

Ministry for Primary Industries
Manatū Ahu Matua



MPI COVERSHEET REMOVED

SQUID (SQU6T) – FINAL ADVICE PAPER

Purpose

- 1 This paper provides you with the Ministry for Primary Industries' (the Ministry's) recommendations for managing the southern squid fishery around the Auckland Islands (SQU6T). This fishery is managed by way of the SQU6T Operational Plan that specifies actions to limit interactions between the SQU6T fishery and the New Zealand sea lion (sea lions). Management action has historically been to set an annual fishing-related mortality limit (FRML) that constrains the number of sea lions that can be caught in the fishery. The Ministry considers that this advice is based on the best available information.

Structure of this paper

- 2 This paper consists of the following parts:
 - a) Part 1: Introduction – Executive summary and summary of consultation.
 - b) Part 2: Background and legislative obligations.
 - c) Part 3: Management approach and recommendations for strike rate and SLED discount rate.
 - d) Part 4: Fishing Related Mortality Limit (FRML) – an overview of the population model and an assessment of the options available to you.
 - e) Part 5: Proposed monitoring and reporting requirements for the SQU6T fishery.
 - f) Part 6: Recommendations.

PART 1: INTRODUCTION

Executive summary

- 3 The fishing grounds of the southern squid fishery that operates around the Auckland Islands (SQU6T) partially overlap with the foraging range of sea lions that inhabit the Auckland Islands; this can lead to the incidental capture of sea lions by vessels that trawl for squid.
- 4 New Zealand sea lions are a protected species and are listed as nationally critical under the New Zealand Threat Classification System. The pup numbers around the Auckland Islands show a long term declining trend and this is the primary reason for the threat classification.
- 5 Although the long-term decline in pup counts remains a concern, the most recent research, discussed in this paper, suggests that fishing is unlikely to be having a direct effect on the sea lion population that could be considered adverse. The Ministry continues to work with the Department of Conservation to investigate the cause of the pup decline.
- 6 To manage the interaction between the SQU6T fishery and New Zealand sea lions, an annual fishing-related mortality limit (FRML) has been placed on sea lions in the SQU6T fishery. To mitigate the risk to sea lions, sea lion exclusion

devices (SLEDs) are used in all trawl nets in the fishery. SLEDs are designed to allow sea lions to escape and survive an interaction with a trawl net.

SLED Research

- 7 Considerable effort has been directed at research to establish the efficacy of SLEDs over the last decade. There are three areas of work that are most relevant.
 - a) First is a detailed analysis of necropsy data from animals caught in trawl nets to assess their injuries and survival prognosis.
 - b) Second is video footage of sea lions interacting with trawl nets to establish the speed and nature of contact and behaviour within and around the net.
 - c) Third is biomechanical modelling of the forces involved in a collision between a sea lion and a SLED. This work assesses the probability of any injury to sea lions that would compromise their survival after exiting a net fitted with a SLED.

SLED Efficacy

- 8 The work on SLED efficacy provides robust evidence that SLEDs greatly increase the survival probability of those sea lions that enter a trawl net. Consequently the Ministry recommends increasing the SLED discount rate from 35% to 82% to reflect the increased likelihood that a sea lion that enters a trawl net will exit via the SLED and survive.

Strike Rate

- 9 Another important component of the management regime is the strike rate. This is the number of sea lions that are presumed to be killed in the fishery and is currently set at 5.65%. This means that for every 100 tows conducted, there are assumed to be 5.65 sea lion interactions with trawls that would be fatal in the absence of SLEDs. The SLED discount rate mentioned above provides a discount on this strike rate to reflect the increased chance of a sea lion surviving.
- 10 The Ministry recommends increasing the strike rate from 5.65% to 5.89% to reflect the most recent modelling work that estimates the strike rate.

The Population Model

- 11 The strike rate and SLED discount rate are key inputs into the Breen-Fu-Gilbert population model. This population model assesses the effects of various management settings against an agreed set of management criteria to derive an FRML. The most recent model outputs suggest that the risk to sea lions from fishing is low enough that an FRML is not required in the SQU6T fishery to ensure the management criteria are met. Consequently, the Ministry consulted on removing the FRML in this fishery.

Ministry's Response to Stakeholders

- 12 Many stakeholders reacted strongly against this proposal. Much of this reaction was based on a lack of understanding about what is a complicated science and management issue. Nonetheless, the Ministry accepts that there remains some uncertainty associated with the science and, although the conclusions drawn from the population model are robust to this uncertainty, the Ministry now recommends a more cautious management approach:
- a) The Ministry recommends retaining the current FRML in the SQU6T fishery of 68 sea lions which is the lowest FRML set in the last 10 years.
 - b) Further, the Ministry recommends reviewing the population model that is used to set the FRML to ensure it remains the best available information and that no better modelling approaches are available.
 - c) The Ministry also recommends adopting the management approach for a four year period. This would be implemented through a SQU6T Operational Plan that would be reviewed before the 2016 SQU6T season.
 - d) In addition, the Ministry recommends a series of six triggers be adopted that would require the Ministry to conduct a management review should any trigger be breached. The nature of that management action would depend on the nature of the trigger and severity of the breach.
- 13 Although the Ministry is confident in the proposal consulted on, and the science that underpinned that proposal, the Ministry is now recommending you adopt a more conservative management approach. The recommended increase to the strike rate from 5.65% to 5.89% and the retention of an FRML of 68 would both represent more cautious management approaches than those in the consultation paper. The increase to the SLED discount rate from 35% to 82% is the same as that proposed in the consultation paper and would represent a less conservative management measure than in 2011.

Information Quality

- 14 The Ministry considers that all of the management measures proposed in the IPP and recommended in this paper are well supported by the most recent science available. These measures are based on a long series of work that dates back more than 10 years, much of which is highly detailed, technically challenging, unusually specialised and builds upon previous analyses.
- 15 All of the research contracted by the Ministry has been through extensive peer review by expert bodies, including in some cases, independent panels of international experts. This peer review was not confined to the results of work but also included the design phase of experiments and at critical steps during the research process. As such, the research relied upon to formulate the management options in this paper complies with the Research and Science Information Standard for New Zealand Fisheries that was approved by Hon Phil Heatley in April 2011.

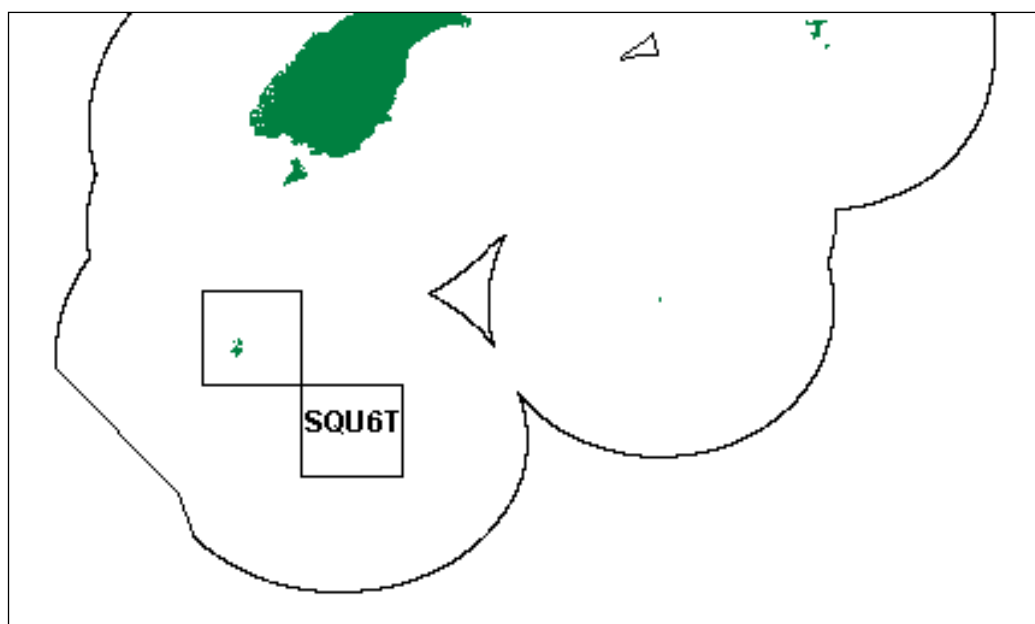


Figure 1: Location of SQU 6T – both boxes.

Summary of Consultation

- 16 The Ministry consulted on the management actions proposed in the attached Initial Position Paper (IPP). The IPP was made available on Friday 2 December 2011 and submissions were invited up to 4 pm on Friday 23 December 2011. Submissions were received from the organisations listed in Table 1.

Table 1: Organisations that submitted on the SQU6T IPP.

Organisations submitting	General view
Royal Forest and Bird Protection Society of New Zealand Inc (Forest & Bird)	Opposed IPP
WWF – New Zealand (WWF)	Opposed IPP
The Environmental Defence Society (EDS)	Opposed IPP
Humane Society International	Opposed IPP
Yellow-eyed Penguin Trust	Opposed IPP
Environment and Conservation Organisations of NZ Inc	Opposed IPP
Otago University – Dr Bruce Robertson	Opposed IPP
New Zealand Sea Lion Trust	Opposed IPP
New Zealand Seafood Industry Council and Deepwater Group Ltd (SeaFIC and DWG)	Supported IPP
Sanford Ltd	Supported IPP
Independent Fisheries Ltd	Supported IPP
Ngati Porou Seafoods Ltd	Supported IPP
Te Ohu Kai Moana Trustee Ltd	Supported IPP

- 17 In addition to the above organisations, several individuals also provided submissions on the Ministry's IPP (Table 2). All individual submitters generally opposed the management measures proposed by the Ministry.

Table 2: Individuals that submitted on the SQU6T IPP.

Individual submitters		
Elain Leung	Christine Rose	Tessa Mills
John Gardiner	Alister Robinson	Alice MacKenzie
John Gibbs	Theresa Downs	Jane Forsyth
Dr Amelie Auge	Chris Miller	Joanne Heatlie
Elisabeth Slooten	Tracey Bowen	Alastair Jamieson
Stephen M Dawson	Nick Goldwater	Lala Frazer
Andrew Maloney	Naomi Ryan	K, E, M and G Waterhouse and R McMahon
Dr Ian Wilkinson	Jennifer Ashby	
Rosiland Horsman	Nathan McNally	

- 18 By the deadline of 4 pm Friday 23 December, 558 form submissions were also received that were generated from the website of the Green Party of Aotearoa New Zealand. The form submission also opposed the management measures proposed in the IPP. Submissions continued to be received up to 14 January 2012, all opposed the measures proposed in the IPP and traversed the same issues as those submitters referred to above.
- 19 The IPP and copies of all submissions are provided in an accompanying volume to this advice paper.

Comment on the science supporting the Ministry's recommendations

- 20 The Ministry notes that the management measures proposed in the IPP were based on a long series of work that dates back more than 10 years. Much of this work is highly detailed, technically challenging, unusually specialised and builds upon previous analyses.
- 21 It was evident from submissions that virtually all stakeholders who discussed the science misunderstood significant aspects of the research that underpins the Ministry's proposed management measures. The approach the Ministry has adopted in this advice paper has been to respond to these misconceptions in a separate paper that is attached to this advice as Appendix A. Where the Ministry considers submitters have raised valid issues, these have been incorporated into this advice paper.

Rigorous peer review

- 22 All of the work relied upon by the Ministry in formulating this advice has been rigorously peer reviewed through the Ministry's science working groups. The working groups are open fora that are attended by a range of technical and non-technical experts who provide high quality scientific review. Consequently, research reviewed by the Ministry's working groups generally receives the highest ranking for information quality under the Research and Science Information Standard for New Zealand Fisheries (the Research Standard). This means that the information "substantially meets the key principles for science information quality ... and can confidently be accorded high weight in fisheries management decisions." Working group Chairs can decide on a lower ranking for particular pieces of research that are considered by their working group, and can attach caveats.

- 23 The Ministry notes that the Research Standard was developed and in collaboration with several other government agencies such as DOC, the Ministry for Research and Science and Technology and the Environmental Risk Management Authority.

Other research

- 24 Several submitters also highlighted published research commissioned by the Department of Conservation (DOC) that draws conclusions that are not consistent with the Ministry's views (including papers by Chilvers 2011,¹ and Robertson & Chilvers 2011).² The Ministry has carefully considered the information contained in these papers and an internal review has been conducted by three Ministry scientists; including the Chief Scientist. These papers were subsequently reviewed against the Research Standard.
- 25 The Ministry's internal peer review identified significant shortcomings associated with both papers. Consequently, the Chilvers paper has been assessed against the Research Standard and has been assigned a quality ranking of three (Low Quality) on a four point scale. This means that the paper "has substantially failed to meet the key principles for science information quality ... and should not be used to inform management decisions."
- 26 The Robertson and Chilvers paper was also reviewed and assessed against the Research Standard, this paper was assigned a quality ranking of two (Medium or Mixed Quality). This means the paper has "some shortcomings with regard to the key principles for science information quality, but is still useful for informing management decisions." Details of the Ministry's peer review and rankings for both papers are contained in Appendix C.
- 27 The Ministry considers it unfortunate that the Chilvers paper was not discussed with the Ministry and subsequently reviewed by the Aquatic Environment Working Group. The poor quality of this work resulted in many submitters making inferences that the Ministry considers have no factual basis. In the Ministry's view, this had a substantial negative impact on the quality of many submissions.
- 28 The Ministry has considered all the available information and, while noting some submitters have different interpretations of the science, the Ministry considers that this advice is based on the best available information.

¹ B. Louise Chilvers (2011). Population viability analysis of New Zealand sea lions, Auckland Islands, New Zealand's sub-Antarctics: assessing relative impacts and uncertainty. *Polar Biology*. Published online 22 December 2011, DOI 10.1007/s00300-011-1143-6.

² Bruce C. Robertson & B. Louise Chilvers (2011). The population decline of the New Zealand sea lion *Phocarctos hookeri*: a review of possible causes. *Mammal Review* 41: 253–275. Published online March 2011, DOI: 10.1111/j.1365-2907.2011.00186.x

PART 2: BACKGROUND AND LEGISLATIVE OBLIGATIONS

Background

- 29 The fishing grounds of the SQU6T fishery partially overlap with the foraging range of sea lions that inhabit the Auckland Islands; this leads to the incidental capture of sea lions by vessels that trawl for squid. The entire 12 nautical mile territorial sea around the Auckland Islands is a marine reserve. As such, all fishing is prohibited in this area which provides a measure of protection to sea lions that inhabit the Auckland Islands; however, the majority of foraging does occur beyond the territorial sea.

Fishing-related mortality limit

- 30 In recent years, the management approach has been to set a fishing-related mortality limit (FRML) to constrain sea lion mortality to an appropriate level and the Minister may choose to close the SQU6T fishery to ensure that the FRML is not exceeded. The FRML is set using a population model that tests the likely performance of different management settings against agreed management criteria (these criteria are described in more detail as part of a later section on the management approach).
- 31 Previous FRMLs are set out in Table 3. In several years the FRML has been reached and the Minister has either closed the SQU6T fishery or the industry has voluntarily withdrawn upon reaching the FRML.

Table 3: Previous FRMLs and management actions.

Year	FRML	Action taken
1993	63	
1994	63	
1995	69	
1996	73	Fishery closed by Minister (4 May 1996)
1997	79	Fishery closed by Minister (28 March 1997)
1998	63	Fishery closed by Minister (27 March 1998)
1999	64	
2000	65	Fishery closed by Minister (8 March 2000)
2001	75	Voluntary withdrawal by industry
2002	79	Fishery closed by Minister (13 April 2002), overturned by the High Court
2003	70	Fishery closed by Minister (29 March 2003), overturned by the High Court
2004	62 (124)	Court of Appeal ruling overturned and increased original decision by Minister
2005	115	Fishery ended before reaching FRML
2006	97 (150)	FRML increased by Minister in mid-March due to abundance of squid
2007	93	Fishery ended before reaching FRML
2008	81	Fishery ended before reaching FRML
2009	113 (95)	Industry agreed to reduce the FRML from 113 to 95 after a drop in the pup count, fishery ended before reaching FRML
2010	76	Fishery ended before reaching FRML
2011	68	Fishery ended before reaching FRML

Risk Mitigation – SLEDs

- 32 The primary risk mitigation practice used by trawl vessels is the sea lion exclusion device (SLED). These devices are fitted inside the trawl net and allow sea lions that enter the net to escape through a hole in the roof of the net (see Appendix D for SLED specifications). SLEDs have been subject to design improvements over the last 10-15 years and since 2007 have been used by all vessels in the SQU6T fishery. The number and rate of observed captures, some of which are released alive, has declined markedly in recent years and the improvements to SLED design and use are likely to have contributed to this trend (Table 4 and Figures 2 and 3).

Table 4: Performance of the SQU6T fishery between 1996 and 2011.

Year	1996	1997	1998	1999	2000	2001	2002	2003
Observed tows	536	706	317	153	434	577	560	410
% observer coverage	12%	19%	22%	38%	36%	99%	34%	28%
Observed captures	13	28	13	5	25	39	21	11
Observed captures per 100 tows	2.4	3.9	4.2	3.2	5.7	6.7	3.7	2.6
Estimated captures	141	144	61	15	68	39	44	20
Year	2004	2005	2006	2007	2008	2009	2010	2011
Observed tows	778	808	689	540	582	770	309	517
% observer coverage	30%	30%	28%	41%	46%	40%	26%	33%
Observed captures	16	9	9	7	5	2	3	0
Observed captures per 100 tows	2.0	1.1	1.3	1.3	0.9	0.3	1.0	0
Estimated captures	42	34	30	17	12	9	13	-



Figure 2: Observed rate of sea lion capture in the SQU6T fishery since 1996.

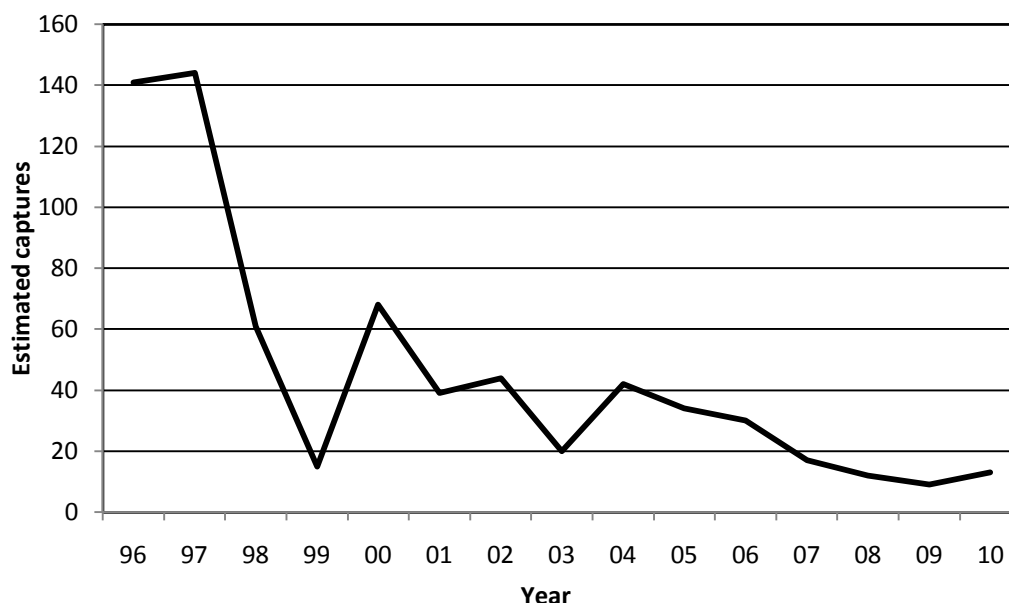


Figure 3: Estimated sea lion captures in the SQU6T fishery since 1996.

Uncertainty regarding SLED efficacy

- 33 Despite the declining trends in observed mortalities and estimated captures, there has been significant uncertainty over the last decade about the efficacy of SLEDs; particularly whether animals sustain fatal injuries in the process of exiting a SLED. Until 2010, sea lions that did not escape from trawl nets were necropsied to examine the extent of their injuries. This information was used to estimate whether those animals that did exit the net would have suffered injuries that compromised their survival chances (e.g. internal injuries or concussion after collision with the SLED grid).
- 34 In 2010, a review of the necropsy programme was conducted by an international panel of four veterinary pathologists and one veterinary neurologist. The Panel's report discounted the possibility that any thoracic or abdominal injury would compromise the survival prognosis of sea lions. Although no fatal head injuries have been observed in necropsied sea lions, mild trauma to the head that may result in drowning remained a possible cause of mortality. The Panel's report concluded that, because head injuries could be obscured by freezing sea lion bodies, and that the same freezing process could mimic lesions, necropsy data were not useful in assessing head injury in sea lions and hence their survival after they exit a net fitted with a SLED.

New information to inform management

- 35 In 2010, an alternative method of assessing the potential for head injury, and the subsequent survival prognosis of animals that interact with a SLED grid, was trialled in a preliminary study. This method used biomechanical modelling to estimate the forces involved in collisions and to assess the likelihood that a sea lion would be killed or concussed if it collided with a SLED grid. This is similar to work conducted using crash-test dummies to record forces that are exerted on human bodies during car accidents.

- 36 In 2011, the preliminary study was reviewed by the Ministry's Aquatic Environment Working Group. Following that review, the Ministry convened a research advisory group, comprised of local and international experts, to design a more comprehensive research programme to build upon and refine the preliminary work. Three new research projects were commissioned and the results reviewed by the Aquatic Environment Working Group. This advice uses the results of this new information to recommend management of the SQU6T fishery.

The New Zealand Sea Lion

- 37 The New Zealand sea lion was reclassified by the DOC in 2010 as "Nationally Critical" under the New Zealand Threat Classification System. This classification was made on the basis of an actual and projected decline in the population.
- 38 Pup counts are used internationally as one of the most reliable indices of population size in pinnipeds, including sea lions. Pup numbers from the Auckland Islands are also an important input into the population model and have been used to calculate FRMLs. (Table 5 and Figure 4). The overall trend in pup production shows a steady decline since the late 1990s; this decline includes several disease events that are known to have caused significant pup mortality in 1998, 2002 and 2003.
- 39 In 2009 there was a significant decline in the pup production estimate that resulted in the fishing industry voluntarily limiting its effort in SQU6T for that season. The pup count increased in 2010 but the cause of the decline in 2009 remains unknown. The pup count in 2011 was lower than in 2010 but extreme weather conditions delayed this pup count, which may affect comparability with previous years. DOC's analysis suggests any such effect is unlikely to be large. The Ministry notes that a new pup count estimate for 2012 will soon be available.
- 40 Although the long-term decline in pup counts remains a concern, the most recent research, discussed in this paper, suggests that fishing is unlikely to be having a direct effect on the sea lion population that could be considered adverse. The Ministry continues to work with DOC to investigate the cause of the pup decline.

Table 5: Pup production estimates from the Auckland Islands rookeries combined, 1995-2011 (Source: Department of Conservation).

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
Pup numbers	2,518	2,685	2,975	3,021	2,867	2,856	2,859	2,282	2,518
Year	2004	2005	2006	2007	2008	2009	2010	2011	2012
Pup numbers	2,515	2,148	2,089	2,224	2,175	1,501	1,814	1,550	-

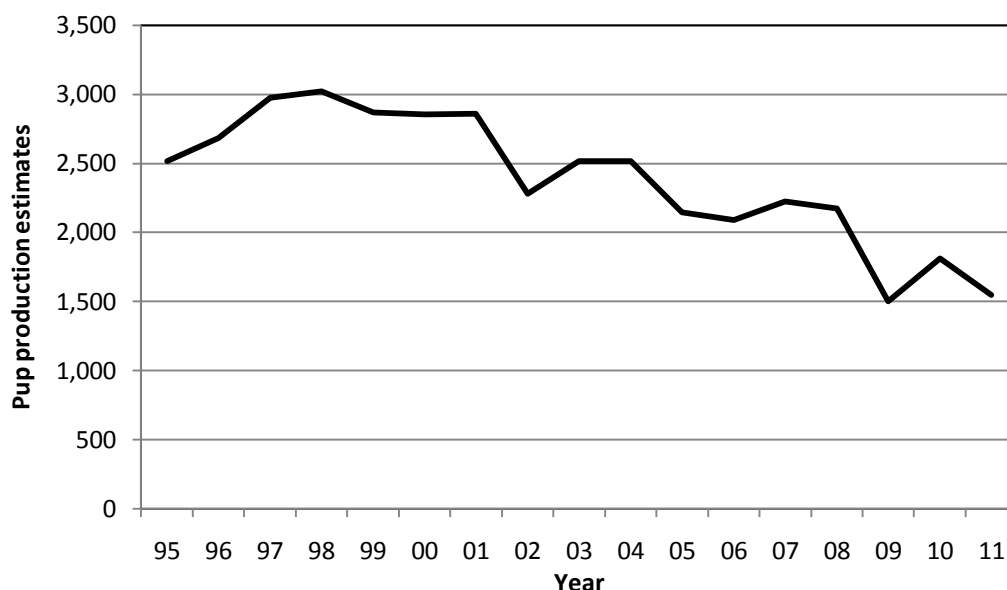


Figure 4: Pup production estimates from the Auckland Islands rookeries combined, 1995-2011. (Source: Department of Conservation).

The Squid Fishery

- 41 Squid continues to be one of the main export earners for the seafood industry. In 2011, the export value for squid was \$120.8 million (Table 6). The export revenues in Table 6 relate to the entire squid fishery and it is not possible to determine how much of this export revenue has come from squid harvested in SQU6T. However, in the 2011 season about 55% of the reported total squid landings were from SQU6T and squid harvested from SQU6T is typically larger and commands a higher price.

Table 6: Total export revenue (\$ millions) and catch (tonnes) from SQU1T and SQU6T. Financial data provided by SeaFIC, collected by the New Zealand Customs Service and held by Statistics New Zealand.

	2004	2005	2006	2007	2008	2009	2010	2011
Export revenue	\$171.8 M	\$168.1 M	\$118.0 M	\$85.7 M	\$71.0 M	\$75.3 M	\$89.4 M	\$120.8 M
Catch (SQU6T)	34,635 t	27,314 t	17,425 t	18,479 t	18,493 t	28,872 t	14,786 t	20,934 t
Catch (SQU1T)	48,060 t	49,779 t	49,149 t	49,495 t	36,171 t	16,407 t	14,957 t	16,759 t

Legislative Considerations

- 42 The New Zealand sea lion is a protected species under the Marine Mammals Protection Act 1978 and that Act provides the opportunity for the Minister of Conservation to approve a population management plan (PMP). A PMP may contain an assessment of known fisheries interactions with sea lions, an assessment of the risk caused by fishing-related mortality and can also be used to set a maximum allowable level of fishing-related mortality. There is no PMP in place for New Zealand sea lions and consequently the interactions between sea lions and the SQU6T fishery are managed under the protected species provisions of the Fisheries Act 1996 (Act).

- 43 Section 15 of the Act sets out your responsibilities for managing the fishing-related mortality of protected species, including marine mammals. Section 15(2) states that, after consultation with the Minister of Conservation, you may take such measures as you consider are necessary to avoid, remedy or mitigate the effect of fishing-related mortality on any protected species, and such measures may include setting a limit on fishing-related mortality.
- 44 In making your decision on management measures for the SQU6T fishery you are required to:
- a) Act in a manner consistent with New Zealand's international obligations relating to fishing and with the provisions of the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992 (section 5).
 - b) Consider the purpose of the Act which is to provide for utilisation while ensuring sustainability (section 8).
 - c) Take into account the environmental principles set out in the Act (section 9):
 - i. "Associated or dependent species should be maintained above a level that ensures their long-term viability:
 - ii. Biological diversity of the aquatic environment should be maintained:
 - iii. Habitat of particular significance for fisheries management should be protected."
 - d) Take into account the information principles in section 10 which require that:
 - i. "Decisions should be based on the best available information:
 - ii. Decision makers should consider any uncertainty in the information available in any case:
 - iii. Decision makers should be cautious when information is uncertain, unreliable, or inadequate:
 - iv. The absence of, or uncertainty in, any information should not be used as a reason for postponing or failing to take any measure to achieve the purpose of this Act."
 - e) Take into account the requirements regarding sustainability measures set out in section 11 of the Act.
 - f) Take into account any relevant and approved fisheries plans under section 11A. The Ministry, in collaboration with industry and environmental organisations, has developed the *National Fisheries Plan for Deepwater and Middle-depth Fisheries* (Deepwater Fisheries Plan) which the Hon Phil Heatley approved in 2010. The Deepwater Fisheries Plan contains the following dual outcomes and the management options recommended in this paper are consistent with those outcomes:
 - i. The Use Outcome: Fisheries resources are used in a manner that provides greatest overall economic, social and cultural benefit.

- ii. The Environment Outcome: The capacity and integrity of the aquatic environment, habitats and species are sustained at levels that provide for current and future use.
- 45 The most relevant Management Objectives under the Deepwater Fisheries Plan are:
- a) MO1.1: Enable economically viable deepwater and middle-depth fisheries in New Zealand over the long-term.
 - b) MO2.5: Manage deepwater and middle-depth fisheries to avoid or minimise adverse effects on the long-term viability of endangered, threatened and protected species.
- 46 You should also be mindful of the following:
- a) The impact the abundance of squid in any particular fishing season has on the likelihood of the FRML being reached.
 - b) The uncertainties that surround setting the predetermined strike rate.
 - c) The uncertainties that surround sea lion survival after they come into contact with a SLED.
 - d) The uncertainties associated with the population model.
- 47 Section 288 of the Ngai Tahu Claims Settlement Act 1998 requires the Crown to acknowledge the cultural, spiritual, historic, and traditional association of Ngai Tahu with their taonga species. Section 287 prescribes the New Zealand sea lion (or Rapoka/Whakaha) as a taonga species under the Ngai Tahu Claims Settlement Act 1998.

Case Law

- 48 In 2004 the fishing industry sought judicial review of the Minister's decision to set an FRML of 62 sea lions (including a strike rate of 5.3 and a SLED discount rate of 20%). The Court found for the Industry and the FRML was increased to 124 for that season. In doing so, the Court of Appeal emphasised that section 15(2) only authorises measures that are "necessary" to avoid, remedy or mitigate the effect of fishing-related mortality on the sea lion population.³ What is necessary is a matter for your judgement; however, this assessment should be guided by the purpose and principles of the Act that are set out above.
- 49 Further, the Court commented that the Minister was required to balance utilisation objectives and conservation values, and in the context of a harvestable species, this requires utilisation to the extent that it is sustainable.⁴
- 50 However, the Court recognised that for a protected species it is not appropriate to think about the concept of sustainability as it relates to a harvested species.

³ *Squid Fishery Management Company v Minister of Fisheries* (7 April 2004) CA 39/04 at [79 and 103].

⁴ *Ibid* at [75].

A precautionary approach is available to the Minister in balancing risk to the protected species against utilisation advantages.⁵

- 51 The Court also commented that the Minister is required to form a view as to the extent which (or perhaps the point at which) utilisation [of squid] threatened the sustainability of the [sea lion] population.⁶ If trawl effort stays within the bounds assumed by the population model, the model's outputs suggest that the agreed, conservative management criteria will be met, even without an FRML and, therefore, the Ministry concludes the sustainability of the sea lion population will not be compromised.
- 52 To ensure that trawl effort remains within the bounds of the population model, the Ministry recommends later in this paper that a limit of 4,700 tows is adopted as a trigger to review the SQU6T Operational Plan.

⁵ Ibid at [77].

⁶ Ibid at [79].

PART 3: MANAGEMENT APPROACH, STRIKE RATE AND DISCOUNT RATE

Management Approach

- 53 The current management approach is to set a mortality limit for the New Zealand sea lion. Since the 2004 fishing season, a population model and recent pup counts have been used to evaluate the performance of management settings against agreed management criteria to derive an appropriate FRML.
- 54 Each management option is examined to estimate the effects of fishing on the sea lion population and the potential fishing opportunities foregone as a result of constraining fishers from catching the squid Total Allowable Commercial Catch (TACC). The SQU6T TACC is currently set at 32,369 tonnes and catch has not exceeded the TACC since 2004. In some years the squid fishery has been closed, and catch foregone, because the level of trawl effort has been constrained by the FRML (see Table 3).
- 55 The population model used to manage the SQU6T fishery assesses management settings against the following management criteria:
- a) The management setting must provide for an increase in the sea lion population to more than 90% of carrying capacity, or to within 10% of the population size that would have been attained in the absence of fishing, and that these levels must be attained with 90% certainty, over 20-year and 100-year projections.
 - b) The management setting must attain a mean number of mature mammals that exceeded 90% of carrying capacity in the second 50 years of 100-year projection runs (to allow for build up of numbers in hypothetical depleted populations over time).
- 56 These management criteria were developed and approved in 2003 by a Technical Working Group comprised of the Ministry, DOC, squid industry representatives, and environmental groups. The Ministry considers the agreed management criteria to be conservative.
- 57 Although you are free to make your own determination as to what is necessary to avoid, remedy or mitigate the effect of fishing-related mortality on the sea lion population, the Ministry considers that these management criteria provide guidance with regard to section 15(2).

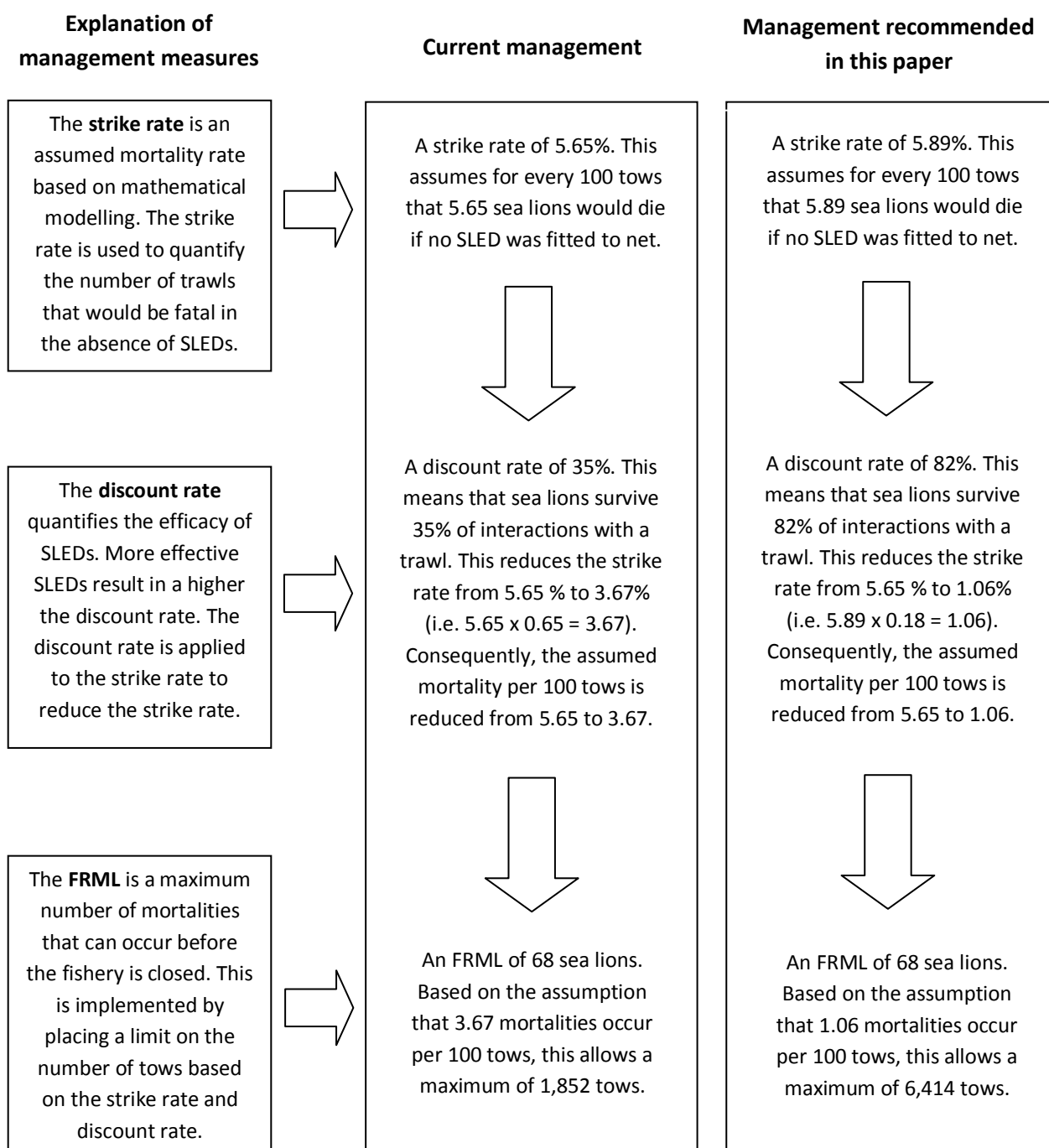
Strike Rate and SLED Discount Rate

- 58 The strike rate and SLED discount rate are important components of the population model and for this reason are discussed prior to the model results. More importantly, new research is now available that demonstrates the discount rate should be higher than the current value of 35%. Figure 5 below sets out the three primary components of the management regime that are explained through the remainder of this paper. The figure also compares the current and proposed management settings.

Strike Rate

- 59 When an FRML is set, fishing activity is monitored against this limit. However, the actual number of sea lions that are incidentally caught in squid fishing gear cannot be directly recorded due to the use of SLEDs which are designed to enable sea lions to escape from the trawl net. Although some dead sea lions are retained in the net, there remains the possibility that sea lions exit the net and subsequently die and cannot be recorded against the FRML.

Figure 5: Schematic diagram explaining management terms and how they interact to form the overall management of the SQU6T fishery. Current and recommended management measures are compared.



- 60 Consequently, an approximation of fatal interactions between squid vessels and sea lions is used. The number of sea lions that are presumed to be killed in the fishery is estimated using a pre-determined strike rate that is currently set at 5.65%. This means that for every 100 tows conducted, there are assumed to be 5.65 sea lion interactions with trawls that would be fatal in the absence of SLEDs.

Submitters' views

- 61 A number of submitters considered that the current strike rate of 5.65% was too low. For example, Otago University highlighted the uncertainty associated with the strike rate and that modelled estimates show the strike rate could be as high as 15.8% (the highest upper 95% confidence interval). Otago University submitted that the Ministry should at least use the mean strike rate of the last 10 years which is 6.1% and re-run the model using that estimate. Similar points were made by Forest & Bird and other submitters stated that the strike rate should be higher but provided no rationale for that view (e.g. Andy Maloney).
- 62 Submitters, such as Forest & Bird and Elisabeth Slooten, also argued that the strike rate should be higher based on the high observed number of captures in the year when all squid tows were observed (2001). In 2001 the strike rate was calculated to be 10.0% (8.3–12.2%). Elisabeth Slooten suggested covering the SLED's escape hole with a net to obtain a more accurate estimate of strike rate.
- 63 SeaFIC and DWG also highlighted the variation in the strike rate. SeaFIC and DWG submitted that the modelling carried out to evaluate FRMLs incorporates this inter-annual variation and recognises that strike rate will change as the population changes. They further submitted that as the population model shows no FRML is needed to meet the management criteria, a decision on strike rate is not required by the Minister.

Ministry's response

- 64 The current strike rate is based on the modelled assessment of the mean strike rate for SQU6T vessels. Further modelling of the strike rate was undertaken in 2008 which estimated a strike rate of 5.6% with a 95% confidence interval from 2.7% to 10%.⁷ At the time of drafting the consultation paper the mean strike rate for the last ten years was 6.1%, this has now been updated based on revised modelling and is now 5.89%.⁸ The Ministry notes that the most recent information on strike rate is summarised in Table 3.4 of the attached AEBAR chapter and may differ slightly from data used to prepare the consultation paper and that mentioned by submitters.
- 65 The Ministry accepts the views of submitters regarding the variability in the strike rate. In the last 10 years, modelled estimates of strike rate in a year have ranged from 3.3% to 10.0%. The Ministry agrees that there remains some

⁷ Thompson, F.N.; Abraham, E.R. (2009). Estimation of the capture of New Zealand sea lions (*Phocartos hookeri*) in trawl fisheries from 1995–96 to 2006–07 New Zealand Aquatic Environment and Biodiversity Report No. 41. 31 p.

⁸ Thompson FN, Abraham ER and Berkenbusch K. 2011. Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. Draft Final Research Report for Ministry of Fisheries project PRO2010-01 (Unpublished report held by the Ministry of Fisheries, Wellington). 80 pages.

uncertainty associated with the modelled strike rate which is likely to vary from season to season. In some years, it will be above the mean while in other years it will be below the mean. This level of variation is not problematic if the average strike rate is close to 5.65%. Despite the variation in estimates of strike rate, the long-term mean of 5.89% is close to the current estimate of 5.65% and the confidence intervals around annual estimates remain relatively wide.

- 66 With regard to the observed mortality in 2001 and 2002, the Ministry accepts that during those years an unusually high sea lion capture rate was recorded by vessels which had SLEDs fitted. However, these higher estimates of strike rate are within the confidence limits associated with recent years.
- 67 Due to the annual variability in strike rate, the Ministry considers it would be inappropriate to base the strike rate on one data point only (such as the 15.8% suggested by Otago University) as this would ignore the variability in interactions and would therefore misrepresent the likely strike rate. For the same reason, the Ministry would not consider a strike rate of 1.1% is appropriate (the lower 95% confidence interval).
- 68 The Ministry recommends setting the strike rate based on an average of modelled estimates. This analysis identifies 5.89% as the long-term mean strike rate which is close to the current value of 5.65% which is used in the population model. However, the Ministry agrees with those submitters that suggested the 10 year mean of 5.89% is a more appropriate estimate and constitutes the best available information. The Ministry recommends increasing the strike rate from 5.65% to 5.89%; this value should be used for the purpose of monitoring the SQU6T fishery and for any future modelling. Further, the Ministry recommends adopting a decision rule that would see the strike rate updated annually and the mean strike rate for the most recent 10 years adopted as a default for the purpose of managing the SQU6T fishery. The Ministry considers this is a technical matter that is best addressed by the Ministry's scientific processes and is similar to selecting estimates of M (natural mortality) or q (catchability) in a fisheries stock assessment model.
- 69 The Ministry does not support the proposal advanced by Elisabeth Slooten to cover the escape hole of SLEDs. This would need to be conducted over several years to get a robust estimate of strike rate and would result in deliberate drowning of sea lions.

SLED Discount Rate

- 70 Sea Lion Exclusion Devices (SLEDs) are installed inside trawl nets and are designed to allow sea lions to escape from the net alive. The "discount rate" refers to the relative survival of sea lions encountering a net with a SLED that would have otherwise drowned in a net without a SLED. Since the 2004 season a discount on the strike rate has been applied to tows where vessels have deployed an approved SLED and where vessel operators have complied with the monitoring and reporting requirements set out in the SQU6T Operational Plan. The current discount rate, approved by the Minister before the 2010 season, is 35%, which means that for all eligible tows the strike rate is reduced from 5.65% to 3.67%.

- 71 Two factors influence how effective SLEDs are at reducing sea lion mortalities: the probability that animals escape from the net via the SLED's escape hole and the probability that those animals that do successfully escape subsequently survive. The discount rate is the product of these two probabilities.
- 72 New information is discussed below that has allowed the Ministry to assess these parameters more accurately, particularly the survival rate of animals that successfully escape from nets. Submitters' views are then discussed and the Ministry responds to those submissions before providing a recommendation.

Probability that animals escape from the net

- 73 The first factor that influences SLED efficacy is the frequency with which animals enter the trawl net and exit the net via the escape hole. This is referred to as the escape probability. The Ministry considers that escape probability may have increased in recent years due to ongoing improvements in SLED design and the ubiquitous use of SLEDs. Improvements include reducing the space between the bars of the SLED grid from 26 cm to 23 cm, which reduces the probability of sea lions passing through the SLED grid and becoming trapped in the cod end of the net. A second improvement is the construction of the SLED kite and adding additional floats to the top of the hood to ensure the escape hole remains open to allow sea lions to exit the SLED. These improvements resulted in the Minister increasing the SLED discount rate in 2007 from 20% to 35% and may be a factor that has contributed to the demonstrated reduction in the rate of observed mortalities and estimated captures (see Table 4 and Figures 2 and 3).
- 74 Two estimates of escape probability have been calculated. The first estimate uses data from all years and does not assume any change to SLED efficacy in recent years. The second estimate allows for the possibility that, based on the design improvements discussed above, SLEDs have become more effective from 2007 and calculates escape probability accordingly. The estimates of escape probability from these models are 80% (67–88%) and 90% (76–96%) respectively. The Aquatic Environment Working Group could find no compelling reason to support one estimate over the other and instead considered that using an average of these two estimates was the most robust approach in the circumstances. This results in an escape probability of 85% (69–96%) and means that, on average 85% of sea lions that enter a trawl net escape from the net.⁹

Probability that animals that escape via SLEDs survive

- 75 In the past, a significant source of uncertainty has been whether animals that interact with the SLED, and subsequently exit the net, sustain fatal injuries in that process. This was initially investigated using necropsies on animals retained in the net. Expert external reviews have discounted the possibility of abdominal or thoracic injury compromising the chances of survival, but concluded that necropsies cannot be used to estimate head injuries because freezing sea lions after capture both mimics and obscures lesions. To assess

⁹ Thompson FN. 2011. Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. PRO2010/01. Aquatic Environment Working Group, 9 November 2011.

the likelihood of head injury, biomechanical modelling has been used to estimate the forces involved in head first collisions between sea lions and SLED grids. This information can be used to assess the likelihood that impacts compromise the chances of a sea lion surviving an impact with a SLED grid. The likely speed and location of collisions were inferred from video footage of Australian fur seals interacting with a Seal Exclusion Device in a trawl. The estimated collision speeds were consistent with the observed swimming speeds for New Zealand sea lions. Australian fur seals are a closely related and similarly-sized species to the New Zealand sea lion and, although the trawl and exclusion devices are not identical, the Ministry considers the information to be a reasonable proxy in the absence of specific video footage.¹⁰

- 76 Biomechanical modelling suggested that the probability of brain trauma sufficient in itself to cause death because of an impact with a SLED grid is zero. Further, the mean probability of a mild traumatic brain injury that could result in the animal drowning after exiting the SLED was estimated to be 2.7%. This accounts for both the probability of an animal having a head first collision with a SLED grid, and the possibility of a single animal having multiple collisions that would compound any injury.¹¹ Consequently, the Ministry's view is that the probability that animals have not had a life-threatening trauma after exiting a trawl net via a SLED is 97%.
- 77 On the basis of this information, the Ministry considers that the SLED discount rate should be increased to 82%. This is based on the 85% probability of escape and the 97% probability of post-escape survival (i.e. $0.85 * 0.97 = 0.82$). This calculation may be mildly pessimistic for two reasons. First, the calculation of discount rate assumes that all sea lions that suffer a mild traumatic brain injury exit the SLED. In reality, it is likely that some, possibly all, of these animals will be retained in the net and may be part of the 15% reflected by the retention probability (i.e. 1 minus the escape probability). Second, the Ministry notes that mild traumatic brain injury is assumed to mean that animals do not survive. This is a conservative assumption as animals may survive after receiving mild trauma to the head.

Uncertainty associated with biomechanical modelling

- 78 The estimate of 2.7% represents the average probability of a mild traumatic brain injury that could compromise sea lion survival. This is the Ministry's best estimate of survival probability and is adopted as the base case in the biomechanical modelling. As with all modelling approaches, there are uncertainties associated with key inputs into the model. A range of sensitivities were conducted to test the influence of changing some of the key model inputs.
- 79 A number of the sensitivity analyses reduce the probability of mild traumatic brain injury; the largest change reduced the risk from 2.7% to 1.6% (Table 7). However, several assumptions could also be made that result in an increased risk to sea lions; the largest change is associated with an assumption that the

¹⁰ Video footage has shown a fur seal and a sea lion exiting a trawl net via a SLED in the SQU6T fishery. Officials will provide you with this footage when meeting to discuss this advice.

¹¹ Abraham ER 2011. Probability of Mild Traumatic Brain Injury for sea lions interacting with SLEDs. Final Research Report for Ministry of Fisheries project SRP2011-03 (Unpublished report held by the Ministry of Fisheries, Wellington). 21 pages.

average impact speed is 20% greater than observed in Australian fur seals. This would increase the risk from 2.7% to 4.6%. The worst case scenario modelled makes multiple pessimistic assumptions; this increased the risk of mild traumatic brain injury from 2.7% to 8.2% (Table 7).

- 80 The Ministry's view is that the risk changes based on the sensitivities are relatively minor which demonstrates the results of the biomechanical modelling are reasonably robust to these uncertainties. For example, if the worst case scenario was used (8.2%), this would reduce the probability that animals successfully escape the net and survive from 97% to 92%. When this is combined with the escape probability of 85%, the SLED discount rate would be reduced from 82% to 78% (i.e. $0.85 \times 0.92 = 0.782$).

Table 7: Influence on the probability of mild traumatic brain injury based on sensitivity analyses.

Description	Percentage of total interactions that result in mild traumatic brain injury
Base Case	2.7%
Most optimistic sensitivity trial	1.6%
Most pessimistic sensitivity trial	4.6%
Worst case scenario that makes three pessimistic assumptions	8.2%

- 81 However, there remains the possibility that those animals that exit the net have done so late in their dive. The time taken to negotiate the SLED and exit the trawl net could result in sea lions drowning before they reach the surface because they exceed their breath-holding capacity. Should this occur, the probability that animals survive after escaping from a trawl net would be lower than 97%. The Ministry considers that this should be taken into account and for that reason has conducted sensitivity trials in the population modelling that assume lower survival probabilities.
- 82 The Ministry is not aware of any specific information that would inform an estimate of the likelihood of post-exit drowning of an animal that exits a SLED without injury. However, at a depth of 200 metres, the approximate depth at which the SQU6T fishery operates, it would take 1-2 minutes for a sea lion to reach the surface. This is fairly short compared to the sea lions' average maximum voluntary dive time (over 10 minutes)¹² and a sea lion in a life-threatening situation is likely to be able to hold its breath longer still.

Submitters' views

- 83 Several submitters considered that there is no robust evidence on the likelihood that sea lions exiting the SLED would survive (e.g. Stephen Dawson). Stephen Dawson did not consider the biomechanical modelling was a credible approach but supplied no rationale for this view.
- 84 A number of submitters, such as Forest & Bird, listed several concerns regarding SLEDs. A number of these concerns are based on observations of

¹² BL Chilvers, IS Wilkinson, PJ Duignan & NJ Gemmell (2006). Diving to extremes: are New Zealand sea lions (*Phocarcos hookeri*) pushing their limits in a marginal habitat? *Journal of Zoology* 269: 233–240.

Seal Exclusion Devices (SEDs) in Australian fisheries. Forest & Bird note instances in Australia where seals have been observed to fall out of SEDs and consider that it is likely that sea lions in New Zealand are drowning in nets and falling out, thus hiding increased mortality (this issue is addressed in Appendix A). Submitters such as WWF also stated that the proportion of animals drowning upon their return to the surface after exiting a SLED could be significantly higher than the 10% estimated by the Ministry and that this makes assumptions about SLED efficacy optimistic. WWF suggested that a sensitivity analysis should consider a more pessimistic scenario.

- 85 Submitters also highlighted the uncertainty associated with the biomechanical modelling and that this should result in a lower SLED discount rate.

Ministry's response

- 86 The Ministry considers that submitters have raised some valid points in relation to SLED efficacy. In response, the Ministry has included in this advice further detail above regarding the uncertainty associated with the biomechanical modelling (Table 7 and associated text). This description of the uncertainty demonstrates that when quite pessimistic assumptions are made in the biomechanical modelling, the information suggests that SLEDs still significantly increase the likelihood that sea lions escape from trawl nets and survive. Further, the Ministry has also included details about design improvements made to SLEDs and considers the 10% sensitivity is reasonable given the depth of trawls and the breath holding capacity of sea lions. The Ministry has responded to other matters raised in Appendix A.
- 87 In summary, the Ministry does not accept that there is no evidence to assess the efficacy of SLEDs as was stated by some submitters. The work summarised above that included necropsy work, underwater camera observations and the biomechanical modelling, together provide robust evidence that SLEDs greatly increase the survival rates of those sea lions that enter a trawl net. This work has undergone extensive peer review from New Zealand-based and international experts and the Ministry considers the estimates of SLED efficacy described herein to be the best available information.

Revision of the Discount Rate

- 88 The SLED discount rate is the product of the probability that animals escape from the net and the probability that those animals that escape subsequently survive. The most recent information has estimated these probabilities to be 85% and 97% respectively. This information results in a discount rate of 82.0% (i.e. $0.85 \times 0.97 = 0.8245$). The Ministry considers this constitutes the best available information and recommends increasing the SLED discount rate from 35% to 82%.
- 89 There is uncertainty associated with this estimate. Although the Ministry recommends adopting a discount rate of 82%, the option is available to be cautious by adopting multiple pessimistic assumptions about the biomechanical modelling, which would reduce the discount rate to 78%. In addition, the option is available to you to be particularly cautious and assume that some animals that exit SLEDs without injury subsequently drown upon returning to the

surface. If you considered it was necessary to be particularly cautious, you could reduce the discount rate further to take into account a range of uncertainties including the possibility of post-exit drowning. For example, you could reduce the discount rate by a further to 10% to 68%.

- 90 Regardless of which discount rate you select, the Ministry recommends that the survival rate of sea lions interacting with a trawl net be used as the default value in any subsequent modelling processes. This recognises the distinction between the estimate of survival probability as an empirical value for use in a science-based process, and the use of a SLED discount rate as a management tool to monitor the fishery. The former should be solely based on the scientific information available, whereas the latter can be modified by you to reflect the degree of caution you wish to exercise in the management of the SQU6T fishery.

PART 4: CALCULATING AN FRML

- 91 The FRML is a limit on the number of sea lions that can be incidentally caught in the SQU6T fishery. Since the 2004 fishing season a population model has been used to evaluate the performance of management settings against the agreed management criteria to derive an FRML.

The Population Model

- 92 This section describes model results and the effect of some of the uncertainty associated with the model and key inputs. The outputs of the population model are used to calculate FRMLs using the average of the last two years' pup counts; as such, the FRMLs will vary annually as pup counts vary.¹³ As with all models there is some uncertainty about how closely the model approximates real life and sensitivity trials are conducted to test the effect that this uncertainty has on determining which management settings, and hence FRMLs, meet the management criteria.

Key model inputs

- 93 For the purpose of running the population model, the Ministry used a strike rate of 5.65% and a range of SLED discount rates. Due to time constraints leading up to the preparation of the consultation paper, the Ministry was required to contract the population modelling prior to final confirmation of the probabilities used to estimate the discount rate. Consequently, the Ministry had the population model run using preliminary information and requested a Base Case using a discount rate of 75% and sensitivities of 65% and 85% to account for the range of possible uncertainty associated with the discount rate. Including previous model runs, the Ministry now has model outputs at discount rates that span the whole range from 0 to 100%.

Sensitivity analyses

- 94 To assess the possibility that post-exit survivability is lower than 82%, due to the possibility that animals drown on their return swim to the surface, the

¹³ The population model also assesses a Rule 2 Series. This generates fixed FRMLs that do not rely on estimating the pup numbers each year. Given recent fluctuations in pup numbers, the Ministry is continuing to assess potential management measures using the Rule 3 Series only.

Ministry ran a sensitivity using a discount rate of 65% (compared with the then assumed Base Case of 75%).

- 95 In addition to the sensitivity trial associated with the SLED discount rate, there is also uncertainty about some of the values of other parameters used in the population model. This uncertainty relates to the following:
- a) The maximum rate of population growth (sensitivity trials 1 & 2)
 - b) How pup survival responds to population size (sensitivity trials 3 & 4)
 - c) The maximum pupping rate (sensitivity trial 5).
- 96 To assess the influence of these, each of the three model runs (65%, 75% and 85%) was also assessed against the five sensitivity trials to test the influence that varying these parameters has on which management settings meet the management criteria. These trials assess the robustness of the modelling results if current assumptions about the outstanding areas of uncertainty are incorrect.
- 97 The 75% Base Case using the Base Model assumptions (i.e. with no sensitivities) indicates that the management criteria would be met without the need for an FRML (Table 8). This remains so using the 65% and 85% discount rates as sensitivities. Under all three models, four of the sensitivity trials indicate that no FRML is required to meet the management criteria. If a new Base Case was run using the best estimate of the discount rate of 82%, the management criteria would also be met without the need for an FRML.
- 98 The most conservative sensitivity trial (sensitivity trial 2 which imposes no prior belief on the rate of maximum population growth rate in the model) did not meet the management criteria at any point (Table 8). Based on this sensitivity trial, even complete closure of the fishery would fail to meet the management criteria. In effect, this sensitivity trial predicts that even if all fishing was stopped, the sea lion population would continue to decline towards extinction. In previous years, the Ministry has questioned the credibility of this sensitivity trial given the sea lion population has sustained significant reductions in the past due to sealing in the early nineteenth century and has subsequently rebounded to a stable higher level.¹⁴ The Ministry considers that sensitivity trial 2 is not plausible over the long term.

¹⁴ The possibility of the sea lion population becoming extinct in the absence of fishing is also considered by the population model's primary author to be unlikely.

Table 8: The results of the population model using the initial Base Case (shaded area) and the described sensitivity trials. “No FRML required” indicates that the management criteria were met without the need for an FRML. “- -” indicates that even the absence of fishing does not meet the management criteria.

	50% SLED discount rate		65% SLED discount rate		75% SLED discount rate		85% SLED discount rate	
	Rule	FRML	Rule	FRML	Rule	FRML	Rule	FRML
Base Model	No FRML required	No FRML required	No FRML required	No FRML required	No FRML required	No FRML required	No FRML required	No FRML required
Most conservative sensitivity trial	- -	- -	- -	- -	- -	- -	- -	- -
All other sensitivity trials	No FRML required	No FRML required	No FRML required	No FRML required	No FRML required	No FRML required	No FRML required	No FRML required

Submitters' views

- 99 Several submitters such as Forest & Bird stated that they did not support the use of the Breen-Fu-Gilbert model to manage the SQU6T fishery because there are too many assumptions, uncertainties and problems associated with it. Forest & Bird submitted that the population model was not realistic as it failed to predict real life data on observed pup counts. Another source of concern was that the outputs of the population model are highly dependent on assumptions about the sea lion population's carrying capacity which is not well known. These comments are typical of many made by submitters that did not consider the Breen-Fu-Gilbert model should be used; issues raised on this matter are addressed in Appendix A.
- 100 Some submitters suggested that at the very least the FRML should be maintained at the current level of 68 sea lions, but preferably lower (e.g. EDS, Nathan McNally). Forest & Bird also suggested reverting to the 2010/11 management option (an FRML of 68) although also suggested modifications.
- 101 Many submitters assumed that removing the FRML was the same as allowing an unlimited number of sea lions to be caught. This is a misconception. Removing the FRML is a response to the reduced risk that fishing has on the sea lion population, largely based on the efficacy of SLEDs. The population model indicates that to meet the management criteria, no constraint of fishing (no FRML) is necessary based on this reduced risk.
- 102 Submitters also raised a number of other matters relating to the management of the fishery. As with issues relating to the science, these have been addressed in Appendix B that is attached to this advice.

Ministry's response

- 103 The Ministry accepts that there are uncertainties associated with the Breen-Fu-Gilbert model; this will always be the case with any population model. The key uncertainties are addressed in the sensitivities conducted and discussed above. However, the Ministry considers that there is merit in reviewing the Breen-Fu-Gilbert model and has already programmed this review into research planning for the 2012/13 year. This review will consider alternative modelling

approaches and will also ensure that the assumptions in any model are based on the most recent information. Despite the inherent uncertainty in the model, the Ministry remains of the view that it constitutes the best available information about the influence of fishing on the sea lion population.

- 104 The Ministry also considers that a cautious management approach would be to retain the current FRML of 68 sea lions. This is discussed further below.

Management options

- 105 The Ministry considers that the best available information demonstrates that the current management, particularly the design and use of SLEDs, adequately manages the risk of fishing to the sea lion population. The most recent research strongly suggests that the direct effect of fishing-related mortality on the sea lion population is minimal and the results of the population model also demonstrate that no FRML is necessary to meet the established management criteria. This conclusion is based on meeting some important assumptions that are made in the model, i.e. that neither fishing effort nor sea lion catchability increases beyond the values assumed in the population model. If these assumptions are not met, the Ministry's proposed management approach includes specific triggers that will result in a management response. These triggers are discussed later in the paper (e.g. minimum SLED use and reporting requirements, a maximum limit on tows, a minimum pup count).
- 106 For this reason, the Ministry proposed in the IPP that an FRML no longer be set in the SQU6T fishery. This management option is justifiable based on the most recent modelling that assumes a higher SLED discount rate than the current estimate of 35%. However, this is based on strict adherence to the current management regime, most importantly the use of SLEDs that comply with the specifications in the SQU6T Operational Plan.

Effect of uncertainty on management options

- 107 The management option above is robust to many of the uncertainties associated with the SLED discount rate and the inputs to the population model that have been noted. Even if you make a conservative assumption about the biomechanical modelling and assume the probability of mild traumatic brain injury that could compromise survival is 8.2% (the worst case scenario that was modelled) and make allowance for uncertainties around post-exit drowning by decreasing the discount by a further 10%, the population model still indicates that no FRML is required (these assumptions would equate to a SLED discount rate of 68% in Table 8).
- 108 Further, even if you were significantly more cautious and reduced the discount by 20 or 25 percentage points to account for uncertainties around post-exit drowning, this would result in SLED discount rates of 58% and 53% respectively. These high post-exit drowning estimates equate to the more pessimistic scenario suggested by WWF as a sensitivity. Table 8 shows that even with all of these very conservative assumptions the population model still indicates that no FRML is required to meet the management criteria (with the caveats on fishing effort and catchability stated above and addressed by implementing the review triggers detailed below).

A more conservative management option

- 109 The Ministry notes the concerns raised by submitters and the long-term reduction in the pup count around the Auckland Islands. Although the most recent information suggests the direct effect of fishing is unlikely to be the cause of this decline, it remains of concern nonetheless.
- 110 If you considered it was necessary to do more to avoid, remedy or mitigate the effect of fishing-related mortality on the sea lion population, you could retain the current FRML of 68 sea lions as a precautionary measure. This would effectively place a limit on the level of fishing effort. There would be no such limit if you removed the FRML. This would provide further assurance that fishing would not have an adverse effect on the sea lion population. This would be a cautious approach to management and place additional weight on the uncertainty associated with aspects of the science information.
- 111 The effect of retaining an FRML of 68 is illustrated in Table 9. The number of available trawl tows is tabulated based on various options available to you regarding the strike rate and the SLED discount rate. In effect, the limit on tows based on higher SLED discount rates are unlikely to be particularly constraining based on recent effort in the SQU6T fishery (tow limits in the last three years have been 1,852, 2,069 and 2,587).¹⁵

Table 9: The number of tows available if based on an FRML of 68 and various assumptions about SLED discount rate and strike rate.

Strike rate	SLED discount rate			
	50%	68%	78%	82%
5.65%	2,407	3,761	5,471	6,686
5.89%	2,309	3,608	5,248	6,414

- 112 However, recent practice has been to limit the number of trawl tows and this is likely to have contributed to the increase in tow length over the last decade. Increasing the number of tows available is likely to result in some vessels reducing the length of tows conducted. This could have two consequences. First it may increase the likelihood that sea lions are caught in trawl nets as nets will be shot and hauled more regularly. Shooting and hauling of nets probably represents a greater risk to sea lions than when nets are fishing at depth. However, the efficacy of SLEDs should mitigate this risk to an extent given sea lions are likely to escape from nets and survive.
- 113 Second, reducing the length of tows generally results in a better quality product being landed and this better product will often result in a higher price and increased revenue for the operator. However, it should be noted that not all vessels will reduce tow times to land better product as it depends on the product state and the market the vessel is supplying. Some markets will be satisfied with lower quality product and therefore changing fishing practice to reduce tow times is not necessary even if more tows are available.

¹⁵ The limit of 2,587 was the number of tows available after the voluntary reduction in tows based on the reduced pup count in 2009.

Monitoring and Review

- 114 The Ministry proposes to continue to implement similar monitoring and reporting procedures to those in place in the 2011 SQU6T season. However, the Ministry intends to increase the target for observer coverage on vessels in the SQU6T fishery from 30% to 50%. This is to ensure that compliance with the Operational Plan remains high and to provide additional monitoring that would become part of the ongoing management of the SQU6T fishery.
- 115 In past years, the Operational Plan has been reviewed annually. This is largely due the influence that changes in information (e.g. strike rate and pup count) can have on the FRML that could be set for the fishery. The most recent science makes it clear that this variation in information has little influence on the FRML that can be set for the fishery while still meet the management criteria. Consequently, the Ministry recommends that the management approach you select remains in place and is reviewed after four years unless an earlier review is triggered by one or more of the following occurring in a year:
- a) Less than 98% of tows undertaken in the SQU6T fishery use a SLED that meets the specifications detailed in the SQU6T Operational Plan;
 - b) Less than 95% of tows undertaken in the SQU6T fishery meet the reporting requirements specified in the SQU6T Operational Plan;
 - c) More than 15 sea lion mortalities observed by Ministry Observers in any one SQU6T season (assuming 50% Observer coverage and pro-rated otherwise);
 - d) More than 4,700 tows;
 - e) A pup count of fewer than 1,501 pups on the Auckland Islands;
 - f) Any new information that indicates the risk to sea lions posed by fishing in SQU6T is appreciably greater than current information suggests.

Rationale for review criteria

- 116 The Ministry considers that the risk to sea lions is reduced significantly by the use of SLEDs and the reporting requirements specified in the SQU6T Operational Plan.
- 117 Any departure from these management measures would result in an increased risk to the sea lion population and this is the reason for the first two review criteria. Should these criteria be breached, a review may result in revisiting procedures to ensure that compliance with the SQU6T Operational Plan remains high or that SLED specifications are well-understood.
- 118 The Ministry considers that SLEDs reduce the risk to sea lions and that the efficacy of SLEDs has contributed to reduced rates of capture in recent years. Should observed sea lion captures increase above expectations, this may indicate that SLEDs are not being deployed correctly. Should the third criterion be breached, a review would concentrate on assessing SLED deployment and compliance with the SLED specifications. The Deepwater Group and SeaFIC suggested a conference among industry will be held should seven observed

captures occur within a season. The Ministry supports this suggestion and would discuss any outcomes of such a conference with industry and assist with implementing any solutions that are identified as part of this in-season action.

- 119 With regard to the fourth criterion, the population model assumes the fishery will attempt a certain number of tows each year. Squid abundance is highly variable and the model incorporates this through an assumption that the number of tows varies between 405 and 6,082. If the real SQU6T fishery undertakes more tows than this, the model's assessment of management settings may be optimistic. The Ministry therefore proposes a trigger of 4,700 tows, being the 90th percentile of the number of tows assumed in the model. It is more appropriate to use some percentile of the distribution rather than the maximum because average tow length has steadily increased from about four hours in 2002 to about eight hours in 2010 and longer tows are expected to catch somewhat more sea lions than shorter tows. The Ministry notes that this trigger is lower than the number of tows allowed by an FRML of 68 under some assumptions about SLED discount rate and strike rate (Table 9). This trigger indicates that fishing activity is approaching the bounds of a key assumption that the model makes about the fishery. This signals that it may be prudent to re-consider the assumptions the model makes about the fishing effort and re-run the model based on that updated information.
- 120 The Ministry notes that pup counts have in the past been used to generate FRMLs from the management settings that meet the management criteria. As all plausible model runs meet the management criteria without the need for an FRML, the pup counts have not been used to generate FRMLs this year. In essence, the latest research strongly suggests that the direct effect of fishing will not compromise the sea lion population's ability to meet the agreed management criteria and fishing-related mortality is not the primary cause of the observed pup decline. However, the population model used to evaluate the management settings predicted a strong increase in the sea lion population after the 2009 nadir and further declines in pup production would be increasingly inconsistent with the model's predictions. If pup production on the Auckland Islands falls below the lowest level previously reported (1,501 in 2009), it would be reasonable to reassess the reliability of the model and the effect on the performance of management settings. As noted, a new estimate of pup counts from the Auckland Islands in 2012 will be available soon.
- 121 The Ministry's proposed management is based on a range of research reports that it has commissioned over several years. Should new information become available that suggests any of the assumptions relied upon to formulate this advice are incorrect, and this would result in the risk to the sea lion population being appreciably greater than we currently infer, the Ministry will review the management approach accordingly and provide you with further advice if necessary. The nature of any review will be dependent upon the new information.

Fishery closure

- 122 The Ministry notes that section 15(5) of the Act provides the Minister with the option of closing the fishery to ensure an FRML is not exceeded and in previous years the SQU6T fishery has been closed when the FRML has been

reached (Table 3). Should you decide not to set an FRML, this would remove your ability to close the SQU6T fishery under section 15. The power to close the SQU6T fishery as an emergency measure under section 16 would still remain but this power is only available if there is:

- a) an outbreak of disease
- b) a serious decline in the abundance or reproductive potential of one or more stocks or species, or
- c) a significant adverse change in the aquatic environment.

PART 5: MONITORING AND REPORTING

Overview of 2011 season

- 123 During the 2011 fishing season, 1,573 tows were conducted. Based on the assumptions in 2011 of a strike rate of 5.65% and a 35% discount rate, 1,573 tows results in an estimate of 58 mortalities from the current FRML of 68. Applying the new estimated survival rate of 82% results in an estimate of about 16 sea lion mortalities for the 2011 season. These estimates are assumed mortalities only based on the assumptions set out.
- 124 The Ministry's Observers observed 517 (33%) of the 1,573 tows in the fishery during the season and no actual mortalities were observed by Ministry Observers or reported by the fishing industry.
- 125 Ministry Observers carried out audits of SLEDs while onboard SQU6T vessels and all SLEDs that were used in the fishery met the agreed specifications and passed in-season checks by Observers and Fishery Officers. Of the 1,573 tows that were undertaken during the 2011 season, 1,551 (98.6%) tows were eligible for the discounted strike rate. Twenty-two tows were not eligible for the SLED discount because one vessel failed to provide the required 72 hour notification to the Ministry (thereby hindering the capacity for the Ministry to place Observers on the vessel).

Monitoring and reporting requirements for 2012

- 126 The Ministry proposes to implement similar monitoring and reporting procedures that were in place for the 2011 season. This will require:
- a) The fishing vessel operator to notify the Ministry's Observer Programme at least 72 hours before leaving port to ensure there is sufficient time to place an observer onboard the vessel before it sails. This notification may also be used as an opportunity for Fishery Officers to undertake a port inspection of the SLED.
 - b) The Master of the fishing vessel is required to report to the Ministry, at the end of the fishing trip, any encounter with a marine mammal that resulted in death or injury. Ministry Observers will notify the Observer Programme immediately following the capture of a sea lion.
 - c) All vessels in the SQU6T fishery will participate in a weekly reporting regime managed by the Deepwater Group Ltd (DWG). Upon the request

of the Ministry's Fisheries Manager Deepwater, reporting will be daily. The information reported will include:

- i. Each tow undertaken in the SQU6T fishery.
- ii. Whether the tow was observed by a Ministry Observer.
- iii. If an approved SLED was deployed during the tow.
- iv. If a sea lion was caught during the tow and whether it was released alive or returned dead to the sea.

127 All SLEDs will be returned to port to be audited prior to the start of the SQU6T season. Both the Ministry Observer Programme and Field Operations will continue to inspect SLEDs throughout the season to ensure the vessel is carrying the SLED for which it was given approval and that the SLED has not been adjusted or modified and is in working order.

128 The Ministry no longer requires frozen sea lions to be returned for necropsy.

129 As specified above, the Ministry intends to increase the minimum target of observer coverage across the SQU6T fishery during the 2012 fishing season from 30% to 50%.

Further work

130 The Ministry considers that the most recent science supports the conclusion that the direct effect of fishing is having a minimal effect on the sea lion population. Other work regarding indirect effects of fishing is ongoing. The Ministry recommends that you discuss with the Minister of Conservation the possibility of directing officials from the Ministry and the Department of Conservation to consider all the available information about non-fishing impacts on the New Zealand sea lion population to assess other possible causes for the population decline. In particular, the long term effects of the epizootic events should be considered.

PART 6: RECOMMENDATIONS

131 The Ministry recommends that you consider the following management measures to manage interactions between vessels operating in the SQU6T fishery and the New Zealand sea lion:

- a) **Note** that you must consult the Minister of Conservation before making your decisions;

Noted

- b) **Agree** to implement an Operational Plan for the SQU6T fishery to ensure the management criteria for the sea lion population (as set out in Part 3 of this paper) are met;

Agreed / Not Agreed

And, with regard to the pre-determined strike rate, select one of the following three options:

- c) **Note** that the strike rate is a pre-determined rate that estimates the number of tows that would be fatal in the absence of a SLED; a higher strike rate is more conservative as it assumes more mortalities per 100 tows;

Noted

- d) **Option 1: Agree** to increase the pre-determined strike rate from 5.65% to 5.89% (*Ministry's recommendation*);

Agreed / Not Agreed

OR

- e) **Option 2: Agree** to retain the current pre-determined strike rate of 5.65%;

Agreed / Not Agreed

OR

- f) **Option 3: Agree** to set a pre-determined strake rate at any other level you consider is appropriate;

Agreed / Not Agreed

And also with regard to the pre-determined strike rate;

- g) **Agree**, as discussed in paragraph 68, to set a decision rule in place that would use the mean of the modelled estimates of strike rate for the most

recent 10 years as the default pre-determined strike rate (**Ministry's recommendation**);

Agreed / Not Agreed

And, with regard to the SLED discount rate, select one of the following five options:

- h) **Note** that the SLED discount rate reduces the strike rate and reflects the efficacy of SLEDs; a higher discount rate is less conservative as it allows more tows to be conducted in the fishery to reflect increased SLED efficacy;

Noted

- i) **Option 1: Agree** to increase the SLED discount rate from 35% to 82% (**Ministry's recommendation**);

Agreed / Not Agreed

OR

- j) **Option 2: Agree** to increase the SLED discount rate from 35% to 78%

Agreed / Not Agreed

OR

- k) **Option 3: Agree** to increase the SLED discount rate from 35% to 68%

Agreed / Not Agreed

OR

- l) **Option 4: Agree** to retain the SLED discount rate at 35%;

Agreed / Not Agreed

OR

- m) **Option 5: Agree** to set the SLED discount rate at any other level you consider appropriate;

Agreed / Not Agreed

And also with regard to the SLED discount rate;

- n) **Agree**, as discussed in paragraph 90, that the survival rate of sea lions interacting with a trawl net be used as the default value in any subsequent modelling processes, noting that this recognises the distinction between the estimate of survival probability as an empirical value for use in a

science-based process and the use of a SLED discount rate as a management tool to monitor the fishery;

Agreed / Not Agreed

And, with regard to the fishing-related mortality limit, select one of the following three options:

- o) **Option 1: Agree**, for the purposes of section 15(2) of the Fisheries Act 1996, to retain the current fishing-related mortality limit (FRML) of 68 sea lions (**Ministry's recommendation**);

Agreed / Not Agreed

OR

- p) **Option 2: Agree** to remove the current fishing-related mortality limit (FRML);

Agreed / Not Agreed

OR

- q) **Option 3: Agree** to set a fishing-related mortality limit (FRML) at any other level you consider is appropriate;

Agreed / Not Agreed

And, with regard to the SQU6T Operational Plan

- r) **Agree** that the SQU6T Operational Plan should remain current for a period of four years and will next be reviewed prior to the 2017 SQU6T season;

Agreed / Not Agreed

AND

- s) **Agree** that the Ministry will review the SQU6T Operational Plan if any of the following trigger points are reached in a year:
- i. Less than 98% of tows undertaken in the SQU6T fishery use a SLED that meets the specifications detailed in the SQU6T Operational Plan;
 - ii. Less than 95% of tows undertaken in the SQU6T fishery meet the reporting requirements specified in the SQU6T Operational Plan;
 - iii. More than 15 sea lion mortalities are observed by Ministry Observers in any one SQU6T season (assuming 50% Observer coverage and pro-rated otherwise);
 - iv. More than 4,700 tows in any one SQU6T season;
 - v. A pup count of fewer than 1,501 pups on the Auckland Islands;

- vi. Any new information that indicates the risk to sea lions posed by fishing in SQU6T is appreciably greater than current information suggests;

Agreed / Not Agreed

AND

- t) **Agree** that the nature of any review under Recommendation s) will be tailored by the Ministry to respond to the nature and severity of any breach;

Agreed / Not Agreed

AND

- u) **Note** that should seven observed captures occur, the Deepwater Group Ltd will initiate a conference with industry to discuss potential causes of the sea lion captures and solutions;

Noted

AND

- v) **Note** that the Ministry has planned to review the Breen-Fu-Gilbert model, and consider other modelling approaches, in the 2012/13 year;

Noted

AND

- w) **Note** that the Ministry proposes to increase its target for observer coverage in the SQU6T fishery from 30% to 50%;

Noted

AND

- x) **Agree** to discuss with the Minister of Conservation the possibility of directing officials to consider all the available information about non-fishing impacts on the New Zealand sea lion population to assess other possible causes for the population decline; in particular, the long term effects of the epizootic events.

Agreed / Not Agreed

Scott Gallacher
Deputy Director General
Resource Management and Programmes

Hon David Carter
Minister for Primary Industries

/ / 2012

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Summary of SQU6T submissions on issues relating to scientific evidence

Individual submissions assessed: Steve Dawson, Elisabeth Slooten, John Gibbs, Jane Forsyth, Tessa Mills, Jennifer Ashby, Naomi Ryan, Nick Goldwater, Tracey Bowen, Chris Miller, John Gardiner, Amélie Augé, Ian Wilkinson, Joanne Heatlie, Alister Robinson, Elaine Leung, Alastair Jamieson, Kate Waterhouse, Andrew Maloney, Lala Frazer, Nathan McNally, Rosalind Horsman, Christine Rose, Vanessa Smith, Charlotte Bueb. In addition, four submitters requested that their details remain confidential.

Organisational submissions assessed: Forest and Bird, Environment and Conservation Organisations of NZ (ECO), WWF New Zealand (WWF), Environmental Defence Society (EDS), University of Otago (Otago University), Yellow-eyed Penguin Trust (YEPT), Humane Society International (HSI), Deepwater Group and SeaFIC (DWG & SeaFIC), Te Ohu Kai Moana, Independent Fisheries Ltd.

NB. The list of submitters above is not the full list of those who responded to the consultation paper; rather these submitters raised substantive science issues that are addressed in this Appendix.

Most of the information underpinning the management of the SQU6T fishery is complex and not easily understood by those who do not attend the Aquatic Environment Working Group (AEWG) that is convened by the Ministry for Primary Industries' This has led to a number of submitters misinterpreting the information. MPI acknowledges that for submitters who have not attended recent AEWG meetings, aspects of the science may be unclear. In order to address this, the NZ sea lion chapter from MPI's forthcoming Aquatic Environment and Biodiversity Annual Review (AEBAR) is included at the end of this Appendix. The AEBAR chapter provides a summary of the science that supports the advice to the Minister, and has been reviewed by the AEWG and signed off by the chair of the AEWG.

Issues raised	Submitters
<p>Survival rate after an encounter with a Sea Lion Exclusion Device (SLED):</p> <ul style="list-style-type: none"> - Reliability of biomechanical modelling - Applicability of fur seal data - Level of cryptic mortality - Escape hole can be temporarily covered by hood - Rotation of SLED could empty dead sea lions from the net - Declining captures related to declining population - Substantiation of improvements in SLED design 	<p>Individual: Steve Dawson, Elisabeth Slooten, John Gibbs, Tessa Mills, Nick Goldwater, Tracey Bowen, Amélie Augé, Ian Wilkinson, Joanne Heatlie, Alister Robinson, Elaine Leung, Alastair Jamieson, Andrew Maloney, Lala Frazer, Nathan McNally, Rosalind Horsman.</p> <p>Organisational: Otago University, Forest and Bird, ECO, WWF, EDS, YEPT, HSI.</p>
Comments and responses	
<p>The outstanding uncertainties in SLED survival (especially regarding cryptic or hidden mortality) reflect the fact that it is inherently extremely difficult to assess. Direct approaches have not proved possible so indirect approaches including biomechanical "crash test dummy" tests and modelling were used. Based on the biomechanical work, the risk of a life-threatening impact with a SLED grid is very unlikely to be greater than 10%. Some sea lions are nevertheless retained and drowned and others may drown after exiting the SLED, but both mortality components are incorporated in the options developed for the Minister.</p> <p>There is almost no information to assess cryptic mortality resulting from drowning after a sea lion exits from a trawl net via a SLED. Similarly, there is no evidence to evaluate whether the escape hole can be temporarily covered by the hood or whether the portion of the net nearest the SLED could rotate and empty dead sea lions from the net. However, based on our understanding of gear design, these possibilities are unlikely. Nevertheless, the application of the sensitivity that reduces the discount rate by 10% is intended to reflect these outstanding uncertainties and is reflected in the final advice.</p> <p>The AEWG has accepted Australian fur seals interacting with SED-equipped trawl nets as a reasonable proxy for NZ sea lions interacting with SLEDs, and the estimated collision speeds are consistent with published</p>	

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foraging speeds for New Zealand sea lions (see attached AEBAR chapter for further details).

An Australian study published in 2008¹ trialled three different SED designs to assess interactions between trawl gear and Australian fur seals. The study found that none of the fur seals that were observed (by video) dead in the net were recovered as they fell out of the escape holes prior to the nets being hauled onboard.

Some submitters argued that sea lions drown in the net and are passively ejected from the SLED. Submitters suggested that if this is occurring in New Zealand then the fact that fewer sea lions are being returned since the introduction of SLEDs may be misleading, as there is no way of being sure that dead animals are not being lost from the net and contributing to a hidden mortality.

MPI notes the following three points when considering the applicability of this aspect of the Australian study. First, in contrast to the Australian study, in New Zealand, sea lions have been recovered from trawl nets fitted with SLEDs every year except 2011, albeit with steadily decreasing frequency (Table 4 and Figures 2 and 3 in the advice paper).

Second, the Australian study predominantly used SEDs with escape holes in the bottom of the net whereas New Zealand SLEDs have escape holes mounted in the roof of the net. Any dead animal in a net would almost certainly fall from the net with a bottom-mounted escape holes as the net is hauled onboard, yet this is very unlikely in the net with a top-mounted escape hole. That said, the Australian study did observe three fur seals passively exit via the top opening escape hole.

These three passive ejections from a top opening escape hole highlight the third significant difference in the design of SLEDs: the absence of SED hoods in the Australian trial. Those animals that were passively ejected from the SLED may be retained in the net by the SLED hood. One of the functions of a SLED hood is to retain dead animals and information from observers and Industry indicates this does occur.

For these reasons MPI does not consider the Australian study can provide any useful comparison regarding the retention probability of sea lions in New Zealand SLEDs.

Quantifying the effect of improvements in SLED design on sea lion survival is technically difficult. However recent modelling provided reasonable evidence that retention probability has improved since 2007, which is consistent with an effect of improved SLED design.

Despite the outstanding uncertainties, the conclusion that fishing is unlikely to breach the agreed management criteria is robust to many of these uncertainties. For example, using the upper sensitivity for the risk of mild traumatic brain injury (MTBI) from the biomechanical modelling gives a discount rate of 78%; within the range of values assessed as not requiring an FRML to satisfy the management criteria. This is discussed further in the advice paper.

¹ Lyle JM and Willcox ST (2008). Dolphin and seal interactions with mid-water trawling in the Commonwealth Small Pelagic Fishery, including an assessment of bycatch mitigation strategies. Final Report Project R05/0996. Australian Fisheries Management Authority.

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Issues raised	Submitters
<p>Reliability of the Breen-Fu-Gilbert (BFG) population model:</p> <ul style="list-style-type: none"> - Estimation of key parameters including K, z, and lambda - The complexity of the model and the risk of over-fitting - Failure to accurately predict pup production trends - Model fit not explicitly tested - Dependent pups not addressed - Not updated with recent information (pup counts, demographics, tow duration) - Bias in model inputs, priors and parameterisations - Needs independent review 	<p>Individual: Steve Dawson, Elisabeth Slooten, John Gibbs, Amélie Augé, Andrew Maloney.</p> <p>Organisational: Otago University, Forest and Bird, ECO, WWF.</p>
Comments and responses	
<p>The Breen-Fu-Gilbert (BFG) integrated Bayesian model is very complex and has evolved over several years and many meetings of the AEWG. This complexity and the nature of the data do mean that there is some risk of “over-fitting” to “noise” in the data², but brings the advantage that more of the available data can be used in an integrated fashion. Some submitters have misunderstood aspects of the model (e.g. the death of dependent pups following the death of their mother is considered explicitly in the model, the model is explicitly fitted to the available data, and the model is not designed to predict the actual trend of pup production). The information is summarised in the attached sea lion chapter of the AEBAR.</p> <p>The model inputs and priors have been reviewed and been accepted by the AEWG, however we note that some aspects of the current parameterisation are problematic (e.g. the inability of the model to converge on K in the absence of fishing). The conclusions of the BFG model are robust to assumed or prior values for the population’s natural maximum rate of increase and density dependence if the SLED survival is higher than about 50% (and recent research suggests that it is much higher than 50% with high certainty).</p> <p>However, and recognising the uncertainty and conflicting signals in the available science, MPI will commission a fully independent review of the BFG model and other modelling approaches (the modelling review). All the specific issues raised in submissions regarding the modelling will be included in the terms of reference for the review.</p>	

Issues raised	Submitters
<p>Use of a 5.65% strike rate:</p> <ul style="list-style-type: none"> - Average rate is 6.1% - 10% with 100% coverage - Tow duration has increased 	<p>Individual: Steve Dawson, Elisabeth Slooten, John Gibbs, Amélie Augé, Ian Wilkinson, Nathan McNally.</p> <p>Organisational: Otago University, Forest and Bird, ECO, WWF.</p>
Comments and responses	
<p>The BFG model assumes that MPI will use a 5.65% strike rate when calculating the permissible number of tows under an FRML, so assessments of rule performance will be mildly pessimistic if a higher rate is used. The submitters’ recommendation that MPI apply the long-term average strike rate (6.1 %) is reflected in the final advice along with a recommendation to update the strike rate with the 10 year average thereafter.</p>	

² A model that suffers from overfitting describes random or unexplained errors in the data at the expense of describing the key underlying relationships. Overfitted models typically have poor predictive performance because they exaggerate minor fluctuations in the information used to develop them. The risk of overfitting increases with the complexity of a model and, especially, as the number of estimated parameters increases relative to the number of observations.

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Modelling commissioned by MPI suggests that the risk of sea lion capture does not increase in proportion to the length of a tow; an 8-hour tow is not twice as likely to catch a sea lion as a 4-hour tow. The changes in tow duration are incorporated in the modelled estimate of strike rate and reflected in the proposed approach of using the 90th percentile of the distribution of number of tows as a review condition.

Issues raised	Submitters
Calculation of discount rate - Contains errors - Should be more conservative	Individual: John Gibbs. Organisational: Forest and Bird.
Comments and responses	
<p>A submitter suggested that the discount rate should be 74% based on 85% (probability of escape) and 87% (probability of survival based on MTBI and incorporating the 10% sensitivity for a sea lion exceeding breath-holding capacity after exiting the SLED). This is another way to reflect the “10% sensitivity” for breath holding but neither is inherently superior.</p> <p>The calculation of the discount rate is slightly conservative because it assumes that none of the animals predicted to have MTBI (i.e. those predicted to be concussed after an interaction with a SLED, 3% of interactions) is included in the dead animals retained in the net. Nevertheless, more pessimistic treatment of the data (e.g. using the upper bounds of the risk of MTBI) leads to similar overall conclusions unless several parameters are assumed to fall close to their limits in a pessimistic direction. The uncertainties associated with the biomechanical modelling and the effect these uncertainties have on the model results are discussed in the advice paper.</p>	

Issues raised	Submitters
Chilvers (2011) Polar Biology paper: - Should be reflected in advice	Individual: Elaine Leung, Vanessa Smith. Organisational: Otago University, Forest and Bird, WWF.
Comments and responses	
<p>This paper was not discussed in the consultation paper as MPI was not aware that it existed and was published online only two days prior to submissions closing. The paper has since been evaluated by three MPI scientists, including the Chief Scientist, against the Research and Science Information Standard for New Zealand Fisheries. The consensus was that the paper be ranked 3 – Low quality. A ranking of 3 is assigned to information that has substantially failed to meet the key principles for science information quality, and the Research Standard states that such information “should not be used to inform management decisions”. The full review of the paper is included in Appendix C. In addition to this internal review, the paper will also be included in the upcoming modelling review.</p>	

Issues raised	Submitters
Robertson & Chilvers (2011) Mammal Review paper: - Should be reflected in advice	Individual: Steve Dawson, John Gibbs, Otago University, Tessa Mills, Jennifer Ashby, Nick Goldwater, Jane Forsyth, Alice MacKenzie, Amélie Augé, Alister Robinson, Elaine Leung, Alastair Jamieson, Andrew Maloney, Lala Frazer, Nathan McNally, Rosalind Horsman, Charlotte Bueb. Organisational: Forest and Bird, WWF, EDS.
Comments and responses	
<p>This paper has been evaluated by three MPI scientists, including the Chief Scientist, against the Research and</p>	

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Science Information Standard for New Zealand Fisheries. The consensus was that the paper be ranked 2 – Mixed quality. A ranking of 2 is assigned to information that has been found to have some quality shortcomings, “but is still useful for informing management decisions”. The useful aspect of the paper is that it brings together a lot of previously scattered information. The less useful aspect is that it does not critically appraise that information to support a robust conclusion. The full review of the paper is included in Appendix C. In addition to this internal review, the paper will also be included in the upcoming modelling review.

Issues raised	Submitters
Comparison of population trends between Auckland islands and Campbell island	Individual: Andrew Maloney, Nathan McNally.
Comments and responses	
The suggestion of submitters that differences in population trends between the Auckland Islands (declining) and Campbell Island (increasing) can be explained solely by the presence of the squid fishery around the Auckland Islands is overly simplistic. There are many differences between the two locations, including other fisheries operating around Campbell Island (e.g. southern blue whiting) that occasionally capture sea lions. There also a difference in the sex ratio of captures between locations, with proportionally more male sea lions captured around Campbell Island.	

Issues raised	Submitters
Females at physiological limit: <ul style="list-style-type: none"> - Low breeding rate - Research papers by Augé and Meynier 	Individual: Steve Dawson, John Gibbs, Chris Miller, John Gardiner, Amélie Augé.
Comments and responses	
Submitters pointed out that recent research indicates that females within the Auckland Islands population show signs of being at or near their physiological limits. This information, including the Augé and Meynier research, is cited and discussed in the attached sea lion AEBAR chapter and any consequent effects on breeding rate should be reflected in the BFG model (although some information in the model may be dated). The conclusions of the BFG model are robust to assumed or prior values for the population’s natural maximum rate of increase or density dependence if the SLED survival is higher than about 50% (and recent research suggests that it is much higher than 50% with high certainty).	

Issues raised	Submitters
Review triggers not sufficiently conservative: <ul style="list-style-type: none"> - High number of tows - Include tow duration - Pup count of 1,501 too low, should be the same as last year’s value (1,550) or higher 	Individual: Steve Dawson, John Gibbs, Otago University, Amélie Augé. Organisational: Forest and Bird, EDS, YEPT.
Comments and responses	
<p>The number of tows specified as a review trigger was justified in the IPP as the 90th percentile of the number of tows assumed in the BGF model. This represents a reasonable upper bound on fishing effort as assumed by the model.</p> <p>As mentioned earlier, modelling commissioned by MPI suggests that the risk of sea lion capture does not increase in proportion to the length of a tow; an 8-hour tow is not twice as likely to catch a sea lion as a 4-hour tow. The changes in tow duration are incorporated in the modelled estimate of strike rate and reflected in the proposed approach of using the 90th percentile of the distribution of number of tows as a review condition.</p> <p>The pup count review condition uses the value from 2009 that represents the lowest level of pup production observed on the Auckland Islands since reliable annual counts commenced in 1995. Given the population is</p>	

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likely to take some time to recover from the recent decline, natural fluctuations in pup production may result in a temporary dip below the 1,550 observed last year. Accordingly, the 1,501 value was chosen to reflect the observed lower bound in pup production and enable a response to any further decline in the population.

It is also worth noting that the advice includes an additional criterion which would allow MPI to respond to any material change in the information separate from the other specific criteria.

Issues raised	Submitters
Review triggers too conservative: <ul style="list-style-type: none"> - Pup trigger should be 1,247 - 15 captures is low but pragmatic - Suggest conference at 7 captures - Support other triggers 	Organisational: DWG & SeaFIC, Te Ohu Kai Moana.
Comments and responses	
The submitters' suggested value of 1,247 for the pup count review trigger comes from the BFG model projections and represents the minimum number of pup births during the 100-year run. Conversely, the maximum number of pup births during the 100-year run is projected to be 4,252. Setting a review criterion at one extreme of a distribution that reflects high levels of uncertainty and natural variability and would be inappropriate, especially when that estimated extreme is below the lowest recorded pup count on the Auckland Islands.	

Issues raised	Submitters
Research information/credibility: <ul style="list-style-type: none"> - Model outputs - Fishing information - References/supporting information - Evidence of peer review - Inconsistent bycatch numbers - Qualifications and expertise of authors 	Individual: Steve Dawson, John Gibbs, Otago University, Jennifer Ashby, John Gardiner, Amélie Augé, Kate Waterhouse, Charlotte Bueb. Organisational: Forest and Bird.
Comments and responses	
Some submitters requested further information to support the statements in the IPP. The attached sea lion chapter of the AEBAR should clarify some of these points. The bycatch numbers included in the sea lion chapter of the AEBAR have been verified and come from the most recent bycatch estimation report (referenced within the chapter). All research information used by MPI is routinely and rigorously peer reviewed by standing working groups, including AEWG, and by experienced and highly-qualified MPI scientists. The bycatch numbers included in the sea lion chapter of the AEBAR are based on MPI observer records, have been peer reviewed by the AEWG, and come from the most recent bycatch estimation report (referenced within the chapter).	

Issues raised	Submitters
Manage other fisheries impacts: <ul style="list-style-type: none"> - SLEDs in other trawl fisheries - Non-SQU6T bycatch - Indirect effects of fishing - Comparative risk from fishing - Interactions with other threats 	Individual: Otago University, John Gardiner, Amélie Augé, Joanne Heatlie, Kate Waterhouse, Andrew Maloney. Organisational: Forest and Bird, ECO, WWF, YEPT.
Comments and responses	

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The BFG model includes bycatch from other trawl fisheries (outside SQU6T) around the Auckland Islands and Stewart Snare shelf. (It doesn't include bycatch around Campbell Island as these animals most likely come from the Campbell Island population.)

The Department of Conservation has commissioned a literature review on possible indirect effects of fishing on sea lions. The report is currently in draft and undergoing review by the DOC CSP technical working group. Further work is required in this area to assess the extent to which indirect effects of fishing are affecting sea lion population viability.

The population-level consequences of interactions and/or synergies between threats are presently unknown, but will be considered as part of future research into the cause(s) of the population decline.

Issues raised	Submitters
Use a Potential Biological Removal (PBR) approach	Individual: Elisabeth Slooten, Otago University. Organisational: ECO.
Comments and responses	
<p>The PBR approach was developed in the USA to guide the management of marine mammal bycatch, not necessarily to close fisheries once breached in a given year. A PBR approach is one of the rules assessed in the BFG model and all other bycatch control rules evaluated are based on multiples of the PBR. Large numbers of candidate rules are assessed against pre-agreed management criteria to evaluate their performance, and the results are searched to find the "cusp rule" (i.e. the rule that just meets the management criteria). A FRML that is calculated based on a cusp rule is projected to meet the management criteria, which are quite conservative (e.g., maintain the Auckland Islands population at or above 90% of carrying capacity with 90% certainty or to within 90% of what would happen in the absence of fishing). The modelling suggests that no FRML is needed to meet the management criteria if SLED survival is higher than about 50%. Nevertheless, it is open to the Minister to choose any FRML that he considers necessary.</p> <p>A PBR is generally applied in situations where there is insufficient information for more sophisticated analysis. In the case of sea lions, substantially more information is available so a customised analysis is possible and more appropriate.</p>	

Issues raised	Submitters
Use a precautionary approach <ul style="list-style-type: none"> - For model assumption - For review conditions - Given threat status - Given population decline 	Individual: Steve Dawson, Elisabeth Slooten, John Gibbs, Otago University, Tessa Mills, Jennifer Ashby, Nick Goldwater, Chris Miller, Ian Wilkinson, Joanne Heatlie, Alister Robinson, Andrew Maloney, Lala Frazer, Rosalind Horsman, Nathan McNally, Christine Rose, Vanessa Smith, Charlotte Bueb. Organisational: Forest and Bird, ECO, WWF, EDS, YEPT, HSI.
Comments and responses	

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While threat status is not incorporated explicitly in the BFG model, the biological determinants of threat status are reflected in the model (although some information in the model may be slightly dated). Similarly, the population decline is incorporated in the model, although it does not predict any further decline, which is the reason for the pup-count-based review trigger.

The management criteria against which bycatch control rules are assessed in the BFG model (e.g., 90% of carrying capacity with 90% certainty or to within 90% of what would happen in the absence of fishing) are quite conservative and, if met, should allow recovery of the population.

It is not appropriate to apply a precautionary approach to the science; the science should aim to estimate the most likely state of affairs as accurately as possible and to describe uncertainty and the consequences of different management choices. A precautionary approach is open to the Minister in his decision and the advice paper provides the Minister with options to exercise caution.

<i>Issues raised</i>	<i>Submitters</i>
Update attributed mortalities with new discount rate	Organisational: DWG & SeaFIC.
<i>Comments and responses</i>	
MPI regularly produces estimates for sea lion bycatch and attributed mortality (i.e. including mortalities where animals are not landed on deck). Any change in the discount rate will be reflected in the next update of this work.	

<i>Issues raised</i>	<i>Submitters</i>
Further investigation of the causes of the decline	Organisational: DWG & SeaFIC.
<i>Comments and responses</i>	
MPI agrees with this suggestion and intends to begin discussions with the Department of Conservation on a joint work programme in this area.	

<i>Issues raised</i>	<i>Submitters</i>
Accuracy of 2011 pup count	Organisational: DWG & SeaFIC.
<i>Comments and responses</i>	
There were some differences in methodology for the 2011 sea lion pup count due to extreme weather events in the Auckland Islands. The effect of these differences on the resulting pup production estimate was evaluated by the Department of Conservation, to MPI's satisfaction, and found to be minimal. In any event the 2012 pup count will soon be made available.	

<i>Issues raised</i>	<i>Submitters</i>
Decision on strike rate not necessary	Organisational: DWG & SeaFIC.
<i>Comments and responses</i>	
The submitters suggest that in the absence of a FRML, a strike rate does not need to be set. However, a strike rate is required for the BFG model and is also required in the event the Minister elects to set an FRML.	

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AEBAR CHAPTER – New Zealand sea lions (*Phocarctos hookeri*)

<i>Scope of chapter</i>	This chapter outlines the biology of New Zealand (or Hooker's) sea lions (<i>Phocarctos hookeri</i>), the nature of fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty.
<i>Area</i>	Southern parts of the New Zealand EEZ and Territorial Sea.
<i>Focal localities</i>	Areas with significant fisheries interactions include the Auckland Islands Shelf, the Stewart/Snares Shelf and Campbell Plateau.
<i>Key issues</i>	Improving estimates of incidental bycatch in some trawl fisheries, improving estimates of SLED post-exit survival, and improving understanding of the ability of the NZ sea lion population to sustain the present levels of bycatch.
<i>Emerging issues</i>	Assessing potential impacts of resource competition and/or resource limitation through ecosystem effects on NZ sea lion population viability. The role of fisheries impacts in light of ongoing declines in population size. Estimation of interactions given low numbers of observed captures.
<i>MFish Research (current)</i>	SRP2010-03, SRP2010-05, PRO2010-01, SRP2011-03, SRP2011-04, IPA2009-09.
<i>Other Govt Research (current)</i>	DOC Marine Conservation Services Programme (CSP): POP2010-01, POP2011-01.
<i>Links to 2030 objectives</i>	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts.
<i>Related issues</i>	See the New Zealand fur seal chapter.

Context

Management of fisheries impacts on New Zealand (NZ) sea lions are legislated under the Marine Mammals Protection Act 1978 and the Fisheries Act 1996. Under s 3E of the Marine Mammals Protection Act, the Minister of Conservation, with the concurrence of the Minister of Fisheries, may approve a population management plan (PMP) to establish a maximum allowable level of fishing-related mortality for the species. Although a NZ sea lion PMP was proposed by the Department of Conservation (DOC) in 2007 (DOC 2007), following consultation DOC decided not to proceed with the PMP.

The Minister of Conservation gazetted the NZ sea lion as a threatened species in 1997. In 2009, DOC approved the *New Zealand sea lion species management plan*³: 2009–2014 (DOC 2009). It aims: “*To make significant progress in facilitating an increase in the New Zealand sea lion population size and distribution.*” The plan specifies a number of goals, of which the following are most relevant for fisheries interactions:

- “To avoid or minimise adverse human interactions on the population and individuals.*
- To ensure comprehensive protection provisions are in place and enforced.*
- To ensure widespread stakeholder understanding, support and involvement in management measures.”*

³ The species management plan differs from the draft Population Management Plan in that it is quite broad in scope; providing a framework to guide the Department of Conservation in its management of the NZ sea lion over the next 5 years. The draft population management plan focused on options for managing the extent of incidental mortality of NZ sea lions from fishing through establishing a maximum allowable level of fishing-related mortality (MALFiRM) for all New Zealand fisheries waters.

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In the absence of a PMP, the Ministry of Fisheries (MFish) manages fishing-related mortality of NZ sea lions under s 15(2) of the Fisheries Act. Under that section, the Minister “*may take such measures as he or she considers are necessary to avoid, remedy, or mitigate the effect of fishing-related mortality on any protected species, and such measures may include setting a limit on fishing-related mortality.*”

Management of NZ sea lion bycatch aligns with Fisheries 2030 Objective 6: *Manage impacts of fishing and aquaculture*. Further, the management actions follow Strategic Action 6.2: *Set and monitor environmental standards, including for threatened and protected species and seabed impacts*.

The relevant National Fisheries Plan for the management of NZ sea lion bycatch is the National Fisheries Plan for Deepwater and Middle-depth Fisheries (the National Deepwater Plan). Under the National Deepwater Plan, the objective most relevant for management of NZ sea lions is Management Objective 2.5: *Manage deepwater and middle-depth fisheries to avoid or minimise adverse effects on the long-term viability of endangered, threatened and protected species*.

Specific objectives for the management of NZ sea lion bycatch will be outlined in the fishery-specific chapters of the National Deepwater Plan for the fisheries with which NZ sea lions are most likely to interact. These fisheries include trawl fisheries for arrow squid (SQU 1T and 6T), southern blue whiting (SBW) and scampi (SCI). The SBW chapter of the National Deepwater Plan is complete and includes Operational Objective 2.2: *Ensure that incidental New Zealand sea lion mortalities, in the southern blue whiting fishery at the Campbell Islands (SBW6I), do not impact the long term viability of the sea lion population and captures are minimised through good operational practices*. Chapters in the National Deepwater Plan for arrow squid and scampi are under development.

Currently, MFish limits the actual or estimated bycatch of sea lions in the SQU6T trawl fishery based on tests of the likely performance of candidate bycatch control rules (and, hence, bycatch limits) using an integrated population and fishery model (Breen *et al.* 2010)⁴. Candidate rules are assessed against the following two management criteria:

- a. A rule should provide for an increase in the sea lion population to more than 90% of carrying capacity⁵, or to within 10% of the population size that would have been attained in the absence of fishing, and that these levels must be attained with 90% certainty, over 20-year and 100-year projections.
- b. A rule should attain a mean number of mature mammals that exceeded 90% of carrying capacity in the second 50 years of 100-year projection runs.

These management criteria were developed and approved in 2003 by a Technical Working Group comprised of MFish, DOC, squid industry representatives, and environmental groups.

Likely performance is also assessed against two additional criteria proposed by DOC:

- a) A rule should maintain numbers above 90% of the carrying capacity in at least 18 of the first 20 years.
- b) A rule should lead to at least a 50% chance of an increase in the number of mature animals over the first 20 years of the model projections.

⁴ The Ministry is currently consulting on changes to this management approach. See the SQU6T Operational Plan: Initial Position Paper for further details (available online: <http://www.fish.govt.nz/en-nz/Consultations/Squid+fishery+around+the+Auckland+Islands/default.htm>).

⁵ Carrying capacity in this instance applies to the current range. For managing the SQU6T fishery, carrying capacity refers to the maximum number of NZ sea lions that could be sustained on the Auckland Islands.

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Biology

Taxonomy

The NZ sea lion (*Phocarctos hookeri*, Gray, 1844) is one of only two species of otariid (eared seals, including fur seals and sea lions) native to New Zealand, the other being the NZ fur seal (*Arctocephalus forsteri*, Lesson, 1828). The NZ sea lion is also New Zealand's only endemic pinniped.

Distribution

Before human habitation, NZ sea lions ranged around the North and South Islands of New Zealand. For example, pre-European remains of NZ sea lions have been identified from at least 47 archaeological sites, ranging from Stewart Island to North Cape, with most occurring in the southern half of the South Island (Smith 1989; Childerhouse and Gales 1998). Subsistence hunting and subsequent commercial harvest of NZ sea lions for skins and oil resulted in population decline and contraction of the species' range (Gales 1995, Childerhouse and Gales 1998). Currently, most NZ sea lions are found in the New Zealand Sub-Antarctic, with individuals ranging to the NZ mainland and Macquarie Island.

NZ sea lion breeding colonies⁶ are highly localized, with most pups being born at two main breeding areas, the Auckland Islands and Campbell Island (Wilkinson *et al.* 2003, Chilvers 2008). At the Auckland Islands, there are three breeding colonies: Enderby Island (mainly at Sandy Bay); Dundas Island; and Figure of Eight Island. On Campbell Island there is one breeding colony at Davis Point, another possible colony at Paradise Point, plus a small number of non-colonial breeders (Wilkinson *et al.* 2003, Chilvers 2008, Maloney *et al.* 2009). Breeding on the Auckland Islands represents 71–87% of the pup production for the species, with the remaining 13–29% occurring on Campbell Island (based on pup counts in 2003, 2008 and 2010; see section 3.2.5).

Although breeding is concentrated on the Auckland Islands and Campbell Island, occasional births have been reported from the Snares and Stewart Islands (Wilkinson *et al.* 2003). Breeding is also taking place on the New Zealand mainland at the Otago peninsula, the result of a single female arriving in 1992 and giving birth in 1993 (McConkey *et al.*, 2002).

On land, NZ sea lions are able to walk long distances and climb high hills, and are found in a variety of habitats including sandy beaches, grass fields, bedrock, and dense bush and forest (Gales 1995, Augé 2006). Following the end of the females' oestrus cycle in late January, adult and sub-adult males disperse throughout the species' range, whereas dispersal of females (both breeding and non-breeding) appears more restricted (Marlow 1975, Robertson *et al.* 2006).

Foraging ecology

Most foraging studies have been conducted on lactating female NZ sea lions from Enderby Island (Chilvers *et al.* 2005a, 2006, Chilvers and Wilkinson 2009). These show that females forage primarily within the Auckland Islands continental shelf and its northern edge, and that individuals show strong foraging site fidelity both within and across years. Satellite tagging data from lactating females

⁶ DOC (2009) defines colonies as "haul-out sites where 35 pups or more are born each year for a period of 5 years or more." Haul-out sites are defined as "terrestrial sites where NZ sea lions occur but where pups are not born, or where less than 35 pups are born per year over 5 consecutive years."

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showed that the mean return distance travelled per foraging trip is 423 ± 43 km ($n = 26$), which is greater than that recorded for any other sea lion species (Chilvers *et al.* 2005a). While foraging, about half of the time is spent submerged, with a mean dive depth of 130 ± 5 m (max. 597 m) and a mean dive duration of 4 ± 1 minutes (max. 14.5 minutes; Chilvers *et al.* 2006). NZ sea lions, like most pinnipeds, may use their whiskers to help them capture prey at depths where light does not penetrate (Marshall 2008, Hanke *et al.* 2010).

Studies conducted on female NZ sea lions suggest that the foraging behaviour of each individual falls into one of two distinct categories, benthic or meso-pelagic (Chilvers and Wilkinson 2009). Benthic divers have fairly consistent dive profiles, reaching similar depths (120 m on average) on consecutive dives in relatively shallow water to presumably feed on benthic prey. Meso-pelagic divers, by contrast, exhibit more varied dive profiles, undertaking both deep (> 200 m) and shallow (< 50 m) dives over deeper water. Benthic divers tend to forage further from their breeding colonies, making their way to the north-eastern limits of Auckland Islands' shelf, whereas meso-pelagic divers tend to forage along the north-western edge of the shelf over depths of approximately 3000 m (Chilvers and Wilkinson 2009).

The differences in dive profiles have further implications for the animals' estimated aerobic dive limits (ADL; Chilvers *et al.* 2006), defined as the maximum amount of time that can be spent underwater without increasing blood lactate concentrations (a by-product of anaerobic metabolism). If animals exceed their ADL and accumulate lactate, they must surface and go through a recovery period in order to aerobically metabolize the lactate before they can undertake subsequent dives. Chilvers *et al.* (2006) estimated that lactating female NZ sea lions exceed their ADL on 69% of all dives, a much higher proportion than most other otariids (which exceed their ADL for only 4–10% of dives; Chilvers *et al.* 2006). NZ sea lions that exhibit benthic diving profiles are estimated to exceed their ADL on 82% of dives, compared with 51% for meso-pelagic divers (Chilvers 2008).

Chilvers *et al.* (2006) and Chilvers and Wilkinson (2009) suggested that the long, deep diving behaviour, the propensity to exceed their estimated ADL, and differences in physical condition and age at first reproduction from animals at Otago together indicate that females from the Auckland Islands may be foraging at or near their physiological limits. Adult females at Otago are generally heavier for a given age, breed earlier, undertake shorter foraging trips, and have shallower dive profiles compared with females from the Auckland Islands (Table 3.1). Caution must be exercised when drawing conclusions based on these comparisons given the small size of the Otago sub-population and the fact that all of its females are descended from a single individual that arrived from the Auckland Islands in 1992. Any observed differences may reflect differences in environment between the Auckland Islands and the Otago peninsula, differences in genetic makeup, or a combination of these or other factors.

1. Table 3.1: Comparison of select characteristics between adult female NZ sea lions from the Auckland Islands and those from the Otago peninsula (Chilvers *et al.* 2006, Augé 2011, Augé *et al.* 2011). Data are means \pm SE (where available).

Characteristic	Auckland Islands	Otago
Reproduction at age 4	$< 5\%$ of females	$> 85\%$ of females
Average mass at 8-13 years of age	112 kg	152 kg
Foraging distance from shore	102.0 ± 7.7 km (max = 175 km)	4.7 ± 1.6 km (max = 25 km)
Time spent foraging at sea	66.2 ± 4.2 hrs	11.8 ± 1.5 hrs
Dive depth	129.4 ± 5.3 m (max = 597 m)	20.2 ± 24.5 m (max = 389 m)
Dives estimated to exceed ADL	68.7 ± 4.4 percent	7.1 ± 8.1 percent

NZ sea lions are generalist predators with a varied diet that includes fish (rattail, red cod, opalfish, hoki), cephalopods (octopus, squid), crustaceans (lobster krill, scampi), and salps (Cawthorn *et al.* 1985; Childerhouse *et al.* 2001; Meynier *et al.* 2009). The three main methods used to assess NZ sea

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lion diets involve analyses of stomach contents, scats and regurgitate, and the fatty acid composition of blubber (Meynier *et al.* 2008). Stomach contents of by-caught animals tend to be biased towards the target species of the fishery concerned (e.g. squid in the SQU6T fishery), whereas scats and regurgitates are biased towards less digestible prey (Meynier *et al.* 2008). Stomach, scat and regurgitate approaches tend to reflect only recent prey (Meynier *et al.* 2008). By contrast, analysis of the fatty acid composition of blubber provides a longer-term perspective on diets ranging from weeks to months (although individual prey species are not identifiable). This approach suggests that the diet of female NZ sea lions tends to include proportionally more arrow squid (*Nototodarus sloanii*) and proportionally less red cod (*Pseudophycis bachus*) and scampi (*Metanephrops challengerii*) than for male NZ sea lions, while lactating and non-lactating females do not differ in their diet (Meynier *et al.* 2008; Meynier 2010).

Reproductive biology

NZ sea lions exhibit marked sexual dimorphism, with adult males being larger and darker in colour than adult females (Walker and Ling 1981, Cawthorn *et al.* 1985). Cawthorn *et al.* (1985) and Dickie (1999) estimated the maximum age of males and females to be 21 and 23 years, respectively, but Childerhouse *et al.* (2010a) recently reported a maximum estimated age for females of 28 years (although the AEWG had some concerns about the methods used and this estimate may not be reliable). Although females can become sexually mature as early as age 2 and give birth the following year, most do not breed until they are 6 years old (Childerhouse *et al.* 2010a). Males generally reach sexual maturity at 4 years of age, but because of their polygynous colonial breeding strategy (i.e., males actively defend territories and mate with multiple females within a harem) they are only able to successfully breed at 7–9 years old, once they have attained sufficient physical size (Marlow 1975, Cawthorn *et al.* 1985). Reproductive rate in females increases rapidly between the ages of 3 and 7, reaching a plateau until the age of approximately 15 and declining rapidly thereafter, with the maximum recorded age at reproduction being 26 years (Breen *et al.* 2010, Childerhouse *et al.* 2010b, Chilvers *et al.* 2010). Chilvers *et al.* (2010) estimated from tagged sea lions that the median lifetime reproductive output of a female NZ sea lion was 4.4 pups, with 27% of all females that survive to age 3 never breeding.

NZ sea lions are philopatric (i.e., they return to breed at the same location where they were born, although more so for females than males). Breeding is highly synchronised and starts in late November when adult males establish territories for their harems (Robertson *et al.* 2006, Chilvers and Wilkinson 2008). Pregnant and non-pregnant females appear at the breeding colonies in December and early January, with pregnant females giving birth to a single pup in late December before entering oestrus 7–10 days later and mating again (Marlow 1975). Twin births and the fostering of pups in NZ sea lions are rare (Childerhouse and Gales 2001). Shortly after the breeding season ends in mid-January, the harems break up with the males dispersing offshore and females often moving away from the rookeries with their pups (Marlow 1975, Cawthorn *et al.* 1985).

Pups at birth weigh 8–12 kg with parental care restricted to females (Walker and Ling 1981, Cawthorn *et al.* 1985, Chilvers *et al.* 2006). Females remain ashore for about 10 days after giving birth before alternating between foraging trips lasting approximately two days out at sea and returning for about one day to suckle their pups (Gales and Mattlin 1977). New Zealand pup growth rates are lower than those reported for other sea lion species, and may be linked to a relatively low concentration of lipids in the females' milk during early lactation (Riet-Sapiriza 2007, Chilvers 2008). Pups are weaned after about 10–12 months (Marlow 1975, Gales and Mattlin 1997).

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Population biology

For NZ sea lions, the overall size of the population is indexed using estimates of the number of pups that are born each year (Chilvers *et al.* 2007). Since 1995, the Department of Conservation (DOC) has conducted mark-recapture counts at each of the main breeding colonies at the Auckland Islands to estimate annual pup production (i.e., the total number of pups born each year, including dead and live animals; Robertson and Chilvers 2011). Auckland Islands pup production ranged between about 1500 and 3000 pups born each year from 1995 to 2010 (Robertson and Chilvers 2011; Table 3.2). The data show a decline of about 49% in pup production from a peak of 3021 in 1997/98 to 1550 ± 41 pups in 2010/11⁷ (Chilvers and Wilkinson 2011), with the largest single-year decline (31%) occurring between the 2007/08 and 2008/09 counts.

Total NZ sea lion abundance at the Auckland Islands has been estimated using Bayesian population models (Breen *et al.* 2003, Breen and Kim 2006a, Breen and Kim 2006b, Breen *et al.* 2010). Although other abundance estimates are available (e.g. Gales and Fletcher 1999), the integrated models are preferred because they take into account a variety of age-specific factors (breeding, survival, maturity, vulnerability to fishing, and the proportion incidentally captured by fishing), as well as data on the resighting of tagged animals and pup production estimates, to generate estimates of the overall size of the NZ sea lion population inhabiting the Auckland Islands (Table 3.2). The most recent estimate of NZ sea lion abundance for the Auckland Islands population was 12 065 animals (95% CI: 11 160–13 061) in 2009. The integrated model suggested a net decline at the Auckland Islands of 23% between 1995 and 2009, or 29% between the maximum estimated population size in 1998 and 2009.

2. Table 3.2: Pup production and population estimates of NZ sea lions from the Auckland Islands from 1995 to 2010. Pup production data are direct counts or mark-recapture estimates from Robertson and Chilvers (2011). Standard errors only apply to the portion of pup production estimated using mark-recapture methods. Population estimates from P. Breen, estimated in the model by Breen *et al.* 2010. Year refers to the second year of a breeding season (e.g., 2010 refers to the 2009-10 season).

Year	Pup production estimate		Population size estimate	
	Mean	Standard error (for mark recapture estimates)	Median	90% confidence interval
1995	2 504		15 675	14 732–16 757
1996	2 685		16 226	15 238–17 318
1997	2 974		16 693	15 656–17 829
1998	3 021		16 911	15 786–18 128
1999	2 867	33	15 091	13 932–16 456
2000	2 856	43	15 248	14 078–16 586
2001	2 859	24	15 005	13 870–16 282
2002	2 282	34	13 890	12 856–15 079
2003	2 518	38	14 141	13 107–15 295
2004	2 515	40	14 096	13 057–15 278
2005	2 148	34	13 369	12 383–14 518
2006	2 089	30	13 110	12 150–14 156
2007	2 224	38	13 199	12 231–14 215
2008	2 175	44	12 733	11 786–13 757
2009	1 501	16	12 065	11 160–13 061
2010	1 814	36		
2011	1 550 ⁸	41		

⁷ Due to extreme weather conditions there was some delay in making the 2010/11 pup count which may affect comparability with previous years. However DOC's analysis suggests any such effect is unlikely to be large (Chilvers and Wilkinson 2011).

⁸ Ibid.

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For the Campbell Island population, pup production was estimated at 726 pups in 2010 (Robertson and Chilvers 2011). Pup production estimates at Campbell Island are increasing over time, although this trend may, to some extent, also reflect differences in methodology (Maloney *et al.* 2009). Previous estimates of total pup production were: 150 in 1992/93; 385 in 2003; and 583 in 2007-08 (Cawthorn 1993, Childerhouse *et al.* 2005, Maloney *et al.* 2009). There were also minimum pup counts of 51 in 1987/88, 122 in 1991/92 and 78 (from a partial count) in 1997/98 (Moore and Moffat 1990, McNally *et al.* 2001, M. Fraser, unpubl. data cited in Maloney *et al.* 2009).

For the Otago sub-population, annual pup production has ranged from 0 to 7 pups since the 1994/95 breeding season, with five pups recorded in 2010/11 (McConkey *et al.* 2002, Augé 2011). A recent modelling exercise suggested that this population can expand to 9–22 adult females by 2018 (Lalas and Bradshaw 2003). The sub-population at Otago is of special interest because it highlights the potential for establishing new breeding colonies, in this case from a single pregnant female (McConkey *et al.* 2002).

Established anthropogenic sources of mortality in NZ sea lion include: historic subsistence hunting and commercial harvest (Gales 1995, Childerhouse and Gales 1998); pup entrapment in rabbit burrows prior to rabbit eradication from Enderby Island in 1993 (Gales and Fletcher 1999); human disturbance, including attacks by dogs, vehicle strikes and deliberate shooting on mainland New Zealand (Gales 1995); and fisheries bycatch (see below).

In addition to the established effects, there are a number of other anthropogenic effects that may also influence NZ sea lion mortality. However their role, if any, is presently unclear. These include: possible competition for resources between NZ sea lions and the various fisheries (Robertson and Chilvers 2011); effects of organic and inorganic pollutants, including polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and heavy metals such as mercury and cadmium (Baker 1999, Robertson and Chilvers 2011); and impacts of eco-tourism.

Other sources of mortality include epizootics, particularly *Campylobacter* which killed 1600 pups (53% of pup production) and at least 74 adult females on the Auckland Islands in 1997/98 (Wilkinson *et al.* 2003, Robertson and Chilvers 2011) and *Klebsiella pneumoniae* which killed 33% and 21% of pups on the Auckland Islands in 2001/02 and 2002/03 respectively (Wilkinson *et al.* 2006). Epizootic events may also affect the fecundity of the surviving pups; reducing their breeding rate relative to other cohorts (Gilbert and Chilvers 2008). There are also occurrences of predation by sharks (Cawthorn *et al.* 1985, Robertson and Chilvers 2011), starvation of pups if they become separated from their mothers (Walker and Ling 1981, Castinel *et al.* 2007), and male aggression towards females and pups (Wilkinson *et al.* 2000, Chilvers *et al.* 2005b).

Despite a historic reduction in population size as a result of subsistence hunting and commercial harvest, the NZ sea lion population does not display low genetic diversity at microsatellite loci and thus does not appear to have suffered effects of genetic drift and inbreeding depression (Robertson and Chilvers 2011).

Conservation biology and threat classification

Threat classification is an established approach for identifying species at risk of extinction (IUCN 2010). The risk of extinction for NZ sea lions has been assessed under two threat classification systems, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2010) and the New Zealand Threat Classification System (Townsend *et al.* 2008).

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In 2008, the IUCN updated the Red List status of NZ sea lions, listing them as Vulnerable, A3b⁹ on the basis of a marked (30%) decline in pup production in the last 10 years, at some of the major rookeries (Gales 2008). The IUCN further recommended that the species should be reviewed within a decade in light of what they considered to be the current status of NZ sea lions (i.e., declining pup production, reducing population size, severe disease outbreaks).

In 2010, DOC updated the New Zealand Threat Classification status of all NZ marine mammals (Baker *et al.* 2010). In the revised list, NZ sea lions had their threat classification increased from At Risk, Range Restricted¹⁰ to Nationally Critical under criterion C¹¹ with a Range Restricted qualifier based on the recent rate of decline (Baker *et al.* 2010).

Global understanding

Reviews of fisheries interactions among pinnipeds globally can be found in Read *et al.* 2006, Woodley and Lavigne (1991), Katsanevakis (2008) and Moore *et al.* (2009). Because NZ sea lions are endemic to New Zealand, the global understanding of fisheries interactions for this species is outlined under state of knowledge in New Zealand. For related information on fishing interactions for NZ fur seals, both within New Zealand and overseas, see the NZ fur seal chapter.

State of knowledge in New Zealand

NZ sea lions interact with trawl fisheries resulting in incidental bycatch, specifically from animals being caught and drowned in the trawl nets. These interactions are largely confined to trawl fisheries in Sub-Antarctic waters (Figure 3.1); particularly the Auckland Islands arrow squid fishery (SQU6T), but also the Auckland Islands non-squid fisheries targeting mainly scampi (SCI6A), the Campbell Island southern blue whiting (*Micromesistius australis*) fishery (SBW6I) and the Stewart-Snares shelf fisheries targeting mainly arrow squid (SQU1T; Thompson and Abraham 2010).¹²

NZ sea lions forage to depths of up to 600 m (Table 3.1), within the habitat where depth ranges for prey species range from 0–500 m for arrow squid, 250–600 m for spawning southern blue whiting and 200–500 m for scampi (Ministry of Fisheries 2011). There is seasonal variation in the distribution overlap between NZ sea lions and the target species fisheries, with breeding male and female NZ sea lions likely to be ashore for prolonged periods between late November and January (Table 3.3). The SQU6T fishery currently operates between February and July, peaking between February and May, whereas the SQU1T fishery operates between December and May, peaking between January and April, before the squid spawn. The SBW6I fishery operates in August and September, peaking in the latter month, when the fish aggregate to spawn. The SCI6A fishery may operate at any time of the year but does not operate continuously.

⁹ A taxon is listed as ‘Vulnerable’ if it is considered to be facing a high risk of extinction in the wild. A3b refers to a reduction in population size (A), based on a reduction of $\geq 30\%$ over the last 10 years or three generations (whichever is longer up to a maximum of 100 years (3); and when considering an index of abundance that is appropriate to the taxon (b; IUCN 2010).

¹⁰ A taxon is listed as ‘Range Restricted’ if it is confined to specific substrates, habitats or geographic areas of less than 1000 km² (100 000 ha); this is assessed by taking into account the area of occupied habitat of all sub-populations (Townsend *et al.* 2008).

¹¹ A taxon is listed as ‘Nationally Critical’ under criterion C if the population (irrespective of size or number of sub-populations) has a very high (rate of) ongoing or predicted decline; greater than 70% over 10 years or three generations, whichever is longer (Townsend *et al.* 2008).

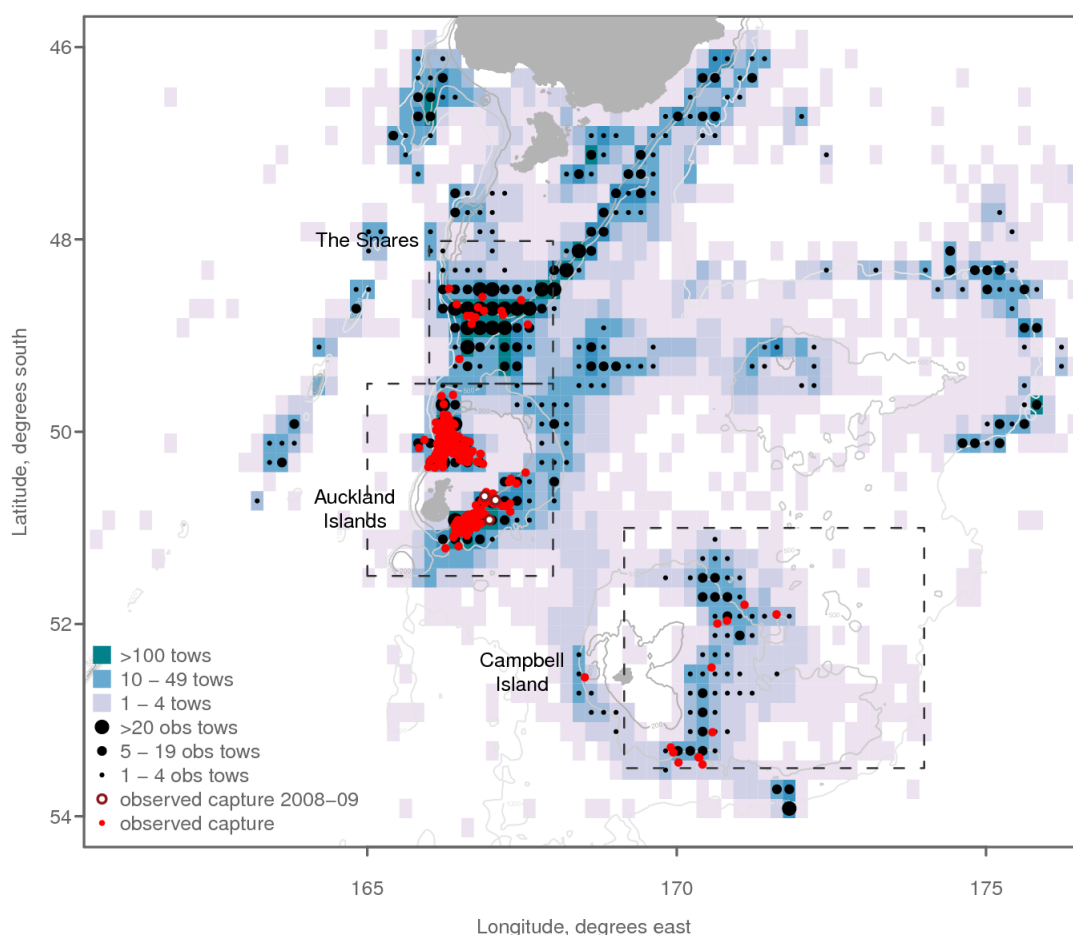
¹² See the Report from the Fisheries Assessment Plenary, May 2011 (Ministry of Fisheries 2011) for further information regarding the biology and stock assessments for these species.

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Quantifying fisheries interactions

Since 1988, the level of NZ sea lion bycatch has been monitored by government observers aboard a proportion of the fishing fleet in the SQU6T fishery (Wilkinson *et al.* 2003), generally amounting to around 20–40% observer coverage between 1995 and 2010 but reaching almost 100% during the 2001/02 season (Table 3.4). Over the same period, there has also been 1–15% observer coverage around the Auckland Islands for non-squid trawl fisheries (primarily targeting scampi, but also jack mackerel, orange roughy and hoki), 20–60% observer coverage in the Campbell Island southern blue whiting fishery, and 8–43% observer coverage for the Stewart-Snares shelf trawl fisheries (primarily targeting squid, but also hoki, jack mackerel and barracouta; Table 3.4). Fishers have tended to report NZ sea lion bycatch at a lower rate than observers. Fishers reported 177 NZ sea lion captures between 1998–99 and 2008–09, while observers reported 196 captures over the same period (Abraham and Thompson 2011). Observers observed an overall average of 4.7–11.2% of trawl tows each year over this time period, but fisheries where most sea lions are caught had higher observer coverage.

3. **Figure 3.1: Annual average trawl effort, annual average observer coverage, and observed NZ sea lion captures in the Sub-Antarctic region of New Zealand's EEZ. Data includes all trawl effort, excluding tows targeting inshore species, for the 14 years from 1 October 1995 to 30 September 2009. Dashed lines indicate the areas containing fishing effort that were used for estimating total captures and interactions in Table 3.4. Reproduced from Thompson and Abraham (2010).**



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The number of NZ sea lion captures reported by observers has been incorporated in increasingly sophisticated models to estimate the total number of captures across the entire fishing fleet in each fishing year (Smith and Baird 2007b, Thompson and Abraham 2010, Thompson *et al.* 2011). Estimates in Table 3.4 for the SQU6T and Campbell Island fisheries were generated using Bayesian models, whereas those for the Stewart-Snares and the non-squid Auckland Islands fisheries were generated using ratio estimates (Thompson *et al.* 2011). Captures comprise the number of NZ sea lions brought on deck (both dead and alive), and necessarily exclude the unknown fraction of animals that exit trawls through Sea Lion Exclusion Devices (SLEDs) as well as those that were decomposed upon capture or that climbed aboard vessels (Smith and Baird 2007b, Thompson and Abraham 2010, Thompson *et al.* 2011). Only 8 of the 248 captures from 1995/96 to 2008/09 were released alive (Thompson and Abraham 2010). Interactions are defined as the number of sea lion that would have been caught if no SLEDs were used (Thompson *et al.* 2011).

4. Table 3.3: Monthly distribution of NZ sea lion activity and the main trawl fisheries with observed reports of NZ sea lion incidental captures (see text for details).

NZ sea lions	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Breeding males	Dispersed at sea or at haulouts			Breeding colony			Dispersed at sea or at haulouts					
Breeding females	Breeding colony and at sea				Breeding colony		Breeding colony and at sea					
Pups	Breeding colony											
Non-breeders	Dispersed at sea, at haulouts or breeding colony periphery											
Major fisheries	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Squid					Stewart-Snares Shelf		Auckland Islands and Stewart-Snares Shelf				Auckland Islands	
Southern blue whiting	Bounty Islands	Pukaki Rise and Campbell Rise										
Scampi	Auckland Islands											

In the years since SLEDs were introduced in the SQU6T fishery, both the observed and estimated numbers of NZ sea lion captures have declined overall, except for a slight increase in 2009/10 (Table 3.4). Conversely, for those other fisheries where SLEDs are not deployed, observed and estimated numbers of NZ sea lion captures increased in the Campbell Island southern blue whiting fishery to a peak in 2010 (Table 3.4). For the Stewart-Snares and the Auckland Islands non-squid fisheries, the observed and estimated numbers of NZ sea lion captures have fluctuated without trend (Table 3.4).

Capture rate is defined as the number of NZ sea lions caught per 100 tows. Strike rate is defined as the number of NZ sea lions that would be caught per 100 tows if no SLEDs were fitted. Models indicate that the interaction rate of female NZ sea lions (synonymous with capture rate in the absence of SLEDs) is influenced by a number of factors including year, distance from rookery, tow duration, and change of tow direction (Smith and Baird 2005). Conversely, the interaction rate of male NZ sea lions is influenced by year, the number of days into the fishery (males leave the rookeries soon after mating whereas females remain with the pups), and time of day (Smith and Baird 2005).

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5. Table 3.4: Annual trawl effort, observer coverage, observed numbers of sea lions captured, observed capture rate (sea lions per 100 trawls), estimated sea lion captures, interactions, and the estimated strike or capture rate (with 95% confidence intervals) for the trawl fisheries operating around the Auckland and Campbell Islands and the Stewart-Snares shelf, and for all trawl fisheries combined (see Fig. 1). Data from Thompson *et al.* (2011).

<i>All trawl fisheries (excluding inshore)</i>		Observer coverage		Observed captures		Estimated captures		Estimated interactions	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.	
1995/96	9466	11	16	1.6	158	91–264	158	90–265	
1996/97	10954	15	28	1.7	160	107–234	160	106–234	
1997/98	9968	14	14	1	82	53–124	82	51–126	
1998/99	10557	16	6	0.4	36	25–51	36	23–53	
1999/00	9046	23	28	1.4	91	66–129	91	62–130	
2000/01	8910	39	46	1.3	66	59–74	85	63–111	
2001/02	9947	19	23	1.2	69	52–92	98	66–142	
2002/03	8304	19	11	0.7	38	28–52	67	41–102	
2003/04	10044	23	21	0.9	66	48–89	200	114–339	
2004/05	11091	23	14	0.5	58	41–81	172	92–295	
2005/06	9313	21	14	0.7	56	39–79	161	88–276	
2006/07	6724	24	15	0.9	49	36–67	109	63–179	
2007/08	6545	33	8	0.4	31	22–42	102	47–204	
2008/09	6676	27	3	0.2	24	15–35	92	35–188	
2009/10	5513	34	15	0.8	48	34–66	120	62–224	

<i>Auckland Islands squid (SQU6T)</i>		Observer coverage	Observed captures		Estimated captures		Estimated interactions		Estimated strike rate	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995/96	4467	12	13	2.4	141	73–245	141	73–244	3.2	1.7–5.4
1996/97	3717	19	28	3.9	144	91–218	144	90–217	3.9	2.6–5.7
1997/98	1441	22	13	4.2	61	34–103	61	32–104	4.2	2.5–6.9
1998/99	402	38	5	3.2	15	7–27	15	5–29	3.7	2.2–5.9
1999/00	1206	36	25	5.7	68	44–104	67	41–106	5.6	3.9–8.3
2000/01	583	99	39	6.7	39	39–40	58	37–82	10.0	8.4–12.4
2001/02*	1647	34	21	3.7	44	30–65	73	42–113	4.4	2.9–6.5
2002/03	1466	28	11	2.6	20	13–32	49	24–83	3.3	2.0–5.4
2003/04	2594	30	16	2	42	27–65	176	90–312	6.8	3.6–11.8
2004/05^	2693	30	9	1.1	34	18–56	147	69–274	5.4	2.6–9.9
2005/06	2459	28	9	1.3	30	17–51	135	62–249	5.5	2.6–10.0
2006/07	1317	41	7	1.3	17	10–28	77	33–144	5.8	2.7–10.7
2007/08	1265	46	5	0.9	12	6–21	82	28–183	6.5	2.4–14.3
2008/09	1925	40	2	0.3	9	3–18	77	19–175	4.0	1.1–9.0
2009/10	1188	26	3	1	13	5–27	85	28–191	7.2	2.5–15.8

<i>Auckland Islands non-squid (scampi)</i>		Observer coverage		Observed captures		Estimated captures		Estimated capture rate	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.	
1995/96	1471	6	3	3.49	13	8–19	0.69	0.37–1.06	
1996/97	1539	13	0	0	11	6–16	0.69	0.37–1.06	
1997/98	1823	13	1	0.42	14	8–20	0.69	0.37–1.06	
1998/99	1801	4	1	1.3	13	8–20	0.69	0.37–1.06	
1999/00	2157	8	0	0	15	8–23	0.69	0.37–1.06	
2000/01	2012	6	4	3.15	18	11–25	0.69	0.37–1.06	
2001/02	2214	8	0	0	15	8–23	0.69	0.37–1.06	
2002/03	1907	11	0	0	13	7–20	0.69	0.37–1.06	
2003/04	1667	13	3	1.38	15	9–21	0.69	0.37–1.06	
2004/05	1457	1	0	0	10	5–15	0.69	0.37–1.06	
2005/06	1370	9	1	0.82	10	6–15	0.69	0.37–1.06	
2006/07	1369	7	1	1.03	10	6–15	0.69	0.37–1.06	
2007/08	1480	11	0	0	10	5–16	0.69	0.37–1.06	
2008/09	1580	8	1	0.81	12	7–18	0.69	0.37–1.06	
2009/10	1021	14	0	0	7	4–11	0.69	0.37–1.06	

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Table 3.4: continued.

<i>Campbell Island SBW</i>		Observer coverage	Observed captures		Estimated captures		Estimated capture rate	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.
1996	474	26	0	-	1	0–4	0.18	0–1.15
1997	641	34	0	-	1	0–4	0.12	0–0.67
1998	963	28	0	-	1	0–5	0.11	0–0.62
1999	788	28	0	-	1	0–4	0.12	0–0.7
2000	447	52	0	-	0	0–2	0.11	0–0.6
2001	672	60	0	-	0	0–2	0.08	0–0.43
2002	980	28	1	0.37	3	1–11	0.35	0.02–1.26
2003	599	43	0	-	0	0–3	0.11	0–0.58
2004	690	33	1	0.43	3	1–9	0.39	0.02–1.38
2005	726	37	2	0.74	5	2–12	0.65	0.09–1.87
2006	521	28	3	2.07	10	3–21	1.76	0.32–4.31
2007	544	32	6	3.47	18	9–32	3.15	1.12–6.32
2008	557	41	2	0.88	5	2–11	0.77	0.1–2.14
2009	627	20	0	-	1	0–6	0.18	0–1.03
2010	527	43	11	4.87	25	16–38	4.58	2.27–7.74

<i>Stewart-Snares (mainly squid)</i>		Observer coverage	Observed captures		Estimated captures		Estimated capture rate	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995/96	3056	9	0	0	3	2–5	0.1	0.05–0.15
1996/97	5066	10	0	0	5	3–8	0.1	0.05–0.15
1997/98	5769	10	0	0	6	3–9	0.1	0.05–0.15
1998/99	7581	16	0	0	7	4–11	0.1	0.05–0.15
1999/00	5257	23	3	0.25	8	6–11	0.1	0.05–0.15
2000/01	5660	43	3	0.12	9	6–12	0.1	0.05–0.15
2001/02	5124	18	1	0.11	6	4–9	0.1	0.05–0.15
2002/03	4343	16	0	0	4	2–7	0.1	0.05–0.15
2003/04	5097	21	1	0.09	6	4–9	0.1	0.05–0.15
2004/05	6226	24	3	0.2	9	6–12	0.1	0.05–0.15
2005/06	4963	19	1	0.1	6	4–8	0.1	0.05–0.15
2006/07	3497	24	1	0.12	4	3–6	0.1	0.05–0.15
2007/08	3247	36	1	0.09	4	3–6	0.1	0.05–0.15
2008/09	2546	31	0	0	3	1–4	0.1	0.05–0.15
2009/10	2781	43	1	0.08	4	2–5	0.1	0.05–0.15

* SLEDs were introduced.

^ SLEDs were standardised and in widespread use.

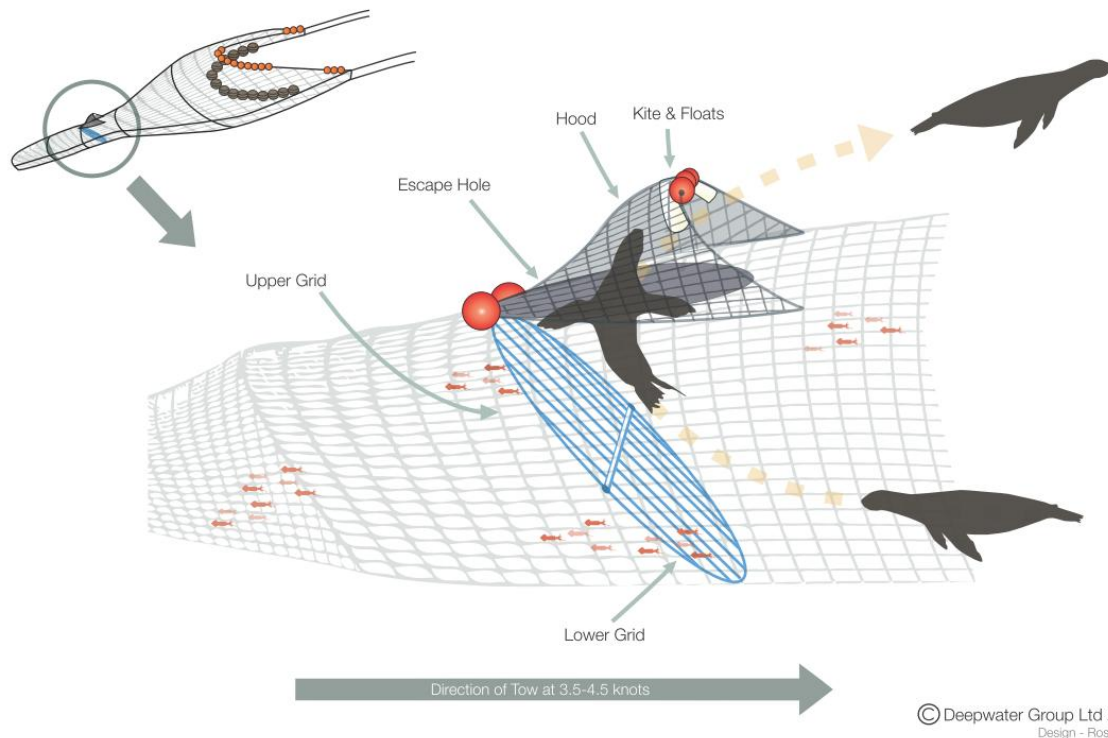
Managing fisheries interactions

For NZ sea lions, efforts to mitigate fisheries bycatch have focused on the SQU6T fishery. Spatial and/or temporal closures have been put in place, SLEDs were developed by industry, codes of practice were introduced, and mortality limits imposed. In 1982 the Minister of Fisheries established a 12 nautical mile exclusion zone around the Auckland Islands from which all fishing activities were excluded (Wilkinson *et al.* 2003). In 1993, the exclusion zone was replaced with a Marine Mammal Sanctuary with the same controls on fishing (Chilvers 2008). The area was also designated as a Marine Reserve in 2003. In addition to these area-based measures, mitigation devices in the form of SLEDs were introduced in the SQU6T fishing fleet in 2001/02 (Figure 3.2), with widespread and standardised use by all the fleet since 2004/05. The use of SLEDs is not mandatory, but is required by the current industry body (the Deepwater Group), fleet wide in application and monitored by MFish observers. In 1992, the Ministry of Fisheries adopted a fisheries-related mortality limit (FRML; previously referred to as a maximum allowable level of fisheries-related mortality or MALFiRM) to set an upper limit on the number of NZ sea lions that could be incidentally drowned each year in the SQU6T trawl fishery (Chilvers 2008). If this limit is reached, the fishery may be mandatorily closed

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for the remainder of the season. This has happened seven times (1996 to 1998, 2000, and 2002 to 2004) since this plan was first adopted in 1993 (Table 3.5; Robertson and Chilvers 2011).

Sea Lion Exclusion Device - SLED



6. **Figure 3.2: Diagram of a NZ sea lion exclusion device (SLED) inside a trawl net. Image courtesy of the Deepwater Group.**

Before the widespread use of SLEDs, NZ sea lions incidentally caught during fishing were usually retained in trawl nets and hauled on board, allowing observers to gain an accurate assessment of the number of NZ sea lions being captured on observed tows in a given fishery. This enabled a relatively simple estimation of the total number of NZ sea lions killed. However, following the introduction of SLEDs, the number of NZ sea lions interacting with SLEDs and the proportion of those surviving are much more difficult to estimate. Since the introduction of SLEDs, therefore, it has become necessary to estimate the number of NZ sea lions interacting with trawls using a predetermined strike rate to monitor performance against any bycatch limits set. Using a predetermined strike rate enables the FRML to be converted into a number of tows. The rate of 5.65% assumed by MFish for the SQU6T fishery is based on rates observed on vessels without SLEDs from 2003/04 to 2005/06 and is also assumed as part of the fishery implementation within an integrated management procedure evaluation model (named the BFG model after its authors, see section 3.3.3). The most recent strike rate modelling suggested rates of 5.8%, 6.5%, 4.0%, and 7.2% for the 2006/07 to 2009/10 fishing years, respectively (Table 3.4; Thompson *et al.* 2011) but the estimated rate has ranged between 3.3 and 10% in the past.

The current management regime for the SQU6T fishery provides for a “discounted” strike rate to apply to all tows when an approved SLED is used (because SLEDs allow some NZ sea lions to escape and survive their encounters with trawl nets; Thompson and Abraham 2010, see Table 3.5). The SLED discount rate is a fisheries management setting and should not be confused with the actual survival of NZ sea lions that encounter a trawl equipped with a SLED, but the discount mechanism is duplicated in the BFG simulations. The current discount rate of 35% means that the strike rate is

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reduced from 5.65% to 3.67%, so that, for every 100 tows using an approved SLED, 3.67 NZ sea lions are presumed killed. Ideally, the discount rate would be equal to the survival rate of NZ sea lions that encounter a trawl in circumstances that would be fatal if no SLED were fitted. This survival rate is the product of the proportion of animals that escape such an encounter via a SLED and their post-exit survival.

7. Table 3.5: Maximum allowable level of fisheries-related mortality (MALFiRM) or fisheries-related mortality limit (FRML) from 1991 to 2011. Note, however, that direct comparisons among years of the limits in Table 3.5 are not possible because the assumptions underlying the MALFiRM or FRML changed over time.

Year	MALFiRM or FRML	Discount rate	Management actions
1991/92	16 (females only)		
1992/93	63		
1993/94	63		
1994/95	69		
1995/96	73		Fishery closed by MFish (4 May)
1996/97	79		Fishery closed by MFish (28 March)
1997/98	63		Fishery closed by MFish (27 March)
1998/99	64		
1999/00	65		Fishery closed by MFish (8 March)
2000/01	75		Voluntary withdrawal by industry
2001/02	79		Fishery closed by MFish (13 April), overturned by the High Court
2002/03	70		Fishery closed by MFish (29 March), overturned by the High Court
2003/04	62 (124)	20%	Fishery closed by MFish (22 March), overturned by the High Court and FRML increased
2004/05	115	20%	Voluntary withdrawal by industry on reaching the FRML
2005/06	97 (150)	20%	FRML increased in mid-March due to abundance of squid
2006/07	93	20%	
2007/08	81	35%	
2008/09	113 (95)	35%	Lower interim limit agreed due to the decrease in pup numbers
2009/10	76	35%	
2010/11	68	35%	

In 2004, the Minister of Fisheries requested that the squid fishery industry organisation (Squid Fishery Management Company), government agencies and other stakeholders with an interest in sea lion conservation work collaboratively to develop a plan of action to determine SLED efficacy. In response, an independently chaired working group (the SLED Working Group) was established to develop an action plan to determine the efficacy of SLEDs, with a particular focus on the survivability of NZ sea lions that exit the nets via the exit hole in the SLED. The group undertook a number of initiatives, most notably the standardisation of SLED specifications across the fleet (Clement and Associates Ltd. 2007) and the establishment of an underwater video monitoring programme to help understand what happens when a NZ sea lion encounters a SLED. The footage was not useful because very few sea lion interactions were observed, but one fur seal and one NZ sea lion have been observed exiting a net equipped with a SLED when white light illumination was used. Given the very small number of observed interactions and that the footage was obtained under conditions that differ from those encountered in typical commercial squid tows, this information is of limited value in assessing

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the average survival rate of NZ sea lions exiting SLEDs. The SLED Working Group was disbanded by group member consensus in early 2010.

The original MALFiRM was calculated using the potential biological removal approach (PBR; Wade 1998) and was used from 1992/93 to 2003/04 (Smith and Baird 2007a). The PBR approach was developed by the United States National Marine Fisheries Service to calculate the maximum number of animals that may be removed from a marine mammal stock, not including natural mortalities, while allowing that stock to reach or maintain its Optimum Sustainable Population size, defined as being at or above the Maximum Net Productivity Level (Wade 1998). PBR is calculated by the following formula:

$$\text{PBR} = N_{\text{MIN}}^{1/2} R_{\text{MAX}} F_R$$

Where: N_{MIN} = the minimum population estimate of the stock;
 R_{MAX} = the maximum theoretical or estimated net productivity rate of the stock at a small population size; and
 F_R = a recovery factor between 0.1 and 1.0

Definitions for the various components of a PBR can be found in Wade (1998) and Wade and Angliss (1997). The PBR approach is appropriate for estimating whether a particular level of human-induced mortality is likely to compromise meeting the optimum sustainable population size objective in the absence of detailed biological data. The PBR approach was not designed to provide for in-season management of fisheries with marine mammal bycatch but rather to trigger longer term bycatch reduction efforts should the bycatch exceed PBR (Wade 1998).

Since 2003/04 the FRML has been translated into a maximum permitted number of tows after which the SQU6T fishing season may be halted by the Minister regardless of the observed NZ sea lion mortality. This approach has been taken because NZ sea lion mortality can no longer be monitored directly since the introduction of SLEDs.

Modelling fisheries interactions

Since 2000, an integrated Bayesian management procedure evaluation model having both population and fishery components has been used to assess the likely performance of a variety of bycatch control rules, each of which can be used to determine the FRML for a given SQU6T season (Breen *et al.* 2003, Breen and Kim 2006a, Breen and Kim 2006b, and Breen, Fu and Gilbert 2010). The model underwent several iterations. An early version, developed in 2000/01, was a relatively simple deterministic, partially age-structured population model with density-dependence applied to pup production (Breen *et al.* 2003). An updated version was constructed in 2003 to render it fully age-structured and to incorporate various datasets supplied by DOC (Breen and Kim 2006a, 2006b). This model was further revised in 2007/08 to incorporate the latest NZ sea lion population data and to address various model uncertainties and called the BFG model (after its authors, Breen, Fu and Gilbert 2010). In 2009, the model was again updated to incorporate the low NZ sea lion pup counts observed in 2008/09 (and thus better reflect the observed variability in pup survival and pupping rates), as well as NZ sea lion bycatch that occurs in fisheries other than SQU6T. The BFG model was re-run in 2011 using the same underlying data and structure as in 2009 to evaluate the effect of different model assumptions about the survival of NZ sea lions that exit trawl nets via SLEDs (see below). Additional details on the NZ sea lion population model can be found in Breen *et al.* (2010).

The BFG model incorporates various population dynamics observations (tag re-sighting observations, pup births and mortality, age at maturity) as well as bycatch counts and catch-at-age data from the SQU6T trawl fishery. The model was projected into the future by applying the observed dynamics and a virtual fishery model that is managed in roughly the same way as the real SQU6T fishery. A

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large number of projections were run and used to assess the likely performance of a wide range of different management control rules against the four performance criteria described in Context (two MFish criteria and two DOC criteria). For each set of runs the population indicators were summarised and the rules compared in tables.

Sources of uncertainty

There are several outstanding sources of uncertainty in modelling the effects of fisheries interactions on NZ sea lions; some are likely to make the results of the BFG model conservative while others may make it optimistic. In particular, the model is sensitive to several key parameters. Some relate mostly to uncertainty about the productivity of the NZ sea lion population (including maximum population growth rate, abundance relative to carrying capacity, maximum rate of pup production, and density dependence), whereas others relate to how the fishery works and is managed (including strike rates and the survival of NZ sea lions that interact with SLEDs but are not retained in the net).

Conclusions drawn from the BFG model results are sensitive to prior assumptions about how fast the NZ sea lion population is able to grow. The maximum population growth rate (λ) for this population of NZ sea lions is not known. Fitting the model to the observed data with an uninformative prior led to an estimated maximum rate of less than 1% per year, potentially as a consequence of attempting to estimate λ for a declining population. This is a very low maximum growth rate for a pinniped (some suggest a default value of 12% per year, Wade 1998), so a prior of 8% was applied to the base model. In a sensitivity run, the model was fitted using a prior of 5% per year, and the results were more consistent with the observed data than when 8% was used.

The estimated abundance of NZ sea lions relative to the carrying capacity of mature individuals (K) is another source of uncertainty. When the model is run in the absence of fishing, the median numbers of mature animals after 100 years was only 94.4% of K as estimated from the model. Although the population is not presently near K , over this timescale, the population would normally be expected to approach K . This is thought to be an artefact of the parameterisation of survival rates in the model, which renders the model conservative when assessing performance against K (Breen *et al.* 2010).

The density dependent response for this population of NZ sea lions is also unknown. Ecological principles suggest that, as numbers in a population decline, individuals compete less with one another for resources. Less competition may result in NZ sea lions growing faster as well as having lower mortality rates and higher rates of pup production and survival. The effect of this type of response is that populations tend to recover from events that reduce their numbers, and populations with strong density dependence recover more strongly than those with weak density dependence. In the BFG model, the density dependent response was assumed to occur entirely in the mortality rate of pups. The strength of this response is unknown, and an assumed “shape parameter” (z) was fixed into the model with a value of $z = 3$. In sensitivity runs, the model was fitted using values of $z = 2$ (relatively weak density dependence) and $z = 4$ (relatively strong density dependence), but there is currently no information to support a strong preference for any of the assumed values. This means the base model results may be either conservative or optimistic.

The maximum rate of pup production for this population is not known but can be estimated in the population model. Other modelling conducted for DOC (albeit using different assumptions, Breen *et al.* 2010) suggests that the maximum rate of pup production is <0.28 pups per mature adult per year (Gilbert and Chilvers 2008), a level thought to be below that required to replace the population (Breen *et al.* 2010). When this value is fixed in the BFG model, the fitting procedure does not converge successfully. The BFG model authors progressively increased the fixed value until overall fitting was successful at 0.315 pups per mature adult per year. Thus, the BFG model estimates, and can accommodate, only maximum rates of pup production that are roughly 15% higher than those estimated by direct modelling.

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In addition to sources of uncertainty for inputs in the BFG model, there are other sources of uncertainty relevant to the management of fisheries interactions. For example, the estimated strike rate has varied considerably over time, and the model estimates of strike rates for recent years are very imprecise (Thompson *et al.* 2011, Table 3.4). Although year on year variation in strike rate is unlikely to appreciably affect the conclusions from the simulations, if the long-term average strike rate is higher or lower than that assumed within the fishery component of the simulations, or if the strike rate or catchability has increased since the introduction of SLEDs, then there may be some bias. If NZ sea lion catchability has increased, as a result of the increased average tow duration in the SQU6T fishery since the introduction of SLEDs (Table 3.6), or by some other factor, then this would make the simulations optimistic.

8. Table 3.6: Tow duration in the SQU6T fishery (i.e. for trawl fishers targeting SQU in statistical areas 602, 603, 617 and 618). Years are calendar years. Data from MFish databases.

Year	No. of tows	Mean tow duration (hours)	Percentage of tows		
			Less than 4 hours	Between 4 and 8 hours	More than 8 hours
1995	4 014	3.7	64.2	33.5	2.2
1996	4 474	3.6	64.3	34.2	1.5
1997	3 719	3.8	62.7	33.7	3.7
1998	1 446	3.2	74.4	24.7	0.9
1999	403	3.5	73.0	24.3	2.7
2000	1 213	3.5	70.3	27.0	2.7
2001	583	3.3	72.9	26.6	0.5
2002	1 647	3.8	59.8	38.8	1.4
2003	1 467	4.1	52.4	44.0	3.6
2004	2 598	5.0	36.7	53.6	9.7
2005	2 693	4.7	43.7	48.6	7.7
2006	2 462	6.3	26.0	49.6	24.3
2007	1 317	7.3	18.9	46.3	34.8
2008	1 265	6.2	20.4	58.7	20.9
2009	1 925	6.5	21.1	51.4	27.5
2010	1 190	7.9	16.4	37.4	46.2

SLEDs are effective in allowing most NZ sea lions to exit a trawl but some are retained and drowned and others may not survive the encounter. An experimental approach to assessing non-retained fatality rate involved intentionally capturing animals as they exited the escape hole of a SLED between 1999/2000 and 2002/03. Cover nets were added over the escape holes of some SLEDs and sea lions were restrained in these nets after they exited the SLED proper. An underwater video camera was deployed in 2001 to assess the behaviour and the likelihood of post-exit survival of those animals that were retained in the cover nets (Wilkinson *et al.* 2003, Mattlin 2004). However, the low number of captures filmed and the inability to assess longer term survival means that this approach could not be used to determine likely survival rates (e.g., Roe 2010, p.4).

Necropsies were conducted on animals recovered from the cover net trials and on those incidentally caught and recovered from vessels operating in the SQU6T, SQU1T and SBW6I fisheries. Although all of the NZ sea lions returned for necropsy died as a result of drowning and not as a direct result of physical trauma resulting from interactions with the trawl gear (including the SLED; Roe and Meynier 2010, Roe 2010), necropsies were designed to assess the nature and severity of trauma sustained during capture and to infer the survival prognosis had those animals been able to exit the net (Mattlin 2004). However, problems associated with this approach limited the usefulness of the results. For example, NZ sea lions were frozen on vessels and stored for periods of up to several months before being thawed for 3–5 days to allow necropsy. Roe and Meynier (2010) concluded that this freeze-thaw process created artefactual lesions that mimic trauma, but could also obscure real lesions. Further, two reviews in 2011 concluded that the lesions in retained animals may not be representative of the injuries sustained by animals that exit a trawl via a SLED (Roe and Meynier 2010, Roe 2010).

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As a result of these reviews, the use of necropsies to infer the survival of sea lions interacting with SLEDs was discontinued.

Notwithstanding the limitations of the necropsy data in assessing trauma for previously frozen animals, it was possible to determine that none of the necropsied animals sustained sufficient injuries to the body (excluding the head) to compromise survival (Roe and Meynier 2010, Roe 2010). Head trauma, however, could not be ruled out as a potential contributing factor, possibly due to impacts with the SLED grid (Roe and Meynier 2010, Roe 2010). In order to quantify the likelihood of a NZ sea lion impacting head first on the grid of the SLED and experiencing trauma sufficient to render the animal insensible, a number of factors need to be assessed. These include the likelihood of a head-first impact, the speed of impact, the angle of impact relative to individual grid bars and relative to the grid plane, the location of impact on the grid, head mass, and the risk of brain injury for a given impact speed and head mass. The effect of multiple impacts also needs to be considered. Estimates for each of these factors were derived from a number of sources, including necropsies (for head mass), video footage of NZ sea lions interacting with SLEDs (for impact speed, location and body orientation) and biomechanical modelling of impacts on the SLED grid (for the risk of brain injury).

In the absence of sufficient video footage of NZ sea lion interacting with SLEDs, footage of fur seals (thought to be Australian fur seals) interacting with a Seal Exclusion Device (SED) in the Tasmanian small pelagic mid-water trawl fishery has been used (Lyle 2011). The SEDs are not identical to the New Zealand SLEDs, but both have steel grids (to separate the catch from the pinniped) located to the rear of an escape hole in the trawl. Lyle and Willcox (2008) conducted a camera trial between January 2006 and February 2007 to assess the efficacy of the SED and documented 457 interactions for about 170 individual fur seals. Lyle (2011) reanalysed the footage to estimate impact speed, impact location across the SED grid and body orientation at the time of impact. The situation faced by NZ sea lions in a squid trawl is not identical to that faced by the fur seals studied by Lyle and co-workers, but these are closely related otariids of similar size and, in the absence of specific data, Australian fur seals are considered a reasonable proxy to estimate impact speed, impact location and body orientation.

The risk of brain injury was assessed by biomechanical testing and modelling. Tests using an artificial “head form” (as used in vehicular “crash test” studies) were used to assess the likelihood of brain injury to NZ sea lions colliding with a SLED grid (Ponte *et al.* 2010). In an initial trial, the head form (weighing 4.8 kg) was launched at three locations on the SLED grid at maximum speed of 10 m.s⁻¹. This was considered a “worst feasible case” collision representing the combined velocities of a sea lion swimming with a burst speed of 8 m.s⁻¹ (after Ray 1963, Fish 2008) and a net being towed at 2 m.s⁻¹ (about 4 knots). A head injury criterion (HIC, a predictor of the risk of brain injury) was calculated based on criteria validated against human-vehicle impact studies and translated into the probability of mild traumatic brain injury (MTBI) for a given collision, taking into account differences between human and sea lion head and brain masses (Ponte *et al.* 2010, 2011). MTBI is assumed to have the potential to lead to insensibility or disorientation and subsequent death through drowning for a NZ sea lion experiencing such an injury at depth. Ponte *et al.* (2010) calculated that a collision at the stiffest part of the SLED grid at this highest feasible speed had a very high risk of MTBI, especially for smaller sea lions. This provides an upper bound for the assessment of risk but Ponte *et al.* (2010) also imputed risk at speeds below the maximum.

In a follow-up study, after a research advisory group meeting with other experts, Ponte *et al.* (2011) tested a wider variety of impact locations on the grid and various angles of impact relative to the bars and to the plane of the grid and combined these to produce a HIC “map” for a SLED grid. This HIC map can be used to estimate the risk of MTBI for a collision by a sea lion at any given speed, location, and orientation.

The data collected from the footage of Australian fur seal SED interactions (Lyle 2011) and the biomechanical modelling (Ponte *et al.* 2010, 2011) were combined in a simulation-based probabilistic model to estimate the risk of a sea lion suffering a mild traumatic brain injury when striking a SLED grid (Abraham 2011). The simulation involved selecting an impact location on the SLED grid (from

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the fur seal data), selecting a head mass (from NZ sea lion necropsy data) and an impact speed (from the fur seal data), calculating the head impact criterion (HIC) (from the HIC map), scaling the HIC to the head mass and impact speed and calculating the expected probability of mild traumatic brain injury, MTBI. Both 45° and 90° degree impacts were considered, with the former, reflecting the angle of a grid when deployed, adopted as the base case. The head masses used may be at the lower end of the range of head masses for NZ sea lions. Impact speeds were drawn from the distribution of speeds observed for fur seals colliding with SEDs (2–6 m.s⁻¹) and these are broadly consistent with the combined tow speed and observed swimming speeds of NZ sea lions in the wild (Crocker *et al.* 2001). Different scaling of HIC values was assessed to gauge sensitivity.

For the base case, the simulation results indicated there was a 3.3% chance of a single head-first collision resulting in MTBI with a 95 percentile of 15.7% risk of MTBI (Abraham 2011). Sensitivities involving changes in single parameters resulted in up to 6.2% probability of a single collision resulting in MTBI. One sensitivity trial involving changes in multiple parameters resulted in a 10.9% probability of MTBI. This scenario considered impact speeds 20% above those measured for fur seals, multiple collisions with the grid, and the least favourable values of scaling exponents used in scaling the test HIC values and calculating MTBI from the HIC (Abraham 2011). These results are probabilities of MTBI resulting from a single head first collision but, because each individual can have multiple interactions with the grid while in a trawl, and some of these will not be head-first, some additional assumptions were made based on the Australian observations. Using these data, Abraham (2011) estimated the number of head-first collisions per interaction as 0.74, leading to an estimated probability of MTBI for a NZ sea lion interacting with a trawl of 2.7%. Single parameter sensitivity runs increased this to up to 4.6% and the multiple parameter sensitivity using the scenario described above increased it to 8.2% (Abraham 2011). Assuming synergistic interaction between successive head-first strikes (each collision carrying 5 times more risk than previous ones) did not appreciably increase the overall risk because few fur seals had multiple head-first collisions.

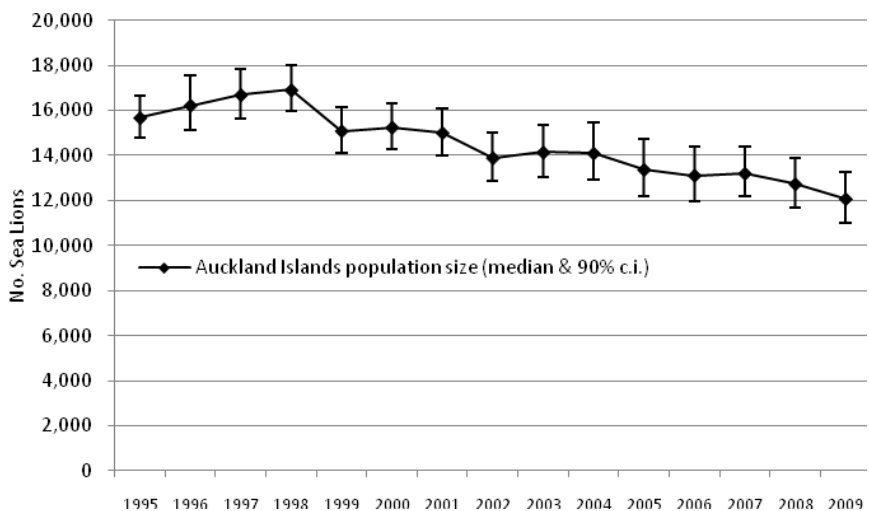
These results indicate that the risk of mortality for NZ sea lions interacting with the SLED grid is probably low, although some remaining areas of uncertainty were identified. The use of linear acceleration, as opposed to rotational acceleration, in the biomechanical modelling may underestimate the risk of MTBI, although this was thought to be accounted for at least in part by sensitivity analysis of the scaling of HIC values. The testing used an artificial “head form” based on human anatomy, so the effect of NZ sea lion scalp thickness and skull morphology is unknown, although differences in head and brain masses are accounted for. Potential effects of differences in the angle of the head on impact (relative to the neck) were not tested. Impact speeds, locations and orientations of NZ sea lions may differ from those of Australian fur seals, although the fur seal data are considered to be a reasonable proxy. The head mass values used may be lower than average for NZ sea lions; this would mean risk is likely to be overestimated. This approach assesses risk associated with collisions with the grid of a SLED and cannot be used to assess other sources of mortality resulting; for example, from an animal being retained in a net long enough for them to exceed their dive limit before reaching the surface after escaping from either the SLED or the front of the net. Such sources of cryptic mortality have always existed, are presently unquantified and are not reflected in the estimated overall survival rate of encounters with trawls.

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Potential indirect threats

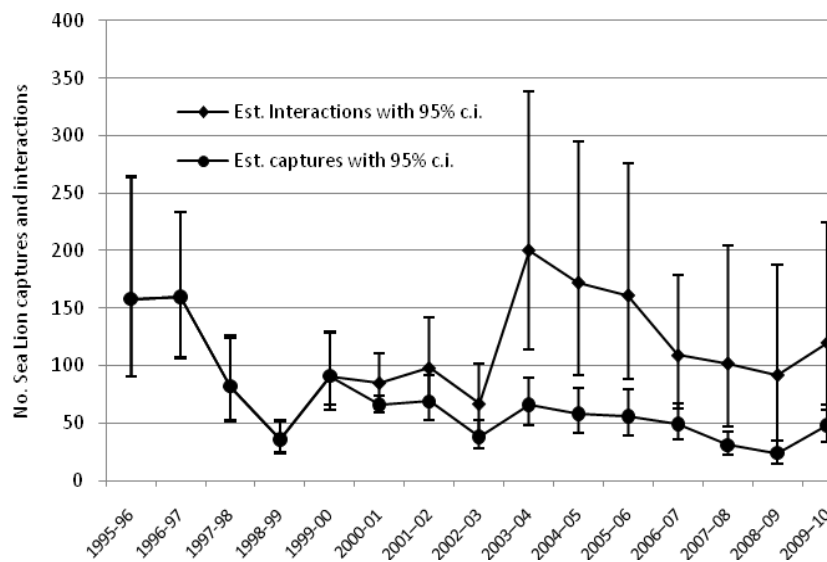
In addition to sources of uncertainty associated with direct fisheries interactions, there is the possibility that indirect fisheries effects may have population-level consequences for NZ sea lions. Such indirect effects may include competition for food resources between various fisheries and NZ sea lions (Robertson and Chilvers 2011). In order to determine whether resource competition is present and is having a population-level effect on NZ sea lions, research must identify if there are resources in common for NZ sea lions and the various fisheries within the range of NZ sea lions, and if those resources are limiting. Diet studies have demonstrated overlap in the species consumed by NZ sea lions and those caught in fisheries within the range of NZ sea lions, particularly hoki and arrow squid (Cawthorn *et al.* 1985, Childerhouse *et al.* 2001, Meynier *et al.* 2009). A recent study focused on energy and amino acid content of prey determined that the selected prey species contained all essential amino acids and were of low to medium energy levels (Meynier 2010). This may indicate that the nutritional content of prey species is not limiting the metabolic activity of NZ sea lions, although vitamin and mineral content were not considered. Meynier (2010) also developed a bio-energetic model and used it to estimate the amount of prey consumed by NZ sea lions at 17 871 tonnes (95% CI 17 738–18 000 t) per year. This is equivalent to ~30% of the tonnage of arrow squid, and ~15% of the hoki harvested annually by the fisheries in the Sub-Antarctic between 2000 and 2006 (Meynier 2010). The extent to which this may result in resource competition has not been assessed but certainly requires more sophisticated trophic or ecosystem modelling.

Indicators and trends

<i>Population size</i>	12,065 animals (including pups < 1 yr old) at the Auckland Islands (90% CI: 11 160–13 061) in 2009 1 550 pups at the Auckland Islands (SE = 41) in 2010/11 726 pups at Campbell Island in 2010 5 pups at the Otago Peninsula in 2010/11																																																																
<i>Population trend</i>	<p>Decreasing at the Auckland Islands, where there was a net decline in overall abundance of 23% between 1995 and 2009 or 29% between the peak in 1998 and 2009. There was concomitant decline in pup production of 38% or 49% over these periods.</p>  <table><caption>Auckland Islands population size (median & 90% c.i.)</caption><tr><th>Year</th><th>Population Size (Median)</th><th>90% CI (Lower)</th><th>90% CI (Upper)</th></tr><tr><td>1995</td><td>15,500</td><td>14,500</td><td>16,500</td></tr><tr><td>1996</td><td>16,000</td><td>15,000</td><td>17,000</td></tr><tr><td>1997</td><td>16,500</td><td>15,500</td><td>17,500</td></tr><tr><td>1998</td><td>17,000</td><td>16,000</td><td>18,000</td></tr><tr><td>1999</td><td>15,000</td><td>14,000</td><td>16,000</td></tr><tr><td>2000</td><td>15,000</td><td>14,000</td><td>16,000</td></tr><tr><td>2001</td><td>15,000</td><td>14,000</td><td>16,000</td></tr><tr><td>2002</td><td>14,000</td><td>13,000</td><td>15,000</td></tr><tr><td>2003</td><td>14,000</td><td>13,000</td><td>15,000</td></tr><tr><td>2004</td><td>14,000</td><td>13,000</td><td>15,000</td></tr><tr><td>2005</td><td>13,500</td><td>12,500</td><td>14,500</td></tr><tr><td>2006</td><td>13,000</td><td>12,000</td><td>14,000</td></tr><tr><td>2007</td><td>13,000</td><td>12,000</td><td>14,000</td></tr><tr><td>2008</td><td>12,500</td><td>11,500</td><td>13,500</td></tr><tr><td>2009</td><td>12,000</td><td>11,000</td><td>13,000</td></tr></table>	Year	Population Size (Median)	90% CI (Lower)	90% CI (Upper)	1995	15,500	14,500	16,500	1996	16,000	15,000	17,000	1997	16,500	15,500	17,500	1998	17,000	16,000	18,000	1999	15,000	14,000	16,000	2000	15,000	14,000	16,000	2001	15,000	14,000	16,000	2002	14,000	13,000	15,000	2003	14,000	13,000	15,000	2004	14,000	13,000	15,000	2005	13,500	12,500	14,500	2006	13,000	12,000	14,000	2007	13,000	12,000	14,000	2008	12,500	11,500	13,500	2009	12,000	11,000	13,000
Year	Population Size (Median)	90% CI (Lower)	90% CI (Upper)																																																														
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	<p>Probably increasing at Campbell Island based on substantial increases in pup counts (although methodology has changed over time). Increasing at the Otago Peninsula through a combination of reproduction and immigration.</p>
<i>Threat status</i> ¹³	NZ: Nationally Critical, C, RR, in 2010 IUCN: Vulnerable, A3b, in 2008
<i>Number of interactions</i>	120 estimated interactions (95% CI: 62–224) in trawl fisheries in 2009/10 48 estimated captures (95% CI: 34–66) in trawl fisheries in 2009/10 15 observed captures in trawl fisheries in 2009/10
<i>Trend in interactions</i>	Decreasing trend in estimated captures and interactions since 2003-04, but with a slight increase in 2009-10.



¹³ See the Conservation biology and threat classification section for definitions of NZ and IUCN threat status terms.

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References

- Abraham, E.R. 2011. Probability of Mild Traumatic Brain Injury for sea lions interacting with SLEDs. Final Research Report for Ministry of Fisheries project SRP2011-03 (Unpublished report held by the Ministry of Fisheries, Wellington). 21 pages.
- Abraham, E.R.; Thompson, F.N. 2011. Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. Final Research Report prepared for Ministry of Fisheries project PRO2007/01. (Unpublished report held by the Ministry of Fisheries, Wellington.) 170 pages.
- Anonymous. 2009. DWG and MFish SLED Specification for SQU 6T 2010 Operation Plan (MK 3/13). Report presented to SLED WG September 2009, Wellington, NZ.
- Augé, A. 2006. Terrestrial spatial ecology of female New Zealand sea lions. Unpublished MSc thesis, University of Otago, Dunedin.
- Augé, A. 2011. Foraging ecology of recolonising female New Zealand sea lions around the Otago Peninsula, New Zealand. Unpublished PhD thesis, University of Otago, Dunedin.
- Augé, A.A., B.L. Chilvers, A.B. Moore, L.S. Davis. 2011. Foraging behaviour indicates marginal marine habitat for New Zealand sea lions: remnant versus recolonising populations. *Marine Ecology Progress Series* 432: 247–256.
- Baker, C.S., B.L. Chilvers, R. Constantine, S. DuFresne, R. Mattlin, A. van Helden, and R. Hitchmough. 2010. Conservation status of New Zealand Marine Mammals (suborders Cetacea and Pinnipedia), 2009. *New Zealand Journal of Marine and Freshwater Research* 44: 101–115.
- Baker, A. J. 1999. Unusual mortality of the New Zealand sea lion, *Phocarctos hookeri*, Auckland Islands, January–February 1998: A report of a workshop held 8–9 June 1998, Wellington, and a contingency plan for future events. pp. 29–33, Department of Conservation, Te Papa Atawhai, Wellington, New Zealand.
- Breen, P.A. 2008. Sea lion data for use in the population model for Project IPA200609. Unpublished Final Research Report for Ministry of Fisheries, 30 March 2008. 18 pp. plus Confidential Appendix of 6p.
- Breen, P.A., R. Hilborn, M.N. Maunder, and S.W. Kim. 2003. Effects of alternative control rules on the conflict between a fishery and a threatened sea lion (*Phocarctos hookeri*). *Canadian Journal of Fisheries and Aquatic Sciences* 60: 527–541.
- Breen, P.A., and S.W. Kim. 2006a. Exploring alternative management procedures for controlling bycatch of Hooker's sea lions in the SQU 6T squid fishery. Unpublished Final Research Report For Ministry of Fisheries Project M0F2002/03L, Objective 3. Revision 5, 3 February 2006. 88 pp.
- Breen, P.A., and S.W. Kim. 2006b. An integrated Bayesian evaluation of Hooker's sea lion bycatch limits. pp. 471–493 In: A. Trites, S. Atkinson, D. DeMaster, L. Fritz, T. Gelatt, L. Rea, and K. Wynne. (eds.). *Sea lions of the world*. Alaska Sea Grant College Program, University of Alaska Fairbanks.
- Breen, P.A., D. Fu, and D.J. Gilbert. 2010. Sea lion population modelling and management procedure evaluations: Report for Project SAP2008/14, Objective 2. Presented to AEWG March 22 2010, Wellington, New Zealand.
- Castinel, A., Duignan, P. J., Pomroy, W. E., López-Villalobos, N., Gibbs, N. J., Chilvers, B. L., and I. S. Wilkinson. 2007. Neonatal mortality in New Zealand sea lions (*Phocarctos hookeri*) at Sandy Bay, Enderby Island, Auckland Islands from 1998 to 2005. *Journal of Wildlife Diseases* 43: 461–474.
- Cawthorn M 1993. Census and population estimation of Hooker's sea lion at the Auckland Islands, December 1992–February 1993. DOC Technical Series 2. Wellington, Department of Conservation. 34 p
- Cawthorn, M.W., M.C. Crawley, R.H. Mattlin, and G.J. Wilson. 1985. Research on pinnipeds in New Zealand. Wildlife Research Liaison Group Report No. 7, Wellington, New Zealand.
- Childerhouse, S., and N. Gales. 1998. The historic distribution and abundance of the New Zealand sea lion *Phocarctos hookeri*. *New Zealand Journal of Zoology* 25: 1–16.
- Childerhouse, S., and N. Gales. 2001. Fostering behavior in New Zealand sea lions *Phocarctos hookeri*. *NZ J. Zoology* 28:189–195.
- Childerhouse, S., B. Dix, and N.J. Gales. 2001. Diet of New Zealand sea lions (*Phocarctos hookeri*) at the Auckland Islands. *Wildlife Research* 28:291–298.
- Childerhouse S, Gibbs N, McAlister G, McConkey S, McConnell H, McNally N, Sutherland D 2005. Distribution, abundance and growth of New Zealand sea lion *Phocarctos hookeri* pups on Campbell Island. *New Zealand Journal of Marine and Freshwater Research* 39: 889–898.
- Childerhouse, S., S.M. Dawson, E. Slooten, D.J. Fletcher, and I.S. Wilkinson. 2010a. Age distribution of lactating New Zealand sea lions: interannual and intersite variation. *Marine Mammal Science* 26: 123–139.
- Childerhouse, S., S.M. Dawson, D.J. Fletcher, E. Slooten, and B.L. Chilvers. 2010b. Growth and reproduction of female New Zealand sea lions. *Journal of Mammalogy* 91:165–176.
- Chilvers, B.L. 2008. New Zealand sea lions *Phocarctos hookeri* and squid trawl fisheries: bycatch problems and management options. *Endangered Species Research* 5: 193–204.
- Chilvers, B.L., and I.S. Wilkinson. 2008. Philopatry and site fidelity of New Zealand sea lions (*Phocarctos hookeri*). *Wildlife Research*, 2008, 35, 463–470.
- Chilvers, B.L., and I.S. Wilkinson. 2009. Diverse foraging strategies in lactating New Zealand sea lions. *Marine Ecology Progress Series* 378: 299–308.
- Chilvers, B.L., and I.S. Wilkinson. 2011. Research to assess the demographic parameters of New Zealand sea lions, Auckland Islands: Draft Final Report November 2011, Contract Number: POP 2010/01. Department of Conservation, Wellington. 20 p.
- Chilvers, B.L., I.S. Wilkinson, P.J. Duignan, and N.J. Gemmell. 2005a. Summer foraging areas for lactating New Zealand sea lions *Phocarctos hookeri*. *Marine Ecology Progress Series* 304:235–247.
- Chilvers, B.L., B.C. Robertson, I.S. Wilkinson, P.J. Duignan, and N.J. Gemmell. 2005b. Male harassment of female New Zealand sea lions: mortality, injury and harassment avoidance. *Canadian Journal of Zoology* 83:642–648.
- Chilvers, B.L., I.S. Wilkinson, P.J. Duignan, and N.J. Gemmell. 2006. Diving to extremes: are New Zealand sea lions pushing their limits in a marginal habitat? *Journal of Zoology* 269:233–240.
- Chilvers, B.L., I.S. Wilkinson, and S. Childerhouse. 2007. New Zealand sea lion, *Phocarctos hookeri*, pup production–1995 to 2006. *New Zealand Journal of Marine and Freshwater Research* 41: 205–213.
- Chilvers, L., I.S. Wilkinson, and D. I. Mackenzie. 2010. Predicting life-history traits for female New Zealand sea lions, *Phocarctos hookeri*: integrating short-term mark–recapture data and population modelling. *Journal of Agricultural, Biological, and Environmental Statistics* 15(2): 259–278.
- Clement & Associates Ltd. 2007. Squid trawl fleet sea lion escape device audit. A report commissioned by the Department of Conservation for Project CSP MIT2004/05. Department of Conservation, Wellington. 19 p.
- Costa, D.P., and N.J. Gales. 2000. Foraging energetic and diving behaviour of lactating New Zealand sea lions, *Phocarctos hookeri*. *Journal of Experimental Biology* 203:3655–3665.

APPENDIX A

- Crocker, D.E., Gales, N.J. and Costa, D.P. 2001. Swimming speed and foraging strategies of New Zealand sea lions, *Phocarctos hookeri*. *Journal of Zoology* 254: 267-277.
- Department of Conservation. 2007. Draft Population Management Plan for New Zealand Sea Lion. Draft Document for Public Consultation, August 2007. Department of Conservation, Wellington. <http://www.doc.govt.nz/getting-involved/consultations/closed/nz-sea-lion-management/>.
- Department of Conservation. 2009. New Zealand sea lion species management plan: 2009–2014. Department of Conservation, Wellington. 31 p.
- Dickie, G. 1999. Population dynamics of New Zealand fur seals (*Arctocephalus forsteri*) and New Zealand sea lions (*Phocarctos hookeri*). M.Sc. thesis. University of Otago, Dunedin, New Zealand. 117p.
- Fish, F. 2008. Streamlining. pp. 1123-26. In W. F. Perrin, B. Wursig, and J. G. M. Thewissen (eds.). *Encyclopedia of Marine Mammals*. Academic Press.
- Gales, N.J. 1995. New Zealand (Hooker's) sea lion recovery plan. Threatened Species Recovery Plan Series 17. Department of Conservation, Wellington.
- Gales, N. 2008. *Phocarctos hookeri*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. www.iucnredlist.org. Downloaded on 1 June 2011.
- Gales, N.J., and D.J. Fletcher. 1999. Abundance, distribution and status of the New Zealand sea lion, *Phocarctos hookeri*. *Wildlife Research* 26: 35-52.
- Gales N.J., and R.H. Mattlin. 1997. Summer diving behaviour of lactating female New Zealand sea lions. *Canadian Journal of Zoology* 75:1695-1706.
- Gilbert, D., and L. Chilvers 2008. Final report on New Zealand sea lion pupping rate. POP2006-01 Objective 3. Analysis from sea lion database to estimate pupping rate and associated parameters. NIWA Report WLG2008-77. 26p.
- Hankel, W., M. Witte, L. Miersch, M. Brede, J. Oeffner, M. Michael, F. Hankel, A. Leder, and G. Dehnhardt. 2010. Harbor seal vibrissa morphology suppresses vortex-induced vibrations. *Journal of Experimental Biology* 213, 2665-2672.
- IUCN, 2010. IUCN Red List of Threatened Species. Version 2010.4. <http://www.iucnredlist.org>. Downloaded on 1 June 2011.
- Katsanevakis S. 2008. Marine debris, a growing problem: Sources, distribution, composition, and impacts. In: Hofer TN (ed) *Marine Pollution: New Research*. Nova Science Publishers, New York. pp. 53–100.
- Lalas, C., and C.J.A. Bradshaw. 2003. Expectations for population growth at new breeding locations for the vulnerable New Zealand sea lion using a simulation model. *Biological Conservation* 114:67-78.
- Lyle, J.M. 2011. SRP2010-03: Fur seal interactions with SED excluder device. Unpublished Final Research Report for Ministry of Fisheries, 26 July 2011. 20 pp.
- Lyle, J.M., and S.T. Willcox. 2008. Dolphin and seal interactions with mid-water trawling in the Commonwealth small pelagic fishery, including an assessment of bycatch mitigation. Final Report Project R05/0996. Australian Fisheries Management Authority, National Library of Australia. 39p.
- Maloney, A., Chilvers, B.L., Haley, M., Muller, C.G., Roe, W., and I. Debski. 2009. Distribution, pup production and mortality of New Zealand sea lion (*Phocarctos hookeri*) on Campbell Island / Motu Ihupuku, 2008. *New Zealand Journal of Ecology* 33: 97-105.
- Marshall, C.D. 2008. Feeding Morphology. pp. 406-413. In W. F. Perrin, B. Wursig, and J. G. M. Thewissen (eds.). *Encyclopedia of Marine Mammals*. Academic Press.
- Mattlin, R. 2004. QMA SQU6T New Zealand sea lion incidental catch and necropsy data for the fishing years 2000-01, 2001-02 and 2002-03. Report prepared for the NZ Ministry of Fisheries, Wellington, NZ. July 2004. 21p.
- Marlow B.J., 1975. The comparative behaviour of the Australasian sea lions *Neophoca cinerea* and *Phocarctos hookeri*. *Mammalia* 39:159-230.
- McConkey S., H. McConnell, C. Lalas, S. Heinrich, A. Ludmerer, N. McNally, E. Parker, C. Borofsky, K. Schimanski, and M. McIntosh. 2002. A northward spread in the breeding distribution of the New Zealand sea lion. *Australian Mammalogy* 24:97-106.
- McNally, N., Heinrich, S., Childerhouse, S. 2001. Distribution and breeding of New Zealand sea lions *Phocarctos hookeri* on Campbell Island. *New Zealand Journal of Zoology* 28: 79–87.
- Meynier, L. 2010. New Zealand sea lion bio-energetic modelling: Final Report for Project IPA2009-09. Presented to AEWG May 17 2011, Wellington, New Zealand. 34p.
- Meynier L., P.C.H. Morel, B.L. Chilvers, D.D.S. Mackenzie, A. MacGibbon, and P.J. Duignan. 2008. Temporal and sex differences in the blubber fatty acid profiles of the New Zealand sea lion *Phocarctos hookeri*. *Marine Ecology Progress Series* 366: 271–278.
- Meynier, L., D.D.S. Mackenzie, P.J. Duignan, B.L. Chilvers, and P.C.H. Morel. 2009. Variability in the diet of New Zealand sea lion (*Phocarctos hookeri*) at the Auckland Islands, New Zealand. *Marine Mammal Science* 25: 302–326.
- Ministry of Fisheries. 2011. Report from the Fisheries Assessment Plenary, May 2011: stock assessments and yield estimates. Ministry of Fisheries, Wellington, New Zealand. 1178p.
- Moore, J.M., Wallace, B., Lewison, R.L., Zydelski, R., Cox, T., Crowder, L. 2009. A review of marine mammal, sea turtle and seabird bycatch in USA fisheries and the role of policy in shaping management. *Marine Policy* 33:435–451.
- Moore, P.J., Moffatt, R.D. 1990. Research and management projects on Campbell Island 1987–88. Science and Research Internal Report Series 57. Wellington, Department of Conservation. 101 p.
- Ponte, G., A. van den Berg, and R.W.G. Anderson. 2010. Impact characteristics of the New Zealand Fisheries sea lion exclusion device stainless steel grid. IPA2009-06 Report prepared for NZ Ministry of Fisheries, Oct. 2010. 24p.
- Ray, G. C. 1963. Locomotion in pinnipeds. *Natural History* 72: 10 -21.
- Read, A.J., Drinker, P. and S. Northridge. 2006. Bycatch of marine mammals in U.S. and global fisheries. *Conservation Biology* 20:163–169.
- Riet-Sapriza, F. 2007. Milk composition of the New Zealand sea lion and factors that influence it. PhD thesis, Massey University, Palmerston North, New Zealand.
- Robertson, B.C., and B.L. Chilvers. 2011. The population decline of the New Zealand sea lion *Phocarctos hookeri*: a review of possible causes. *Mammal Review* doi: 10.1111/j.1365-2907.2011.00186.x.
- Robertson, B.C., B.L. Chilvers, P. Duignan, J.S. Wilkinson, and N.J. Gemmel. 2006. Dispersal of breeding adult male *Phocarctos hookeri*: implications for disease transmission, population management and species recovery. *Biological Conservation* 127:227-236.
- Roe, W.D. 2010. External review of NZ sea lion bycatch necropsy data and methods. Report prepared for the NZ Ministry of Fisheries, Wellington. 8p.
- Roe, W.D., and L. Meynier. 2010. Review of Necropsy Records for Bycaught NZ sea lions (*Phocarctos hookeri*), 2000-2008. Report prepared for the NZ Ministry of Fisheries, Wellington. 46p.
- Smith, I.W.G. 1989. Maori Impact on the Marine Magafauna: Pre-European Distributions of New Zealand Sea Mammals. In Sutton, D. G. (ed.) *Saying so doesn't make it so. Papers in Honour of B. Foss Leach*. New Zealand Archaeological Association Monograph. 17:76-108.

APPENDIX A

- Smith, M.H.; Baird, S.J. (2005). Factors that may influence the level of incidental mortality of New Zealand sea lions (*Phocarctos hookeri*) in the squid (*Nototodarus* spp.) trawl fishery in SQU 6T. New Zealand Fisheries Assessment Report 2005/20. 35 p.
- Smith, M.H.; Baird, S.J. 2007a. Estimation of incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2003-04, with particular reference to the SQU 6T squid trawl fishery. New Zealand Fisheries Assessment Report 2007/7. 32 p.
- Smith, M.H.; Baird, S.J. 2007b. Estimation of incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2004-05, with particular reference to the SQU 6T squid trawl fishery. New Zealand Aquatic Environment and Biodiversity Report No. 12. 31 p.
- Thompson, F.N., and E.R. Abraham. 2010. Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries, from 1995–96 to 2008–09. New Zealand Aquatic Environment and Biodiversity Report 66, Wellington.
- Thompson, F.N., E.R. Abraham., and K. Berkenbusch. 2011. Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. Draft Final Research Report for Ministry of Fisheries project PRO2010-01 (Unpublished report held by the Ministry of Fisheries, Wellington). 80 pages.
- Townsend, A.J., P.J. de Lange, C.A.J. Duffy, C.M. Miskelly, J. Molloy, and D. Norton. 2008. New Zealand Threat Classification System Manual. Department of Conservation, Wellington, New Zealand.
- Wade, P.R. 1998. Calculating limits to the allowable human caused mortality of cetaceans and pinnipeds. *Marine Mammal Science* 14: 1–37.
- Wade, P., and R. Angliss. 1997. Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop. NOAA Tech. Memo. NMFS-OPR-12.
- Walker G.E., and J.K. Ling. 1981. New Zealand sea lion. In Ridway S.H., Harrison R.J. (eds.). *Handbook of Marine Mammal*, Vol. 1. Academic Press Inc., London, United Kingdom.
- Wilkinson, I.S., J. Burgess, and M.W. Cawthorn. 2003. New Zealand sea lions and squid—managing fisheries impacts on a threatened marine mammal. pp 192–207 In: N. Gales, M. Hindell, and R. Kirkwood (eds.). *Marine mammals: Fisheries, tourism and management issues*. CSIRO Publishing, Melbourne.
- Wilkinson I.S., Childerhouse S.J., Duignan P.J., Gulland F.M.D., 2000. Infanticide and cannibalism in the New Zealand sea lion. *Marine Mammal Science* 16:495-500.
- Wilkinson, I.S., P.J. Duignan, A. Grinberg, B.L. Chilvers, and B.C. Robertson. 2006. *Klebsiella pneumonia* epidemics: Possible impact on New Zealand sea lion recruitment. pp. 455–471. In: A. Trites, S. Atkinson, D. DeMaster, L. Fritz, T. Gelatt, L. Rea, and K. Wynne. (eds.). *Sea lions of the world*. Alaska Sea Grant College Program, University of Alaska Fairbanks.
- Woodley, T. H. and Lavigne, D. M. 1991. Incidental capture of pinnipeds in commercial fishing gear. *International Marine Mammal Association Technical Report* 91-01: 35 p.

APPENDIX B

Summary of SQU6 submissions on non-scientific matters

Briefing H0427– Analysis of alternative management options in the Southern squid fishery

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Summary of SQU6T submissions on non-scientific matters

Issues raised	Submitters
Use a population management plan approach: <ul style="list-style-type: none"> - Manage under the Marine Mammals Protection Act 1978 - Enact a population management plan - Department of Conservation to take the lead role 	Individual: Elisabeth Slooten, Otago University, Jane Forsyth, Alice MacKenzie, John Gardiner, Elaine Leung, Alastair Jamieson, Caroline Phillips, Andrew Maloney, Lala Frazer, Nathan McNally, J M Logan, Olivia Macassey. Organisational: ECO, EDS, YEPT.
Comments and responses	
The Department of Conservation administers the Marine Mammals Protection Act. Any decision to progress a population management plan rests with the Department of Conservation.	

Issues raised	Submitters
Other management approaches: <ul style="list-style-type: none"> - Switch to jigging - Economic analysis needed - Transfer quota - Close SQU6T area to trawling 	Individual: Elisabeth Slooten, Otago University, Jane Forsyth, Alice MacKenzie, Elaine Leung, Alastair Jamieson, Caroline Phillips, Andrew Maloney, Vanessa Smith, Olivia Macassey. Organisational: Forest and Bird, ECO, WWF.
Comments and responses	
These issues have been raised in previous submissions on the SQU6T Operational Plan. The Ministry has previously briefed Minister Heatley of these matters and that paper is attached for you reference (H0427).	

Issues raised	Submitters
Kahui (2011) bioeconomic paper: ¹ <ul style="list-style-type: none"> - Should be reflected in advice 	Organisational: WWF.
Comments and responses	
This paper details a modelling approach based on bio-economics. This has not been formally evaluated by the science team due to the economic nature of the analysis. However, the current science and management approach indicates the risk to sea lions is adequately managed. This paper will be considered in the proposed review of modelling approaches.	

Issues raised	Submitters
Extend area protection <ul style="list-style-type: none"> - Out to 500m deep for Auckland Islands - Out to 12nm for Campbell Island 	Individual: Jane Forsyth, Alice MacKenzie, Elaine Leung, Alastair Jamieson, Caroline Phillips, Andrew Maloney, Lala Frazer, J M Logan, Olivia Macassey. Organisational: Forest and Bird, YEPT.
Comments and responses	

¹ Kahui, V. (2011) A bioeconomic model for Hooker's sea lion bycatch in New Zealand. *The Australian Journal of Agricultural and Resource Economics* 55, pp. 1–20.

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The Ministry considers that further spatial management is not necessary to manage the effect of fishing on the sea lion population at either the Auckland or Campbell Islands. Trawling does not currently occur within either territorial sea and expansion of no-trawl zones is not considered necessary.

<i>Issues raised</i>	<i>Submitters</i>
Increase observer coverage up to as much as 100%	Individual: Jane Forsyth, Alice MacKenzie, Alister Robinson, Alastair Jamieson, Caroline Phillips, J M Logan. Organisational: Forest and Bird, EDS.
<i>Comments and responses</i>	
The Ministry is proposing to increase the target for observer coverage from 30% to 50%. By-catch estimates can already be made accurately from the existing observer coverage and are not dependent on fisher reports as some submitters assumed. The Ministry is working to increase observer coverage across all deepwater fisheries.	

<i>Issues raised</i>	<i>Submitters</i>
Close the fishery after one sea lion capture	Individual: Jane Forsyth, Alice MacKenzie, Alastair Jamieson, Caroline Phillips, J M Logan.
<i>Comments and responses</i>	
The Ministry considers that closing the fishery after one sea lion mortality is unnecessarily restrictive and may not be consistent with the purpose of the Fisheries Act, which is to provide for utilisation while ensuring sustainability. The Ministry has proposed a review limit of 15 observed captures (based on 50% observer coverage).	

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Ministry of
Fisheries
Te Tautiaki i nga tini a Tangaroa



To:	James Stevenson-Wallace			
CC:	Pamela Mace, Rohan Currey, Jeremy Helson			
From:	Martin Cryer			
Date:	19 January 2012		File Ref:	
Subject:	New research relevant to the development of final advice on the SQU6T operation plan and effects on sea lions			
Remarks	<input type="checkbox"/> Urgent	<input type="checkbox"/> Reply ASAP	<input type="checkbox"/> For Your Review	<input type="checkbox"/> Please Comment

James

You asked us to review any new information relating to the development of the final advice on the SQU6T operational plan. Pamela, Rohan and I have reviewed the science papers published by Chilvers [2011] and Robertson & Chilvers [2011] about NZ sea lions to assess the extent to which we might rely on them in formulating management advice. Specifically, we have reviewed them against the Research and Science Information Standard for New Zealand Fisheries (the Research Standard), published in April 2011 [MFish 2011]. The Department of Conservation (DOC) had considerable input into the Research Standard – in particular they designed a frequently-referenced footnote, which specifies that we will work collaboratively on research plans and peer review processes for relevant research (viz. research that could be used to inform fisheries management decisions).

B. Louise Chilvers (2011): Population viability analysis of New Zealand sea lions, Auckland Islands, New Zealand's sub-Antarctics: assessing relative impacts and uncertainty. Polar Biology. Published online 22 December 2011, DOI 10.1007/s00300-011-1143-6.

In a general sense, assessing the effect of fishing related mortality on the sea lion population using modelling approaches substantively different to the model MAF has been developing since 2003 is something we've considered in the past and could be potentially very useful. Results similar to our current Breen-Fu-Gilbert (BFG) integrated model [Breen *et al.* 2010, 2011] would lend credence to that approach, whereas results very different would cause us to think twice about the conclusions we draw and the weight we put on those conclusions in advice to the Minister. Unfortunately, the way the Chilvers [2011] population viability analysis has been done does not greatly increase our understanding of the effect of fishing related mortality on the sea lion population, partly because of the constraints of the software

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and partly because of the modelling assumptions. We summarise our major concerns below, but our consensus is that this piece of work should be ranked **3 – Low quality** against the Research Standard. A ranking of 3 is assigned to information that has failed to meet the quality requirements of the Research Standard, which states that such information “*should not be used in management decisions*” [MFish 2011: page 21].

One general concern we note is that Chilvers [2011] contains confusing and, in places, conflicting descriptions of the parameters used in the population models. One example of this is the description of the effect of epizootics on pup survival. In the text, this is described as pups having 75% of non-epizootic survival. Conversely, in Tables 1 and 2 this is portrayed as a 25% increase in pup mortality, which is not mathematically equivalent. This confusion extends to the descriptions of the models in Table 2, which contains errors that render the parameterisation of several models virtually indecipherable. Such ambiguity undermines the ability for the work to be replicated and raises questions as to the accuracy of information in other parts of the paper where errors would be less readily apparent.

The analysis uses VORTEX, a standard population viability analysis (PVA) programme [Miller and Lacy 2005]. This limits the range of model inputs that can be included, particularly with regard to parameter uncertainty. In a PVA, uncertainty should be included for as many parameters as possible, and ideally, it should be partitioned into statistical uncertainty and underlying (environmental) variation. In Chilvers [2011], uncertainty is included only for natural mortality rates (excluding epizootics) and fecundity and for these two parameters, it is treated inappropriately as environmental variation.

The parameter values used in the VORTEX models to reflect epizootic impacts on the population appear to duplicate the effects of epizootics on adult and pup mortality. The scenarios consider pup mortality increasing at 5 or 10 year intervals along with a combined increase in pup and adult mortality at 10 year intervals. However, the underlying mortality rates used in the model were estimated during periods over which epizootic events took place. This means epizootic effects are already included in the baseline model so the inclusion of separate epizootic scenarios is inappropriate duplication that will overestimate the epizootic effect on the population.

Notwithstanding the fact that epizootics effects appear to be duplicated in the model, the parameterisation of the epizootic scenarios does not appear to reflect observed epizootic mortality. As stated earlier, the description of the effect of epizootics on pup survival is inconsistent in the text, so it is difficult to evaluate the accuracy of the scenarios. In particular, it is difficult to gauge if the scenarios incorporate effects of epizootics after the first month of life. Another concern is that increases in adult mortality are considered only at 10-year intervals. Given that epizootics have been observed during 3 of 15 years of monitoring, a 5-yearly frequency would have been more consistent with the data. Some consideration of the effects on the subsequent fecundity of pups born in those years (as indicated by Gilbert and Chilvers 2008) would also be useful. However, fecundity was

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estimated from the population during periods over which epizootic events took place, which may mean these effects are already be incorporated in the model indirectly.

The parameter values used in the VORTEX models to reflect fisheries bycatch (89 or 105 fatalities per year between 1995–96 and 2009–10) are higher than the number we have estimated to have been caught (see Table 1 below, which uses data from Thompson *et al.* 2011) and is higher than the numbers cited in Robertson & Chilvers [2011; their Table 2].

Table 1: Estimated total interactions and “on deck” bycatch of NZ sea lions in squid and other fisheries (primarily scampi) close to the Auckland Islands, after Thompson *et al.* 2011. Note that “captures” refers to the number of sea lions bought on deck (mostly dead animals but including some that are alive), whereas “interactions” refers to the number of sea lions that would have been captured if SLEDs were not used and hence are not necessarily fatalities. In the absence of SLEDs, such as for the non-squid Auckland Island trawl fisheries, captures and interactions are synonymous.

Auckland Islands Year	Estimated sea lion captures			Estimated sea lion interactions		
	Squid	Non-squid	Total	Squid	Non-squid	Total
1995/96	141	13	154	141	13	154
1996/97	144	11	155	144	11	155
1997/98	61	14	75	61	14	75
1998/99	15	13	28	15	13	28
1999/00	68	15	83	67	15	82
2000/01	39	18	57	58	18	76
2001/02	44	15	59	73	15	88
2002/03	20	13	33	49	13	62
2003/04	42	15	57	176	15	191
2004/05	34	10	44	147	10	157
2005/06	30	10	40	135	10	145
2006/07	17	10	27	77	10	87
2007/08	12	10	22	82	10	92
2008/09	9	12	21	77	12	89
2009/10	13	7	20	85	7	92
Mean	45.9	12.4	58.3	92.5	12.4	104.9

The higher figure of 105 is the same as our estimate of total interactions but is applied in the model as if all interactions with SLED-equipped trawls are fatal. The derivation of the lower figure of 89 is not clear. It is possible to arrive at a bycatch figure of about 89 sea lions by applying the Ministry’s SLED discount rate for the last few years (35%) as a survival rate for sea lion interactions that do not lead to on-deck capture (and death). If this is the basis of the figure of 89 sea lion fatalities per year, that calculation is flawed because the discount rate is not an appropriate estimate of post-exit survival. The discount rate relates to the survivability of all interactions, including those retained in the net and drowned — post-exit survival would be higher than the true discount rate. In addition, our most recent research suggests post-exit survival is >90%. This research has been progressing through the Aquatic Environment Working Group (AEWG) for many months and the results would have been

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available for inclusion in the analysis. For these reasons, the use of 89 fishing-related deaths is almost certainly pessimistic and the option of 105 should not have been used at all.

The derivation of the sex ratios used in the VORTEX models for bycaught animals is not clear but the assumed ratios appear to have been applied to periods that are not comparable. The paper uses 58:42 (female: male, 1995–2007) and 82:18 (2004–09 when SLEDs were in widespread use). Both ratios are combined with the long run average number of captures 1995–2010 extrapolated into the future. This is inappropriate; estimates of captures and sex ratio should come from the same time period, or the model should be modified to provide for time-varying sex ratio. The estimate of 82% females cited as being derived from Table 2 of Robertson & Chilvers [2011] cannot be derived from that table. The value calculated from the data in Robertson & Chilvers [2011] is 79% (observed animals only) or 77% (scaled to estimated fatalities). The data in Table 2 of Robertson & Chilvers [2011] are also inconsistent with the 58% females assumed in the first scenario.

The VORTEX model's assumed starting population of 11,200 animals in 1995 is from Gales & Fletcher [1999] and is based on approximate scalars of pups to total individuals. This estimate is substantially less than the ~15,500 estimated by the integrated BFG model (which estimates the number from all the available data) and therefore the input value for the VORTEX model may be an underestimate of the size of the population. This is important because the bycatch in the VORTEX model (already overstated) is taken from a population smaller - potentially as much as 25–30% smaller - than best available estimates, further increasing the probable bias in the rate of fishing mortality input to the VORTEX models.

The Chilvers [2011] model is not fitted to the available data in any way, it is simply a “what if” simulation exercise. The results do not seem to fit the available data very well (none of the models, including the one with the most exaggerated fisheries bycatch, reproduces the observed decline in the population) and there is limited critical analysis of the reasons for the discrepancy. For example, in the Discussion it is stated that “the current rate of decline in the Auckland Islands population would result in this population being functionally extinct by 2035, 24 years from now”. But even with the most extreme parameters in Table 2, the shortest time period for this to happen is given as 59 years.

The paper states that the model with the higher rate of fishing related mortality of 105 per year with a sex ratio biased heavily towards females and the highest impact of epizootics (which we think is probably double-counted) is the only one that came close to replicating the observed trend in the population. This scenario requires something like 90 females per year to have been killed compared with our best estimate of about 30. Thus, to attribute the observed decline to fisheries bycatch, one has to assume that SLEDs have zero effect and the real fishing related mortality (of females) has been more than three times as big as our best estimate and is unlikely to continue declining (there was no observed bycatch in SQU6T last year despite >30% observer coverage). Our estimates and the modelled trends may turn out to be wrong, but these are very large differences for which there is no current logical explanation.

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Any conclusions about the probability of extinction or the predicted time to extinction (whether functional or absolute) depend critically on assumptions about future fishing related mortality. The VORTEX models all assume the estimated average mortality since 1995 (89 or 105 per year) continues at the same absolute value into the future. This approach assumes no decrease in interactions or on-deck captures as the population decreases (i.e., increasing catchability), zero density-dependent response, and very low or zero effectiveness of SLEDs in allowing sea lions to escape the nets.

We were also disturbed by the substantial number of editorial issues with the Chilvers [2011] paper, including several in the critical Table 2 specifying the model inputs and results; if the table is taken as accurate, it is simply not possible to infer what model runs are being reported. For instance, model runs that we infer include a bycatch of 89 sea lions per year are variously described in the same table as having: “*fishing mortality 89/year at 58♀:42♂ ratio ... fishing mortality 89r 82♀:18♂ ratio ... fishing mortality 8/year 58♀:42♂ ratio ... fishing mortality 89 years 58♀:42♂ ratio*”. This poor attention to detail in an important table does nothing to convince us that the paper has undergone a rigorous review.

The Chilvers [2011] paper is clearly based on a DOC project. From the acknowledgements: “*The work was funded by the New Zealand Department of Conservation (DOC, Investigation no. 1638). Thanks to K. McInnes, B. Robertson S. Cooper, A. Todd and two anonymous for [sic] reviewers all provided helpful, critical reviews of the manuscript.*” Despite the submission date of 23 August 2011, this work was not mentioned to any of us during the development of the Initial Position Paper and we became aware of it only on reading the SQU6T IPP submissions. The paper was a key theme in several submissions even though it was published online only the day before submissions closed on 23 December 2011.

Bruce C. Robertson & B. Louise Chilvers (2011): *The population decline of the New Zealand sea lion *Phocarctos hookeri*: a review of possible causes*. Mammal Review 41: 253–275. Published online March 2011, DOI: 10.1111/j.1365-2907.2011.00186.x

Our primary concern with this paper is that the cause of the population decline is deemed, by a simplistic process of elimination and confusion of correlation with causation, to be direct or indirect effects of fishing. Although direct sources of fishing mortality obviously have some population level consequence, and indirect sources may do (there is currently no evidence either way), other factors are also likely to contribute, yet these are dismissed, unjustifiably in our opinion. The main other source of mortality that is likely to help explain recent sea lion population trends is bacterial epizootics, but we are open to other suggestions given the high degree of current uncertainty. We summarise our major concerns with Robertson & Chilvers [2011] below but our consensus is that this piece of work should be ranked **2 – Mixed quality** against the Research Standard. A ranking of 2 is assigned to information that has been found to have some quality shortcomings, “*but is still useful for informing management decisions*” [MFish 2011: page 21]. The useful aspect of the paper is that it brings together a

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lot of previously scattered information. The less useful aspect is that it does not critically appraise that information to support a robust conclusion.

On page 6, Robertson & Chilvers [2011] states: “*At the Auckland Islands, epizootics resulted in the death of 53, 32 and 21% of pups in the first month of their lives in the 1998, 2002 and 2003 seasons, respectively; a 20% drop in pup production in 2002; and the deaths of at least 74 adult females during the 1998 epizootic (Baker 1999, Duignan 1999, Wilkinson et al. 2003, 2006).*” In the next paragraph it is stated: “*These epizootic events are likely to have demographic consequences, such as the high early pup mortality, which may lead to reduced recruitment into the breeding population 4–7 years later, but the presence or extent of this effect has not been seen in either population from current research.*” This is not correct. Examination of trends in pup production at the Auckland Islands show that sharp declines in pup production (in 2002 and 2009) correspond quite well with the expected 4–7-year lag. The epizootic events may also have had a cumulative effect – the reduced pup production in 2002 coincided with two years of epizootics, which might help explain the magnitude of the decline in 2009. Previous analysis by Gilbert and Chilvers [2008] suggests that the breeding success of the 1998 cohort of sea lions has been low, indicating a persistent impact of the outbreaks on population fecundity. This is not discussed in the Robertson & Chilvers [2011] review despite Chilvers being an author of both papers.

It is inconsistent for the review to reject resource limitation as a cause for the population decline under the “population overshoot hypothesis” yet invoke resource limitation as an indirect impact of fishing. At the very least, this distinction should be discussed more fully.

The review cites the outdated Breen-Kim model [2003, 2005] as the basis for the Ministry’s management regime even though one of the authors has supplied data to Paul Breen and been to AEWG meetings where the substantially revised Breen-Fu-Gilbert [2010, 2011] model has been developed and reviewed.

The review cites an outdated Wilkinson *et al.* [2003] paper on post-SLED exit survival even though one of the authors has been to AEWG meetings where reviews of the necropsy programme that underpinned this [Roe & Meynier, Roe *et al.*, both 2010] were examined and accepted. The current state of knowledge here is that necropsy analysis of frozen bodies cannot be used to assess the cause of death, except for very traumatic, “instantly fatal” head lesions, and no such lesions have been found in animals that have been subject to necropsy. (The reason for this is that freezing itself can cause some of the same tissue abnormalities as injuries).

As with the Chilvers [2011] paper, we identified a large number of errors and internal inconsistencies in a key table in this paper (Table 2 summarising bycatch statistics) and it was not clear to us how many of the tabulated values were calculated. We were unable to reproduce many of the estimates of sex ratio, observer coverage, etc. This poor attention to detail in an important table (cited as a basis for model runs by Chilvers [2011]) does nothing to convince us that the paper has undergone a rigorous review.

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The points raised in our review are no substitute for a formal quantitative assessment to explore the role of fisheries and or epizootics in population trends for NZ sea lions (e.g. using alternative population model projections), but they do suggest that the cursory dismissal of epizootics (or a combination of, for example, epizootics and resource limitation) by Robertson and Chilvers [2011] is misleading.

References

- Breen, P.A., R. Hilborn, M.N. Maunder & S.W. Kim. 2003. Effects of alternative control rules on the conflict between a fishery and a threatened sea lion (*Phocarctos hookeri*). Canadian Journal of Fisheries and Aquatic Sciences 60: 527–541.
- Breen, P.A. & S.W. Kim. 2005. Modelling the effects of bycatch on the New Zealand sea lion (*Phocarctos hookeri*) population. Unpublished NIWA Client Report: WLG2005-66. September 2005. 60 pages.
- Breen, P.A., D. Fu & D.J. Gilbert. 2010. Sea lion population modelling and management procedure evaluations: Report for Project SAP2008/14, Objective 2. Unpublished Final Research Report to the Ministry of Fisheries, 16 April 2010. 90 pages.
- Breen, P.A., D. Fu & D.J. Gilbert. 2011. Sea lion population modelling and management procedure evaluations: Report for Project SAP2008/14, Objective 2. Unpublished Final Research Report to the Ministry of Fisheries, 30 November 2011. 95 pages.
- Chilvers, B.L. 2011. Population viability analysis of New Zealand sea lions, Auckland Islands, New Zealand's sub-Antarctics: assessing relative impacts and uncertainty. Polar Biology. Published online 22 December 2011, DOI 10.1007/s00300-011-1143-6.
- Gales, N.J. and D.J. Fletcher. 1999. Abundance, distribution and status of the New Zealand sea lion, *Phocarctos hookeri*. Wildlife Research 26:35–52.
- Gilbert, D. and B.L. Chilvers 2008. Final report on New Zealand sea lion pupping rate. POP2006-01 Objective 3. Analysis from sea lion database to estimate pupping rate and associated parameters. NIWA Report WLG2008-77. 26 pages.
- Miller, P.S. and R.C. Lacy. 2005. VORTEX: a stochastic simulation of the extinction process, version 9.50 user's manual. Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, MN.

APPENDIX C

Ministry of Fisheries. 2011. Research and Science Information Standard for New Zealand Fisheries. Ministry of Fisheries, Wellington, New Zealand. 32pp. Available online: <http://www.fish.govt.nz/NR/rdonlyres/D1158D67-505F-4B9D-9A87-13E5DE0A3ABC/0/ResearchandScienceInformationStandard2011.pdf>

Robertson, B.C. and B.L. Chilvers. 2011. The population decline of the New Zealand sea lion *Phocarctos hookeri*: a review of possible causes. Mammal Review 41: 253–275. Published online March 2011, DOI: 10.1111/j.1365-2907.2011.00186.x

Roe, W.D. 2010. External review of NZ sea lion bycatch necropsy data and methods. Report prepared for the NZ Ministry of Fisheries, Wellington. 8 pages.

Roe, W.D., and L. Meynier. 2010. Review of Necropsy Records for Bycaught NZ sea lions (*Phocarctos hookeri*), 2000-2008. Report prepared for the NZ Ministry of Fisheries, Wellington. 46 pages.

Thompson, F.N., E.R. Abraham., and K. Berkenbusch. 2011. Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. Draft Final Research Report for Ministry of Fisheries project PRO2010-01 (Unpublished report held by the Ministry of Fisheries, Wellington). 80 pages.

Wilkinson, I.S., J. Burgess, and M.W. Cawthorn. 2003. New Zealand sea lions and squid—managing fisheries impacts on a threatened marine mammal. pp 192–207 In: N. Gales, M. Hindell, and R. Kirkwood (eds.). Marine mammals: Fisheries, tourism and management issues. CSIRO Publishing, Melbourne.

APPENDIX D

DWG AND MPI SLED SPECIFICATION FOR SQU6T OPERATIONAL PLAN

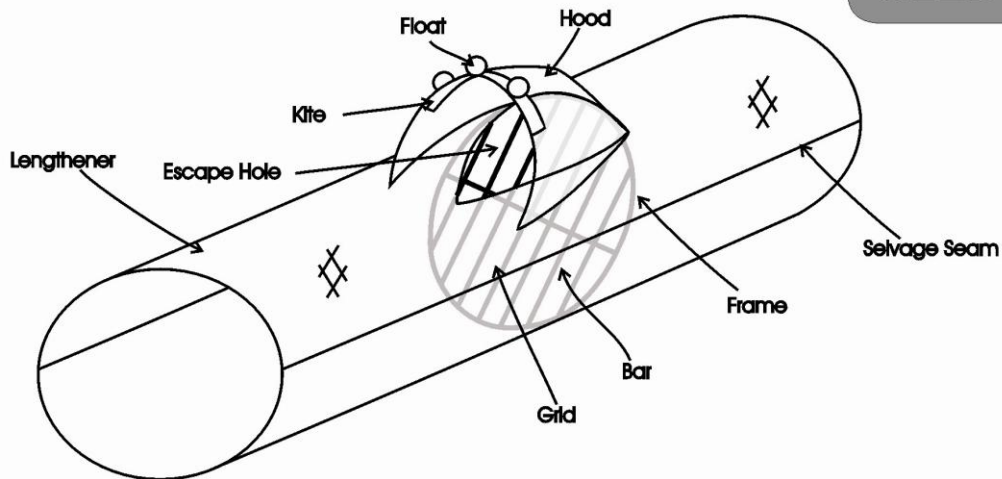
October 2010 MK 3/13 SLED approved by SLED WG September 2009. Clause 11 modified by MFish November 2010; clause 7 modified by MAF January 2012.

The SLED required for use by all vessels in the SQU6T fishery is an approved type that meets the following criteria:

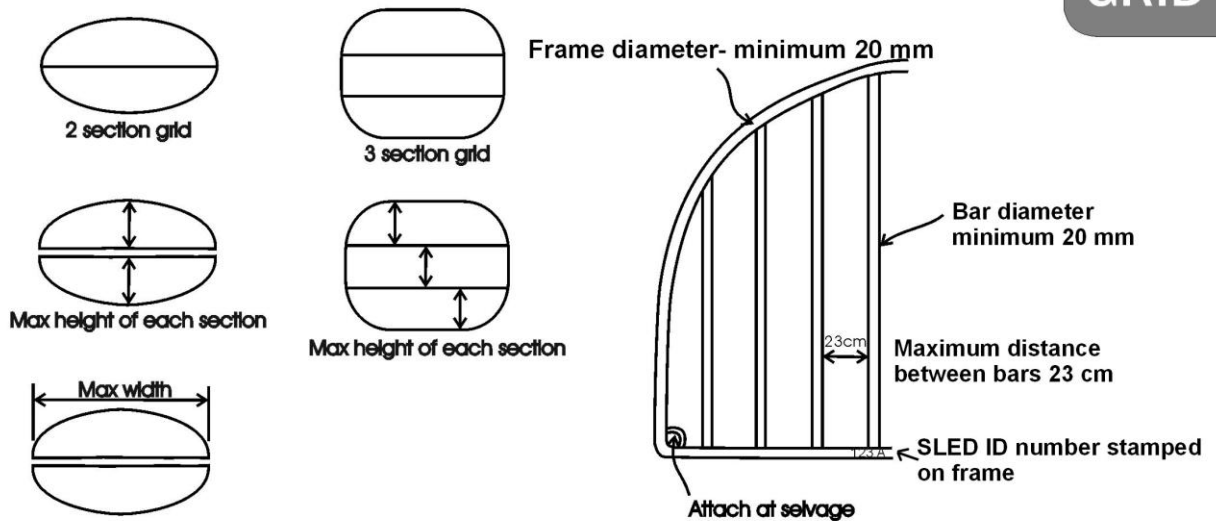
1. The SLED must consist of a lengthener section of net, with either 2 or 4 seams, containing a 2 or 3 piece grid, hinged horizontally along the middle. The grid must be set in the net at about $45^{\circ} \pm 5^{\circ}$ from the vertical with the top of the grid closest to the cod end section and continuously sewn to the net meshes around its outer edge.
2. The grid must be constructed of **minimum 20 mm outside diameter solid stainless steel bar** and should be shaped to conform to the working parameters of the net (refer diagram).
3. Vertical **grid bars** must be **evenly spaced at a continuous maximum distance of 23cm between bars** (see diagram). There will be no minimum number of bars, provided they are **evenly spaced** and do not exceed the required maximum spacing. It may be necessary to have the last spacing between the final bar and the grid frame differing from the rest of the spacings provided they are **less than 23 cm** apart between bars and frame.
4. The escape hole must be triangular and cut into the upper surface of the lengthener section. This hole must be a **minimum of 130 cm wide at the base**, measured along the top bar of the grid. The apex of the triangle must be a **minimum of 150 cm forward** of the base (refer diagram).
5. Above the escape hole, a hood-shaped mesh scoop must be attached with its open (leading) end facing into the water-flow and its closed (trailing) end attached and over stretched to the top bar of the grid. The leading edge of the hood must be a **minimum of 90 cm high** when fully open. The leading edge rope around the mouth of the hood must be a **minimum of 320 cm long** after attachment of kite and floats. **The hood must be a minimum length of 170cm long** (refer diagram).
6. The hood must have a semi rigid kite 220 cm long by 32 cm wide (both measurements $\pm 10\%$; a piece of thick conveyor-belt is ideal) attached under the meshes of the hood. The leading edge of the kite must be continuously stitched to the leading edge of the hood and the trailing edge also attached to the hood netting. The leading corners of the hood must extend forward of the escape hole.
7. Three floats of between 19 and 30 cm in diameter (a centre hole float is best) must be each attached to the leading edge on the kite. One float must be in the centre of the kite length and the other two equidistant between the centre float each end of the kite (refer diagram).
8. The SLED should be inserted into the trawl (between the body of the trawl and the lengthener) with the escape hole always on the upper surface when the net is fishing.
9. Each SLED grid frame must have a unique registration number, identifying it as a unit, clearly stamped into the frame bar at each end of each hinge section. Deepwater Group Ltd will record each SLED registration number. DWG's register of SLED numbers must be provided to MFish on an annual basis before fishing commences.
10. Depending on the net for which the SLED is built, there are elements of the SLED configuration that may vary, including: the presence or absence of floats attached to the outside of the grid or back of the kite, the shape, width and height of the grid, the number of vertical bars in the grid, the number of meshes in the hood and the number and size of meshes in the lengthener section.
11. No extra panels or mesh material may be fitted inside the net or lengthener before the SLED. Additional floats may be fitted outside the lengthener to the top of the grid frame. Floats may also be fitted inside the lengthener behind the grid or frame but **NOT** in front of the grid.
12. Alterations are not to be made to the design outside of this specification. For new builds or major repairs contact Motueka Nets Ltd or Hampidjan NZ Ltd.

APPENDIX D

SLED TERMS



GRID



ESCAPE HOLE and HOOD

