Assessment of the impact of incidental fisheries mortality on the Campbell Island New Zealand sea lion *Phocarctos hookeri* population using the Potential Biological Removal technique

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Abstract.

The New Zealand sea lion (NZSL), *Phocarctos hookeri*, a New Zealand endemic, is classified as Nationally Critical. NZSL are known to have been caught in the Campbell Island southern blue whiting trawl fishery (SBW6I) and knowledge is required as to whether or not the incidental interactions between this fishery and NZSL is having any impact on the Campbell Island sea lion population. The Potential Biological Removal (PBR) approach was used to assess the sustainability of the incidental mortalities of NZSL in the SBW6I fishery by estimating levels of 'biologically acceptable removals (deaths)' for the adjacent Campbell Island NZSL population. Based on PBR estimates derived from the use of conservative parameter inputs, the population is able to sustain low levels of fishery-induced mortalities (≤ 8 or ≤ 16 sea lions per year depending on population size estimates and the population recovery factor).

To strengthen the reliability of population estimates and, in turn, estimates derived from the PBR analysis, more accurate data on the Campbell Island NZSL population status and demography would be required. However, given that this could take many years of research and monitoring, immediate conservation and management should continue to focus on implementation of mitigation approaches that have resulted in a reduction in NZSL mortalities in this fishery for the

2012 season as well as maintaining high levels of observer coverage to sustain confidence in annual mortality estimates. With continued commitment to mitigation and increased observer coverage, it should be achievable that interactions with NZSL in the southern blue whiting trawl fishery remain at the low level recently observed.

Introduction

The New Zealand sea lion (NZSL), *Phocarctos hookeri*, is New Zealand's only endemic pinniped. It is classified as Nationally Critical and is considered to be the world's rarest sea lion (Baker et al. 2010). The species once bred from the northernmost cape of the North Island to the sub-Antarctic islands (Figure 1; Childerhouse and Gales 1998) but, historically, commercial sealing and subsistence harvesting reduced the population and the breeding distribution (Childerhouse et al. 2010a). Breeding is now mainly concentrated at the Auckland Islands and Campbell Island, with limited breeding also reported from the Snares Islands, Stewart Island and the Otago Peninsula (MPI 2012) (Figure 1). Based on pup production estimates from the Auckland Islands in 2010 (Chilvers 2011a) and from Campbell Island in 2008 (Maloney et al. 2009), 76% of all NZSL pups are born at the Auckland Islands with most others born at Campbell Island.

Since the mid-1990s a population monitoring study has been carried out at the Auckland Islands (e.g. Childerhouse et al. 2010a, Childerhouse et al. 2010b, Chilvers 2011b). Over the last decade there has been a considerable decline in pup production at the Auckland Islands (Chilvers 2010, 2011a) and this decrease is thought to be aggravated by a combination of disease events and incidental mortality in commercial fishing activities. The foraging areas of NZSL at the Auckland Islands have been shown to overlap with commercial trawl fishing activity targeting squid and scampi (Chilvers 2008, 2009, 2010) with high numbers of incidental mortalities recorded in the past (Thompson et al. 2010).

In contrast to the Auckland Islands population, pup production of NZSL at Campbell Island, the second major breeding location for the species, appears to have increased based on estimates from 2003, 2008 and 2010 (Maloney et al. 2012). NZSL are known to have been caught in the southern blue whiting trawl fishery (SBW6I) which operates near Campbell Island (Ministry for Primary Industries, MPI unpublished data) and concern exists about the impact of this fishery on the adjacent Campbell Island NZSL population. This paper aims to assess the sustainability of NZSL incidental mortalities in the Campbell Island southern blue whiting trawl fishery (SBW6I) by estimating levels of 'biologically acceptable removals (deaths)' for the Campbell Island NZSL population using the Potential Biological Removal approach developed by Wade (1998).

Methods

Campbell Island NZSL population size

The size of a pinniped population is difficult to determine as the proportion of the population that is ashore is usually unknown. The commonly used and best method for estimating the population size is based on the numbers of young pups in breeding colonies, as this age group is easily recognised, confined to land and is easily counted. The total number of animals in a population is then extrapolated to account for other age categories by multiplying the number of pups by a ‘multiplier’ value which is the ratio of the total population to the number of pups born each year taking into account various demographic parameters (Shaughnessy and McKeown 2002). Pup multipliers are usually population-specific and based on estimates of age at first breeding, birth rate, age-related mortality, and sex and age structure of a stable population. However, there is currently insufficient demographic data available for the Campbell Island NZSL population to allow a specific pup multiplier to be developed, although a multiplier of 4.5 can be derived from the estimated number of pups and a total population size estimate for the NZSL on the Auckland Islands (Chilvers 2011b). Harwood and Prime (1978) suggested that the size of most increasing polygynous pinniped populations can be estimated by multiplying pup numbers by a factor between 3.5 to 4.5. Values of 4.5 and 5.1 have been estimated for the Steller sea lion *Eumetopias jubatus* (Calkins and Pitcher 1982, Trites and Larkin 1996 cited in

NMFS 2008). Therefore, multiplication factors of 3.5, 4.5 and 5.0 were used to derive a range of NZSL population estimates for Campbell Island.

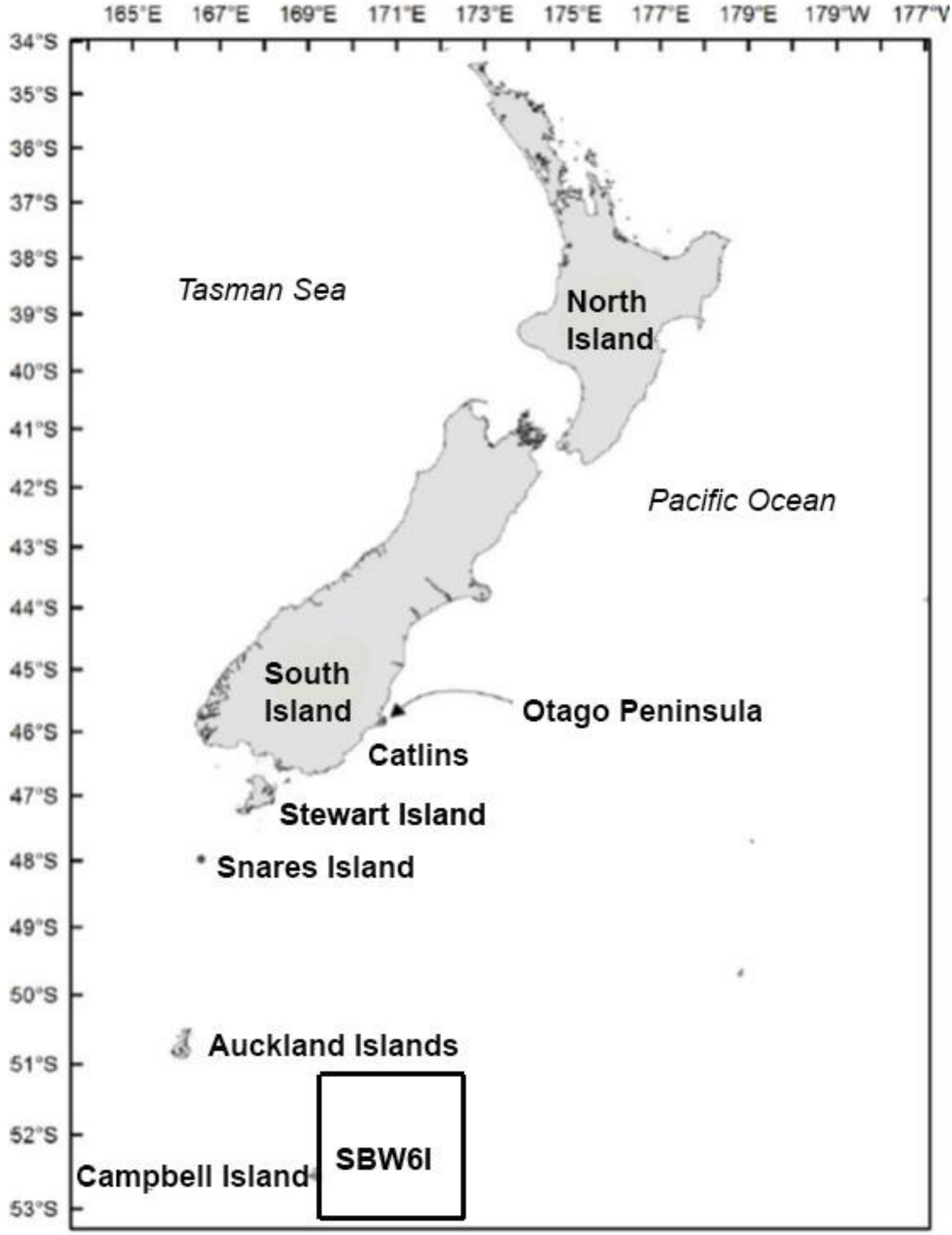

Figure 1: Location of New Zealand sea lion breeding populations and the southern blue whiting trawl fishery around Campbell Island (SBW6I).

In 2010, the minimum pup production at the Campbell Islands was estimated to be 681 pups by a direct count (Maloney et al. 2012). Pup production at Campbell Island is thought to be increasing although this trend may reflect differences in methodology (Maloney et al. 2009, MPI 2012) and may not necessarily indicate an increasing total population. 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, MPI 2012). Applying multiplication factors of 3.5, 4.5 and 5.0 to the 2010 pup estimate gives a range of total population estimates (N) of 2,384, 3,065 and 3,405 respectively for the Campbell Island NZSL population.

Potential Biological Removal (PBR)

Wade (1998) developed a simulation model for identifying pinniped populations with non-sustainable levels of human-caused mortality which takes into account the uncertainty of available information. The mortality limit, termed the Potential Biological Removal level (PBR), is defined as "the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population (OSP)" (NMFS 2005) and is calculated as:

$$PBR = N_{MIN} ½R_{MAX} F_R$$

where:

N_{MIN} = the minimum population estimate,

$½R_{MAX}$ = one-half the maximum theoretical or estimated net productivity rate of the stock at a small population size, and

F_R = a recovery factor ranging between 0.1 and 1.0 that introduces an extra level of precaution into the results (Wade 1998).

<u>Minimum population estimate, N_{MIN}</u>

Minimum population estimates for NZSL were calculated using Equation 4 from Wade (1998):

$$N_{MIN} = N/\exp(z)*[\ln(1+[CV(N)]^2)]^{1/2})$$

where

N= total population estimate,

z = a standard normal variate (set at the default 20th percentile of a log-normal distribution, 0.842), and

CV(N) = coefficient of variation of the population estimate.

In the absence of data on population size variance for the Campbell Island NZSL population, and consistent with recommendations in Wade (1998), a default coefficient of variation, CV(N), of 0.2 was used in calculations of N_{MIN}. A range of values for N_{MIN} were calculated based on the range of total population estimates of 2,384, 3,065 and 3,405.

Maximum theoretical or estimated net productivity rate, R_{MAx}

A range of 0.039 to 0.056 was used for the maximum theoretical net productivity rate based on calculations for the Auckland Islands NZSL population by Breen et al. 2012 (see Table 12, posterior probability of lambda).

A recovery factor between 0.1 and 1.0, F_R

A key factor of PBR is the recovery factor which ensures the recovery of populations to optimum sustainable population (OSP) levels (NMFS 2005). For populations listed as endangered, threatened or depleted, lower values increase the probability of reaching OSP (Lonergan 2011). Based on the idea that recovery factors should reflect the different risks associated with populations that have different population trends, PBR guidelines currently set the default recovery factor at 0.1 for a population listed as endangered, 0.5 for a population that is listed as threatened or depleted or of unknown status, and 1.0 for a population known to be within OSP (Barlow et al. 1995, Wade and Angliss 1997, Taylor et al. 2003).

Although different, often subjective, criteria are used for the value of the recovery factor for different populations, the recommended guidelines are based on simulation testing (Cooke et al. 2012). Based on recommendations in Taylor et al. (2003 - see Table 2), the recovery factor should be set at either 0.1 or 0.2 (based on an assessment of "vulnerability") for the Campbell Island population of the endangered (DOC threat status Nationally Critical) NZSL which has a population estimate <5000 (with unknown CV) and unknown population status.

Based on guidelines for using PBR to assess marine mammal populations, the recovery factor can be adjusted to accommodate additional information and to allow for management discretion as appropriate (NMFS 2005). For example, if human-caused mortalities include less than 50% females (as is strongly and particularly the case with NZSL capture data from the southern blue whiting trawl fishery at Campbell Island - see below), to allow for the lesser impact of a male bias in incidental mortalities the recovery factor could be increased (NMFS 2005) thereby increasing the PBR estimates.

Barlow et al. (1995) adjusted a PBR estimate for the Beaufort Sea population of polar bear *(Ursus maritimus)* to reflect a 2 male:1 female sex ratio in the harvest of this species by altering the estimate from 48 (calculated with a recovery factor of 1.0) to 72 animals. It is unclear how Barlow et al. (1995) adjusted the PBR although it was not based on altering the recovery factor (which was already at the highest possible value) and was possibly as simplistic as adding 50% to the initial PBR estimate. In the absence of a clear rationale for how and why the PBR was adjusted in this way, it was not considered the most appropriate method to reflect the strong male bias in NZSL fishery mortalities.

The Campbell Island NZSL population is thought to have increasing pup production but it also has the highest known pup mortality of any NZSL population (Maloney et al. 2012). Due to the endangered status of NZSL and uncertainties surrounding whether the Campbell Island population is increasing or not, it was decided to apply a precautionary approach and to calculate PBRs using the default recovery factor of 0.1 recommended by Wade and Angliss (1997). However, to reflect the recorded male bias in NZSL mortalities (Thompson et al. 2010), PBR estimates were also calculated using a recovery factor of 0.2.

Southern blue whiting trawl fishery at Campbell Island (SBW6I) data

Southern blue whiting (*Micromesistius australis*) is a schooling finfish almost entirely restricted in distribution to sub-Antarctic waters. The species is dispersed throughout the Campbell Plateau and Bounty Platform for much of the year, but during August and September fish aggregate to spawn at four spawning grounds — the Auckland Islands (SBW6A), the Bounty Platform (SBW6B), the Campbell Island Rise (SBW6I) and the Pukaki Rise (SBW6R).

A fishery for southern blue whiting has operated since 1970, with the four stocks managed through a Quota Management System since 1999. Annual catch since then has ranged between 25,000 t and 40,000 t, with most fishing effort directed toward the Campbell Island Rise (SBW6I) and the Bounty Platform (SBW6B). For reasons of fishing efficiency, associated with the smaller size of the spawning aggregations in these areas, together with the relatively low value of the product, less effort has been directed toward the Pukaki Rise and Auckland Islands Shelf stocks.

New Zealand sea lions are only known to interact with the SBW6I fishery at Campbell Island. Between 1996 and 2010, the estimated mean number of NZSL captured in the southern blue whiting trawl fishery was 5 (95% CI 2 – 11, range 1 to 25) (MPI unpublished data). The mean number of annual mortalities over the last five years of reported data (2006-10) was 12 (95% CI 6 – 22) and the largest number of NZSLs estimated killed in any one year was 25 in 2010 (MPI 2012). Most (96%) of the mortalities around the Campbell Islands has comprised male animals (MPI unpublished data) and mortality is biased towards juvenile males (Maloney et al. 2012, Thompson et al. 2010).

In applying the PBR approach to assess the impacts of fisheries on the Campbell Island NZSL population, it was assumed that all NZSL killed in the southern blue whiting trawl fishery (SBW6I) originated from the Campbell Island NZSL breeding colonies. There is limited evidence that some male sea lions from the Auckland Islands forage around Campbell Island and may spatially overlap with the southern blue whiting trawl fishery near Campbell Island (SBW6I) (Geschke and Chilvers 2009) and some tagged males resighted at Campbell Island had been tagged as pups on the Auckland Islands (Maloney et al. 2012). However, there are no reports of tagged Auckland Islands' animals being captured in the SBW6I fishery to date (DOC unpublished data).

Results

Potential Biological Removal (PBR)

Based on the currently available fisheries observer data and NZSL data, and using the recommended recovery factor for endangered species of 0.1, only one of the PBR estimates, which was based on the lowest population estimate and R_{MAX} = 0.039 (Table 1), was below the mean estimate of annual NZSL mortalities attributable to fishing in the (SBW6I) fishery (5 animals, 95% CI 2-11, range 1-25; MPI unpublished data) for the 15 year period (1996 - 2010).The eight remaining PBR estimates were equal to or higher than the mean level of estimated NZSL mortalities over the last 15 years. Doubling the recovery factor (to account for male bias in those captured, Thompson et al. 2010) resulted in double the PBR values.

The highest estimate of the mean level of mortalities in any year is 25 animals, which occurred in 2010 (MPI 2012). The annual mean for the latest five years of reported data (2006-10) is 12 animals (95% CI 6-22; MPI unpublished data). Both values exceed the range of PBRs estimated using the recovery factor of 0.1 (Table 1). The 25 NZSL estimated to have been captured in 2010 (MPI 2012) also exceeded the range of PBRs using the recovery factor of 0.2 (8-16, Table 2), and five of the nine PBR values derived from this recovery factor were also lower than the annual mean mortality rate for 2006-10. The PBR estimates that were equal to or above the estimated annual number of mortalities from the last five years (12) are from calculations based on total populations of either 3,065 (pup multiplier 4.5) or 3,405 (pup multiplier 5.0) NZSL, a recovery factor of 0.2 and an R_{MAX} value of 0.047 or 0.056 (Table 1).

Table 1: Total population estimates based on pup counts, minimum population estimates (N_{MIN}) and Potential Biological Removal (PBR) estimates for the Campbell Island New Zealand sea lion population. F_R = recovery factor; *R_{MAX} = maximum theoretical net productivity rate.

Estimated no. of pups	Pup multiplier	Total popn estimate	N_{MIN}	PBR estimates					
				$F_R = 0.1$			$F_R = 0.2$		
				R_{MAX} 0.039	R_{MAX} 0.047	R_{MAX} 0.056	R_{MAX} 0.039	R_{MAX} 0.047	R_{MAX} 0.056
681	3.5	2,384	2,017	4	5	6	8	9	11
681	4.5	3,065	2,594	5	6	7	10	12	15
681	5.0	3,405	2,882	6	7	8	11	14	16

*from Table 12, Breen et al. 2010

Discussion

PBR estimates are useful for guiding conservation management and research but it is important to note that any modelling cannot be expected to provide absolute certainty in situations where population-specific field information, that may take years to collect, is lacking. To illustrate the potential range of PBRs based on the currently available NZSL population data, PBRs were calculated on a selection of possible variables. Due to the limited available population data for Campbell Island, default values were used for some of the key variables in the PBR calculations. The actual value of these variables could be higher or lower than these default values which could significantly alter the estimated PBRs.

The methodology used for determining the Campbell Island NZSL population size was by extrapolating from counts of pups. However, deriving population estimates based on pup multipliers developed from other populations or other species are imprecise as the ratio of total population size to number of pups can vary based on local population demographics and on whether the population is increasing, stable or decreasing (Shaughnessy and McKeown 2002).

The Campbell Island NZSL population is at the geographical edge of the species' known historic range (Figure 1) and, therefore, they may be exposed to sub-optimal habitats in this region (Childerhouse and Gales 1998). The Campbell Island breeding population has the highest recorded early pup mortality (55%) of any NZSL population which has been attributed to the climate and harsh habitat (e.g. basalt substrate, peat mires) on the island (Maloney et al. 2012). Remnant sea lion populations located at the edges of historic distribution ranges may exploit much poorer food resources than those at the core of their distribution (Augé et al. 2011). Augé et al. (2011) showed that female NZSL from the Otago Peninsula (located at the core of the known historic range) had significantly shorter foraging ranges and improved demographic characteristics compared with the Auckland Island NZSL population (located at the spatial edge of the known historic range).

Due to the extant population being greatly reduced from historical exploitation by humans (Childerhouse and Gales 1998), the endangered status of NZSL (Baker et al. 2010) and the unknown population status and high pup mortality of NZSL at Campbell Island (Maloney et al. 2012), PBR estimates were calculated with the precautionary recovery factor of 0.1 (Wade and Angliss 1997). However, almost all (96%) of the fishery-induced mortalities around the Campbell Islands have been comprised of male animals (MPI unpublished data) and most of these were juvenile males (Maloney et al. 2012, Thompson et al. 2010). Due to the low fecundity, polygamous mating system and high rates of adult survival of NZSL (Chilvers 2011b), populations are susceptible to small increases in adult mortality especially of adult females and the impact of this level of fishery-induced mortality on the NZSL population would be greater if there was a female bias or no bias. It is reasonable to account for the observed male bias in captured animals (Thompson et al. 2010) and so, higher PBR estimates, based on a doubling of the recovery factor, were also presented.

A review of the literature revealed that other authors developing PBRs have not always considered only biological information but have taken into account political considerations. For example, in an assessment of dugong (*Dugong dugon*) harvest in Torres Strait using the PBR technique, a recovery factor of 0.5 (for threatened or vulnerable species) was used (Marsh et al. 2004). It was considered that, even though there may be some justification of using a more conservative value of 0.1 mainly due to conservation politics, it was considered that the reduced allowable catch due to lower PBR estimates, would be a major obstacle in progressing co-management of the species with Torres Strait indigenous groups (Marsh et al. 2004).

Based on the PBR estimates, the Campbell Island NZSL population is able to sustain levels of ≤ 8 animals per year (or ≤ 16 animals per year depending on population size estimates and population recovery factor) being captured by fishing. Therefore, the recent mean level of estimated annual mortalities in the southern blue whiting trawl fishery around Campbell Island (SBW6I) may not be sustainable. The mean of 12 animals per year, captured from 2006-10

(95% CI 6-22; MPI unpublished data) is close to, or exceeds, many of the 18 calculated PBRs which ranged from 4-16 (depending on population size estimates and recovery factor). The PBR results emphasise the importance of the mitigation approaches described below that are currently undertaken in the southern blue whiting trawl fishery at Campbell Island, which has resulted in reducing the level of mortalities recorded for the 2012 season (MPI unpublished data).

It is of concern that the level of mortalities in the southern blue whiting trawl fishery increased to a annual estimated mortality level of 25 NZSL in 2010 (MPI unpublished data) which exceeded all PBR estimates. It is thought that several factors occurred that increased the risk of mortalities and the level of mortalities recorded by individual vessels in this particular year (DWG 2012). Between 2007 and 2010 there appeared to be an increase in the amount of fishing activity due east of the Campbell Islands and most of the increase in mortalities occurred in that area (DWG 2012). Due to a large storm event in 2010, a shift in fishing effort to this area resulted in the highest annual level and rate of NZSL mortalities recorded (DWG 2012). Weather and fishing practices that led to larger than usual offal discharges or loss of fish also may have contributed to large numbers of NZSL being attracted to vessels fishing southern blue whiting, thereby increasing the risk of NZSL mortalities (DWG 2012).

In response to the increasing trend in NZSL mortalities in the SBW6I fishery, the deepwater fleet implemented a number of mitigation approaches which appear to have been very effective in reducing mortalities of NZSL. In particular, individual vessels and operators are informed at the beginning of the fishing season about the increased risk from fishing operations in what appear to be foraging areas of male NZSL, vessels move away from congregations of pinnipeds before shooting gear, and at all times operators maintain a focus on management of fishmeal plants and offal control (as is also required for risk management of seabird interactions). The risks to NZSL created by any extended time the fishing gear is on the surface is understood and crew are required to keep this time to an absolute minimum (DWG 2012).

Management of offal discharge and minimising losses of fish from trawl nets is very important in reducing the numbers of NZSL that are attracted to a vessel. To mitigate the risk of interactions with NZSL, all deepwater vessels have offal management procedures and recommended fishing practices that are detailed in individual Vessel Management Plans (DWG 2012). Adequate observer coverage has been critical in enabling a full and accurate assessment of NZSL mortalities and immediate reporting of all NZSL mortalities has been crucial in enabling assessment of risk and interaction levels in real time: all vessels are required to inform DWG immediately on any sea lion capture event so the appropriate management response can be considered (DWG 2012). Encouragingly, no NZSL were observed caught (with a preliminary estimate of around 60% observer coverage) in the 2012 Campbell Island southern blue whiting trawl fishery (SBW6I) season (MPI unpublished data). However, based on previous mortality levels and the uncertainties associated with less than 100% observer coverage, a number of mortalities (c. four, but yet to be calculated and released) will be estimated for the 2012 season (MPI pers. comm.).

Accurate data on the population status, as well as demographic data for the Campbell Island NZSL population, would strengthen the reliability of population estimates and, in turn, estimates derived from the PBR analysis. However, given that many years of research and monitoring would be required before good population-specific demographic data could be obtained, the management of the fishery should continue to focus on the continued implementation of effective mitigation approaches (particularly crew training and real time management of incidents), as well as maintaining high levels of observer coverage to sustain confidence in annual mortalities estimates. There has been an encouraging reduction in NZSL mortalities in this fishery in 2012 from the observed peak in 2010 and, with continued commitment to mitigation and increased observer coverage, the low number of incidental mortalities observed in the last year is likely to be maintained.

Acknowledgements

We are grateful to the Deepwater Group Ltd who provided funding for this study, and to Simon Childerhouse, Louise Chilvers, Rohan Currey and Richard Wells for providing references and information on New Zealand sea lion demography and fisheries interactions that were useful in the development of the PBR. We also thank Simon Childerhouse for providing a critical review of the manuscript.

References

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., Chilvers, B.L., Constantine, R., DuFresne, S., Mattlin, R., van Helden, A., and Hitchmough, R. 2010. Conservation status of New Zealand Marine Mammals (suborders *Cetacea* and *Pinnipedia*), 2009. N Z J Mar Freshwater Res 44:101–115.

Barlow, J., Swartz, S.L., Eagle, T.E. and Wade, P.R. 1995. U.S. Marine Mammal Stock Assessments: Guidelines for Preparation, Background, and a Summary of the 1995 Assessments. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-6, 73 p.

Breen, P.A., Fu, D. and Gilberts, D.J. 2010. Sea lion population modelling and management procedure evaluations: Report for Project SAP2008/14, Objective 2, National Institute of Water and Atmospheric Research Ltd.

Calkins, D. G. and Pitcher, K. W. 1982. Population assessment, ecology and trophic relationships of Steller sea lions in the Gulf of Alaska. Pages 447-546, in: Environmental assessment of the Alaskan continental shelf. U.S. Dept. Comm. And U.S. Dept. Int., Final Rep. Principal Investigators, 19:1-565.

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

Childerhouse, S., Dawson, S.M., Slooten, E., Fletcher, D.J., and Wilkinson, I.S. 2010(a). Age distribution of lactating New Zealand sea lions: interannual and intersite variation. Marine Mammal Science 26: 123-139.

Childerhouse, S.J., Dawson, S.M., Fletcher, D.J., Slooten, E. and Chilvers, B.L. 2010(b). Growth and reproduction of female New Zealand sea lions. Journal of Mammalogy 91(1): 165-176.

Childerhouse S. and Gales N.J. 1998. The historic and modern distribution and abundance of the New Zealand sea lion. NZ J Zool 25:1–16.

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.

Chilvers, B.L. 2008. Foraging site fidelity of lactating New Zealand sea lions. *Journal of Zoology* 276: 28-36.

Chilvers, B.L. 2009. Foraging locations of female New Zealand sea lions (*Phocarctos hookeri*) from a declining colony. New Zealand Journal of Ecology 33 (2). Available on-line at: http://www.newzealandecology.org/nzje/

Chilvers, B.L. 2010. Research to assess the demographic parameters and at sea distribution of New Zealand sea lions, Auckland Islands. Draft Final Report POP2007-01 for Department of Conservation, Wellington. 32 p. Available for download at http://www.doc.govt.nz/mcs

Chilvers, B.L. 2011(a). Research to assess the demographic parameters of New Zealand sea lions, Auckland Islands: Draft Final Report POP2010-01 for Department of Conservation, Wellington. 20 p. Available for download at http://www.doc.govt.nz/mcs

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

Cooke, J., Leaper, R., Wade, P., Lavigne, D. and Taylor, B. 2012. Management rules for marine mammal populations: A response to Lonergan. Marine Policy 36: 389-392.

Deepwater Group (DWG). 2012. Southern Blue Whiting Fishery Briefing Paper. Briefing paper prepared for fishing operators in the Southern Blue Whiting Trawl Fishery, Deepwater Group unpublished.

Geschke, K. and Chilvers, B.L. 2009. Managing big boys: a case study on remote anaesthesia and satellite tracking of adult male New Zealand sea lions (*Phocarctos hookeri*). Wildlife Research 36: 666-674.

Harwood, J. and Prime, J.H. 1978. Some factors affecting the size of British grey seal populations. Journal of Applied Ecology 15: 401-411.

Lonergan, M. 2011. Potential biological removal and other currently used management rules for marine mammal populations: a comparison. Marine Policy 35: 584–589.

Maloney A., Chilvers B.L., Haley M., Muller C.G., Roe W., Debski I. 2009. Distribution, pup production and mortality of New Zealand sea lion *Phocarctos hookeri* on Campbell Island, 2008. New Zealand Journal of Ecology 33: 97-105.

Maloney, A.; Chilvers, B.L.; Muller, C.G. and Haley, M. 2012. Increasing pup production of New Zealand sea lions at Campbell Island/Motu Ihupuku: can it continue? *New Zealand Journal of Zoology*, 39:1, 19-29.

Marsh, H., Lawler, I.R., Kwan, D., Delean, S., Pollock, K. and Alldredge, M. 2004. Aerial surveys and the potential biological removal technique indicate that the Torres Strait dugong fishery is unsustainable. *Animal Conservation* 7: 435–443.

Ministry for Primary Industries (MPI). 2012. Squid (SQU6T) - Final advice paper. Wellington, New Zealand.

National Marine Fisheries Service (NMFS). 2005. Revisions to Guidelines for Assessing Marine Mammal Stocks. 24 pp. Available at: *http://www.nmfs.noaa.gov/pr/pdfs/sars/gamms2005.pdf*

NMFS. 2008. Recovery Plan for the Steller Sea Lion (*Eumetopias jubatus*). Revision. National Marine Fisheries Service, Silver Spring.

Shaughnessy, P.D. and McKeown, A. 2002. Trends in abundance of New Zealand fur seals, *Arctocephalus forsteri*, at the Neptune Islands, South Australia. *Wildlife Research 29:* 363-370.

Taylor, B.L., Scott, M., Heyning, J.E. and Barlow, J. 2003. Suggested Guidelines for Recovery Factors for Endangered Marine Mammals under the Marine Mammal Protection Act. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum NMFS.

Thompson, F.N., Oliver, M.D. and Abraham, E.R. 2010. Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri)* in trawl fisheries from 1995_96 to 2007_08. New Zealand Aquatic Environment and Biodiversity Report No. 52.

Trites, A. W. and Larkin, P. A. 1996. Changes in the abundance of Steller sea lions (*Eumetopias jubatus*) in Alaska from 1956 to 1992: how many were there? Aquatic Mammals 22:153-166.

Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of Cetaceans and Pinnipeds. *Marine Mammal Science 14(1):* 1-37.

Wade, P., and R. Angliss. 1997**.** Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop. NOM Tech. Memo. NMFS-OPR-12.