands (MHI) has become a central focus of the species' recovery. Several lines of evidence suggest that mainland NZ represents under-occupied habitat that may hold potential for population recovery of sea lions. As such, efforts to foster re-colonization of the mainland should be a focus conservation planning.

Threat Assessment Modelling Process

- Threat assessment modelling for the Auckland Islands and Otago area will primarily be conducted using the Seabird software.
- The integrated demographic model will be fitted to available historical since 1960, including tag-resight data, pup census data, age structure and available data on mortality resulting from known threats.
- Assessment for Campbell Island and Stewart Island will be conducted using simpler Lesley matrix approaches.
- Demographic assessments will use a starting year of 1960.
- Demographic models will extend to including a 15+ age class. Alternative groupings of younger age classes (such as the 2 - 5 years, prime breeding females) will be evaluated and selected.
- Projections will be run over 20 year periods, with indicators of status against appropriate reference levels at 5, 10 and 20 years.
- Appropriate metrics and reference levels will be chosen to measure projected status. These may include mature numbers, mature female numbers, pup numbers, population reproductive capacity, age structure or relevant demographic rates, as appropriate to the projection.
- All parameter estimates, and projections and measures against reference levels will be provided with credibility intervals.
- Results of demographic model fits to historical data will be evaluated to inform decisions on which years to use for determining demographic rate parameters to use in projections. Options include using averages over shorter or longer periods of recent years, sampling from a range of values over a selected period of years and excluding recent years of high uncertainty. The choice of approach will be discussed and finalised at an Aquatic Environment Working Group meeting at which initial exploratory modelling results are discussed.
- Threats for which data are available will be modelled in projections by providing the projection model with estimated future mortality vectors in the form of 'pseudo-fisheries, or by providing the model with values or distributions of changes in demographic rates resulting from those threats.
- Potential effects of other threats will be investigated by running projections varying key demographic rates, and then mapping results against threats that could have caused those changes in demographic rates.
- The effect of past mortality resulting from key threats for which data are available (such as disease and fishing mortality), or for which plausible estimates are available (such as cryptic mortality), will be explored by fitting the historical demographic model including data on mortality arising from known threats to estimate starting (1960) and current population structure. Threat-derived mortality will then

be excluded from the model and re-run from the estimated starting population to predict population structure in the absence of such mortality.

- Identified episodic threats (such as periodic catastrophic disease outbreaks) identified in the threat characterisation process will be modelled as characterised. However, it is not expected that other unexpected periodic threats will be modelled.
- The potential impact of other unexpected periodic threats (such as oil spills) will be evaluated by modelling the impact of loss of 90% of the population at the Auckland Islands or Otago, using Otago (small population) demographic rates to project the Auckland Islands population after the population loss.

APPENDIX 4: Glossary for Threat Characterisation Spreadsheet

Population:

AI = Auckland Islands
ML = Mainland (Otago, Southland)
SI = Stewart Island
CI = Campbell Island

Justification/Confidence Score:

Confidence scores, given for each estimation of impact, were characterised using the rating system from Hobday 2007:

Confidence rating	Score	Rationale for confidence score
Low	1a	Data exists, but is considered poor or conflicting.
	1b	No data exists.
	1c	Agreement between experts, but with low confidence
	1d	Disagreement between experts
High	2a	Data exists and is considered sound.
	2b	Consensus between experts
	2c	High confidence exposure to impact cannot occur (e.g. no spatial overlap of fishing activity and at-sea seabird distribution)

Model or Not:

Rows shaded blue indicate the threats which will be carried forward into the first modelling phase. This distinction was often based on the amount and quality of information available on the threat.

APPENDIX 5: Threat Characterisation Spreadsheet

Description of Potentially Threatening Activities				Scale of impact								
Threat Class	Threat	Description of threat	Population likely to affect	Units used	Estimated actual Impact	Shape of distribution	Lower bound of impact	Upper bound of impact	Justification / Confidence score around estimates	Periodicity of threat	Model or not?	Duration of impact if not annual
Coastal development	Noise	Injury/mortality, indirect effect on pup, & compromised health	ML, SI		0				1b		No	
Coastal development	Habitat alterations & related issues (ex: pollution)	Displacement & compromised health	ML, SI		0				1b		No	
Disease	Klebsiella	Pup mortality	AI, others?	Pup mortality rate			6%	Highest (from the model) mortality rate from all causes of death	2a	Annual	Yes	N/A
Disease	Klebsiella	Adult mortality	AI, ML, others?	# of adults	1 in 15 yrs (in Otago - ML), none anywhere else (that we know)		0	2 in 15 years (ML)	2b	Annual	Yes	N/A
Disease	Klebsiella	Indirect effect on pup	AI, ML, others?	# of pups			0	1 in 30 years	1c	Annual	Yes	N/A
Disease	Hookworm	Compromised health	AI, others?	Pup mortality rate			0	13% of pup mortality in the first year	2a	Annual	Yes	N/A
Disease	Hookworm	Pup mortality	AI, others?	# of pups			2 pups per year (Enderby)	10 pups per year (Enderby)	2b	Annual	Yes	N/A
Disease	Wildlife vectors	Adult & pup mortality, & compromised health	ML, SI		0				1b		No	
Disease	TB	Adult mortality	ALL	# of adults			3 for AI (0 for ML)	1% of the adult population	2c	Annual	Yes	N/A
Disease	Novel agent	Pup mortality	ALL	# of pups				90% of the pups born at the site in question	2a	Decadal	Yes - Sensitivity	
Disease	Novel agent	Adult mortality	ALL	# of adults				70% of the adults at the site in question	2a	Decadal	Yes - Sensitivity	

Appendix 3. Development of the Threat Management Plan for New Zealand sea lions: NZSL Threat workshop 1

Description of Potentially Threatening Activities				Scale of impact								
Threat Class	Threat	Description of threat	Population likely to affect	Units used	Estimated actual Impact	Shape of distribution	Lower bound of impact	Upper bound of impact	Justification / Confidence score around estimates	Periodicity of threat	Model or not?	Duration of impact if not annual
Environmental change	Coastal erosion/sand dune loss	Lack of suitable habitat & indirect effect on pup	All, mostly MI, SI		0				1b		No	
Environmental change	Pups drowning in holes	Pup mortality	AI	# of pups	2 a year*	Skewed towards lower bound	0	70 per year	2b	Fluctuates - AI	Yes	
Environmental change	Pups drowning in holes	Pup mortality	CI	# of pups	80 out of 600 pups		20	160 (out of 600)	2b	Annually - CI	Yes	
Environmental change	Storms	Direct effects	All						1b		No	
Trophic effects	Prey availability	Direct & indirect effects of nutritional stress, competition for prey, & changes in prey and predator abundance	All	Pup production rate & pup survival rate, pup survival in current yr, pupping rate in subsequent yr			Good years	Change in pupping rate b/w good yrs (03,04,08) and bad yrs (02,05,06,09) AND change in pup survival rate b/w good yrs (03,04,08) and bad yrs (02,05,06,09)	2a	4 in 15 yrs	Yes	1 yr
Finfish farming	Habitat modification	Displacement	MI, SI	# of adults	0		0	0	2c	Annual	No	-
Finfish farming	Pollution	Compromised health	MI, SI	# pups	0		0	0	1a	Annual	No	-
Finfish farming	Negative human interactions	Shooting/mortality	MI, SI	# of adults	0		0	-	1b		No	N/A
Finfish farming	Entanglement	Adult mortality	MI, SI	# of adults			0	2	2a	Annual	Yes	-
Shellfish farming	Habitat alterations, pollution, & negative human interactions	Displacement, compromised health, effect on food availability, harassment (fatal or not), & indirect impact on pup	MI, SI		0		0	0	2a		No	

*This is the estimated actual impact if the 'plank for pups' program continues, if it does not it will most likely be higher.

Appendix 3. Development of the Threat Management Plan for New Zealand sea lions: NZSL Threat workshop 1

Description of Potentially Threatening Activities				Scale of impact								
Threat Class	Threat	Description of threat	Population likely to affect	Units used	Estimated actual Impact	Shape of distribution	Lower bound of impact	Upper bound of impact	Justification / Confidence score around	Periodicity of threat	Model or not?	Duration of impact if not annual
Fishing	SLEDs	Adult female mortality that is not retained (cryptic mortality)	AI, CI (AI-F, CI-M)	# of females	3% of interactions (including those retained)		0	(# of Female Interactions - # of retained dead females)* 10%	1c	Annual	Yes	N/A
Fishing	SLEDs	Indirect effect on pup from cryptic death (non-retained breeding female)	AI	# of pups			0	(# of Breeding females interactions - retained dead breeding females) * 10%	1c	Annual	Yes	N/A
Fishing	Commercial set net	Incidental capture	SI, ML	# of females			0	Theoretical upper bound from estimated observed captures of HSL in comparison to effort over the NZ range (OBS/fishing), and female population size	1a	Annual	Yes	N/A
Fishing	Commercial set net	Entanglement/injury	SI, ML	# of females			0	Theoretical upper bound from estimated observed captures of HSL in comparison to effort over the NZ range (OBS/fishing), and female population size	1a	Annual	Yes	N/A
Fishing	Commercial set net	Indirect effect on pup	SI, ML	# of pups			0	Theoretical upper bound from estimated observed captures of HSL in comparison to effort over the NZ range (OBS/fishing), and female population size	1a	Annual	Yes	N/A
Fishing	Recreational set net	Incidental capture	ML, SI				0	-	1b	Annual	No	N/A
Fishing	Recreational line	Entanglement/incidental capture/injury	SI, ML	# of adults				Based on recorded observations of entangled/hooked NZSLs	1a	Annual	Yes	N/A
Fishing	Recreational line	Indirect effect on pup	SI, ML	# pups				Based on female proportion of recorded observations of entangled/hooked NZSLs	1a	Annual	Yes	N/A
Fishing	Commercial potting	Incidental capture	SI, ML		0		0	-	1a	Annual	No	N/A
Fishing	Commercial potting	Entanglement	SI, ML		0		0	-	1a	Annual	No	N/A
Fishing	Commercial potting	Indirect effect on pup	SI, ML		0		0	-	1a	Annual	No	N/A
Fishing	Surface long line	Entanglement/incidental capture/injury & indirect effect on pup	SI, ML		0				1a		No	

Appendix 3. Development of the Threat Management Plan for New Zealand sea lions: NZSL Threat workshop 1

Description of Potentially Threatening Activities				Scale of impact								
Threat Class	Threat	Description of threat	Population likely to affect	Units used	Estimated actual Impact	Shape of distribution	Lower bound of impact	Upper bound of impact	Justification / Confidence score around estimates	Periodicity of threat	Model or not?	Duration of impact if not annual
Fishing	Commercial trawl*	Incidental capture	All? Or AI, CI	# of females					2a		Yes	
Fishing	Commercial trawl*	Indirect effect on pup	All? Or AI, CI	# of pups					2a		Yes	
Fishing	Vessel noise	Compromised health	All		0				1b		No	
Fishing	Habitat modification	Displacement	All		0				1b		No	
Mining and oil activities	Noise	Compromised health, injury/mortality, indirect effect on pup	ML		0		0	-	1b		No	
Mining and oil activities	Habitat alterations/degradation & related issues (ex: pollution)	Displacement & compromised health	ML		0				1b		No	
Natural behaviour	Male NZSL aggression	Female mortality	All, mostly ML, SI	# of females	Enderby - Avg 1 F/year relative to # of F on the beach, need to be scaled to other colonies; Otago - 3 F in 15 years)		0	11 F / year	2a	Annual	Yes	N/A
Natural behaviour	Male NZSL aggression	Pup mortality	All, mostly ML, SI	# of pups	Wendi to provide #s for Enderby, Otago - 2 in 15 years; scaled relative to the population present in each location		0	20% of pup mortality for that season	2a	Annual	Yes	N/A
Natural behaviour	Male NZSL aggression	Female injury	All, mostly ML, SI		84% of F (Enderby) have scars from males, but no information on how many of that have reproductive success impacted				1c		No	

Appendix 3. Development of the Threat Management Plan for New Zealand sea lions: NZSL Threat workshop 1

Description of Potentially Threatening Activities				Scale of impact								
Threat Class	**Threat**	**Description of threat**	**Population likely to affect**	**Units used**	**Estimated actual Impact**	**Shape of distribution**	**Lower bound of impact**	**Upper bound of impact**	**Justification / Confidence score around estimates**	**Periodicity of threat**	**Model or not?**	**Duration of impact if not annual**
Other humans	Dogs	Injury & compromised health	ML, SI		0				1b		No	
Other humans	Dogs	Adult mortality	ML, SI	# of adult females			0	0	2a	Annual	Yes	N/A
Other humans	Dogs	Pup mortality	ML, SI	# of pups	1 pup in 15 yrs		0	4 in 15 years	1c	Annual	Yes	N/A
Other humans	Deliberate harassment	Injury & compromised health	All, mostly ML, SI				0	-	1b		No	
Other humans	Deliberate mortality	Adult mortality	All, mostly ML, SI	# of adults	SI-8 (1 F) ; Sthland 5 (1 F), Otago - 4 (1 F), Blenheim - 1 (in 15 years)		18 in 15 years	3x lower bound	1c	annual	Yes	N/A
Other humans	Deliberate mortality	Pup mortality	All, mostly ML, SI	# of pups	0		0	9	1c	annual	Yes	N/A
Other humans	Deliberate mortality	Indirect effect on pup	All, mostly ML, SI				0	9	1c		No	
Other humans	Domestic animals as disease vectors	Compromised health	ML, SI		0				1b		No	
Other humans	Domestic animals as disease vectors	Adult mortality	ML, SI		0				1b		No	
Other humans	Domestic animals as disease vectors	Pup mortality	ML, SI		0				1b		No	
Other humans	Disease vectors	Compromised health, adult & pup mortality	All		0				1b		No	
Pollution	Plastics - entanglement	Adult mortality	All	# of adults	Enderby - 4 in 25 yrs (2 F (1 trawl net) & 2 M (other 3 longline)); 5 in 15 years - Otago (all M)		0	Enderby - 8 in 25 years; Otago - 10 in 15 years	2a		Yes	
Pollution	Plastics - entanglement	Juvenile mortality	All	# of juveniles	0		0	Enderby - 1 per year; Otago - 10 in 15 years	1c		Yes	
Pollution	Plastics - entanglement	Compromised health	All		0				1b		No	
Pollution	Agricultural & industrial run-off, & sewage related issues	Compromised health & displacement	ML, SI, All		0				1b		No	
Pollution	Plastics - ingestible	Adult & pup mortality, & compromised health	All		0				1b		No	
Pollution	Oil spills - ingestion & inhalation	Adult & pup mortality, & compromised health	All		0				1b		No	

Appendix 3. Development of the Threat Management Plan for New Zealand sea lions: NZSL Threat workshop 1

Description of Potentially Threatening Activities				Scale of impact								
Threat Class	Threat	Description of threat	Population likely to affect	Units used	Estimated actual Impact	Shape of distribution	Lower bound of impact	Upper bound of impact	Justification / Confidence score around estimates	Periodicity of threat	Model or not?	Duration of impact if not annual
Predation	Orca	Injury, adult & pup mortality	ML, SI		0				1b		No	
Predation	Sharks	Injury	All	# of adults	AI 6 to 9 fresh shark bites in 2015; CI - less than 1% scarring rate	Enderby - trend is flat			1c		Yes	
Predation	Sharks	Adult mortality	All	# of adults	Otago - 2 in 15 yrs				1c		Yes	
Predation	Sharks	Pup mortality	All		0				1b		No	
Research	Injury/stress	Compromised health	All	Pupping rate	0				1b		No	
Research	Mortality	Adult/juvenile mortality	All	# of adults	3 (2 AI; 1 CI) in 25 years (2 F, 1 M)		0	rate per animal anesthetised	2a		No	
Research	Mortality	Pup mortality	All	# of pups	0		0	0	2a		No	
Research	Possible disease vectors & disturbance	Compromised health, adult/juvenile mortality, & displacement	All		0		0	-	1b		No	
Tourism & General recreation	Noise	Compromised health	All		0	-	0	0	2a		No	
Tourism & General recreation	Disturbance	Compromised health	All		0		0	0	2a		No	
Tourism & General recreation	Displacement	Displacement from suitable habitat	All		0		0	0	2a		No	
Vehicles	Vehicle strike	Physical injury	ML, SI		0		0	-	1b		No	
Vehicles	Vehicle strike	Adult mortality	ML	# of females	1 F per 7 yrs	skewed low	0	2 F per 7 years	2c	Annual	Yes	N/A
Vehicles	Vehicle strike	Indirect effect on pup	ML, SI	# of females	1 F per 7 yrs	skewed low	0	2 F per 7 years	2c	Annual	Yes	N/A
Vehicles	Boat strike	Injury/mortality & indirect effect on pup	All		0				1b		No	
Vehicles	Disturbance	Compromised health & displacement from suitable habitat	ML, SI		0				1b		No	

Development of the Threat Management Plan for New Zealand Sea Lions:
NZSL Threat Workshop 2

Purpose of Document:

This document reports on the outcomes of Workshop 2, held 1-3 September 2015, including a summary of the outputs of the risk assessment modelling, and reports on the next steps for the development of the TMP.

Background:

The TMP is a five year plan that works towards the TMP Vision for New Zealand sea lions. The TMP will assess all threats on the population, prioritise threats for management and mitigation, and will include all sub-populations and breeding sites.

For further information on the process involved in the development of the New Zealand sea lion TMP, please see http://www.doc.govt.nz/nzsl-tmp.

The purpose of the second workshop was to review a number of topics associated with the development of the TMP including:

- the draft management goals,
- the demographic modelling approach developed at the first workshop,
- a second modelling approach developed by Otago University, and
- initial threat projections using the demographic model.

For full details of the purpose of the workshop, please see the Terms of Reference for the Workshop in **Appendix 1**.

Invited subject matter experts were present in the capacity of 'Advisors' to provide support to the Expert Panel on their particular topic of expertise. The Expert Panel was comprised of the same four people as first NZSL Threat Workshop, who were considered independent of current New Zealand sea lion research or management, yet have expertise relevant to the assessment of risk to the sea lion. A list of participants is included in **Appendix 2**.

Workshop 2 Outputs:

Key outcomes:

1. A document detailing all three days of discussions, including outcomes and recommendations from the Expert Panel, is included in **Appendix 3**.

Management goals

2. A number of suggestions were made on the draft management goals, mostly pertaining to the population goal and the importance of ensuring that progress is able to be measured against the goal. The revised management goals will be made available on the TMP website.

Demographic modelling

3. The expert panel made some minor technical recommendations to fine-tune the NIWA demographic modelling, but overall considered the approach to be robust and appropriate to underpin the development of the TMP. The only issue that the panel noted was that, due to the complexity of the model, it takes a long time to produce outputs which could affect the ability to prioritise management actions in a timely manner. Some suggestions to improve the running time of the model were made.

4. The panel were presented with an additional model developed by the University of Otago (Otago Model). The panel considered the Otago model provided largely similar outputs to NIWA's model, but was too simple to accurately reflect the complexities of the Auckland Island population dynamics. For this reason the Panel agreed that the NIWA-developed model continue to be used as a tool for developing management options.

Retrospective analysis – Auckland Islands

5. The NIWA model was used in a retrospective analysis that estimated the population trajectory if each of the identified threats had been removed in the year 2000. This analysis indicated that no single threat was responsible for the decline in the sea lion population at the Auckland Islands.

6. The retrospective analysis suggested that the population would have declined even with the removal of any of the threats modelled. It was estimated that the removal of *Klebsiella* would have resulted in a 30% decline instead of the observed 50% decline. Likewise, the removal of unmitigated direct effects of fishing would have resulted in a 40% decline instead of the observed 50% decline. This supports the need for an integrated management response addressing a number of the identified threats.

Forward projections removing effects of threats – Auckland Islands

7. The model was used to examine the impact of removing mortalities caused by each threat from 2017 onwards. Results showed that the removal of any single threat would not be enough to reverse the decline in the population.

8. The results of the projections suggest that the greatest gain is likely to result from addressing the effects of the bacterial disease *Klebsiella*. There are currently no known methods for treating *Klebsiella* in sea lions, and research is considered as the first step in addressing *Klebsiella*. Research programmes are currently being implemented to address this threat, but are still in early planning.

9. The direct impacts of fishing were modelled under a number of assumptions regarding the number of mortalities caused by fishing activity. Even under an assumption that all sea lions that come into contact with fishing gear are killed, the population continues to decline, albeit at a marginally slower rate.

Mainland breeding population

10. The mainland breeding site was also modelled by NIWA and forward population projections with the removal of the effects of identified threats were completed. Overall, the population on the mainland was modelled to be increasing significantly, and projected to continue to increase under all threat scenarios. However, removal of certain threats could help improve the rate of population growth.

Campbell Island and Stewart Island breeding sites

11. There is insufficient information for a full demographic model for either the Campbell Island or Stewart Island breeding sites.

12. The expert panel recommended that, given nearly 30% of the total sea lion population breeds at Campbell Island, it will be increasingly important to understand the population dynamics at Campbell Island.

13. Stewart Island will also require ongoing monitoring, and the expert panel noted the importance of collecting additional demographic data about Stewart Island and initiating educational campaigns to minimise impacts of humans interacting with sea lions.

Research priorities

14. A number of research priorities were identified by the expert panel. These were mainly focused on continuing or establishing monitoring programmes, and research to understand the sources and behaviour of, and potentially identify treatment options for *Klebsiella*.

15. One priority specifically mentioned was sampling and data collection at Campbell Island. In recognition of the costs, a three-year intensive programme was proposed, with less frequent but regular field seasons following.

APPENDIX 1: New Zealand sea lion Threat Management Plan Workshop 2 Terms of Reference

Department of Conservation
Te Papa Atawbai

Ministry for Primary Industries
Manatū Ahu Matua

New Zealand sea lion Threat Workshop 2 September 1-3

Introduction

There are concerns for the New Zealand sea lion (NZSL), primarily because pup production at the Auckland Island, the main breeding area, has been in a decline for over a decade. In 2014 the Minister of Conservation and Minister for Primary Industries instructed officials to begin work to develop a Threat Management Plan (TMP) as a means to further the recovery of the species throughout its range.

A number of potential factors are thought to be contributing to the sea lion decline. In developing the NZSL TMP it is envisaged that the Department of Conservation (DOC) and Ministry for Primary Industries (MPI), in consultation with iwi and stakeholders, will look at all potential threats to all breeding sites, and develop management options to minimise or mitigate key threats to the sea lions.

A plan and timeline for developing the NZSL TMP was agreed by Ministers in April 2014. An integral part of developing the NZSL TMP is conducting a comprehensive risk assessment for the whole sea lion population. As the amount of information on each possible threat to sea lions varies it was decided that two workshops were needed to inform the risk assessment.

The first workshop was held in April 2015 and focused on characterising threats and reviewing the demographic assessment framework. The second workshop is being held in September 2015 and will be focused on reviewing the outputs of the risk assessment model.

The final outputs of the risk assessment will be used to inform management options that might make up the NZSL TMP. Prior to the finalisation of the NZSL TMP, and to aid decision-making, a public consultation over the draft NZ TMP will be undertaken. It is expected that Ministers will be presented with the options on the content of the NZSL TMP, as well as all submissions, in April 2016.

Purpose

The purpose of this workshop is to review the following topics:

1. TMP population goal and criteria (Day 1)
2. Updates to the demographic model (Day 1)
3. Model review (Day 1)
4. Threat characterisation (Day 2)
5. Risk triage projections (Day 2)
6. Retrospective impact analysis (Day 2)
7. Population projections under different threat scenarios (Day 2)
8. Treatment of the Campbell Island/ Stewart Island populations (Day 3)
9. Treatment of low information threats that may still be managed within the TMP (i.e. shootings, dogs) (Day 3)

Scope

The focus of the workshop is risk assessment. Development and evaluation of threat management options will be addressed separately, however, identification of threat management options, including mitigation and/or research priorities will be considered.

Conduct of the Workshop

The workshop will be conducted in a professional, collegial and scientifically objective manner. Members of the Advisory Group will have their own views and interpretations of available evidence and are expected to provide these views objectively, explaining how they consider them to be supported by the available evidence. A clear distinction will be made between evidence-based interpretation and personal opinion.

All members of the Scientific Panel will be accorded equal opportunity to express their views, and are required to respect the views of other participants, whether they share those views or not.

All workshop participants will commit to:

- facilitating an atmosphere of honesty, openness and trust;
- having respect for the role of the Chair; and
- listening to the views of others, and treating them with respect.

All Members of the Scientific Panel and Advisory Group will further commit to:

- participating in the discussion in an objective and unbiased manner;
- adopting a constructive approach.

Participants who do not adhere to the above protocols of participation may be excluded by the Chair from a particular part of the workshop or, in more serious instances, from the remainder of the workshop.

Participants

The workshop participants will include:

- An independent workshop Chair;
- A facilitation group of nominated DOC and MPI scientists that will assist the chair;
- A science panel comprising invited national and international experts to address each workshop topic;
- A group of advisors consisting of nominated national experts; and
- Observers.

The workshop is open for observers, however due to limited space being available at the workshop venue, space will be made available first and foremost for the expert panel and invited advisors. Expectations and responsibilities of participants are explained in more detail below.

Chairperson

The Chair of the workshop will be an independent scientist selected by MPI and DOC to be an objective, impartial and respected scientists in their field. The Chair is primarily a facilitator, and is responsible for:

- ensuring that all participants adhere to the workshop terms of reference and agenda, including adhering to allotted times specified in the agenda.
- implementing the rules of procedure consistent with the workshop's purpose and scope;
- promoting full participation and constructive discussion by all participants;
- working to achieve consensus from the Expert Panel where possible, based on available evidence. Where consensus cannot be reached, the Chair may refer to the facilitation group for support in identifying or clarifying and recording alternative views; and
- identifying and managing conflicts of interest.

Expert Panel

The expert panel will be comprised of invited national/international persons with expertise relevant to the assessment of risk to the sea lion, who are considered not to be directly invested in NZSL research or management. The expert panel members will be responsible for:

- familiarising themselves with the material circulated to them prior to the workshop
- adhering to the workshop terms of reference
- provide constructive review/input into all discussions
- drawing on the information and experience of the invited advisors

The panel is not required to produce any reports as a result of this workshop. However they are asked to review the workshop meeting notes to ensure their thoughts/ideas and recommendations have been effectively and accurately communicated.

Advisors

Advisors are national experts that have been invited to attend the workshop by the TMP Project Team to advise the panel and to ensure transparency in the scientific process.

Advisors are responsible for:

- adhering to the workshop terms of reference
- providing information to the expert panel on the topic which they have been invited to communicate on

Observers

Those participating as observers are only there to observe the proceedings. To facilitate transparency and understanding of the process observers will not be permitted to contribute to workshop discussion unless specifically asked to by the Chair.

Observers will include any persons who are interested in attending the workshop and are not participating as a chosen advisor or expert panel member. Observers are responsible for adhering to the workshop terms of reference.

Conflicts of Interest

Participants will be asked to declare any interests that may give rise to actual, perceived or likely conflicts of interest before involvement in the workshop is approved. Expert panel members and advisors will be expected to declare any conflicts of interest that arise during the workshop. These will be clearly documented in the notes of the workshop. Observers will be expected to register on the sign in sheet the group or groups which they represent.

The Chair will be responsible for managing any conflicts of interest that arise during the workshop in consultation with the facilitation group, to ensure that conflicts of interest do not jeopardise the objectivity of the workshop outcomes.

Documents and record-keeping

The workshop will be run formally with an agenda and background documents circulated prior to the workshop and formal records kept of recommendations, conclusions and action items.

Other than publically available published reports, workshop working documents circulated to participants are done so in confidence. Participants may not distribute these to others without the prior agreement of DOC and MPI in writing. Participants who do not maintain the confidentiality of workshop papers will be excluded from the workshop.

The overall responsibility for record-keeping rests with nominated DOC and MPI staff, including:

- Recording any recommendations, conclusions or follow-up actions; and
- In cases designated by the facilitation group, recording the extent to which agreement or consensus was achieved, and recording any disagreement.

Material provided to the International experts will be circulated prior to the workshop so everyone is aware of the material. Information provided in advance will have been reviewed by both the MPI Aquatic Environment Working Group and the DOC Conservation Services Programme Technical Working Group.

TMP Expert Panel Workshop – Participants

Chair: Neil Gilbert
MPI and DOC Facilitators: Nathan Walker and Laura Boren
Record Keeping and Workshop Administration: Katie Clemens-Seely and Tiffany Bock
Expert Panel Members:

- Mark Hindell
- Jason Baker
- Mike Lonergan
- David Hayman

TMP Expert Panel Workshop – Schedule

DAY 1: Tuesday 1 September

9:00 am	**Coffee and Welcome (general admin)**
	Introductions
	DOC and MPI present TMP management goals
10:30 am	Morning Tea
	Review of updates to the demographic model (NIWA)
12:30 – 1:00	Lunch Break
	Review of updates to the demographic model (NIWA)
2:30 pm	Afternoon Tea
	Meyer modelling approach (Otago)
4:30 pm	**MEETING CLOSES**
	Icebreaker session

DAY 2: Wednesday 2 September

9:00 am	**Coffee and Welcome (general admin)**
	Review outcomes of day 1
	Threat characterisation (DOC & MPI – Ian)
10:30 am	Morning Tea
	Risk Triage (NIWA)
12:30 – 1:00	Lunch Break
	Retrospective impact analysis (NIWA)
	Threat scenarios used for population projections (NIWA)
3:00 pm	Afternoon Tea
	Population projections (NIWA)
4:30 pm	**MEETING CLOSES**

DAY 3: Thursday 3 September

9:00 am	**Coffee and Welcome (general admin)**
	Review outcomes of day 2
	Treatment of Campbell Island
10:30 am	Morning Tea
	Treatment of Stewart Island (Rakiura)
	Treatment of low information risks
12:30 – 1:00	Lunch Break
	Focussed discussion on how to do strategy evaluation using the model
3:00 pm	Afternoon Tea
	Focussed discussion on alternate management options
	Focussed discussion on research priorities
4:30 pm	**Wrap-up and concluding remarks**
5:00 pm	**MEETING CLOSES**

DAY 4: Contingency day – Friday 4 September

There is currently not a schedule for this day as it may not be needed. However, if the Panel and Chair feel it is useful to have a session to finalise their recommendations then time can be allocated on this day.

APPENDIX 2: List of Attendees

Chair:
Neil Gilbert

TMP Project Team Attendees:
Nathan Walker, Laura Boren, Katie Clemens-Seely, Tiffany Bock

TMP Project Executive:
Ian Angus, Vicky Reeve

Independent Expert Panel:
- David Hayman
- Jason Baker
- Mark Hindell
- Mike Lonergan

Advisors:
- Simon Childerhouse
- Ed Abraham
- Darryl MacKenzie
- Paul Breen (observer only for Otago model presentation)

Observers:
- Richard Wells
- Dave Middleton
- Martin Cryer
- Katrina Goddard
- Amanda Leathers

APPENDIX 3: Discussion outcomes, including recommendations from the panel members

Day 1 – September 1st 2015

The first day of the workshop: presented the threat management plan's draft management goals and criteria, an update on the NIWA demographic model, and an alternative model approach developed by Otago University.

Threat Management Plan Goals & Criteria

The draft, overarching management goals and criteria of the threat management plan (TMP) were presented for the panel's consideration.

- The panel suggested that an annual process be initiated to monitor progress against the population goal. This would not involve any significant reworking of the model parameters or structure, just imputation of the new data and running the model. This would allow for an annual check on progress against targets and the status/success of management actions.
- The panel commented that the scope of the research covered in the research and monitoring goal should address both sea lion population and threats. MPI and DOC acknowledged that it is intended to be wider than just sea lion population research, and would include research and monitoring in relation to identified and potential threats to sea lions. This will be clarified in the management goals.
- The panel suggested that target setting should be based on realistic numbers, and not be affected by the fear that some targets may not be met. The point was made that failure to meet a target may trigger response action, including potential urgent reporting to Ministers, which may result in more readily available resources.
- Support for the management criteria was expressed in that they focus on the most important issue at hand, that is, unfavourable vital rates that are driving a decline. In the future, these criteria can be altered to address emerging issues as appropriate.
- The panel agreed to review the goals (in particular the Population Goals) again after seeing the outputs from the modelling. The project team will also provide some minor updates to the goals and criteria based on feedback received to date, prior to that review on Day 3.

Update on Demographic model

NIWA provided a progress report on the development and testing of the demographic model.

- It was noted that if age structure of the population is considered an important input to the model, consideration should be given to repeating this work in the near future, especially since it easier now with the tags and chips including more information on the age of animals.
- A practical problem was identified and discussed with the speed that the MCMC runs are progressing at. At the current rate, it is estimated that they may take another 3 weeks to complete. The reason for this is unknown, although it was attributed to the number of states and parameters (incl. tag loss classes).
- It was noted that the Otago population is small and volatile and as such, may not be a top priority for modelling going forward with the TMP. However, it was noted that based on age structure and vital rates observed to date, the existing model suggests that it is highly unlikely that the Otago population will become an official "subpopulation" within 20 years.

- It was suggested that showing confidence intervals would be crucial for management to understand what the impacts of management would need to be in order to see measurable changes in projections. It was also suggested that the demographic rate scenario graph rates should/could be converted back into numbers, and then they could be used to inform management options (i.e. to get from pup survival from 0.4 to 0.6, how many animals need to be saved).
- It was noted that using the most recent 10 years' observations to project into the future doesn't include past observations of more favourable rates. To investigate the effects of this, we might want to evaluate the sensitivity of the triage results to which set of years are drawn from for projections to help demonstrate robustness of conclusions. This exercise will be time consuming unless the MCMC process can be accelerated.
- As a recommendation for future work, the Panel suggested that because of the low numbers of individuals in the population, parameters be estimated for each individual, instead of resampled, i.e. stochasticity in projections. This would allow some scope for one off events that could significantly affect a small population like this.

Alternative model approach

Otago University provided an alternative model that the workshop agreed would be appropriate to assess as a comparative or benchmarking exercise.

- There was a question about whether branded & chipped individuals were included in his analysis, or whether they were ignored. An Advisor mentioned that as long as the model only used those that were identified as "tagged" then there might not be a significant problem.
- There was a question about the scale used for survival. It was suggested that the data be transformed (arc sin transformation), which has helped others in the past with similar issues.
- There was a concern expressed about the low pup survival estimate. This led to additional concern that other parameters may be poorly or wrongly estimated in the model as well.
- There was interest from the Panel in getting more information on exactly why the estimation of pup survival is lower than the NIWA model.
- It was noted that a simple binominal, yes or no disease was present, is overly simplistic to assess if disease is compensatory. There needs to be a measure of the level of effect of disease in those particular years to be able to confirm whether or not you are seeing a compensatory effect of disease on the overall population.
- It was noted that in the years with high pup mortality, pup production rate was also depressed at the same time, potentially as a result of disease. It doesn't appear that any conclusions can be drawn from the model, given its simplicity, as to the presence or absence of any compensatory mechanism because it cannot detect changes in pup survival and the relative impacts due to disease. It is inappropriate to look at the effects of epizootics in isolation.
- With regard to the analysis that was presented of the correlation of trawl captures with the number of adult females that must be prevented to maintain a stable population, many questions were raised, including the concern that the use of just Sandy Bay sea lion data to correlate with the captures of sea lions in northern portion of the Auckland Island squid fishery is overly simplistic It was also noted that the difference in the timing of the kernel density (foraging) plots threw some doubt as to the confidence with which these areas could be attributed back to home colonies (i.e. Sandy Bay and Dundas Island). The different foraging locations could just as easily be a function of different foraging strategies by both groups between the two time periods.

<u>Feedback from Panel</u>

- The panel concluded that the most appropriate model would be an approach that incorporates the available data and gives the smallest uncertainties with regards to the forward projections.
- It was considered reassuring that while there were some distinctions, the two models seem to generate largely similar parameter estimates.
- Overall, the panel concluded that they continue to have confidence in the work that has been done on the NIWA model and that it should be carried forward. The panel appreciates that all models rely on assumptions and have pitfalls (for example: BFG - density dependence, Otago - not able to deal with complexity of the situation and the data available, & NIWA - takes a long time to run with current model configuration and observations used).
- It was agreed that the projections are likely to provide the real differentiation between the models, as the model that can demonstrate its applicability and can produce projections with less uncertainty, is likely to be best at using the available data to inform projections and subsequent management.

Day 2 – September 2nd 2015

The second day of the workshop: revisited the Otago model, described the updates to the threat characterisation process, and discussed the risk triage outcomes, the best estimate projections, and the retrospective impacts analysis. The workshop also briefly considered the cumulative effects of threats.

Discussion outcomes, including recommendations from the panel members:

Revisit of Otago Model

Darryl MacKenzie provided a technical review of the compensatory mortality used in Stefan Meyer's model. A written assessment was provided, which has been recorded with other technical workshop outputs.

The Panel liked the simplicity of the model, yet had reservations about the resulting parameter estimates (i.e. low pup survival and high juvenile survival). Likely this was because the model was too simple to deal with complexities in the data. The Panel also noted that the interpretation regarding the impacts of fishing is highly questionable. For example the assertion that all Auckland Island mortalities were attributed to the Sandy Bay population is unlikely.

The Panel considered that for the TMP purposes, whilst the Otago model was broadly in agreement with the NIWA model that is being used, there is no value in pursuing the Otago model further for this process. The Panel concluded that the model might potentially be useful for some applications if it could be improved slightly, but in its current state the Panel agreed that it is unable to add anything to the TMP process.

Threat Characterisation – Laura Boren (DOC) & Nathan Walker (MPI)

It was suggested that a new metric for estimating incidental captures be used, potentially employing a cryptic mortality approach as a multiplier on the estimated observable captures. This approach has the advantage of transparency and simplicity. A running mean approach could be taken, using a multiplier on the observable capture rate over a 5-y period, for example. However, the difficulty with this approach would be developing the methods to estimate the cryptic mortality multiplier.

The Panel recommended that:

- There needs to be confidence that sufficient upper bounds have been selected, and that other potentially high threats are not being neglected during the triage stage.
- The upper bound and best estimate of female mortality from male aggression should be reviewed.
- The upper bound and best estimate of pups in holes should be reviewed by the project team. The current upper bound value, which assumes that all drowned pups died, may be an overestimate.
- The upper bound and best estimate of female (adult) mortality from deliberate mortality should be reviewed as the resight probability of females that have been shot is very low. There is confirmation of one female being shot, but there is an obvious struggle in determining how to accurately represent those that are in fact being killed.
- The upper bound and best estimate of shark predation is likely to be underestimated, given the lack of observation of mortalities from shark predation. 27% of adult sea lions at Sandy Bay have shark scars (according to a single speculative study without details of methods or confirmation of predatory species).

There was further discussion around the interaction with Sea Lion Escape Devices (SLEDs). The Panel noted their concern that because of a lack of data informing the later model results, there were large upper bounds of interactions and the upper 95 percentile of the estimate of strike rate is likely skewed above the mean to an implausible level.

Risk triage outcomes – Jim Roberts (NIWA)

A question was raised about why only mature females were modelled. Dr. Roberts noted that the population goals were originally focused on female survival, hence the modelling on mature females.
Dr Roberts also reminded the workshop that the triage is not a detailed analysis of impacts, but instead identifies what threats need to be carried forward to more detailed analyses.

There was discussion around which threats are included in the triage, which need to be modelled, which should be modelled, which have come out looking odd (i.e. lower than anticipated), and how to address these issues. It was suggested that pups drowning in holes be included in the projections going forward because of the possibility to manage this particular threat.
Questions were raised around how 'trophic effects' were estimated and incorporated into the triage projections. Dr Roberts noted that the four worst years were averaged. The panel noted that the upper bound of trophic effects is probably set too low, given that it was set during a time of decline.
It was suggested that it could be more appropriate to compare 2005-2008 (low years) to a period when the population was growing (i.e. the early 90s, as was done for *Klebsiella*), and adjust demographic rates manually for *Klebsiella* and trophic effects.

With regards to cumulative effects, the Panel agreed that no single threat is likely to be responsible for the demographic changes that have been seen. Therefore, eliminating any single threat through triage might be futile, and the best estimate of total cumulative threats may be achieved by including the best estimates in the next stage, then removing them all, and comparing the outcome with growth patterns observed in the 1990s.

It was noted that the λ of Otago and Campbell Island populations is around 1.07 or 1.08 at present, and that this growth rate could be used as an aspirational target of growth for the population as a whole.

There was a concern that the effect of removing *Klebsiella* may be over estimated. Might need to re-examine how *Klebsiella* is represented in the best estimates/upper bounds.

Best estimate projections

Auckland Island population projections

It was recommended that "pup drowning in holes" and "male aggression" be added to the list of threats to model for the Auckland Islands.

There was a concern that estimates of pup mortality assume that the pre-weaning pup mortality and the pup mortality for the remainder of the year would be attributable to the same causes of mortality.

The Panel recommended that longer field seasons would allow for a determination of other possible causes of death later in the season, and would allow us to develop a proper disease mortality curve.

The Panel reiterated its view that no single intervention is likely to reverse the decline in the New Zealand sea lion population.

Fishing

- It was noted that the model projections indicate that removing the direct effects of fishing will not in itself reverse the population decrease. However, it was highlighted that potential indirect effects of fishing are currently considered as part of trophic effects and thus the removal of fishing effort may result in additional benefits.

Klebsiella

- It was noted that the model projections (using the mortality numbers in the threats spreadsheet as provided to Jim Roberts) indicate that the removal of *Klebsiella* does not result in an increase in the population.
- Based on the projections, it was estimated that resolving *Klebsiella* completely might have about a 50% chance of stabilising the population (assuming this mortality is additive, rather than compensatory).
- It was agreed that the occurrence of *Klebsiella* is likely to continue. It is not known if pups develop resistance to the infection. Such resistance might potentially result from evolutionary selection within the population due to mortality or improvements in the physical condition of the pups, though it is unclear how likely these responses might be, or when they might occur. Klebsiella has been found in the environment and other animals at Auckland Islands (and may have been found on Campbell Island as well). This disease ecology means that the threat from disease may continue because the infection is not maintained simply in the sea lion population. Molecular techniques could potentially identify if the arrival of the more aggressive form of *Klebsiella* was a modification of an already present bacteria or an entirely new infection introduction (based on genetic diversity).

Trophic

- The Panel noted the importance of clearly communicating what "trophic effects" incorporates. There remains a risk that this could be interpreted simply as the indirect effects of fishing, and that simple management of the fishery would negate this effect.
- The 'best estimate' for trophic effects was considered to be trivial given large uncertainties around what these impacts are and the scale of those impacts. The Panel recommended that publication of this

information should be accompanied by caveats noting the lack of data and that this component is little more than an educated “stab in the dark”.

Otago population projections

There was brief discussion on the amount of effort that should go into management and continued modelling for this sub-population. The current status and increasing projections imply that this population is not under any significant threat at this point. However, the projection is useful in that it indicates that, assuming current demographic rates continue without immigration, the Otago population is not likely to achieve “subpopulation” (35 pups per year) status within the next 20 years.

It was noted that it is important to recognise demographic stochasticity in the model, because chance events can have substantial impacts on small populations. The current setup also inherently assumes that one-off ‘catastrophic’ effects do not occur, which, if they did, could significantly affect the increase as modelled.

Retrospective Impacts Analysis

It was noted that starting in 2000 may not provide an accurate analysis of the impacts, since it is known that many of these threats were occurring prior to that time. The population impacts may have happened prior to 2000, but we are unable to see those impacts because this is only modelled from 2000. However, the outcome describing the effect on lambda as a result of alleviating the threats will not be influenced by where the positive change occurs given that the rate of decline has been fairly consistent since 2000.

Commercial fishing impacts could fairly easily be taken back to 1995 since information is available on both captures and interactions back to that year.

For some of the other impacts, there is little data that would support any extension backwards beyond 2000. Trophic effects and hookworm have very limited data before 2000, and even the census data, prior to 1998 is less reliable.

A better understanding of the impacts of *Klebsiella* and the potential of it having been in the population longer than currently thought is very important and would contribute to our ability to understand and monitor the overall threats to the sea lion population, especially at Auckland Islands. This could be considered a key area for research going forward (e.g. by analysing historic tissue samples for *Klebsiella*).

Actions/Recommendations

The extent of the reversal in threats that would need to be made to get to a λ of 1.0 and 1.07/1.08 will be conducted. The demographic scenario assessments will be expanded, and a plot similar to Figure 3 in Meyer’s paper will be produced to show what management actions would be required to meet the management ‘targets’.

It was noted that the NIWA model will need to be published in the primary literature. Otherwise, other analyses published in the primary literature will be viewed by the public as the authoritative source.

It was agreed that it would be helpful to improve the ability to assess the threats in a cumulative manner, and to consider options to address the fact that not all of the causes of the decline have been found and accounted for.

It was suggested that correlative analyses could be done in more detail using regression-based models with interaction terms, where outputs could provide more information on what is driving the changes in the population. These analyses would be useful for assessing the relative impact of specific threats. For example changes in catch per unit effort as proxies for trophic effects could be assessed against adult and pup survival now there is greater confidence in the age-specific mortality rates.

<u>Input data</u>

Male aggression – Auckland Island
The impact of male aggression on female (adult) survival got dropped out after the triage and was not carried forward to MCMC projections. This may have been due to a transcriptional error in the upper-bound. It is proposed that the best estimates and upper bound be amended and be re-run through the triage and then taken forward to MCMC runs.

Sharks
No change.

Drowning in holes
This threat should be taken forward to MCMC projections, as this is a manageable threat and it should have been included previously.

Trawling
It was noted that there is controversy around the 'interactions' number, which is likely related to the lack of transparency and understanding in how it is calculated and what data is used in its calculation (note 'interactions' are those sea lions that would have been observed as killed if there were no SLEDs).

Trophic/Klebsiella
It was noted that best estimate plots for disease will be subject to a high level of scrutiny and the parameters used must be defensible. The panel recommended a regression analysis on the proportion of pup mortality caused by disease might prove helpful to identify if there is a similar sized effect on first year survival to that from the model. This may also help provide better estimates of mortality from disease (noting that it is currently difficult to identify good vs. bad disease years).

General
The Panel recommended that regression modelling be conducted for all of the main hypothesized threats to better understand the interactions of all of the threats.

Given time constraints, it was agreed that the recommended regression analysis work could be progressed later, for the primary literature publication or in a separate piece of work as part of future research effort.

Cumulative effects

To determine if the estimated total magnitude of all threats identified is plausible, the Panel suggested that all of the effects be added up outside the model and compared to the best year for survival. This could show whether addressing everything that is known about would be sufficient or if there is still a gap due to other threats that are not currently understand or identified (i.e. if after all threats are removed lambda is still below 1.08, then it is possible that a threat has been missed, or the best estimates are not accurate). This could be a powerfully illustrative exercise to help communicate the level of understanding. If a lambda of greater than 1.1 is achieved then this could indicate that it is inappropriate to assume additive effects are at play

Day 3 – September 3rd 2015

The third day of the workshop: considered the potential treatment of the Campbell Island and smaller Stewart Island populations; revisited the overarching threat management goals in light of the outcomes to the modelling work, and made use of the panel's expertise to begin to identify potential research, monitoring and management options. The workshop also briefly considered future strategy evaluation using the NIWA model.

Discussion of Data Poor Breeding Areas

Campbell Island

- It was recognised that data on the Campbell Island colony is limited. Noting that only a few NZ sea lions were found at Campbell Island before the late 1990s, it is unknown, for example, when the switch to colonial breeding may have occurred.
- Concern was raised that the early counts may have only counted a portion of the NZ sea lion population, and later counts were more methodical and likely counted the majority of the population. This is likely to have artificially inflated the growth rate of the population, though it was acknowledged the population has grown.
- It was suggested that it might be helpful to take a backwards look at the pup counts based on current pup count and a given lambda. A value less than 1.06, might be considered suggestive of the early counts being an under estimation of pup production, though some caution is necessary given the limited information available on the various impacts on this population.
- Whilst *Klebsiella* was found in Campbell Island necropsies in 2014/15, no analyses of historical samples have been undertaken to determine its presence in earlier seasons. The extent of the effect of *Klebsiella* at Campbell Island remains unknown. It was noted that 62% of pup mortality in the 2014/15 season was due to starvation, most likely as a result of pups being stranded in holes.
- The Panel recommended more surveys on this population to determine what might be causing the pup mortalities and determine if the population is in fact reaching a plateau.

Stewart Island

- The Panel recommended that the most effective way to manage the main identified threats to the Stewart Island population (i.e. human impacts), given its small population, would be to invest in social campaigns and engagement.
- The Panel also recommended increased monitoring and a focus on the collection of better data to improve understanding of this population, which would allow for modelling to be undertaken in the future.

Threat Management Plan Goals & Criteria

- It was considered that the 5 and 20 year goals could be applied to the overall population and that rather than demographic or even population rate targets, the aim might be to have a New Zealand sea lion population at or above the current size by 2037. This approach might then be supported by site-specific subsidiary goals which would allow for the management responses to be targeted to each population. For example:
  - Auckland Islands – stop or reverse the decline based on demographic rates
  - Mainland – manage threats that may impair further growth

- Campbell Island – monitor to allow for characterisation of population and trends
- Stewart Island - manage threats that may impair further growth and monitor to allow for characterisation of population and trends

- It was agreed that it will be important to specify what aspect of the 'population' is being monitored, i.e. pup production, or mature females, or the whole population, or rate of decline. The potential for time lags in detection based on the part of the population being measured was also noted i.e. a change in pup survival will not be measurable until at least 2022.
- It was also suggested that the 20-year goal could be linked back to generation times for New Zealand sea lions.

Research/Monitoring/Management Recommendations

Auckland Islands

A wide range of research, management and monitoring options were proposed by the Panel in relation to the various threats at each of the colonies:

Impacts from the Trawl fishery

- Quantifying the encounter rate (i.e. how often sea lions do come in contact with trawl gear).
- A rigorous analysis of the historic proportional representation of tagged sea lions from the various subantarctic colonies caught in commercial fisheries may indicate whether Sandy Bay animals are disproportionately caught.
- Simultaneous tracking studies from Dundas and Sandy Bay may help to determine foraging separation and the potential for 'bias' in the animals that are bycaught in the squid fishery.

Impacts from *Klebsiella*

- Identifying environmental reservoirs of *Klebsiella*
- Determining the level of exposure to compare to actual disease occurrence
- Assessing the extent of survival of the bacteria amongst pups
- Using epidemiological models to estimate numbers infected throughout the entire year, preferably with data from extended field studies
- Determining if *Klebsiella* was present prior to the observed population decline
- Genetic investigation can help improve understanding of a number of factors related to the *Klebsiella* infection, including:
    - the history of the bacteria;
    - what made it suddenly more virulent or lethal;
    - increased vulnerability among sea lions;
    - any bacterial mutation that may have occurred, and
    - if *Klebsiella* found in the environment is the same as the one that kills the pups.
- Genetic and microbiological studies could also provide information on treatment options.
- Epidemiological analyses, e.g. case-control studies and randomised controlled trials, to determine risk factors for the disease. These will help inform management strategies.
- Treatment of sea lions is likely to be prophylactic. Treatment once clinical signs are observed is likely to be ineffective. Therefore risk factor analyses are important to inform therapy.
- It was noted treatment was likely to be an ongoing control measure if an environmental reservoir and lack of adaptation to resist infection exist.

- Mapping spatial development of cases across breeding sites could help identify how the disease is spread and should be part of a risk factor analyses. This may provide insights into risk and allow behavioural management of the sea lions to prevent disease spread.

Trophic impacts

- Researching the differences in and reasons for nutritional stress between populations (see Campbell Island).
- Monitoring pup growth and condition.

Campbell Island

- Monitoring for the specific drivers of pup mortality.
- A short high-intensity period (i.e. 3 yrs of annual) may provide the underlying information on variability and a number of demographic factors that could help determine what the frequency of monitoring might need to be in future. The timing of future field trip visits should allow for the management of holes that pups can fall into.
- The collection of further foraging information (tracking foraging behaviour) and diet information, from that population will inform differences between Auckland Islands and Campbell Island population
- Improving autopsy data to understand actual causes of mortalities.
- Enhancing monitoring and collection of demographic data wherever possible

Stewart Island

- Documenting the current sampling programme with an aim of increasing the effort and bringing observations forward to January.
- Characterising the distribution and improving estimates of abundance to support model development and projection, which in turn will yield better understanding of the Stewart Island population.

General

- The importance of extended field seasons, especially at Auckland Islands, in order to better understand the effects of *Klebsiella*.
- Improving collection of summer and winter diet information for a range of analyses.
- Further analysis of already-collected data and samples from previous years.
- Exploring opportunities for “value adding” science projects to existing and planned field trips
- The Panel noted the importance of thinking creatively about future research and management approaches rather than replicating historic approaches.
- It was noted that there is some information on the proportion of adult females that are bycaught in the fishery that have been necropsied and found to have been lactating. This information might be used to better inform the number of pups that may have died as a result of fisheries captures. (Currently 70% of females are considered to be breeding, yet the necropsies of bycaught animals, which is likely to include a number of immature animals (i.e. aged 3-7), suggests it’s actually closer to 30%). Potentially resample breeding probability in the years that you’re sampling the fisheries captures amount from?

Management Options

<u>Mainland</u>

- Social campaigns to minimise human interference and impacts on the populations. It was suggested that this could even include a rehabilitation and education centre if the Otago / mainland population continues to grow.
- Develop options for dealing with overly aggressive males.
- Use translocation intervention as a management tool for cases where mums and pups are in heavily populated locations.

<u>Stewart Island</u>

- Provide educational material (on sea lions) to hunters. It was noted that there is an ability to educate people as they enter the island due to limited entry points.
- Seek assistance from hunters and muttonbirders to report sea lion sightings (i.e. Titi Islands).

As a general comment, the Panel recommended that all data collected on sea lions should be made available, and serious efforts should be made to access any data that is not currently available, noting that unavailable data could impede understanding and subsequent management. The Panel commented that ongoing management of sea lions will need to be an all-of-New Zealand effort and international engagement should be sought wherever possible.

It was made clear that there cannot be any relenting on management processes that are currently in place with regards to mitigating/minimising sea lion captures in the fishing industry.

All management interventions will require rigorous and defensible experimental designs to be developed to ensure that the impacts of management actions can be measured.

Low Information Threats

There was a brief discussion on how to deal with the threats that were not carried through to the modelling, and it needs to be made clear that no threats have been left out entirely. The TMP Project Team confirmed that these will be included in full in the public reporting of the workshop outcomes. It was noted that these additional threats could all be components of the 'other environmental factors' category that is coming out in the model.

The Panel also highlighted the potential for one-off, unforeseen 'catastrophic events' may trigger the need for mid-term review of the TMP.

Evaluation Strategy Using the NIWA Model

- The preferred approach was to examine what combination of adult and pup survival would be needed to reach an increasing or stable population (Auckland Islands), and then examine what the effects on adult and/or pup survival would be following management action to address particular threats.
- A suggested approach for prioritisation was to identify those actions where the biggest gains towards achievement of the goal could be made.
- It was suggested that the MCMC process could be made more efficient by coding portions of the model in C. This could enable better estimates of uncertainty in addition to making it run faster.

The Panel recognised the challenges involved in attempting to fund New Zealand sea lion work solely from government sources. The Panel strongly recommended seeking external, including international collaboration and philanthropic funding. Globally, this is the only population of mammals where a bacterial disease is having such a major population impact, and there should be international interest from this point of view. There is also an established track record of strong international collaborations for studies of New Zealand sea lions and this needs to be maintained and even extended.

- It was also suggested that New Zealand sea lion research requirements be made clear to universities and other potential research providers who may be interested in tackling aspects of these.