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Assessment of the risk to New Zealand marine mammals from commercial fisheries

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This study provides an assessment of the impact of fishing-related fatalities on the populations of 35 marine mammal (sub)species that inhabit New Zealand waters. The assessment included mortalities caused by trawl, longline, set-net and purse-seine fisheries within New Zealand's Exclusive Economic Zone (EEZ). The risk assessment was an implementation of the Spatially Explicit Fisheries Risk Assessment (SEFRA) method. Risk was defined as the ratio of Annual Potential Fatalities (APF; an estimate of the number of marine mammals killed in fisheries each year) to the Population Sustainability Threshold (PST; a measure of the population productivity). A risk index higher than one indicates that fisheries mortalities are at a level that may prevent the population increasing to, or remaining above, half the carrying capacity in the long term.

In New Zealand, a proportion of commercial fishing is monitored by independent observers. Marine mammal captures are recorded by observers when they are on board fishing vessels. The vulnerability of the marine mammals to capture was estimated from the relationship between observed captures and the overlap of marine mammal species and observed fishing effort. From this vulnerability, the total annual potential fatalities were estimated in all fishing effort. The annual potential fatalities include an estimate of fatalities that are not recorded by observers, and they also allow for the post-release survival of some live-captured animals. Estimates of annual fishing-related mortalities were derived for averaged fishing effort over the three-year period from 2012–13 to 2014–15. The scope of this assessment did not include fishing methods without routine observer coverage, even where marine mammal interactions are known to occur. In particular, the entanglement of marine mammals in the rock lobster (*Jasus edwardsii*) pot fishery was not included in this study.

Estimation of the PST required information on the maximum growth rate and the total population size for each of the 35 marine mammal taxa included in this study. In the absence of reliable data, demographic and distribution information was estimated via a Delphi survey of marine mammal researchers. The Delphi survey provided participants with a summary of available data, and requested information of the spatial distribution, population size, and maximum population growth of marine mammal taxa. For Hector's dolphin, population data were also used from a recent survey of the South Island; for Māui dolphin distribution information was used from a recent risk assessment.

Of the 35 taxa, common dolphin was the species with the highest estimated risk, with a mean risk of 1.6 (95% c.i: 0.43 to 4.47). Common dolphin were estimated to be caught in trawl and set-net fisheries, and many of the estimated captures were primarily in poorly-observed small-vessel trawl fisheries in the Taranaki region. Killer whale was the other species with a mean risk higher than one (1.28; 95% c.i.: 0.00 to 7.55). No captures of killer whale have been observed, and the considerable uncertainty in the risk ratio was partly due to overlap between killer whale and poorly-observed coastal fisheries. The PST for killer whale was estimated to be 1.5 (95% c.i.: 0.5 to 3.6) annual fatalities. This value indicates that only a small number of annual fisheries-related fatalities will impact the New Zealand population. The risk ratio for Hector's dolphin was entirely below one; however, overlap between Hector's dolphin and set-net fisheries was almost entirely on the East Coast South Island. The risk to the East Coast South Island sub-population from set-net fisheries was estimated as 0.59 (95% c.i.: 0.21 to 1.33)—there was a 9.4% probability that the fatalities from set-net fishing on the East Coast South Island exceed the PST of this sub-population. The mean risk to Māui dolphin was also less than one (0.47; 95% c.i: 0.00 to 1.33), with the credible interval extending above one. Overlap between Māui dolphin and set-net fisheries was primarily in West Coast North Island harbours, and with set-net fisheries close to New Plymouth. For all other marine mammal species, the median risk was below 0.4. In many cases, the distribution was skewed, with an upper 95% credible interval that extended above one. For almost all whales, including beaked whales, the mean annual potential fatalities were less than one; with the exception of humpback whale that had a mean of annual potential fatalities of 1.4. Observer data are not sufficient for constraining

such low numbers of captures, and consequently the uncertainty in the estimates was high, with many risk ratios for whales and beaked whales having a coefficient of variation over four.

This risk assessment is the first time that a comprehensive analysis of marine mammal bycatch and its population impact has been attempted for New Zealand fisheries. The assessment highlights the need for improved observer coverage in poorly-observed inshore fisheries, especially set-net and inshore trawl fisheries. For most species, the assessment relied on expert judgement to derive distributions for marine mammals. A quantitative analysis of the distribution of New Zealand marine mammals would help improve the estimation of fisheries-related fatalities.

1. INTRODUCTION

Interactions with commercial fisheries lead to incidental captures of non-target species, including marine mammals. Bycatch of cetaceans and pinnipeds has been documented in a range of fisheries worldwide, and fishery-related mortalities have been implicated in the declines of some marine mammal populations (Wickens 1995, Fertl & Leatherwood 1997, Campbell et al. 2008, Hamer et al. 2012, Reeves et al. 2013). As data on the number and identity of captured individuals are generally limited, the extent of incidental captures is difficult to quantify, and the impact of fisheries on marine mammal populations remains largely unknown (Lewison et al. 2004, Read 2008).

Scarcity of bycatch data has led to the use of risk assessments to identify and evaluate potential impacts of fishing-related mortalities while also accounting for uncertainty (e.g., Grech et al. 2008, Brown et al. 2015). Risk assessments provide a formal framework to consider different management options, and also highlight gaps in knowledge that require additional research (Treweek 1999). In New Zealand, a spatially explicit fisheries risk assessment framework (SEFRA; Sharp 2017) has been developed for assessing the impact of fisheries bycatch. In this framework, estimates of the annual potential fatalities (APF) of protected species resulting from fisheries bycatch are compared with a Population Sustainability Threshold (PST). The PST is defined so that fatalities below this threshold allow population recovery to a defined management target, including consideration of uncertainty and environmental stochasticity. The PST is closely related to the Potential Biological Removal (PBR) index, developed by Wade (1998) for assessing marine mammal bycatch under the United States Marine Mammal Protection Act. This risk assessment framework has been used to evaluate the risk to seabirds (most recently Richard & Abraham 2017), and the present study applied this approach to New Zealand marine mammal populations.

In New Zealand waters, documented incidental captures of marine mammals include pinniped and cetacean species in different commercial fisheries, such as trawl, longline, set-net, purse-seine and pot fisheries (Berkenbusch et al. 2013). In some of these fisheries, government observers monitor the interactions between fishing operations and marine mammals (and other protected species), providing an independent record of incidental captures. Observer coverage varies greatly across fisheries, but for fisheries with sufficient observer data, observer records combined with fishing effort data allow estimation of the total number of incidental captures across species and fisheries (e.g., Smith & Baird 2009). Bycatch estimation is regularly carried out for trawl and longline fisheries in New Zealand's Exclusive Economic Zone (EEZ), providing formal bycatch assessments for common dolphin (*Delphinus delphi*), New Zealand fur seal (*Arctocephalus forsteri*), and New Zealand sea lion (*Phocarctos hookeri*) (see most recently Abraham et al. 2016, Thompson et al. 2016, Abraham & Berkenbusch 2017).

The methods used by Abraham and Berkenbusch (2017) are not applicable to marine mammal species that have had few observed captures. The current study provides a more general risk assessment of the interactions between different commercial fisheries and 35 marine mammal (sub)species that inhabit New Zealand waters. This approach required an assessment of the potential fatalities from fishing-related bycatch, relative to the population demography.

For many of these marine mammal taxa, population size and growth rates are poorly known. In the absence of formal demographic information, a Delphi survey was carried out, asking participants to provide population information for each of the taxa. The Delphi technique is suitable for data-poor situations, as it provides an approach for soliciting expert judgement in a systematic and transparent way (Linstone & Turoff 2002, MacMillan & Marshall 2006, Cole et al. 2013). It involves an iterative process based on existing information, facilitating contributions by participating experts, and including a feedback approach to build consensus. In the current study, information sought through the Delphi survey included the New Zealand distribution, maximum population growth rate, and population size of the marine mammal (sub)species included in the risk assessment.

Previous New Zealand mammal risk assessments have been carried out for Hector's and Māui dolphins (*Cephalorhynchus hectori hectori* and *C. hectori maui*), and New Zealand sea lion (*Phocarctos hookeri*) (Currey et al. 2012, Slooten & Davies 2012, Roberts & Doonan 2016), using a range of methodologies. The current study is an assessment of the risk of commercial fisheries to marine mammals in New Zealand waters, using a consistent methodology to evaluate risk for 35 taxa. Estimates of annual fishing-related mortalities were derived based on the spatial distribution and intensity of commercial fishing effort over the three-year period from 2012–13 to 2014–15. The focus was on fatalities caused by fisheries bycatch. Other threats, such as disease, or the ecological impacts of fishing, were not considered. The assessment was based on observer data, and the scope did not include fishing methods without routine observer coverage, even where marine mammal interactions are known to occur. In particular, the entanglement of whales (or other marine mammals) in the rock lobster (*Jasus edwardsii*) pot fishery (Berkenbusch et al. 2013) was not included in this study.

2. METHODS

2.1 New Zealand marine mammals

New Zealand waters are inhabited by a wide range of marine mammals, including the endemic subspecies Hector's and Māui dolphins (*Cephalorhynchus hectori hectori* and *C. hectori maui*) and New Zealand sea lion (*Phocarctos hookeri*) (Childerhouse & Gales 1998, Currey et al. 2012). An assessment of the conservation status of marine mammal species in New Zealand considered all taxa that have been recorded in New Zealand's EEZ since 1800 (Baker et al. 2010). This assessment has recently been updated, including changes to the New Zealand status of some species (Baker et al. 2016). Both assessments followed the New Zealand Threat Classification System (see Townsend et al. 2008), and distinguished between resident, migrant and vagrant taxa, based on their occurrence and breeding status in New Zealand waters. Migrant taxa do not breed in New Zealand waters, but regularly visit this region as part of their life cycle, with at least 15 individuals known or presumed to visit here each year. Migratory species with fewer than 15 individuals each year are considered vagrant, and this category also includes taxa that are unexpectedly found in New Zealand waters.

The initial assessment by Baker et al. (2010) included a total of 56 marine mammal taxa (species, subspecies, and unnamed forms or types), of which 35 taxa were considered to be resident or migrant in New Zealand's EEZ. These taxa included 10 species or subspecies of baleen whale, 23 taxa of toothed whale (including dolphins and nine species of beaked whale), and three pinniped species (Table 1). All of these taxa were included in the present assessment, based on the initial classification by Baker et al. (2010). Recent updates to the classification of three marine mammal species in New Zealand resulted in changes in status from vagrant to migrant for Arnoux's beaked whale (*Berardius arnouxii*) and spectacled porpoise (*Phocoena dioptrica*) (Baker et al. 2016). In addition, True's beaked whale (*Mesoplodon mirus*) was added to the list of data deficient species. These three species were not included in the current study.

Marine mammal (sub)species were grouped, and taxa within each group were assumed to have a similar capture rate in fisheries, at a similar population density. The five species groups used in the assessment included whales (Balaenidae, Cetotheriidae, Balaenopteridae, Physeteridae, Kogiidae), large dolphins (5 m length or over; the larger delphinid genera; *Globicephala*, *Orcinus*, *Pseudorca*), small dolphins (3 m length or less; other delphinids), beaked whales (Ziphidae), and pinnipeds (Otariidae, Phocidae) (see Table 1). Amongst the whales, there is wide variation in size (e.g., from 3.8 m length in pygmy sperm whale to 31 m length in blue whale) and in ecology (including both sperm and baleen whales). As there are limited interactions between species in these groups and the fisheries included in this assessment, however, there is little information to justify further splitting of this group. Placement of killer whale within the large dolphin group is also difficult. While taxa within this grouping were all large-sized delphinids, killer whale and pilot whales differ in their feeding ecology, and this difference is expected to affect how these taxa interact with fisheries.

2.2 Risk ratio

The methodology used for estimating the risk follows the Spatially Explicit Risk Assessment Framework (SEFRA; Sharp 2017). Following this method, the risk ratio (RR) is estimated as the ratio of the annual potential fatalities (APF) in trawl, longline, set-net and purse-seine fisheries within New Zealand's EEZ

Table 1: New Zealand marine mammal taxa included in the present risk assessment. Taxa were allocated to one of five species groups: whales (Balaenidae, Cetotheriidae, Balaenopteridae, Physeteridae, Kogiidae), large dolphins (Delphinidae, at least 5 m length) (Jefferson et al. 2008), small dolphins (Delphinidae, up to 3 m length), beaked whales (Ziphidae), and pinnipeds (Otariidae, Phocidae). Shown for each taxon are the International Union for Conservation of Nature (IUCN) red-list classification (IUCN 2016) and the New Zealand Threat Classification (NZTC; Baker et al. 2016). Lengths (in metres) are of adults, and indicative of species size, but vary in how they were defined between species (Perrin et al. 2009).

Species group	Common name	Scientific name	IUCN	NZTC	Length
Pinnipeds	Southern elephant seal	*Mirounga leonina*	Least concern	Nationally critical	5.0
	New Zealand sea lion	*Phocarctos hookeri*	Endangered	Nationally critical	3.5
	New Zealand fur seal	*Arctophoca australis forsteri*	Least concern	Not threatened	2.5
Small dolphins	Southern right whale dolphin	*Lissodelphis peronii*	Data deficient	Not threatened	3.0
	Bottlenose dolphin	*Tursiops truncatus*	Least concern	Nationally endangered	2.5
	Common dolphin	*Delphinus delphis*	Least concern	Not threatened	1.6
	Dusky dolphin	*Lagenorhynchus obscurus*	Data deficient	Not threatened	1.6
	Hourglass dolphin	*Lagenorhynchus cruciger*	Least concern	Data deficient	1.4
	Hector's dolphin	*Cephalorhynchus hectori hectori*	Endangered	Nationally endangered	1.2
	Māui dolphin	*Cephalorhynchus hectori maui*	Critically endangered	Nationally critical	1.2
Large dolphins	Killer whale	*Orcinus orca*	Data deficient	Nationally critical	7.7
	Long-finned pilot whale	*Globicephala melas*	Data deficient	Not threatened	6.0
	Short-finned pilot whale	*Globicephala macrorhynchus*	Data deficient	Migrant	6.0
	False killer whale	*Pseudorca crassidens*	Data deficient	Not threatened	5.0
Beaked whales	Cuvier's beaked whale	*Ziphius cavirostris*	Least concern	Data deficient	6.1
	Shepherd's beaked whale	*Tasmacetus shepherdi*	Data deficient	Data deficient	6.0
	Southern bottlenose whale	*Hyperoodon planifrons*	Least concern	Data deficient	6.0
	Gray's beaked whale	*Mesoplodon grayi*	Data deficient	Data deficient	5.0
	Spade-toothed whale	*Mesoplodon traversii*	Data deficient	Data deficient	5.0
	Dense-beaked whale	*Mesoplodon densirostris*	Data deficient	Data deficient	4.4
	Andrews' beaked whale	*Mesoplodon bowdoini*	Data deficient	Data deficient	4.3
	Hector's beaked whale	*Mesoplodon hectori*	Data deficient	Data deficient	4.3
	Strap-toothed whale	*Mesoplodon layardii*	Data deficient	Data deficient	4.3
Whales	Antarctic blue whale	*Balaenoptera musculus intermedia*	Criticially endangered	Migrant	31.0
	Fin whale	*Balaenoptera physalus*	Endangered	Migrant	25.0
	Pygmy blue whale	*Balaenoptera musculus brevicauda*	Data deficient	Migrant	24.0
	Sei whale	*Balaenoptera borealis*	Endangered	Migrant	15.0
	Humpback whale	*Megaptera novaeangliae*	Least concern	Migrant	14.0
	Southern right whale	*Eubalaena australis*	Least concern	Nationally endangered	13.0
	Sperm whale	*Physeter macrocephalus*	Vulnerable	Not threatened	11.0
	Bryde's whale	*Balaenoptera edeni brydei*	Data deficient	Nationally critical	7.0
	Antarctic minke whale	*Balaenoptera bonaerensis*	Data deficient	Not threatened	6.5
	Pygmy right whale	*Caperea marginata*	Data deficient	Data deficient	6.0
	Dwarf minke whale	*Balaenoptera acutorostrata*	Least concern	Not threatened	4.5
	Pygmy sperm whale	*Kogia breviceps*	Data deficient	Data deficient	3.8

to the Population Sustainability Threshold (PST):

$$\mathrm{RR} = \mathrm{APF}/\mathrm{PST}, \tag{1}$$

where annual fatalities of less than the PST allow for long-term management outcomes to be achieved. In the current study, the PST was defined such that annual fatalities lower than the PST (corresponding to a risk ratio less than one) allow a population to increase (or remain at) above half the carrying capacity, in the long term. Uncertainty is carried through all parameters in the calculation, so there is uncertainty in the resulting risk ratio. In the application of the seabird risk assessment (Ministry for Primary Industries 2013), the risk ratio was converted to a risk category, which was derived from criteria associated with both the mean risk ratio and the upper credible interval of the risk ratio. This risk category informed policy related to seabird bycatch. A similar process may be undertaken for marine mammals, where the risk ratio could be used to derive a risk category that is related to policy actions. In this study, however, the focus was on estimating the quantitative risk ratio.

2.3 Population Sustainability Threshold (PST)

The PST is an estimate of the maximum number of annual human-caused mortalities that can occur, while still allowing a population to achieve a defined population recovery or stabilisation outcome, including explicit consideration of uncertainty. In this case, the PST is defined with reference to a population outcome whereby the population will be at or above half of the carrying capacity, with 95% certainty, after 200 years. Actual population recovery objectives are a policy decision and may vary between species, but are outside the scope of the risk assessment. To achieve this outcome, the PST is here defined as

$$\mathrm{PST} = \frac{1}{2}\phi r_{\mathrm{max}} N, \tag{2}$$

where r_{max} is the maximum population growth rate, under optimal conditions, and N is the population size. The parameter ϕ ($0 < \phi < 1$) is chosen so that the management outcome may be achieved. The PST was derived for New Zealand seabirds (most recently by Richard & Abraham 2017), and is a modification of the Potential Biological Removal (PBR) of Wade (1998).

The PST includes a factor ϕ allowing for calibration of the PST. Numerical simulations of seabird populations were carried out to calibrate the PST—ensuring that populations with a fisheries mortality less than the critical mortality limit were able to meet a long-term outcome of being above half the carrying-capacity, with a 95% probability. These simulations found that the long-term outcome was achieved with $\phi = 0.5$ in the presence of environmental stochasticity (simulated to cause variation in the long-term population with a coefficient of variation (CV) of 0.2, in the absence of fisheries mortality) (Richard & Abraham 2016). Although similar population modelling was not carried out for marine mammals to calibrate the PST, the same factor of $\phi = 0.5$ was used for the current marine mammal risk assessment.

2.4 Estimating annual potential fatalities

The total number of incidental captures of marine mammal species was estimated by assuming that, for similar species, and for similar fishing effort, the number of protected species capture incidents is proportional to the overlap between the density of the populations and the fishing (Sharp 2017). Here, the density overlap (θ) between a species (s) and a fishery group (g) was calculated by summing the product of fishing intensity, population size, and the relative density of a species at the location of the fishing:

$$\theta_{sg} = N_s O_{sg}, \tag{3}$$

$$O_{sg} = \sum_i p_{si} a_{gi}, \tag{4}$$

where N_s is the total population size, O_{sg} is the population-independent overlap, i is an index of the fishing events within the fishery group, p_{si} is the relative population density at the location of the fishing, and a_g is the fishing intensity associated with the event. The risk assessment was carried out for all trawl, longline, set-net, and purse-seine fisheries within the outer boundary of New Zealand's EEZ. Fishing intensity was measured as the number of fishing events for trawl and purse-seine fisheries, thousands of hooks for longline fisheries, and kilometres of net for set-net fisheries. The relative population density (p) was normalised so that it integrated to one over New Zealand's EEZ: when multiplied by the population size, it gave the expected population density (animals per unit area) at each point.

Captures of marine mammals are recorded by observers when they are on board fishing vessels. The expected number of incidents is assumed to be proportional to the density overlap. In its simplest form, the number of observable captures recorded by observers (C'_{sg}) is then given by

$$C'_{sg} \sim \text{Poisson}(p_{\text{observable}} v_{sg} \theta'_{sg}), \tag{5}$$

where v_{sg} is the vulnerability of a species, s, to capture in a fisheries group, g, per unit density overlap, θ'_{sf}. Here the prime symbol is used to indicate observed quantities. The probability, $p_{\text{observable}}$, is the probability that an incident that occurred while an observer was on the vessel would be recorded. Reasons for not recording the incident could be that the animal fell off the fishing gear before being brought on board, or that the observer was somewhere else on the vessel when the incident occurred and was not notified. The probability, $p_{\text{observable}}$, is the inverse of the cryptic multiplier used in the seabird risk assessment (Richard & Abraham 2013, 2015). The total number of incidents was assumed to be proportional to the overlap, whereas in previous applications to seabirds (e.g., Richard & Abraham 2013, 2015), the observable captures were assumed to be proportional to the overlap.

In applying the SEFRA, there were further complexities to be considered. First, observers recorded captured animals as either dead or released alive. Second, not all animal captures were fully identified, some captures were only identified to a species group (z). In the case of marine mammals in the current assessment, the species groups included pinnipeds, small dolphins, large dolphins, beaked whales, and whales (see Table 1). Further, some captures were recorded as unidentified whales (which could have been any species in the large dolphins, beaked whales, or whales groups). In each stratum, there were six estimated quantities that could be compared with the observed data, depending on whether the capture was alive or dead, and whether it was identified to the species, species group, or unidentified whale level (the partitioning of an incident into these categories is illustrated in Figure 1). If the mean number of incidents involving a species on observed fishing within a fishing group stratum was $\mu'_{\text{I}sg} = v_{sg}\theta'_{sg}$, then the mean number of captures within each category was given by the following set of equations:

$$\begin{aligned}
\mu_{\text{I}sg} &= v_{sg}\theta'_{sg}, \\
\mu_{\text{O}sg} &= p_{\text{observable}}\mu_{\text{I}sg}, \\
\mu_{\text{OS}sg} &= p_{\text{identified}}\mu_{\text{O}sg}, \\
\mu'_{\text{OSA}sg} &= p_{\text{alive}}\mu_{\text{OS}sg}, \\
\mu'_{\text{OSD}sg} &= (1 - p_{\text{alive}})\mu_{\text{OS}sg}, \\
\mu_{\text{OU}zg} &= (1 - p_{\text{identified}}) \sum_{s \in z} \mu_{\text{O}sg}, \\
\mu_{\text{OUW}g} &= p_{\text{whale}} \sum_{z} \mu_{\text{OU}zg}, \\
\mu'_{\text{OUWA}g} &= p_{\text{alive}}\mu_{\text{OUW}g}, \\
\mu'_{\text{OUWD}g} &= (1 - p_{\text{alive}})\mu_{\text{OUW}g}, \\
\mu_{\text{OUZ}zg} &= (1 - p_{\text{whale}})\mu_{\text{OU}zg}, \\
\mu'_{\text{OUZA}zg} &= p_{\text{alive}}\mu_{\text{OUZ}zg}, \\
\mu'_{\text{OUZD}zg} &= (1 - p_{\text{alive}})\mu_{\text{OUZ}zg},
\end{aligned}$$

where roman indices indicate the state of the capture (I–incident; O–observable; S–identified to the (sub)-species level; A–alive; D–dead; W–unidentified whale; Z–identified to the species group level), and italic indices indicate the strata (s–(sub)-species; g–fishery group; z–species group). The prime symbols ($'$) indicate that the mean may be estimated by comparison with observed data, and that the density overlap (θ') is observed. For example, the number of observed captures of a species s in a fishing group g, that were released alive is given by:

$$C'_{\text{OSA}sg} \sim \text{Poisson}(\mu'_{\text{OSA}sg}).$$

It was assumed that the vulnerabilities of Māui dolphin and Hector's dolphin were the same, and that the vulnerabilities of long-finned and short-finned pilot whales were the same. Within the model, this equivalence was enforced by defining a species-leaf index, with the vulnerabilities of species with the same leaf index being identical. In addition, fishery groups were created for squid trawl fishing and pelagic trawl fishing that used sea lion exclusion devices (SLEDs). For New Zealand sea lion, the vulnerability when SLEDs were used was assumed to be p_{sled} times the vulnerability when SLEDs were not used. For all other species, SLEDs were assumed to not affect the vulnerability. The bars of SLEDs are designed to restrict the entry of sea lion into the cod end of trawl nets, but the spacing would not prevent fur seal from going through into the cod end.

Different structures may be assumed for the vulnerability. After initial exploration of the models, the following representation of the vulnerability was chosen:

$$\log(v_{sg}) = \log(v_{zg}) + \log(r_{lg}),$$

where v_{zg} is an independent vulnerability for each species group, z, and fishery-group, and r_{lg} is a random effect, drawn for each species-leaf, l, and fishery-group:

$$\log(r_{lg}) \sim \text{Normal}(0, \sigma_{\text{leaf}}).$$

Given the vulnerability and the overlap, the annual potential fatalities were estimated from the total number of incidents (Figure 2). To determine fatalities, a further parameter, the survival probability (p_{survival}) is required, which gives the probability that an animal that was released alive survived. Whether incidents are observable or not, and whether they are identifiable or not, does not affect the annual potential fatalities, and so they are estimated as:

$$\text{APF}_{sg} \sim \text{Poisson}((1 - p_{\text{survival}} p_{\text{alive}}) v_{sg} Y \theta_{sg})/Y,$$

where θ_{sg} is the overlap with annual fishing effort (all fishing effort in the fishing groups over a fishing year). The parameter Y allows for annual potential fatalities to be estimated as an average over a number of years. In the case of marine mammals, we used a time period of $Y = 20$, appropriate for long-lived species. For small populations with low capture rates, this time period reduces the uncertainty associated with interannual variation. (Note that in estimating the annual potential fatalities, it was assumed that the same live release probability and survival probability apply to unobservable incidents. This assumption could be refined if more information was available on the nature and outcomes of these incidents.)

We applied a constraint to the APFs, requiring that the total annual potential fatalities of each species were less than one-fifth of the total population, on the assumption that fatalities beyond this level would not have permitted the species' continued presence in New Zealand waters. Formally, we required that

$$\sum_g \text{APF}_{sg} < 0.2N_s.$$

We fitted the model to the observed overlap and capture data within a Bayesian framework, using the software JAGS (Just Another Gibbs Sampler; Plummer 2016) (see Appendix A for model code). A burn-in of 10 000 iterations was discarded, and then the models were run for a further 20 000 iterations. There was uncertainty in both the population size and in the spatial distribution. The models were fitted 100 times, for independent draws of these parameters. The posterior samples from the 100 runs of each model were combined, allowing uncertainty in the distribution and population size to be reflected in the

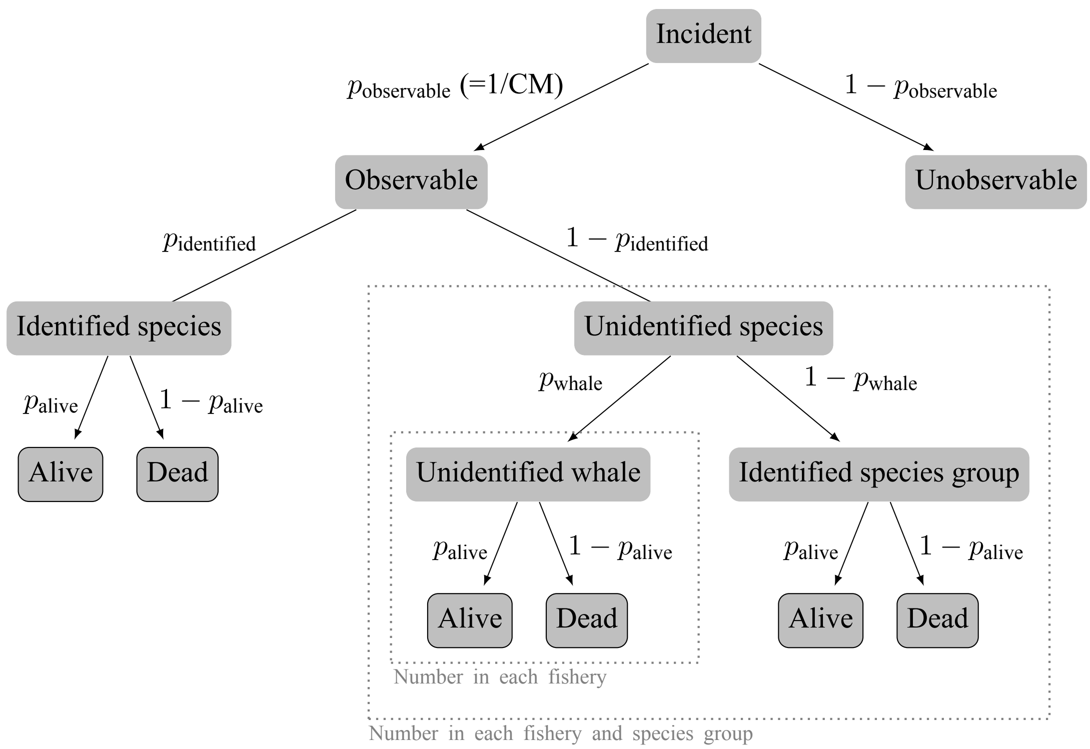


Figure 1: Representation of capture incidents within the model. For each incident, there is a probability $p_{\text{observable}}$ that the incident would have been recorded by observers, if they were on board the vessel. This probability is the inverse of the cryptic multiplier (CM). Observable captures may be identified to the species level, with probability $p_{\text{identified}}$. Captures that are not able to be identified to the species level are either recorded by the observers as an unidentified whale, with probability p_{whale}, or they are assigned to one of the species groups. Each capture recorded is either released alive (with probability p_{alive}) or is dead. Data on the alive and dead captures (indicated by the boxes with solid borders) were used to estimate the parameters. For the captures that were assigned to species groups, the number of captures was available by fishery and species group, and for the unidentified whale captures, the number of captures was available by fishery. This grouping is indicated by the dotted lines.

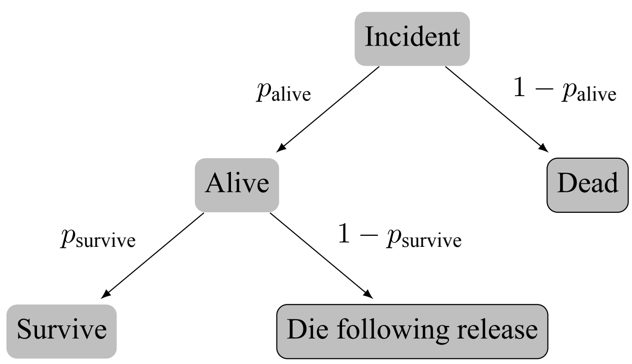


Figure 2: Annual potential fatalities, defined as the estimated number of incidents that involved marine mammals that were not released alive, as well as marine mammals that died following release. Animals that were released alive survived with probability p_{survive}.

Table 2: Model parameters and priors used in the current marine mammal risk assessment. Shown are the dimension over which each parameter varies, and the prior. Dimensions include: species leaf, (sub)species that are assumed to have identical vulnerabilities; fishery group; method, fishing method; species group; class, three-level species class (pinnipeds, small dolphins, and a composite group including large dolphins, beaked whales, and whales); SLED, sea lion exclusion device.

Parameter		Dimension	Prior
Random effect standard deviation	σ_{leaf}	Species leaf	Uniform$(0, 10)$
Vulnerability random effect	$\log(r_{lg})$	Species leaf, fishery group	Normal$(0, \sigma_{\text{leaf}})$
Vulnerability	$\log(v_{zg})$	Species leaf, fishery group	Normal$(0, 10)$
Survival probability	p_{survive}	Species class, fishing method	Uniform$(0, 1)$
Identification probability	$p_{\text{identification}}$	Species group	Uniform$(0, 1)$
Observable probability	$p_{\text{observable}}$	Species class, fishing method	Uniform$(1/3, 1)$ for set net; Uniform$(1/2, 1)$ for other fishing methods
Live probability	p_{live}	Species class, fishing method	Beta$(1, 3)$
Unidentified whale probability	p_{whale}	Species group	Uniform$(0, 1)$ for whale groups, 0 otherwise
SLED effect	p_{sled}		Uniform$(0, 1)$

uncertainty in the estimated observable captures. For each of these 100 draws, the same population size was used both for estimating the annual potential fatalities and for estimating the PST.

Most model parameters had uninformed priors (Table 2). The observable probability (the inverse of the cryptic multiplier) had a uniform prior between one-third and one (mean two-thirds) for set-net fisheries, and between one-half and one (mean three-quarters) for all other fisheries. This prior means that in set-net fisheries, up to three times as many incidents may occur as are reported by observers when they are on board the vessels. In set-net fisheries, this prior corresponds to a cryptic multiplier with a mean of 1.65 (95% c.i.: 1.02 to 2.86). In other fisheries, the prior corresponds to a cryptic multiplier with a mean of 1.39 (95% c.i.: 1.01 to 1.95). The range of this prior was suggested by Ministry for Primary Industries (MPI), following video observations of dolphin caught in set-net fisheries, including a study by McElderry et al. (2007). Their study concluded that of two Hector's dolphin captures recorded on video, one capture was not witnessed by the fishing crew.

The parameter for the probability of captures being released alive was assumed to be the same within fishing methods, and within a three-level species class (pinnipeds, dolphins, and a group including large dolphins, beaked whales, and whales). The prior was not uniform but was chosen as a beta distribution with one success and three failures: in method–species-class strata with no captures, the live capture parameter has a mean of 0.25 (95% c.i.: 0.01 to 0.71), corresponding with the scenario of one observed live release and three dead captures. The mean is close to the overall proportion of live-release captures (27% of all observed marine mammal captures in the dataset), and biases the model against live-release in the absence of other information. The survival probability is not informed, so the posterior distribution remains close to the prior. This approach implies that, on average, 50% (95% c.i.: 2.5 to 97.5%) of captures released alive were assumed to survive. In implementing the model, a small value (1×10^{-10}) may be added or removed from the bounds of the priors, to prevent any difficulties with numerical stability.

The models were fitted with a range of assumptions about the structure of the vulnerabilities, v_{sf} (Table 3). The models were compared using the Bayesian leave-one-out cross validation measure (LOO; Vehtari et al. 2016a, 2016b). The LOO measure estimates the error in point-wise out-of-sample predictions from the model. A lower LOO measure indicates a more accurate model. Here, the model with the lowest LOO score was chosen as the most adequate model.

When estimating the risk, annual potential fatalities for most species were estimated from the vulnerability and spatial overlap. Nevertheless, for common dolphin, New Zealand fur seal, and New Zealand sea lion in trawl fisheries, and for New Zealand fur seal in surface-longline fisheries, estimated captures were used from the study by Abraham and Berkenbusch (2017). These estimates were made using a general-

Table 3: Model structures used for estimating number of marine mammal capture incidents. Vulnerability was estimated with model structures based on the fishery, the species group of the marine mammal taxon, and the marine mammal species. Fisheries and species-group effects were fixed effects, while species effects were included through random effects.

Vulnerability	Description
Fishery × Species group	Fishery and species-group effects, with interactions.
Fishery × Species	Fishery and random species effects, with interactions.
(Fishery × Species group) + Species	Fishery and species-group effects with interaction terms, and an additional random species effect.
Fishery × Species group × Species	Fishery, species-group, and random species effects, with interaction terms.

ised linear model (GLM). For these species and fishing methods, there have been sufficient records of observed captures to directly estimate the total number of captures, without needing assumptions about the spatial distribution. Annual potential fatalities were estimated by adjusting the estimated captures for cryptic mortalities (through $p_{\text{observable}}$) and for survival of captures. If the observation (or not) of each incident occurs independently, and the probability of a capture being observed is $p_{\text{observable}}$, then the distribution of unobserved captures can be represented by the negative binomial distribution. In a series of independent trials, this distribution estimates the number of failures that would occur before a specified number of successes. If the number of observed captures estimated from the generalised linear model is $C_{\text{O}}^{\text{GLM}}$ (Abraham & Berkenbusch 2017), and an observed capture is considered a "success", then the number of unobserved captures may be estimated as:

$$C_{\text{U}}^{\text{GLM}} \sim \text{Negative Binomial}(\text{successes} = C_{\text{O}}^{\text{GLM}} + 1, p = p_{\text{observable}}). \tag{6}$$

From the total number of incidents ($C_{\text{O}}^{\text{GLM}} + C_{\text{U}}^{\text{GLM}}$), the fatalities may be estimated by drawing from a binomial distribution, with the number of trials being the number of incidents:

$$\text{APF}^{\text{GLM}} \sim \text{Binomial}(\text{trials} = C_{\text{O}}^{\text{GLM}} + C_{\text{U}}^{\text{GLM}}, p = 1 - p_{\text{live}} p_{\text{survive}}), \tag{7}$$

where the parameters p_{live}, and p_{survive} are from the fit of the vulnerability model to the observer data. This approach assumes that the probability of each capture incident resulting in a fatality is independent for each capture. For species such as common dolphin, which are frequently caught in multiple captures, these independence assumptions are a simplification, and could result in the variance of the annual potential fatalities being underestimated. The estimation of the annual potential fatalities was carried out for samples from the posterior distributions of both the estimated captures and the model parameters.

When using the results of the GLM modelling to estimate the annual potential fatalities of sea lion in trawl fisheries, the estimated number of captures was used (Abraham & Berkenbusch 2017). We did not allow for a change in $p_{observable}$ associated with the use of SLEDs, i.e., the cryptic multiplier for sea lion in tows with SLEDs was assumed to be the same as with other trawl fisheries.

2.5 Demographic parameters

2.5.1 Delphi survey

Demographic parameters are poorly known for many New Zealand marine mammals. To derive the information needed for the risk assessment, an internet-based Delphi survey approach was used. The Delphi technique is suitable for data-poor situations, providing an approach for soliciting expert judgement in a systematic and transparent way (Linstone & Turoff 2002, MacMillan & Marshall 2006, Cole et al. 2013). Marine mammals experts were invited to participate in the Delphi survey based on three criteria, including active participation in marine mammal research in New Zealand, peer-reviewed and professional publications (including research theses within the previous six years), and involvement in current research activities on marine mammals in New Zealand (and elsewhere). A total of 78 researchers were invited to participate in the survey. The survey was conducted through a website that provided a summary of existing information to the participating experts, in addition to the questions for each marine mammal taxon (see example in Figure 3). The information summary was focused on available population data, and included a link to a published review of the population information and interactions between marine mammals and commercial fisheries in New Zealand waters for the 35 cetacean and pinniped (sub)species (Berkenbusch et al. 2013).

The survey questions for each marine mammal (sub-)species sought information on the spatial distribution of each taxon (p_s); the maximum population growth rate (r_{max}); and the population size (N). For each parameter, respondents were asked to estimate the lower and upper bounds of the 95% confidence interval. The population size was assumed to be log-normally distributed, while the population growth rate was assumed to be logit-normal. A plot of the distribution was shown to help respondents visualise their responses. Each question had the option to either provide information or decline the answer, and individual responses were complete when all questions were either answered or declined. Following this initial survey round, participants were invited to contribute to a second round, allowing them to review and modify their initial answers in view of the combined answers of the other respondents.

2.5.2 Deriving a consensus distribution

We used a Bayesian hierarchical framework to derive consensus answers for each of the questions asked in the survey. Subjective prior information is an inherent part of the Bayesian approach to probabilities and statistical computation, and methods for eliciting and combining prior information have a long history in Bayesian statistics (Lindley 1986, Jacobs 1995). In the supra-Bayesian approach, expert information is seen as data that are combined with a prior to provide a posterior distribution for a quantity of interest (Jacobs 1995). The prior can be thought of as the decision maker's prior (which can be uninformed), where the decision maker is the person (or group) deciding how to combine and use the judgements. This approach contrasts with the linear opinion-pools method, which combines expert judgement in an ad-hoc way by taking a mean of expert answers as the consensus. The mean can be weighted by giving each answer a weight as chosen by the decision maker. This method is widely used in ecology for eliciting priors for subsequent Bayesian analysis as it is straightforward (Martin et al. 2005, Martin et al. 2012).

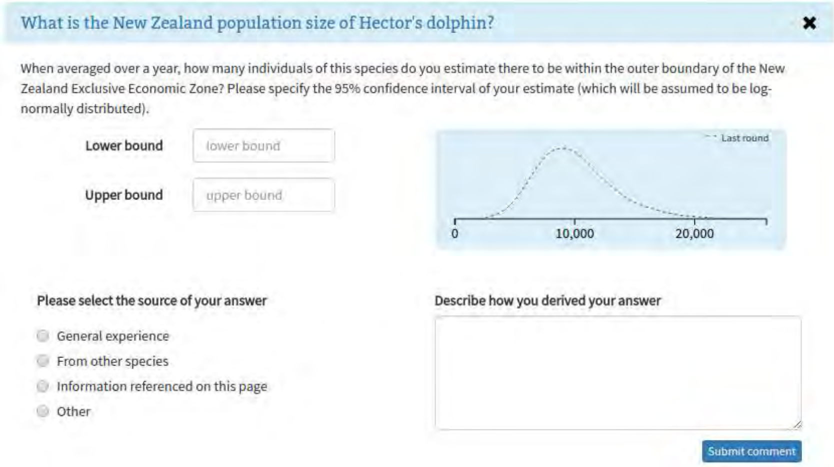
Here, we employed the supra-Bayesian approach to estimating consensus from multiple expert judgements. Our approach was conceptually and methodologically similar to Lipscomb et al. (1998), who applied a Bayesian hierarchical model for expert judgement to improve physician staffing in care centres. We assumed that individual expert answers were a sample from an underlying consensus distribution of expert judgements. This assumption allowed us to employ a hierarchical model structure for the questions, and use Bayesian methods to estimate the parameters of the consensus distribution. This approach is similar to conducting a formal meta-analysis of separate studies, each of which lead to an estimate about some quantity (the expert judgement), with a measure of uncertainty (the expert's uncertainty). To make predictions based on the expert consensus, we drew samples from the posterior predictive distribution, which can be interpreted as predictions from the expert consensus for each question. This prediction integrates over uncertainty in the consensus distribution parameters. All analyses were performed in the R language for statistical computing (R Development Core Team 2008), with Bayesian models run using the `rjags` package for the Bayesian estimation software JAGS (Plummer 2016).

2.5.3 Model for population size

The Delphi survey asked participants to provide the upper and lower bounds of a 95% confidence interval for the population size, with the underlying distribution assumed to be a log-normal distribution. Since the confidence interval uniquely determines the mean and variance of the log-normal distribution, the answers given by an expert, i, were converted to the log-normal mean m_i and standard deviation σ_i of their judgement.

In the meta-analysis, the log-normal mean m_i was assumed to be only one answer the expert could have given, and the greater an expert's uncertainty about population size, the wider the range of values that

(a) Population size



(b) Spatial distribution

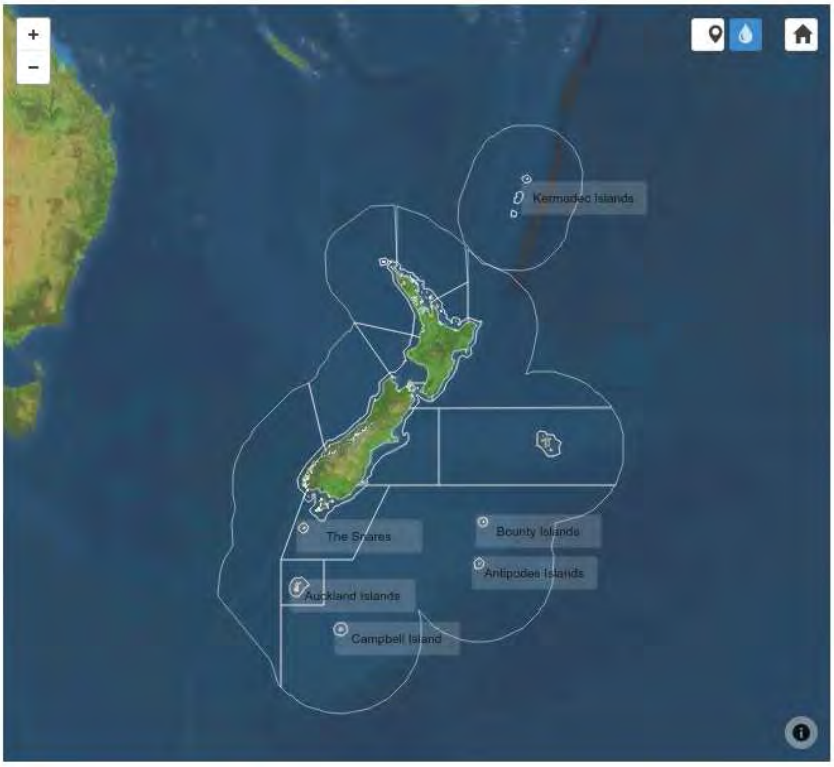


Figure 3: Screenshots of the web-based Delphi survey of marine mammals in New Zealand waters, showing (a) an example of the question of population size (for Hector's dolphin), and (b) the interactive map for obtaining spatial information. The distribution shown in (a) is an analysis of answers from the previous round, and illustrates how the question appears to someone who had not answered previously. The interactive map in (b) was used to obtain information about the spatial distribution of each marine mammal taxon included in the assessment. The New Zealand region was divided into broad areas, with inshore and offshore regions separated by a boundary at either 100 m water depth, or 12 nautical miles (22.2 km) from the coast, whichever was further. The population was at first distributed evenly, with an equal density in each of the areas that respondents clicked on. The percentage of the population in each region could subsequently be set at a known value by clicking on an area again and manually adjusting the percentage.

they could have specified. Specifically, we assumed:

$$\log(m_i) \sim N(\mu_i, \sigma_i) \quad \text{data model,} \quad (8)$$
$$\mu_i \sim N(\nu, \sigma) \quad \text{consensus distribution,} \quad (9)$$
$$\log(m_p) \sim N(\nu, \sigma) \quad \text{prediction.} \quad (10)$$

In this analysis, m_p was an estimate of the mean population size that another expert (who did not respond to the study) may have answered. The posterior distribution of the population size that was used in the risk assessment was derived from m_p. Simulations were carried out to determine how the model performed in deriving a consensus distribution from the individual responses (see Appendix B).

2.5.4 Model for r_{max}

The model for maximum population growth, r_{max}, was conceptually the same as the model for the population size; however, in analysing the responses, we applied a logit transformation and assumed normality on the logit scale. For low population growth rates ($r_{\text{max}} < 0.1$), this approach is similar to a log transformation, but the logit transform prevented the consensus distributions generating occasional unrealistic values ($r_{\text{max}} > 1$).

2.5.5 Model for spatial distribution

The spatial model was the most complex model due to the structure of the answers. New Zealand waters were divided into discrete regions, and the experts had the option to give percentage answers for the proportion of the total population in New Zealand waters in each region, or to select regions in which they thought a species occurred without providing a precise estimate (Figure 3(b)). When percentages entered for regions did not sum to 100%, the remaining percentage was estimated only over regions selected (using regions selected by all experts who answered for a particular species). If no regions were selected and the sum of percentages entered for regions did not sum to 100%, proportions were estimated for all remaining regions.

The model assumed a logistic-normal model for expert answers, with answers transformed using the centred log-ratio transform (Aitchison 1986). The centred log-ratio transform has the following form: $\kappa = f(c) = \log(c_{1,\ldots,a}/g(c))$, for a p dimensional composition vector c, where the function g is the geometric mean. Here, c represented the proportion of the population in each of the a areas. Given that answers can be incomplete, the data model for κ included left-censored data for answers that did not sum to 100%. The compositional nature of the data suggested a multivariate (normal) model (MVN) for κ, since the constraint that data need to sum to 100% placed an implicit correlation structure on the data. The missing data, however, made it impossible to assume a multivariate normal distribution at the data level, and we assumed independent normal models for each proportion at this level of the model.

The mean parameter for these (transformed) proportions was drawn from an underlying consensus distribution. At the level of the consensus distribution in the hierarchical model, it was not necessary to consider missing data, so that the data level means were modelled as arising from a multivariate normal consensus distribution, and its parameters were estimated using an uninformed prior (i.e., an inverse-Wishart distribution with scale matrix with a scale of 0.01 on the diagonal for the multivariate normal precision). The prior mean vector for regional means (at the data level) was proportional to the area of each region. This underlying multivariate model allowed the introduction of the dependency among area proportions at the consensus distribution level of the hierarchical model. The model was specified as:

$$\kappa_{i,a} \sim N(\mu_a, \sigma_a) \quad \text{data model,} \quad (11)$$
$$\mu \sim \text{MVN}(\Delta, \Sigma) \quad \text{consensus distribution,} \quad (12)$$
$$f(\mu_p) \sim \text{MVN}(\Delta, \Sigma) \quad \text{prediction.} \quad (13)$$

Table 4: Population estimates of Hector's dolphin (MacKenzie & Clement 2014, 2016) from aerial surveys of coastal South Island waters, carried out between 2012 and 2015.

Region	Season	Mean	Standard error
South Coast South Island	Summer	177	66
	Winter	299	140
	Combined	238	94
East Coast South Island	Summer	9 728	1 644
	Winter	8 208	2 210
	Combined	8 968	1 377
West Coast South Island	Summer	5 482	1 433
	Winter	5 802	1 205
	Combined	5 642	936
Total	Combined	14 849	1 668

2.5.6 Distribution and population size of Hector's and Māui dolphin

Distribution information for Hector's dolphin, and a recent population estimate, were available from aerial surveys conducted between 2012 and 2015 (MacKenzie & Clement 2014, 2016). The surveys covered the South Island's east, west and south coasts in both summer and winter. The survey data resulted in a mean estimate of 14 849 (standard error: 1668) Hector's dolphin for the South Island population, within the surveyed areas (Table 4). For each region, samples were taken from a log-normal distribution with the same mean and variance as the 'combined' estimate (MacKenzie & Clement 2014, 2016). It was assumed that both the summer and winter surveys were estimates of the same population, and so the same distribution was used for estimating overlap with fishing effort in summer or winter. Samples from each survey region were then summed to obtain a total population estimate. The population estimate was not adjusted to account for dolphin that may have been outside the survey area.

In addition to the population estimate, the surveys provided population distributions (see Appendix C, Figure C-4). These distributions were used instead of the distributions from the Delphi survey for estimating the overlap between Hector's dolphin and fisheries. The number of dolphin within each of the Delphi areas was estimated by drawing from a multinomial distribution, with probabilities given by the mean proportion within each of the areas (calculated from the distributions), and with a total number given by a draw from the distribution of population estimates within each of the three Hector's dolphin survey regions. The relative numbers were then used to estimate the proportion of Hector's dolphin within the areas of the Delphi survey. When estimating overlap, the summer distribution was used for fishing effort that occurred during the six months between 1 November and 30 April, and the winter distribution was used for the remainder of the year (dates for the transition were chosen following advice from D. Clement, Cawthron Institute, pers. comm.). The method of using draws from multinomial distributions to generate an estimate of the proportion of dolphin within each Delphi area allowed for uncertainty in the spatial distribution to be generated. This uncertainty was carried through to the repeated fitting of each model.

The aerial surveys for Hector's dolphin did not extend into coastal areas, or into harbours such as Marlborough Sounds or Akaroa Harbour. The grid used by MacKenzie and Clement (2016) was extended into the coastal area, and a flooding process was used to generate a spatial distribution in those areas by progressively setting grid cells to the mean value of neighbouring non-empty cells. The density of Hector's dolphin within the Marlborough Sounds area was set to be uniform, and was set so that the abundance integrated to 55.6 Hector's dolphin through the region. A previous estimate of abundance for Marlborough Sounds was derived from boat surveys during the summer of 1999–2000, with a mean of 20 and a CV of 100% (Dawson et al. 2004). The abundance of 55.6 individuals is the upper 95% confidence interval of a log-normal distribution with mean 20 and standard deviation 20. This abundance allows for a higher overlap with Marlborough Sounds than would be obtained by using the mean value. Hector's dolphin abundance within Marlborough Sounds was assumed to be the same in summer and winter.

From the spatial distribution of Hector's dolphin, the proportion of overlap with set-net fisheries that was within each of the three regions (West Coast, East Coast and South Coast South Island) was calculated. In turn, this approach allowed the proportion of the risk to Hector's dolphin from set-net fishing that is within each of these regions to be calculated. The distribution also allowed calculation of the proportion of the population that was within areas that were closed to set-net fishing to be calculated.

The distribution of Māui dolphi was determined in a recent risk assessment (Currey et al. 2012), and this distribution was used instead of the distribution obtained through the Delphi survey. The number of Māui dolphin within each of the Delphi areas was estimated by a draw from a multinomial distribution, with the probability given by the proportion of the distribution within each area, and the total population being a draw from the consensus estimate of the population. For Māui dolphin, the recent population estimate from mark-recapture data (Baker et al. 2013) was not used directly, as this information was available to Delphi survey participants.

2.6 Fisheries and observer data

Estimation of the total number of marine mammal captures requires data on the fishing effort, observed fishing effort, and observed captures. Incidental captures of marine mammals by fishing vessels are recorded by fisheries observers when they are on board fishing vessels. Fishers also reported marine mammal captures; however, estimation of the annual potential fatalities relied solely on observer data.

Data on fishing and observed fishing effort were obtained from the MPI catch-effort database. Data on marine mammal bycatch were extracted from the Centralised Observer Database (COD). The estimation of incidental captures used fisheries effort data for the three-year period from 2012–13 to 2014–15. The fisheries included trawl, surface-longline, bottom-longline, set-net and purse-seine fishing. Some fishing events had no latitude or longitude information, and for these events, an imputation process was used to allocate positions. For all fisheries, other than set-net fishing targeting flatfish or mullet species, the imputation was carried out by randomly sampling from located fishing events within the same statistical area and target fishery (the main target fisheries are defined in Table 5).

Set-net flatfish and mullet fisheries are primarily located in harbours, estuaries or other shallow coastal waters. Considerable effort from these fisheries was recorded on forms without location data. The Land Cover Database (LCDB v4.1[1]) was used to identify estuarine habitat, and New Zealand bathymetry data (Mitchell et al. 2012) were used to identify water less than 10 m depth. Harbours were manually identified using Geographic Information Systems (GIS) software. A grid of points (spaced at 250 m) was then generated, for each month of the year, across shallow water within estuaries or harbours, to provide candidate points for flatfish effort. A shapefile of set-net restrictions provided by MPI was used to exclude points where set-net fishing is prohibited (the use of a set of points for each month allowed for seasonal exclusions to be considered). Flatfish and mullet set-net fishing effort without a location was then allocated by randomly sampling from this grid of points, within each statistical area and month. Set-net effort that could not be allocated was not included in the assessment (for example, some effort was reported from Statistical Area 001, which is offshore). Unlocated set netting for flatfish and mullet targets in the South Canterbury statistical area (022) was assumed to be in Lake Ellesmere, as all other potential habitat in this area is covered by a set-net restriction, and was not allocated a position.

Fishing was assigned to fishery groups, based on the method and target species of each fishing event (Table 5). Squid and southern blue whiting trawl were each further split into two groups, according to whether sea lion exclusion devices (SLEDs) were used. In addition to the COD data, we used data from the inshore fishery observer programme for Hector's dolphin that was carried out in Canterbury during 1997–98 by the (then) Seafood Industry Council under contract to Department of Conservation (Baird & Bradford 2000, Starr & Langley 2000). The data were made available for this project by one of the authors of the original report (P. Starr). This programme reported the capture of Hector's dolphin, and both the

[1]https://lris.scinfo.org.nz/layer/423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/

observer effort data and the capture data from this programme were included with the COD dataset. It was assumed that there were no other marine mammal captures (other than the reported Hector's dolphin captures). Hector's dolphin have been recorded as entangled during video monitoring of set-net fishing in the Canterbury region (McElderry et al. 2007). Electronic monitoring data from this study or from subsequent video-monitoring trials were not included in this analysis.

Observer data were used from the 1995–96 to the 2014–15 fishing year. An exception was made for the subantarctic southern blue whiting trawl fishery. For this fishery, data were only used from the 2009–10 to the 2014–15 fishing year. This restriction was made as there has been a marked increase in the capture rate of New Zealand sea lion in this fishery, with three or fewer observed captures in any year before the 2004–05 fishing year, compared with eleven New Zealand sea lion captures in this fishery in 2009–10. The risk assessment assumes a constant capture rate over the period of the observer data. All observer trips over these periods were included in the study unless they were cancelled, operated exclusively outside of New Zealand's EEZ, were research trips, did not record any fishing effort, or were not using the fishing methods included here (trawl, surface and bottom longline, set net, and purse seine).

Information on observed captures and observed fishing effort was used for estimating captures. For each marine mammal capture, the observer identified the animal to the extent that they were able to. For some marine mammal captures, the identity was subsequently confirmed by an expert, either by necropsy or from photographs. During the data preparation, all captures where the observer had been unable to provide identifications to the species level were reviewed. For each capture, the observer also recorded whether the animal was dead, or released alive. The capture records were all linked to observer effort data, from COD. When observer data were not available, but the trip was known to have been observed, the observed effort was reconstructed from the fisher-reported catch effort data, assuming that all effort on the observed days was observed. This reconstruction was carried out by linking the vessel key and the dates.

The fisheries observer, effort, and capture data were summed over fishing events to determine the total overlap within fishery group and species strata. This summation reduced the estimation from a row for each observed fishing event (hundreds of thousands of rows in total), to a model with a row for each stratum (hundreds of rows), greatly increasing the speed of the model estimation. The summation had no effect on the results of the model estimation (see Appendix D), with the exception that when the model was fitted to summed data, any captures that occurred where the overlap was zero contributed to the model. If the data were not summed, these captures did not contribute to the vulnerability. From this perspective, the summed model performed better than a model that is estimated using event-level data, as it is preferable that all recorded captures contribute to the vulnerability.

Since October 2008, fishers have been reporting protected species captures using the non-fish/protected species catch return (NFPSCR). All marine mammal captures reported using this form were extracted from the MPI database and summarised. Information from this form was not used for the estimation; however, these records provide additional information on the species and fisheries where marine mammal captures occur.

3. RESULTS

3.1 Demographic parameters and the PST

Expert knowledge from the Delphi survey provided demographic information for the different marine mammal (sub-)species included in the assessment, with a total of 31 researchers participating in the survey (Tables 6 and 7; and see Appendix E) for detailed Delphi survey results for all individual taxa). The number of experts providing information was dependent on the marine mammal species. Overall, the response rate was low. The highest number of answers was for Hector's dolphin, with 10 respondents. For 12 of the 23 dolphin and whale taxa, there were only one or two responses. A single response was provided for three of the beaked whale taxa, with no responses for the other six beaked whales. Between three and 10 responses were received for estimates of pinniped populations. Little additional information

Table 5: Fishery groups used for estimating marine mammal bycatch. Commercial fishing by trawl, longline, set net, or purse seine was allocated to one of these groups. Allocation to target fisheries was based on the fisher-declared target species of the fishing event, and target fisheries were grouped into fishery groups. Target species are shown if they were targeted on more than 300 fishing events per year for the associated fishing method between 2012–13 and 2014–15. Common names or descriptions and scientific names corresponding to the target species codes used by fishers are from Ministry for Primary Industries. Squid and southern blue whiting trawls were each further split into two groups, according to whether sea lion exclusion devices (SLEDs) were used.

Fishery group	Target fishery	Target species
Inshore trawl	Inshore	Tarakihi (*Nemadactylus macropterus*, *N.* sp. (King tarakihi)), gurnard (*Chelidonichthys kumu*), snapper (*Pagrus auratus*), trevally (*Pseudocaranx georgianus*), red cod (*Pseudophycis bachus*), John dory (*Zeus faber*), giant stargazer (*Kathetostoma spp.*), elephant fish (*Callorhinchus milii*)
	Flatfish trawl	Flats, lemon sole (*Pelotretis flavilatus*), sand flounder (*Rhombosolea plebeia*), N.Z. sole (*Peltorhamphus novaezeelandiae*)
Pelagic trawl	Mackerel trawl	Jack mackerel (*Trachurus declivisi*, *T. murphyi*, *T. novaezelandiae*)
	Southern blue whiting	Southern blue whiting (*Micromesistius australis*)
Squid trawl	Squid	Arrow squid (*Nototodarus sloanii*, *N. gouldi*)
Other trawl	Hoki	Hoki (*Macruronus novaezelandiae*)
	Scampi	Scampi (*Metanephrops challengeri*)
	Ling trawl	Ling (*Genypterus blacodes*)
	Hake	Hake (*Merluccius australis*)
	Deepwater	Orange roughy (*Hoplostethus atlanticus*), smooth oreo (*Pseudocyttus maculatus*)
	Middle depths	Barracouta (*Thyrsites atun*), common warehou (*Seriolella brama*), silver warehou (*Seriolella punctata*), Alfonsino & long-finned beryx (*Beryx splendens*, *B. decadactylus*), ghost shark (*Hydrolagus novaezealandiae*)
Set net	Flatfish	Flats, yellowbelly flounder (*Rhombosolea leporina*)
	Shark	Rig (*Mustelus lenticulatus*), school shark (*Galeorhinus galeus*)
	Mullet	Grey mullet (*Mugil cephalus*)
	Mixed set net	Tarakihi (*Nemadactylus macropterus*, *N.* sp. (King tarakihi)), butterfish (*Odax pullus*), kahawai (*Arripis trutta*, *A. xylabion*), trevally (*Pseudocaranx georgianus*), hāpuku & bass (*Polyprion oxygeneios*, *P. americanus*), common warehou (*Seriolella brama*)
Bottom longline	Snapper	Snapper (*Pagrus auratus*)
	Ling bottom longline	Ling (*Genypterus blacodes*)
	Hāpuku	Hāpuku & bass (*Polyprion oxygeneios*, *P. americanus*)
	Bluenose	Bluenose (*Hyperoglyphe antarctica*)
	Mixed bottom longline	School shark (*Galeorhinus galeus*)
Surface longline	Southern bluefin	Southern bluefin tuna (*Thunnus maccoyii*)
	Bigeye	Bigeye tuna (*Thunnus obesus*)
	Swordfish	Broadbill swordfish (*Xiphias gladius*)
Purse seine	Skipjack	Skipjack tuna (*Katsuwonus pelamis*)

was obtained from the second round, and so the differences between survey rounds were generally small. The uncertainty associated with expert answers varied greatly, depending on the species.

Experts provided information on the population size of the marine mammal taxa in New Zealand waters, but no population estimates were provided for Andrews' beaked whale, dense-beaked whale, Hector's beaked whale, Shepherd's beaked whale, southern bottlenose whale, or spade-toothed whale (Table 6). For these species, the population was drawn from a log-uniform distribution with between 100 and 10 000 individuals (corresponding to a mean population of 2151, and a 95% interval of 112 to 8916 individuals). Several other species had population estimates that contained considerable uncertainty (CV values $\geq$1), including hourglass dolphin, pygmy right whale, humpback whale, and sei whale. Instead of the Delphi survey values, the same default population sizes that were used for beaked whales were used for hourglass dolphin, pygmy right whale, and sei whale. For humpback whale, a population estimate by Constantine et al. (2012) was used (a mean of 4253 individuals, 95% c.i.: 3354 to 5193). For Hector's dolphin, the population estimate from the recent aerial surveys was used (mean 14 883 individuals, 95% c.i.: 12 235 to 18 548; MacKenzie & Clement 2014, 2016). The estimated Hector's dolphin population from the Delphi process (mean 9926 individuals, 95% c.i.: 4334 to 19 274) overlapped with the estimate from the field survey, but had a wider range and a lower mean. The 2014–15 population of New Zealand sea lion (including pups) was estimated by Roberts and Doonan (2016) as 11 755 individuals. This value was presented without uncertainty, but was close to the mean from the Delphi survey (mean 11 650 individuals, 8558 to 14 379 individuals). We retained the Delphi values for New Zealand sea lion, as they included uncertainty.

For the maximum population growth rate, there were fewer expert answers across the different marine mammal taxa than for the population survey questions (Table 7). One expert, who participated in the second round, contributed many answers for the maximum population growth using default values. While this participation resulted in all species having a maximum population growth rate estimated within the Delphi survey, many of these estimates were made by a single expert only. A recent estimate of the PBR for the Campbell Island sub-population of New Zealand sea lion used an $r_{\max}$ value of 0.08 for the base case, with sensitivities carried out using values of 0.06 and 0.10 (Roberts et al. 2014). The lower bound was chosen to be consistent with the population increase that has occurred at Campbell Island since the mid-1980s. The Delphi survey $r_{\max}$ value for New Zealand sea lion (mean 0.092, 95% c.i.: 0.065 to 0.13) broadly overlaps with the range used by Roberts et al. (2014), albeit with a higher mean value.

The final population size and $r_{\max}$ estimates were used to calculate the PST (Tables 8 and 9). Comparison of the $r_{\max}$ estimates from the Delphi survey with the default values recommended by Wade (1998) showed that the 95% credible interval of $r_{\max}$ values from the Delphi survey included the default value recommended by Wade (1998) in most cases. Exceptions included Hector's and Māui dolphin, which had lower $r_{\max}$ values than the default value of 0.04 for cetaceans recommended by Wade (1998): for Hector's dolphin, the $r_{\max}$ estimate was 0.026 (95% c.i.: 0.018 to 0.036), and for Māui dolphin, it was 0.023 (95% c.i.: 0.015 to 0.034). Humpback whale and southern right whale had a higher $r_{\max}$ value of 0.087 (95% c.i.: 0.051 to 0.13). The values for humpback whale were close to the range found from simulations (mean 0.073, 95% c.i: 0.035 to 0.10, or mean 0.086, 95% c.i.: 0.05 to 0.11, depending on the approach) (Zerbini et al. 2010). The estimated $r_{\max}$ for southern right whale (mean 0.068, 95% c.i.: 0.046 to 0.094) was higher than the current rate of population increase estimated for the New Zealand southern right whale population. Matrix modelling of this population estimated a population increase of 0.048 (95% c.i.: 0.025 to 0.064) (Davidson 2016).

3.2 Observer and fisheries data

Over the period used for estimating the annual potential fatalities, New Zealand fur seal had the highest number (3009) of observed captures (Table 10). Most of the observed fur seal captures were in trawl fisheries, followed by surface longlining (Table 10). There were fewer New Zealand fur seal captures in other fisheries. New Zealand sea lion had the second highest number (299) of incidental captures,

Table 6: Summary of the posterior prediction (posterior mean and 95% credible interval) from the consensus distributions of expert answers about the population size, N_s, of marine mammal taxa found in New Zealand waters. Data shown are from the first and second round of the Delphi survey for the different marine mammal taxa.

Species group	Species	First round			Second round		
		Answers	Mean	95% c.i.	Answers	Mean	95% c.i.
Pinnipeds	New Zealand fur seal	6	126 757	61 883–233 271	9	126 833	71 970–206 123
	New Zealand sea lion	8	11 654	8 917–14 954	10	11 160	8 558–14 379
	Southern elephant seal	3	271	143–446	3	267	141–451
Small dolphins	Bottlenose dolphin	5	1 501	916–2 390	5	1 640	1 080–2 468
	Common dolphin	2	19 427	8 728–37 919	2	19 051	8 658–35 367
	Dusky dolphin	3	25 109	11 045–51 360	3	19 673	12 041–32 995
	Hector's dolphin	10	10 389	4 581–20 294	10	9 926	4 334–19 274
	Hourglass dolphin	2	4 461	13–2 082	2	2 629	10–2 341
	Māui dolphin	8	67	48–92	8	66	47–90
	Southern right whale dolphin	1	3 251	846–8 834	1	3 311	844–8 944
Large dolphins	False killer whale	4	394	178–779	5	361	175–674
	Killer whale	5	253	125–455	5	240	118–419
	Long-finned pilot whale	2	3 641	536–12 604	2	3 807	955–10 115
	Short-finned pilot whale	2	2 149	300–8 022	2	1 485	569–3 151
Beaked whales	Andrews' beaked whale	0		–	0		–
	Cuvier's beaked whale	1	5 136	1 653–12 293	1	5 056	1 622–12 124
	Dense-beaked whale	0		–	0		–
	Gray's beaked whale	1	3 232	456–10 832	1	3 174	447–11 346
	Hector's beaked whale	0		–	0		–
	Shepherd's beaked whale	0		–	0		–
	Southern bottlenose whale	0		–	0		–
	Spade-toothed whale	0		–	0		–
	Strap-toothed whale	1	3 170	449–10 839	1	3 177	452–11 396
Whales	Antarctic blue whale	2	69	18–130	2	67	28–134
	Antarctic minke whale	2	293	75–761	2	312	97–761
	Bryde's whale	6	153	60–291	7	151	67–266
	Dwarf minke whale	2	160	58–331	2	140	53–299
	Fin whale	2	87	26–217	2	84	26–203
	Humpback whale	4	1 449	33–7 783	4	4 317	4–6 101
	Pygmy blue whale	3	192	97–344	3	202	111–337
	Pygmy right whale	1	196	42–545	1	78	17–229
	Pygmy sperm whale	2	151	35–318	2	181	51–472
	Sei whale	2	1 154	10–2 323	2	1 035	7–2 719
	Southern right whale	6	2 194	1 618–2 909	7	2 162	1 620–2 820
	Sperm whale	4	285	153–502	4	242	139–401

Table 7: Summary of the posterior prediction (posterior mean, and 95% credible interval) from the consensus distributions of expert answers about maximum population growth rate, r_{max}, of marine mammal taxa found in New Zealand waters. Data shown are from the first and second round of the Delphi survey for the different marine mammal taxa.

Species group	Species	First round			Second round		
		Answers	Mean	95% c.i.	Answers	Mean	95% c.i.
Pinnipeds	New Zealand fur seal	5	10.4	6.4–15.3	7	10.7	7.2–14.8
	New Zealand sea lion	4	9.7	6.6–13.5	5	9.2	6.5–12.5
	Southern elephant seal	0		–	1	12.6	9.0–16.8
Small dolphins	Bottlenose dolphin	0		–	1	5.2	2.3–10.0
	Common dolphin	1	2.6	0.8–5.9	2	4.0	1.9–7.2
	Dusky dolphin	1	4.2	1.5–9.3	2	4.8	2.5–8.2
	Hector's dolphin	6	2.5	1.7–3.5	7	2.6	1.8–3.6
	Hourglass dolphin	0		–	1	4.1	1.6–8.6
	Māui dolphin	4	2.1	1.4–3.1	5	2.3	1.5–3.4
	Southern right whale dolphin	0		–	1	4.1	1.6–8.5
Large dolphins	False killer whale	0		–	1	4.1	1.6–8.3
	Killer whale	1	1.9	0.8–3.8	2	2.6	1.2–4.9
	Long-finned pilot whale	0		–	1	4.1	1.6–8.6
	Short-finned pilot whale	0		–	1	4.1	1.6–8.6
Beaked whales	Andrews' beaked whale	0		–	1	4.1	1.6–8.5
	Cuvier's beaked whale	0		–	1	4.1	1.6–8.7
	Dense-beaked whale	0		–	1	4.1	1.6–8.5
	Gray's beaked whale	0		–	1	4.1	1.6–8.5
	Hector's beaked whale	0		–	1	4.1	1.6–8.6
	Shepherd's beaked whale	0		–	1	4.1	1.6–8.3
	Southern bottlenose whale	0		–	1	4.1	1.6–8.6
	Spade-toothed whale	0		–	1	4.1	1.6–8.6
	Strap-toothed whale	0		–	1	4.1	1.6–8.4
Whales	Antarctic blue whale	2	4.3	1.5–9.6	3	4.0	2.0–7.1
	Antarctic minke whale	0		–	1	4.1	1.6–8.5
	Bryde's whale	2	4.9	2.2–9.3	3	4.4	2.4–7.3
	Dwarf minke whale	0		–	1	4.1	1.6–8.5
	Fin whale	1	2.6	0.8–6.1	2	3.8	2.0–6.5
	Humpback whale	3	9.4	5.2–14.2	4	8.7	5.1–12.8
	Pygmy blue whale	3	4.4	2.0–8.4	4	4.1	2.2–7.0
	Pygmy right whale	0		–	1	4.1	1.6–8.9
	Pygmy sperm whale	1	4.1	1.6–8.5	2	3.9	2.0–6.8
	Sei whale	1	2.6	1.3–4.7	2	3.0	1.6–5.2
	Southern right whale	5	7.1	4.9–9.7	6	6.8	4.6–9.4
	Sperm whale	4	1.2	0.6–2.4	5	1.7	0.5–4.8

Table 8: Population size and maximum annual growth rate (r_{max}) used for calculating the Population Sustainability Threshold (PST) for New Zealand marine mammals. Included for both population parameters are the mean, 95% confidence interval (c.i.) and coefficient of variation (CV). Also included are the 20th percentile of the population size and the r_{max} values from Wade (1998). Population information was obtained in a Delphi survey of experts, except where footnotes indicate another data source. Footnotes also indicate estimates derived from a single response in the Delphi survey.

Species group	Species	New Zealand population				r_{max}			
		Mean	95% c.i.	CV	20th perc.	Mean	95% c.i.	CV	Default
Pinnipeds	New Zealand fur seal	126 945	64 620–220 998	0.30	97 838	0.107	0.072–0.148	0.19	0.12
	New Zealand sea lion	11 188	8 793–13 675	0.12	10 038	0.092	0.065–0.126	0.17	0.12
	Southern elephant seal	270	149–467	0.30	205	0.126[c]	0.090–0.168	0.16	0.12
Small dolphins	Bottlenose dolphin	1 576	1 081–2 318	0.18	1 373	0.053[c]	0.024–0.100	0.38	0.04
	Common dolphin	18 145	9 669–33 726	0.33	12 757	0.040	0.018–0.072	0.39	0.04
	Dusky dolphin	19 129	11 973–32 284	0.29	14 853	0.047	0.025–0.082	0.34	0.04
	Hector's dolphin	14 883[a]	12 235–18 548	0.11	13 583	0.026	0.018–0.036	0.19	0.04
	Hourglass dolphin	1 997[b]	108–7 886	1.02	277	0.041[c]	0.016–0.087	0.46	0.04
	Māui dolphin	67	50–85	0.15	59	0.023	0.015–0.034	0.22	0.04
	Southern right whale dolphin	3 593[c]	917–9 767	0.65	1 758	0.041[c]	0.016–0.084	0.44	0.04
Large dolphins	False killer whale	354	175–663	0.59	249	0.041[c]	0.016–0.084	0.45	0.04
	Killer whale	236	117–395	0.34	176	0.026	0.012–0.050	0.47	0.04
	Long-finned pilot whale	3 746	705–18 012	1.05	1 557	0.041[c]	0.016–0.085	0.44	0.04
	Short-finned pilot whale	1 551	599–3 512	0.46	967	0.041[c]	0.016–0.086	0.47	0.04
Beaked whales	Andrews' beaked whale	2 198	114–8 879	1.16	237	0.041[c]	0.016–0.085	0.45	0.04
	Cuvier's beaked whale	5 523[c]	1 656–12 621	0.52	3 241	0.041[c]	0.016–0.089	0.47	0.04
	Dense-beaked whale	2 074[d]	124–9 084	1.18	270	0.041[c]	0.017–0.084	0.46	0.04
	Gray's beaked whale	3 324[c]	457–11 020	0.85	1 196	0.041[c]	0.017–0.086	0.46	0.04
	Hector's beaked whale	2 530[d]	116–9 403	1.15	249	0.041[c]	0.016–0.086	0.45	0.04
	Shepherd's beaked whale	2 197[d]	114–8 218	1.11	335	0.041[c]	0.016–0.084	0.46	0.04
	Southern bottlenose whale	2 132[d]	112–8 698	1.15	267	0.041[c]	0.016–0.085	0.46	0.04
	Spade-toothed whale	2 258[d]	118–8 459	1.07	347	0.041[c]	0.016–0.086	0.46	0.04
	Strap-toothed whale	3 150[c]	409–8 885	0.78	1 240	0.041[c]	0.016–0.084	0.46	0.04
Whales	Antarctic blue whale	67	30–120	0.35	47	0.040	0.020–0.071	0.36	0.04
	Antarctic minke whale	318	104–883	0.84	179	0.041[c]	0.016–0.088	0.47	0.04
	Bryde's whale	145	58–240	0.32	112	0.044	0.023–0.073	0.31	0.04
	Dwarf minke whale	144	52–351	0.70	83	0.041[c]	0.016–0.084	0.45	0.04
	Fin whale	84	25–279	0.65	48	0.038	0.020–0.065	0.33	0.04
	Humpback whale	4 253[e]	3 354–5 193	0.11	3 834	0.087	0.050–0.128	0.24	0.04
	Pygmy blue whale	202	127–311	0.26	158	0.041	0.022–0.070	0.30	0.04
	Pygmy right whale	81[c]	19–373	1.00	39	0.041[c]	0.016–0.088	0.47	0.04
	Pygmy sperm whale	169	38–404	0.55	89	0.039	0.020–0.068	0.33	0.04
	Sei whale	2 473[b]	114–9 042	1.08	286	0.030	0.016–0.051	0.33	0.04
	Southern right whale	2 152	1 641–2 644	0.12	1 942	0.068	0.045–0.095	0.18	0.04
	Sperm whale	250	156–583	0.36	193	0.018	0.005–0.048	0.89	0.04

[a] Data from South Island aerial surveys (MacKenzie & Clement 2014, 2016) were used.
[b] Delphi estimate had high variance, so a default range (log-uniform between 100 and 10 000) was used.
[c] Derived from a single Delphi response.
[d] No Delphi estimate was provided, so a default range (log-uniform between 100 and 10 000) was used.
[e] Delphi estimate had high variance, so estimate by Constantine et al. (2012) was used.

Table 9: Population Sustainability Threshold (PST) of marine mammal populations in New Zealand. Shown are mean values, with 95% credible interval (c.i.) and coefficient of variation (CV).

Species group	Species	Expert opinion		
		Mean	95% c.i.	CV
Beaked whales	Andrews' beaked whale	22.4	0.9–104.4	1.36
	Cuvier's beaked whale	56.7	12.5–166.5	0.75
	Dense-beaked whale	21.3	0.9–103.7	1.37
	Gray's beaked whale	34.3	3.7–134.1	1.07
	Hector's beaked whale	26.0	0.9–119.0	1.36
	Shepherd's beaked whale	22.4	0.9–103.9	1.30
	Southern bottlenose whale	22.1	0.9–104.1	1.35
	Spade-toothed whale	23.0	0.8–104.6	1.27
	Strap-toothed whale	32.1	3.4–113.3	0.96
Large dolphins	False killer whale	3.6	1.1–9.8	0.81
	Killer whale	1.5	0.5–3.6	0.58
	Long-finned pilot whale	37.9	5.7–159.0	1.25
	Short-finned pilot whale	16.0	3.9–42.9	0.68
Pinnipeds	New Zealand fur seal	3 393.7	1 644.0–6 414.0	0.36
	New Zealand sea lion	257.6	168.9–379.8	0.21
	Southern elephant seal	8.5	4.2–16.0	0.34
Small dolphins	Bottlenose dolphin	20.7	8.1–42.5	0.43
	Common dolphin	183.3	60.7–408.3	0.54
	Dusky dolphin	227.8	95.4–477.8	0.45
	Hector's dolphin	95.4	61.7–143.0	0.22
	Hourglass dolphin	20.7	0.8–87.6	1.22
	Māui dolphin	0.4	0.2–0.6	0.27
	Southern right whale dolphin	36.9	6.9–121.2	0.86
Whales	Antarctic blue whale	0.7	0.2–1.5	0.51
	Antarctic minke whale	3.3	0.6–11.1	1.07
	Bryde's whale	1.6	0.5–3.2	0.45
	Dwarf minke whale	1.5	0.3–4.5	0.89
	Fin whale	0.8	0.2–2.5	0.78
	Humpback whale	93.1	52.3–143.7	0.26
	Pygmy blue whale	2.1	0.9–4.2	0.42
	Pygmy right whale	0.8	0.1–3.4	1.23
	Pygmy sperm whale	1.7	0.3–4.5	0.67
	Sei whale	18.6	0.8–73.7	1.18
	Southern right whale	36.7	22.8–53.6	0.22
	Sperm whale	1.1	0.3–3.4	0.94

Table 10: Number of observed captures of marine mammals in New Zealand's Exclusive Economic Zone between the fishing years 1995–96 and 2014–15, by species and fishing method. The latter included trawl, surface longline (SLL), set net (SN), bottom longline (BLL), and purse seine (PS). For each taxon and fishing method, the total number of observed captures and the percentage that were released alive are shown.

Species	Trawl		SLL		SN		BLL		PS		All
	All	Live (%)	All	Live (%)	All	Live (%)	All	Live (%)	All	Live (%)	
New Zealand fur seal	2 273	12.7	692	94.4	39	7.7	4	25.0	1	0.0	3 009
New Zealand sea lion	298	8.4	1	100.0							299
Common dolphin	206	1.0	3	66.7	6	0.0					215
Pilot whale long-finned	16	0.0	2	100.0	1	100.0	3	33.3			22
Dusky dolphin	10	0.0	2	100.0	6	0.0					18
Hector's dolphin	1	0.0			15	20.0					16
Unidentified whale			3	100.0							3
Unidentified beaked whale			3	100.0							3
Leopard seal	1	0.0									1
Bottlenose dolphin	1	0.0	2	100.0							3
Unidentified pinniped	1	0.0									1
Humpback whale			1	100.0							1
Unidentified toothed whale			1	100.0							1
Unidentified dolphin			1	100.0							1
Elephant seal	1	0.0									1
All	2 808		711		67		7		1		3 594

with all but one capture recorded in trawl fisheries. Amongst the cetacean species reported by observers, common dolphin was the most frequently caught species (215 captures), predominantly in trawl fisheries. Other cetaceans, but markedly fewer observed captures, included long-finned pilot whale, dusky dolphin, Hector's dolphin, and bottlenose dolphin. There was one recorded capture of humpback whale (in surface longlining) and one capture of an elephant seal (in trawl). There was one capture of a leopard seal (*Hydrurga leptonyx*). Leopard seal are vagrant in New Zealand waters, and this species was not included in the current assessment.

Most marine mammals caught in surface-longline fisheries (92.1% of all captures) were released alive (Table 10), whereas in other fisheries, most animals that were observed caught were dead. In trawl fisheries, 11.2% of marine mammal captures that were observed caught were released alive, while in set-net fisheries, 10.4% of marine mammals that were observed caught were released alive.

Since the 2008–09 fishing year, fishers have reported marine mammal captures on the non-fish/protected species catch return (NFPSCR). The data were not useful for the estimation, as the reporting is not reliable; however, they provide an insight into the impact of fisheries on marine mammals (Table 11). Between 2008–09 and 2014–15, fishers reported captures of two humpback whale, one minke whale, and an unidentified baleen whale. Common dolphin were reported caught in trawl, set-net, purse-seine, surface-longline, and bottom-longline fisheries. In set-net fisheries, there were 18 captures of common dolphin, even though there have been no observer records of common dolphin in set-net fisheries. In purse seine, there were four capture events reported by fishers, involving a total of 21 dolphins. Although dolphin captures are commonly reported in purse-seine fisheries elsewhere (e.g., González-But & Sepúlveda 2016), they have not been recorded during observed purse-seine fishing in New Zealand. There was also a killer whale reported killed during pot fishing for rock lobster (*Jasus edwardsii*). Entanglement of killer whale in rock lobster pots have been reported in the media[2]; however, the fisher-reported capture is the only formal report to MPI.

Expert review of unidentified marine captures in COD identified three captures of beaked whales, and one capture of an unidentified toothed whale (Table 12). Observer comments indicated that the unidentified toothed whale capture was either a pilot whale, a false killer whale, or a melon-headed whale, and this capture was assigned to the large dolphins group. A capture was recorded by an observer as a porpoise,

[2]e.g., http://www.stuff.co.nz/environment/87601011/Harbourmaster-stood-down-after-helping-to-save-orca

Table 11: Fisher-reported marine mammal captures for the period between 2008–09 and 2014–15, reported on the non-fish/protected species catch return form (NFPSCR; the form was introduced in October 2008). Included are the number of fishing events with captures, the number of captures, and the percentage of captures that were released alive, for each taxon and fishing method. Reported captures with fishing method indicated as unknown could not be directly linked to fishing effort records.

Method	Species	Capture events	Captures	
			All	Live (%)
Trawl	New Zealand fur seal	1 175	1 468	13.3
	Common dolphin	75	140	2.1
	New Zealand sea lion	54	66	16.7
	Unidentified pinniped	44	52	19.2
	Long-finned pilot whale	3	7	0.0
	Unidentified dolphin or toothed whale	5	5	0.0
	Bottlenose dolphin	4	4	0.0
	Unidentified dolphin	3	3	0.0
	Dusky dolphin	2	2	0.0
	Leopard seal	1	1	0.0
Surface longline	New Zealand fur seal	207	269	92.9
	Unidentified pinniped	62	102	83.3
	Common dolphin	4	4	50.0
	Long-finned pilot whale	2	2	100.0
	Bottlenose dolphin	2	2	100.0
	Minke whale	1	1	100.0
	Humpback whale	1	1	100.0
Set net	New Zealand fur seal	75	81	6.2
	Common dolphin	18	18	0.0
	Hector’s dolphin	9	9	11.1
	Unidentified pinniped	8	8	0.0
	Dusky dolphin	5	5	0.0
	Unidentified dolphin or toothed whale	3	3	0.0
	Humpback whale	1	1	100.0
	Unidentified baleen whale	1	1	100.0
Unknown	New Zealand fur seal	33	40	50.0
	Long-finned pilot whale	5	6	100.0
	Common dolphin	2	2	50.0
	Dusky dolphin	1	1	0.0
Purse seine	Common dolphin	4	21	33.3
Bottom longline	Common dolphin	3	3	66.7
	Unidentified pinniped	1	1	0.0
Troll	New Zealand fur seal	1	1	100.0
Lobster pot	Killer whale	1	1	0.0

Table 12: Review of unidentified marine mammal captures in the Centralised Observer Database (COD). All captures of marine mammals that were recorded by the observer as "unidentified" or as "porpoise" were reviewed by Ministry for Primary Industries. Shown is the status of the captures following review.

Observer identification	Reviewed identification	Number
Unidentified whale	Unidentified whale	3
Unidentified whale	Unidentified beaked whale	3
Unidentified whale	Unidentified toothed whale	1
Porpoise	Unidentified dolphin	1
Unidentified pinniped	Unidentified pinniped	1

Table 13: Annual fishing effort between 2012–13 and 2014–15, and total observed effort between 1995–96 and 2014–15 for different commercial fisheries in New Zealand waters. Effort was measured as number of events for trawl and purse seine (PS), thousands of hooks for surface (SLL) and bottom longline (BLL), and kilometres of net for set net (SN). Trawl fisheries were distinguished by target fishery and the use of a sea lion exclusion device (SLED).

Method	Fishery	Annual effort	Observed effort
Bottom longline	BLL	37 569	65 131
Purse seine	PS	1 285	1 481
Surface longline	SLL	2 611	18 299
Set net	SN	20 558	4 823
Trawl	Pelagic trawl	2 344	17 978
	Pelagic trawl (SLED)	547	1 645
	Squid trawl	1 417	20 917
	Squid trawl (SLED)	799	8 535
	Inshore trawl	48 344	9 523
	Other trawl	29 100	105 772

but in their comments they noted "Slow fishing again 1 dolphin possibly hectors caught early evening, line cut once identified". The capture was reported in the 2002–03 fishing year, in the surface-longline fishery to the north of New Zealand, beyond the edge of the continental shelf (at 33.375° S, 173.475° E). The record was outside the geographical and depth ranges of Hector's dolphin; following review, it was classified as an unidentified dolphin capture. There remained three unidentified whale captures, which lacked further information. These records may have been any species from the large dolphins, beaked whales, or whales species groups.

Both fishing effort and observer coverage varied greatly across the different fisheries (Table 13). For the period between 2012–13 and 2014–15, inshore trawling had the highest annual fishing effort, compared with trawl fisheries targeting squid, pelagic, and other species (see target fisheries in Table 5). The observed fishing effort in the model data set was higher than the annual effort for all of the fisheries groups, apart from inshore trawl and set net.

For most fishing methods, relatively little of the effort required an imputed position (Table 14). The exception was set-net effort, as only half of this effort had a position. Rig and shark set-net effort could be imputed based on the statistical area and the fishery, while flatfish and mullet set-net effort was allocated to shallow water and harbours (around one-third of all set-net effort was in this category). After carrying out the imputation, around 3% of the set-net effort was not allocated, and was, therefore, not included in the risk assessment.

Table 14: Fishing effort with imputed locations, by method. Shown are the total effort, effort reported with location, effort imputed by sampling from fishing with the same target fishery and statistical area, effort allocated to harbours, and effort that remained with a missing location. Effort is represented as annual effort, by number of events for trawl and purse seine (PS), thousands of hooks for surface (SLL) and bottom longline (BLL), and kilometres of net for set net (SN).

Method	Total	Located	Imputed by fishery-area	Allocated to harbours	Missing location
Trawl	82 551	81 873	677		< 1
Bottom longline	37 570	36 988	580		3
Set net	20 559	10 198	2 016	7 672	672
Surface longline	2 611	2 610	< 1		
Purse seine	1 285	1 147	138		

Table 15: Summary of model selection. Included for each model structure are the mean and standard error (s.e.) of the LOOIC (leave-one-out information criterion). Model structures were based on the fishery, the species group of the marine mammal taxon, and the marine mammal species. Models with a lower LOOIC are expected to derive more accurate out-of-sample estimates of observed captures.

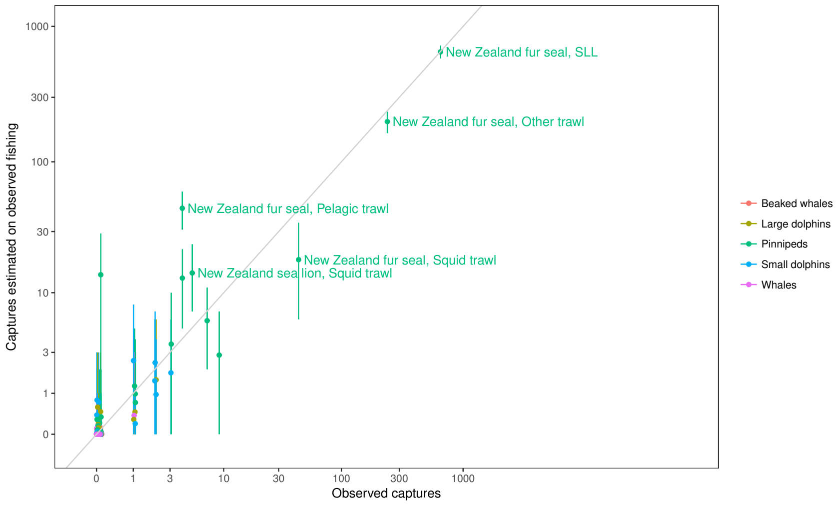
Model structure	LOOIC mean	LOOIC s.e.
Fishery x Species group x Species	1 898	774
Fishery x Species	1 921	773
(Fishery x Species group) + Species	3 133	1 001
Fishery x Species group	5 628	1 522

3.3 Model selection and model fit

Of the different vulnerability structures, the model with the lowest LOOIC had a fishery group by species group fixed effect, with a fishery group by species random effect (Table 15). Although the simpler model with only a fishery group by species effect had a similar LOOIC to the best model, when the model selection was carried out independently on each of the 100 models fitted to draws from the overlap and population size, the best model was selected 96 times. On this basis, the model with fishery group, species group, and species levels to the vulnerability was chosen as the most adequate model. The LOOIC calculation is an approximation to a leave-one-out estimate of the predictive skill of the model. During calculation of the LOOIC from the best model, 57.1% Pareto-k estimates were greater than one, indicating that the conditions needed for making an accurate approximation were not satisfied (Vehtari et al. 2016a, 2016b). This outcome is likely caused by the sporadic nature of fisheries bycatch, which makes model selection difficult.

To assess the fit of the model, the observed captures were compared with the captures estimated by the model on the observed effort (Figure 4; following the nomenclature of the model code in Appendix A, the plots show a comparison between the input data (`LIVE`, `DEAD`), and the posterior predictions (`obs.alive`, `obs.dead`). There was close agreement between the model and the observations for both live and dead captures. An exception was the captures on tows with SLEDs. For New Zealand fur seal, there were fewer live captures on squid tows with SLEDs than were estimated by the model, but more dead captures on pelagic trawls with SLEDs than were estimated. This finding suggests that either the SLEDs are affecting fur seal captures, or the overlap is incorrectly specified (capture rates of New Zealand fur seal are high near Bounty Islands, and the model may be fitting these captures, causing poor fit to New Zealand fur seal captures in pelagic trawl near Campbell Island). There were also more captures of New Zealand sea lion on tows with SLEDs in pelagic trawl fishing than were estimated; this outcome may also either be owing to a different efficacy of SLEDs in pelagic and squid trawl, or to the overlap being incorrectly specified. The distributions from the Delphi survey assume uniform density within large areas. This is not appropriate for central place foragers. In the sea lion estimation model, for example, distance from colony is an important covariate (Thompson & Abraham 2011).

(a) Live captures



(b) Dead captures

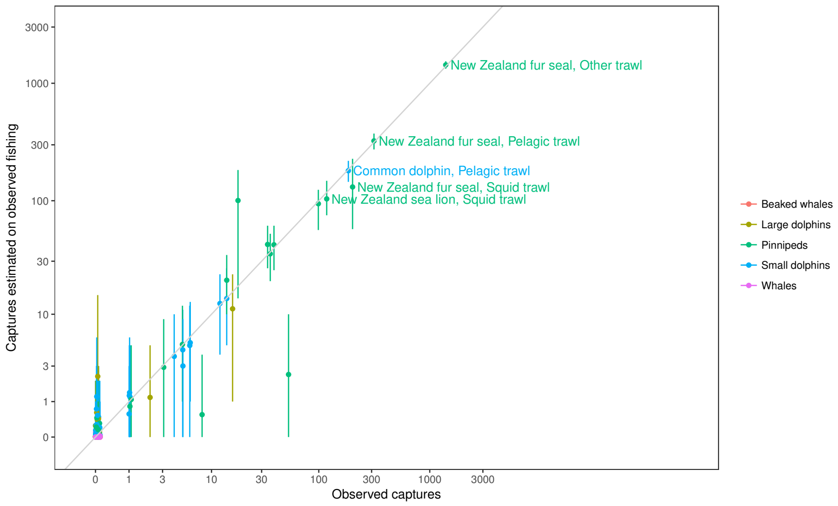


Figure 4: Comparison between observed captures and captures estimated on the observed fishing effort, for (a) live captures and (b) dead captures of the marine mammal species groups used in the present risk assessment (SLL, surface longlining). For each species-fisheries-group stratum, a point indicates the mean value, with the lines indicating the 95% credible interval of the posterior predictive distribution.

The probability a capture was identified reflected the observer data where captures had been recorded (see Appendix F, Table F-59, for a summary of the posterior distributions of all model parameters). The probability a capture was identified was close to one for pinnipeds, with a mean of over 90% for small dolphins and large dolphins. For beaked whales the identification probability was low (an upper credible interval of less than 50%), while for whales, there was little information and the posterior distribution reflected the prior. The probability that an incident is observable, and the post-release survival of live releases, remained close to the prior in all cases. The only information in the model that was potentially able to influence these parameters was the constraint that the annual potential fatalities were less than 20% of the population. This constraint had little (if any) influence on these parameters. If information on adult survival was available, either from field data or demographic modelling, then this could be used to specify a tighter constraint (as was done for a recent seabird risk assessment, e.g., Richard et al. 2017). The probability of live release was influenced by the model fitting, reflecting patterns evident in the data where information was available. The live-release probability was high for pinnipeds and dolphins in surface-longline fisheries, and lower for trawl and set-net fisheries. (Note that for this parameter, the grouping whales included large dolphins, beaked whales, and whales. Its low value was owing to observed captures of pilot whales.) The prior distribution of the sea lion SLED effect was a uniform distribution (between 0 and 1, see Table 2). The mean of the sea lion SLED effect remained close to the mean of the prior (50%), while the lower limit of the credible interval increased to around 30%. This parameter did not appear to have been well estimated by the risk assessment model—the SLED retention probability was estimated elsewhere as 0.148 (95% c.i.: 0.087 to 0.243), assuming a single SLED retention probability throughout the period (Abraham & Berkenbusch 2017). The estimation of the SLED effect in the risk assessment model did not affect the results, however, as capture estimates of sea lion in trawl fisheries used here were from the bycatch assessment by Abraham and Berkenbusch (2017) instead of estimates from the overlap model.

3.4 Estimated vulnerability

Across all fishery groups, pinniped species had the highest mean vulnerabilities (Figures 5, 6, Table F-59), and the highest vulnerabilities were in pelagic trawl, followed by squid trawl (Figure 5). The vulnerabilities of the small- and large-dolphin groups were similar in trawl fisheries, and the highest vulnerability was of common dolphin in pelagic trawl fishing. Among all trawl fisheries, vulnerability of marine mammals to capture was lowest in inshore trawl.

In bottom-longline fisheries, the highest vulnerabilities were of species in the large-dolphin group (Figure 6). The only observed captures in bottom-longline fisheries were of three pilot whale (see Table 10) and four New Zealand fur seal. Vulnerabilities in purse seine were similar across species groups, while in set net, the vulnerabilities of species in the pinniped, small- and large- dolphin groups were similar. Vulnerabilities to capture in surface-longline fisheries were higher than in bottom-longline fisheries. In surface-longline fisheries, New Zealand fur seal had the highest vulnerability, while the vulnerabilities of other pinnipeds, small dolphins, and large dolphins were similar. Across all fisheries, the vulnerabilities of whales and beaked whales were low.

The model estimates a random effect for each combination of fishery and species-leaf. The uncertainty in these random effects was high (the chains were correlated with the chains for the fishery vulnerability and the species-group vulnerability). The only random effect that was significantly different from one was the common-dolphin–pelagic-trawl random effect. This multiplicative effect had a mean of 72.9 (95% c.i.: 3.2 to 415.7), indicating that the capture rate in this stratum was higher than would be predicted from the product of the small-dolphins vulnerability and the pelagic trawl vulnerability.

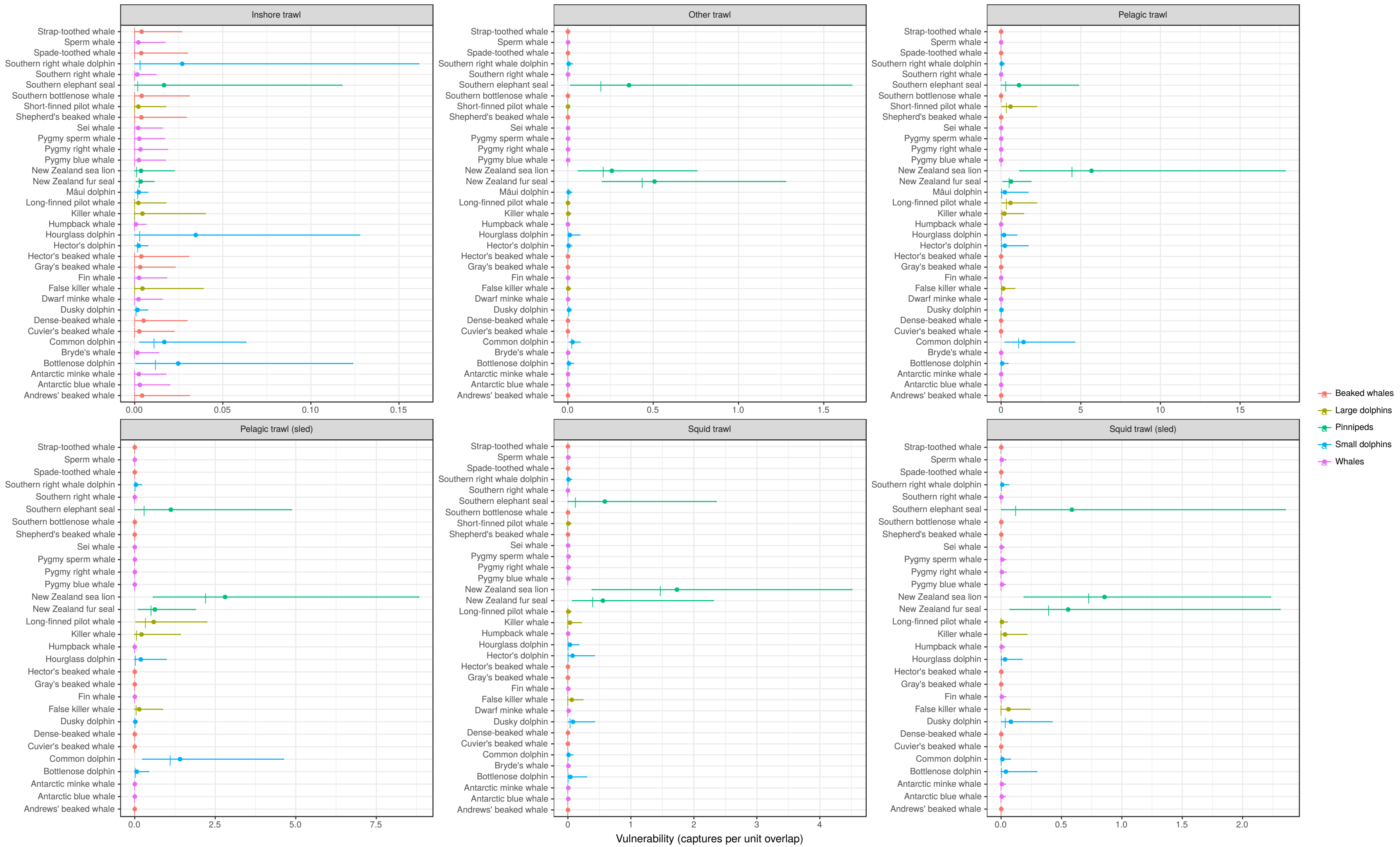


Figure 5: Estimated vulnerabilities of marine mammal taxa for trawl fisheries. Lines indicate the 95% credible interval, points mark the mean, and vertical bars indicate the median vulnerability. Taxa are in decreasing order of the mean vulnerability over all fishery groups. Trawl fisheries were distinguished by target fishery and the use of a sea lion exclusion device (SLED) (see Appendix F for values of the vulnerabilities).

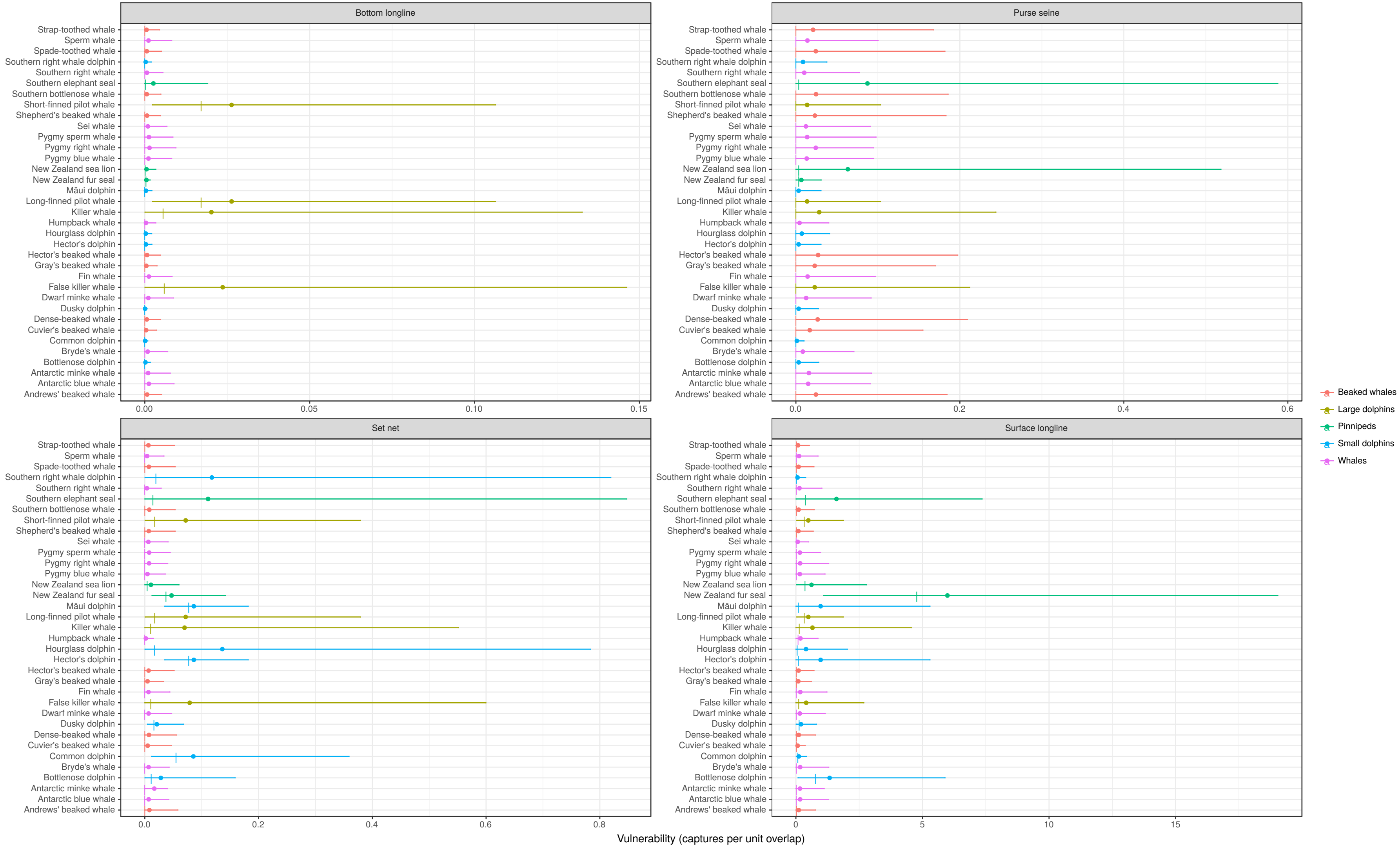


Figure 6: Estimated vulnerabilities of marine mammal taxa for longline, set-net and purse-seine fisheries. Lines indicate the 95% credible interval, points mark the mean, and vertical bars indicate the median vulnerability. Taxa are in decreasing order of the mean vulnerability over all fishery groups (see Appendix F for values of the vulnerabilities).

3.5 Estimated annual potential fatalities

The number of annual potential fatalities of any marine mammal in New Zealand fisheries was highest for New Zealand fur seal in trawl fisheries, followed by fur seal fatalities in set-net and surface-longline fisheries (Table 16, Figure 7). Other species and fisheries with a mean of more than ten annual potential fatalities included New Zealand sea lion in trawl fisheries; common dolphin in trawl fisheries; common dolphin in set-net fisheries; Hector's dolphin in set-net fisheries; and dusky dolphin in set-net fisheries. Dusky dolphin and Hector's dolphin were each estimated to have close to ten annual potential fatalities in trawl fisheries.

In the large-dolphins group, there were between one and five mean estimated annual potential fatalities of long-finned pilot whale in trawl, set-net and bottom-longline fisheries; of short-finned pilot whale in set-net and bottom-longline fisheries; and of false killer whale in set-net fisheries.

Estimated annual potential fatalities of species in the beaked whales and whales groups had a mean of 0.5 or less for all species and fisheries. For all species in these groups, and for all fisheries, the lower limit of the credible interval was zero.

For many marine mammal species, no captures have been observed (see Table 10). If the distribution of the species overlaps with poorly observed fisheries, then the estimated captures may be weakly constrained by the observations, allowing for a long right hand tail to the posterior distribution. For example, killer whale have estimated mean annual potential fatalities of 1.6, with a 95% credible interval of 0.0 to 9.5.

Figure 7: Estimated annual potential fatalities (APF) of each species by model fishery group. Lines indicate the 95% credible interval, points mark the mean, and vertical bars indicate the median of the posterior distribution of APF. Species are sorted alphabetically, and lines are coloured by fishing method.

Table 16: Estimated number of annual potential fatalities of marine mammals species within New Zealand's Exclusive Economic Zone in commercial trawl, set-net, surface-longline (SLL), bottom-longline (BLL), and purse-seine fisheries, by fishing method, between the fishing years 2012–13 and 2014–15 (inclusive). Cases where the mean and 95% credible interval (c.i.) limits were zero after rounding to one decimal place were left blank.

Species group	Species	Trawl		Set net		SLL		BLL		Purse seine		Total	
		Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Pinnipeds	New Zealand fur seal	569.9	345.0–917.0	236.5	97.0–517.6	138.6	19.0–314.0	2.5	0.4–7.3	1.5	0.0–5.5	948.9	610.9–1 401.6
	New Zealand sea lion	24.5	13.0–41.0	1.2	0.0–6.0	0.0	0.0–0.1	0.0	0.0–0.3		–	25.8	13.5–43.0
	Southern elephant seal	0.9	0.1–3.5	0.4	0.0–3.3	0.0	0.0–0.3	0.0	0.0–0.1	0.0	0.0–0.1	1.4	0.1–5.7
Small dolphins	Bottlenose dolphin	5.1	0.2–23.8	3.5	0.0–21.4	0.6	0.0–2.4	0.0	0.0–0.2	0.0	0.0–0.1	9.3	1.1–36.0
	Common dolphin	157.3	72.0–299.0	71.3	14.4–207.5	1.7	0.1–5.1	0.1	0.0–1.4	0.1	0.0–0.9	230.4	115.8–421.7
	Dusky dolphin	9.8	2.5–28.1	18.4	5.7–43.2	0.3	0.0–1.6	0.0	0.0–0.2	0.0	0.0–0.1	28.6	11.7–58.4
	Hector's dolphin	9.0	1.1–26.6	32.3	13.8–65.8	0.0	0.0–0.1	0.0	0.0–0.1		–	41.3	19.1–77.7
	Hourglass dolphin	0.8	0.0–6.3	0.9	0.0–6.1	0.0	0.0–0.3	0.0	0.0–0.1		–	1.7	0.0–11.2
	Māui dolphin	0.0	0.0–0.1	0.2	0.0–0.5		–		–		–	0.2	0.0–0.5
	Southern right whale dolphin	0.5	0.0–3.8	0.3	0.0–3.1	0.0	0.0–0.1		–		–	0.9	0.0–6.6
Large dolphins	False killer whale	0.2	0.0–1.2	1.1	0.0–9.1	0.1	0.0–0.8	0.5	0.0–3.4	0.0	0.0–0.3	1.9	0.0–10.8
	Killer whale	0.2	0.0–1.4	1.0	0.0–7.9	0.1	0.0–0.4	0.4	0.0–2.6	0.0	0.0–0.2	1.6	0.0–9.5
	Long-finned pilot whale	3.3	0.2–8.7	3.4	0.0–13.9	0.5	0.0–2.3	1.5	0.1–7.1	0.0	0.0–0.3	8.7	2.1–25.2
	Short-finned pilot whale	0.9	0.0–4.9	3.1	0.0–20.9	0.3	0.0–1.6	2.8	0.0–11.9	0.1	0.0–0.6	7.0	0.0–30.5
Beaked whales	Andrews' beaked whale	0.1	0.0–0.6	0.0	0.0–0.4	0.1	0.0–0.5	0.0	0.0–0.1	0.0	0.0–0.1	0.2	0.0–1.2
	Cuvier's beaked whale	0.2	0.0–1.3	0.1	0.0–0.9	0.1	0.0–0.8	0.0	0.0–0.1	0.0	0.0–0.2	0.4	0.0–2.4
	Dense-beaked whale	0.1	0.0–0.6	0.0	0.0–0.3	0.1	0.0–0.5	0.0	0.0–0.1	0.0	0.0–0.1	0.2	0.0–1.3
	Gray's beaked whale	0.3	0.0–2.4	0.1	0.0–1.0	0.2	0.0–1.1	0.0	0.0–0.1	0.0	0.0–0.1	0.6	0.0–3.8
	Hector's beaked whale	0.1	0.0–0.6	0.0	0.0–0.4	0.1	0.0–0.5	0.0	0.0–0.1	0.0	0.0–0.1	0.2	0.0–1.4
	Shepherd's beaked whale	0.1	0.0–0.6	0.0	0.0–0.3	0.1	0.0–0.5	0.0	0.0–0.1	0.0	0.0–0.1	0.2	0.0–1.2
	Southern bottlenose whale	0.1	0.0–0.6	0.0	0.0–0.3	0.1	0.0–0.5	0.0	0.0–0.1	0.0	0.0–0.1	0.2	0.0–1.2
	Spade-toothed whale	0.1	0.0–0.6	0.0	0.0–0.3	0.1	0.0–0.5	0.0	0.0–0.1	0.0	0.0–0.1	0.2	0.0–1.2
	Strap-toothed whale	0.1	0.0–0.8	0.1	0.0–0.6	0.1	0.0–0.6	0.0	0.0–0.1	0.0	0.0–0.1	0.3	0.0–1.6
Whales	Antarctic blue whale	0.0	0.0–0.1	0.0	0.0–0.1	0.0	0.0–0.1	0.0	0.0–0.1		–	0.0	0.0–0.3
	Antarctic minke whale	0.1	0.0–0.5	0.0	0.0–0.2	0.0	0.0–0.1	0.0	0.0–0.1	0.0	0.0–0.1	0.1	0.0–1.0
	Bryde's whale	0.0	0.0–0.3	0.1	0.0–0.9	0.0	0.0–0.1	0.0	0.0–0.3	0.0	0.0–0.1	0.2	0.0–1.6
	Dwarf minke whale	0.0	0.0–0.2	0.1	0.0–0.3	0.0	0.0–0.2	0.0	0.0–0.1	0.0	0.0–0.1	0.1	0.0–0.8
	Fin whale	0.0	0.0–0.1	0.0	0.0–0.2	0.0	0.0–0.1	0.0	0.0–0.1	0.0	0.0–0.1	0.1	0.0–0.5
	Humpback whale	0.4	0.0–3.8	0.3	0.0–3.3	0.4	0.0–2.1	0.1	0.0–0.8	0.1	0.0–0.7	1.4	0.0–6.6
	Pygmy blue whale	0.0	0.0–0.3	0.0	0.0–0.3	0.0	0.0–0.1	0.0	0.0–0.1	0.0	0.0–0.1	0.1	0.0–0.8
	Pygmy right whale	0.0	0.0–0.1		–	0.0	0.0–0.1		–		–	0.0	0.0–0.1
	Pygmy sperm whale	0.0	0.0–0.2	0.0	0.0–0.1	0.0	0.0–0.3	0.0	0.0–0.1	0.0	0.0–0.1	0.1	0.0–0.8
	Sei whale	0.1	0.0–0.5	0.0	0.0–0.3	0.0	0.0–0.2	0.0	0.0–0.1	0.0	0.0–0.1	0.1	0.0–0.9
	Southern right whale	0.2	0.0–1.3	0.1	0.0–0.8	0.0	0.0–0.1	0.0	0.0–0.2	0.0	0.0–0.2	0.3	0.0–2.2
	Sperm whale	0.1	0.0–0.5	0.0	0.0–0.3	0.0	0.0–0.1	0.0	0.0–0.1		–	0.1	0.0–0.9

In calculation of the risk, estimates of the annual potential fatalities of common dolphin, New Zealand fur seal, and New Zealand sea lion in trawl, and New Zealand fur seal in surface longline, were replaced with estimates from the bycatch assessment by Abraham and Berkenbusch (2017). The latter used a hierarchical generalised linear model specifically developed for individual species and methods that had sufficient captures to allow model development. In the absence of reliable marine mammal distributions, estimates from the capture estimation were considered to be more reliable than the estimates from the spatially explicit risk assessment methodology for these species and fisheries.

In most cases, the credible intervals of the estimated annual potential fatalities from the two approaches overlapped (Figure 8). For common dolphin in trawl fisheries, the mean estimate of annual potential fatalities in the bycatch assessment was about twice the value estimated in the current study, with a mean 157 (95% c.i.: 71 to 301) annual potential fatalities estimated by Abraham and Berkenbusch (2017) compared with 77 (95% c.i.: 44 to 128) annual potential fatalities estimated in the present study. For fur seal in trawl fisheries, the estimate from the bycatch assessment was about one-third of the value in the current risk assessment, with an estimated 570 (95% c.i.: 343 to 927; Abraham & Berkenbusch 2017) compared with 1592 (95% c.i.: 912 to 2505; present study) annual potential fatalities of fur seal. The variation between these estimates, made using the same underlying observer data, indicates the effect of the structural assumptions of the modelling on the estimated annual potential fatalities.

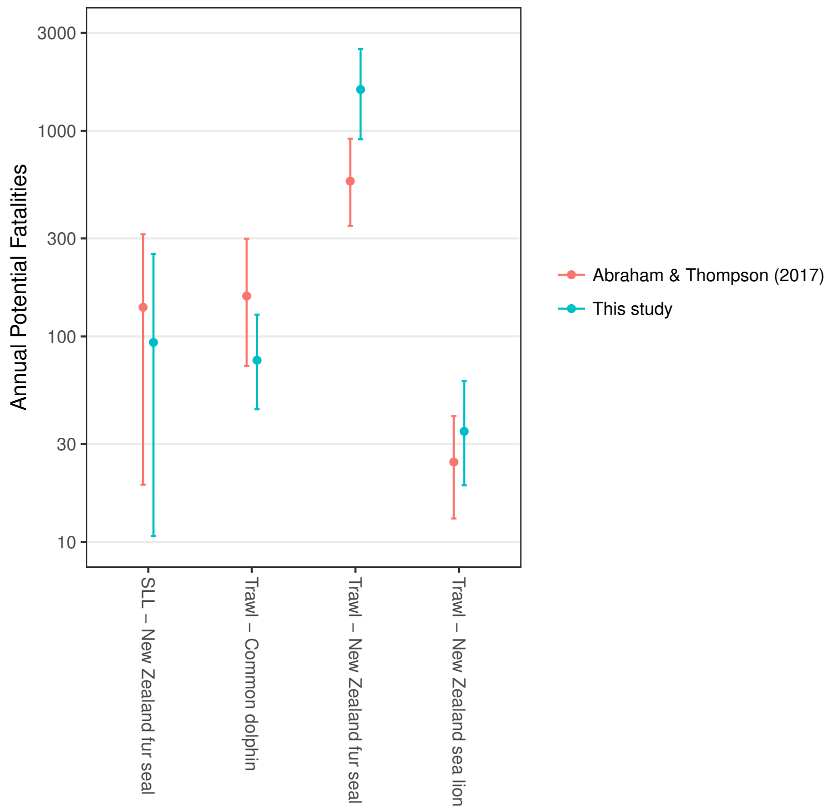


Figure 8: Comparison of estimates of annual potential fatalities (APF) from this study, and derived from the capture estimation by Abraham and Berkenbusch (2017). For each method and species, the lines indicate the 95% credible interval of the estimates, and the dots mark the mean estimate (SLL, surface longline).

3.6 Estimated risk

The risk ratio derived from the ratio of the annual potential fatalities to the PST allowed a ranking of the different marine mammal taxa by risk (Table 17, Figure 9). For cetaceans, common dolphin had the highest mean risk ratio, with a mean of 1.61 (95% c.i.: 0.43 to 4.47). Killer whale was the only other species with a mean risk ratio higher than one (1.28, 95% c.i.: 0.00 to 7.55). It is notable that, despite the high mean risk ratio of killer whale, the lower bound of the uncertainty was zero (indicating the possibility of no captures in any of the fisheries included in the model over a 20-year time period). Common dolphin was the only species with a median risk ratio higher than one (Figure 9), for all other species both the mean and the median risk ratios were less than one. Of the pinnipeds, the highest risk ratio was for New Zealand fur seal, with a mean of 0.31 (95% c.i.: 0.13 to 1.64). The median risk of all species in the beaked whales and whales groups was less than 0.2.

Many other species also had risk ratios with high uncertainties (CVs of 2 or higher), indicating skewed distributions. These skewed distributions were associated both with uncertain estimates of the annual potential fatalities, and also with uncertain estimates of the population size. The CV of the estimated risk of all beaked whales was higher than 2, and the CV of the estimated risk of all whale species (other than humpback whale) was higher than two. All small dolphins (other than Dusky dolphin, Hector’s dolphin and southern right whale dolphin), all large dolphins, Bryde’s whale, and sperm whale had the upper credible interval of the risk ratio above one. All beaked whales, all whales, hourglass dolphin, Māui dolphin, southern right whale dolphin, false killer whale, killer whale, and short-finned pilot whale, had the lower limit of the credible interval at zero.

The risk ratio for Hector’s dolphin was entirely below one, with a mean value of 0.45 (95% c.i.: 0.18 to 0.92), but this risk estimate was for the entire New Zealand population. For Hector’s dolphin, the overlap with set-net fisheries was largely on the East Coast of the South Island (over 99% of the overlap, Table 18). Based on the total annual potential fatalities from set-net fishing, the size of the East Coast South Island sub-population, and the ratio of the overlap with set-net fisheries in this area to the total overlap with set-net fisheries, it was estimated that the mean risk from set-net fishing to the East Coast South Island sub-population was 0.59 (95% c.i.: 0.21 to 1.33). Although the mean risk was less than one, the 95% credible interval exceeded one. Given the assumptions of the assessment, there was a 9.4% probability that Hector’s dolphin fatalities from set-net fishing on the East Coast South Island exceeded the PST of the sub-population in this area.

Within the East Coast South Island area, 55.4% of the Hector’s dolphin population was within set-net exclusion areas during the summer survey. Using the distribution from the winter survey, when Hector’s dolphin were further offshore, 23.7% of the population were within set-net exclusion areas.

Table 17: Risk ratios for New Zealand marine mammals. The risk ratio is the number of annual potential fatalities in fisheries to the Population Sustainability Threshold (PST) for each marine mammal population in New Zealand, using PST values based on expert opinion. Shown are mean values, with 95% credible interval (c.i.) and coefficient of variation (CV).

Species group	Species	Risk ratio		
		Mean	95% c.i.	CV
Pinnipeds	New Zealand fur seal	0.31	0.13–0.64	0.42
	New Zealand sea lion	0.10	0.05–0.19	0.37
	Southern elephant seal	0.18	0.01–0.77	1.50
Small dolphins	Bottlenose dolphin	0.53	0.05–2.22	1.37
	Common dolphin	1.61	0.43–4.47	0.84
	Dusky dolphin	0.15	0.04–0.38	0.65
	Hector's dolphin	0.45	0.18–0.92	0.43
	Hourglass dolphin	0.20	0.00–1.32	4.52
	Māui dolphin	0.47	0.00–1.33	0.73
	Southern right whale dolphin	0.03	0.00–0.23	3.06
Large dolphins	False killer whale	0.70	0.00–4.21	2.12
	Killer whale	1.28	0.00–7.55	2.21
	Long-finned pilot whale	0.38	0.04–1.48	1.26
	Short-finned pilot whale	0.56	0.00–2.65	1.53
Beaked whales	Andrews' beaked whale	0.02	0.00–0.11	5.35
	Cuvier's beaked whale	0.01	0.00–0.06	2.54
	Dense-beaked whale	0.02	0.00–0.11	6.94
	Gray's beaked whale	0.03	0.00–0.18	3.73
	Hector's beaked whale	0.01	0.00–0.10	4.23
	Shepherd's beaked whale	0.01	0.00–0.10	4.12
	Southern bottlenose whale	0.02	0.00–0.11	4.73
	Spade-toothed whale	0.02	0.00–0.11	4.01
	Strap-toothed whale	0.01	0.00–0.08	5.65
Whales	Antarctic blue whale	0.06	0.00–0.46	5.24
	Antarctic minke whale	0.06	0.00–0.36	8.02
	Bryde's whale	0.17	0.00–1.16	4.36
	Dwarf minke whale	0.09	0.00–0.69	4.50
	Fin whale	0.09	0.00–0.71	4.64
	Humpback whale	0.02	0.00–0.08	1.73
	Pygmy blue whale	0.06	0.00–0.43	4.24
	Pygmy right whale	0.02	0.00–0.18	6.42
	Pygmy sperm whale	0.07	0.00–0.51	4.26
	Sei whale	0.01	0.00–0.10	3.80
	Southern right whale	0.01	0.00–0.06	4.37
	Sperm whale	0.16	0.00–1.18	4.34

Table 18: Protection of Hector's dolphin sub-populations from set-net fishing. For the three main Hector's dolphin sub-populations, the table shows the mean population size (MacKenzie & Clement 2014, 2016), the percentage of the total overlap with set-net fishing, and the proportion of the population within set-net exclusion areas in summer and winter.

Region	Population size	Set-net overlap (%)	Proportion protected (%)	
			Summer	Winter
South Coast South Island	238	0.1	88.7	88.7
West Coast South Island	5 642	0.8	50.6	34.2
East Coast South Island	8 968	99.1	55.4	23.7
All	14 849	100.0	54.6	30.8

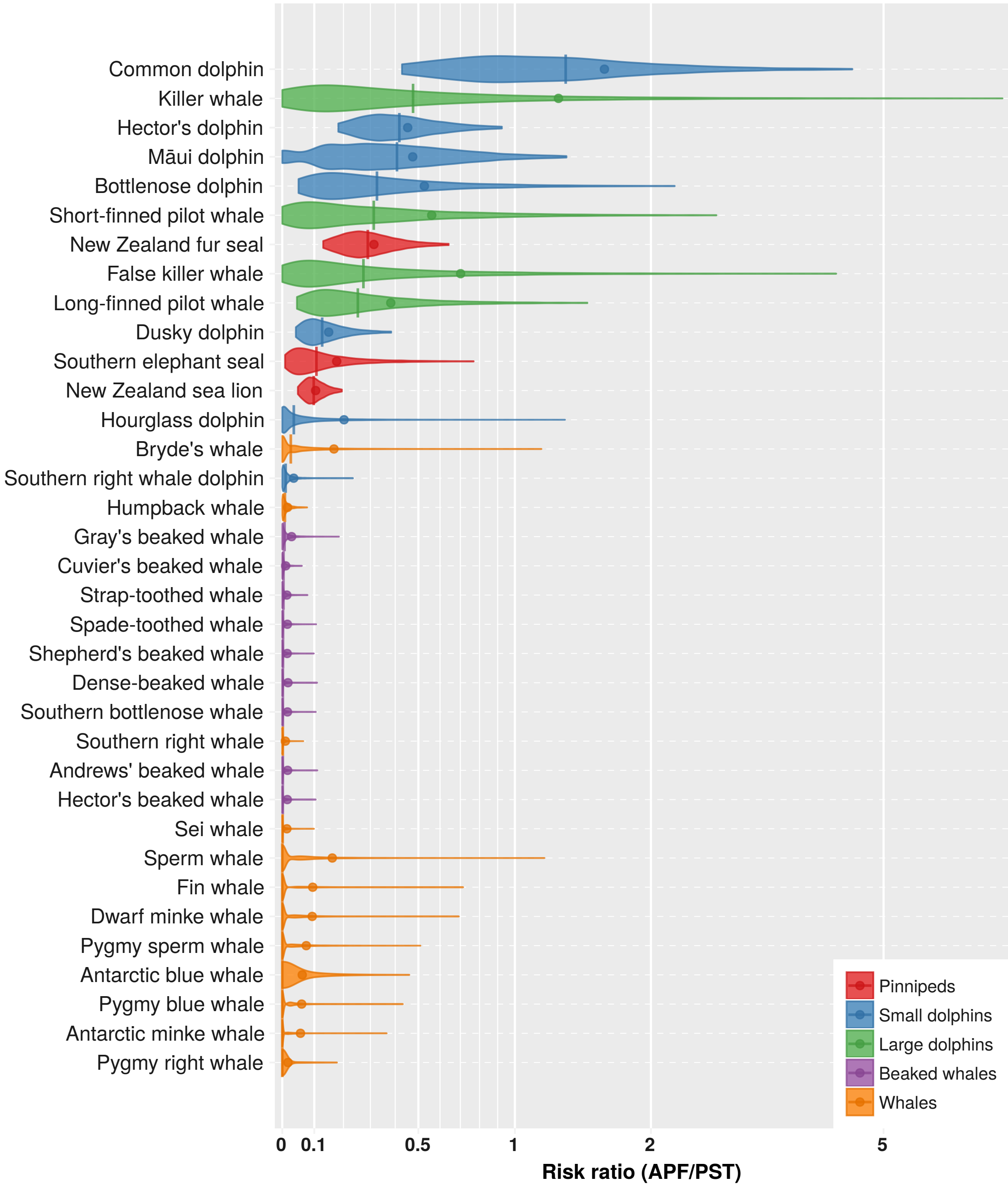


Figure 9: Risk ratio for New Zealand marine mammals, calculated as the ratio of the annual potential fatalities (APF) to the Population Sustainability Threshold (PST). Values are displayed on a logarithmic scale, and the distribution of the risk ratios within their 95% credible interval indicated by the coloured shapes, including the median risk ratio (vertical line). Species are listed in decreasing order of the median risk ratio.

4. DISCUSSION

4.1 Common dolphin

For common dolphin, both the mean and the median value of the risk exceeded one. Nevertheless, there was considerable uncertainty in both the estimated population size and the estimated fatalities. There have been no national surveys or other empirical estimates of the common dolphin population in New Zealand waters, and there were only two respondents in the Delphi survey who provided answers about this population measure (both were experienced marine mammal researchers). One researcher estimated the population size at between 10 000 and 30 000 individuals, whereas the other researcher estimated the population at between 5000 and 70 000 individuals. From these two responses, a posterior distribution of mean 19 000 (95% c.i.: 9000 to 35 000) individuals was derived.

There were a total of 215 observed captures of common dolphin during the period, of these 186 (86.5%) were in the large-vessel (90 m and over) jack mackerel trawl fishery. The total estimated annual potential fatalities of common dolphin in trawl fisheries were 104 (95% c.i.: 50 to 189). Of the estimated APF, 68 (95% c.i.: 20 to 148) were in the Taranaki area (including Golden and Tasman bays to the south, and bounded to the north by a line extending offshore from Tirua Point, north of Awakino). Most of the estimated common dolphin APF in trawl fisheries in the Taranaki area (63, 95% c.i.: 15 to 143) were by small trawl vessels, less than 28 m long. Observer coverage of small trawl vessels in this area has been low, so that the uncertainty in the APF estimates was high. For example, only a single tow of a total 5157 tows was observed in the 2014–15 fishing year. The low observer coverage makes the estimates sensitive to the assumptions of the modelling. Increased observer coverage of small trawl vessels in the Taranaki area would improve the estimation of common dolphin captures, and reduce the uncertainty in the estimation of the risk.

There has been a focus on common dolphin captures in the large-vessel jack mackerel trawl fishery that operates on the North Island west coast. This fishery has the highest number of observed captures of common dolphin, and total captures in this fishery have been regularly estimated (e.g., Thompson et al. 2013). The total number of estimated common dolphin captures in this fishery peaked at 128 (95% c.i.: 54 to 243) during the 2002–03 fishing year. By 2014–15, captures declined to 21 (95% c.i.: 19 to 28) estimated captures (Abraham & Berkenbusch 2017); the reduction in captures was associated with both a decrease in fishing effort and a decrease in the capture rate. In this fishery, dolphin captures are associated with shallow headline depths. Incidental captures tend to occur at night, when jack mackerel are close to the surface.

There were also high (but uncertain) numbers of estimated annual potential fatalities of common dolphin in set-net fisheries (71.3, 95% c.i.: 14.4 to 207.5). Between 1995–96 and 2014–15, there were six observed captures of common dolphin in set-net fisheries. Of these six observed captures, five were in the Taranaki area (four during set-net fishing targeting warehou, and one during set-net fishing targeting school shark).

Fisher-reported captures show that common dolphin are caught in a wide range of fisheries (see Table 11). In particular, fishers reported multiple capture events of common dolphin in purse-seine fisheries, and also in bottom-longline fisheries. In purse-seine fisheries, there were 21 common dolphin captures in four capture events reported by fishers between 2008–09 and 2014–15. However, there have been no observer records of common dolphin captures in either of these fishing methods. For purse-seine fisheries, the vulnerability model estimated the annual potential fatalities of common dolphin as less than one. Further observations of purse-seine fishing are required to accurately quantify the annual potential fatalities of common dolphin (and of other marine mammals that may also be caught).

4.2 Killer whale and large dolphins

New Zealand has a small population of killer whale (with a mean estimate of 236 individuals, 95% c.i.: 117 to 395), corresponding to a PST of only 1.5 (95% c.i.: 0.5 to 3.6) annual fatalities. Killer whale are coastal, and their distribution overlaps with a range of poorly-observed inshore fisheries. Although no captures of killer whale have been observed, there was large uncertainty in the estimated annual potential fatalities (mean 1.6, 95% c.i.: 0.0 to 9.5). The killer whale captures were estimated to occur in set-net fisheries. Killer whale were included in the large-dolphins group (with long-finned and short-finned pilot whales, and false killer whale), and all four species in this group had a relatively high (and uncertain) vulnerability to capture in set-net fisheries. The estimated risk to killer whale from set-net fisheries were supported by a single observed capture of a long-finned pilot whale in these fisheries. All of the species in the large-dolphins group had risk ratios with the upper 95% credible interval exceeding one, indicating that the observer data were insufficient to rule out the possibility that fisheries fatalities exceed the PST. At the same time, it is possible that killer whale, short-finned pilot whale and false killer whale had zero annual potential fatalities. Spatial distributions derived from the Delphi method are unlikely to be sufficient to accurately estimate spatial overlap with fisheries for these species; for this reason risk estimates should be regarded as indicative only until improved spatial distributions are available. Furthermore, set-net fisheries have been poorly observed, and increasing observer coverage in these fisheries will reduce the uncertainty in the estimated annual potential fatalities of killer whale and other large dolphins. Development of a constraint on the annual potential fatalities that was based on survival estimates (e.g., Richard & Abraham 2017) or possibly on demographic modelling of marine mammal populations, may also reduce the high risk estimates.

In addition, not all New Zealand commercial fisheries were included in this assessment. In particular, rock lobster pot fishing is a significant New Zealand fishery, but was not included here. Entanglements of marine mammals have been documented to occur in rock lobster pot float-lines, including a killer whale that was reported caught (e.g., Table 11). Because the PST for killer whale is low, only a few fatal entanglements of this species a year would exceed the threshold.

4.3 Hector's dolphin

The estimated annual potential fatalities of Hector's dolphin were 41.3 (95% c.i.: 19.1 to 77.7), with 32.3 (95% c.i.: 13.8 to 65.8) estimated captures in set-net fisheries. The Hector's dolphin subspecies has three genetically distinct sub-populations: East Coast South Island, West Coast South Island, and South Coast South Island (Baker et al. 2002). The overlap between set-net fisheries and Hector's dolphin was almost entirely on the East Coast South Island (see Table 18). The current estimate of captures in set-net fisheries overlaps with a previous estimate of 23 Hector's dolphin (CV: 0.21) caught in East Coast South Island set-net fisheries during 2009–10 (Slooten & Davies 2012). The risk to Hector's dolphin was entirely less than one, however, there was a 9.4% probability that the risk to the East Coast South Island Hector's dolphin population from set-net fishing in that area exceeded one.

There are already extensive areas of South Island waters where set-net fishing is prohibited, including restrictions within 4 nautical miles (7.4 km) off the coast, and a larger marine mammal protection area surrounding Banks Peninsula.The effect of these restrictions is evident on the map of overlap between Hector's dolphin and set-net fisheries (see Appendix C), as there is no overlap close to shore along most of the South Island coast. The set-net closures are reflected in the fishing effort used for the risk assessment (from the period 2012–13 to 2014–15).

For Hector's dolphin, the uncertainty in the risk was high. This uncertainty were partly due to the low observer coverage of set-net fisheries: around half of the observed captures were from a dedicated programme that was carried out in the late 1990s (Baird & Bradford 2000, Starr & Langley 2000). Trials of video monitoring on set-net vessels have demonstrated that Hector's dolphin bycatch can be recorded by video cameras (e.g., McElderry et al. 2007), and it appeared that the video was able to record captures that would not have been seen by observers on the vessels. Expanding observer coverage (either via human observers or video monitoring) would help to reduce uncertainty in the estimated captures. In addition, improving knowledge of cryptic mortality would reduce uncertainty, as estimated annual potential fatalities are in part associated with an assumed cryptic mortality. For set-net fisheries, the probability that a capture incident is observed was assumed to be uniformly distributed between one-third and one, with a mean of two-thirds. Obtaining better information on the drop-out rates, i.e., the proportion of dolphin that are caught but not recovered on board the vessel, would help reduce the uncertainty. Another source of uncertainty in the estimation of risk to Hector's dolphin was the estimation of the maximum growth rate ($r_{\max}$; mean 0.026, 95% c.i.: 0.018 to 0.036) which relied on expert judgement. Research to estimate $r_{\max}$ empirically from demographic data or life history parameters may be useful to reduce this uncertainty. The analysis of overlap relied on surveys conducted during two seasons (winter and summer), and no information was available on the variation in the distribution of Hector's dolphin within those seasons.

From the observed set-net captures, the model estimated a live-release probability of 12.8% (95% c.i.: 3.7% to 26.4%) for small dolphin in set-net fisheries (see Appendix F for all model parameters). The post-release survival of these animals was unknown, and so was assumed to be uniformly distributed between zero and one, with a mean of one-half. Taken together, around 6% of the capture incidents were assumed to not have resulted in a fatality.

4.4 Māui dolphin

The mean and median values of the risk ratio for Māui dolphin were below 0.5, but the upper credible limit extended above one. Set-net fisheries were the only fisheries with a mean of more than 0.05 annual potential fatalities of Māui dolphin, highlighting that efforts to reduce the potential capture of this species in fisheries need to focus on set-net fishing.

The estimated overlap between set-net fisheries and Māui dolphin was concentrated inside harbours on the North Island west coast (see Appendix C, Figure C-5). In the region of overlap, much of the fishing effort had the location imputed. To help refine the overlap, and consequently the estimated captures, it is necessary to clarify where fishing effort in these harbours is occurring, and how the distribution of Māui dolphin extends into them. Uncertainty in estimates of risk to Māui dolphin also reflected uncertainty in the maximum growth rate, $r_{\max}$, which was estimated by experts as mean 0.023 (95% c.i.: 0.015 to 0.034).

Based on the assumed distribution of Māui dolphin, the risk assessment suggest that potential fatalities of Māui dolphin would be reduced by extending the set-net ban into North Island west coast harbours, particularly Kaipara, Raglan, Aotea, and Kāwhia harbours. There was also overlap with set-net fisheries operating near New Plymouth, toward the south of the range of Māui dolphin (see Appendix C). Conclusions from the current study are sensitive to assumptions about the distributions of Māui dolphin and of unlocated set-net effort within harbours. The vulnerability of Māui dolphin was assumed to be the same as for Hector's dolphin (they were treated as the same species in the model). The estimated capture rate largely depended on observations made on the South Island East Coast of Hector's dolphin. Since 2012–13, there has been observer coverage of set-net fisheries in the Taranaki area, focused on the warehou set-net fishery that operates near New Plymouth. Between 2012–13 and 2014–15, observer coverage of the minor species set-net fishery (which includes warehou targets) in the Taranaki region has varied between 38% and 73%. There were no observed captures of Māui dolphin.

4.5 Bottlenose dolphin

Bottlenose dolphin have sub-populations centred around Northland, Fiordland, and Marlborough Sounds, with limited exchange between them (Tezanos-Pinto et al. 2009). There is also a more widespread oceanic sub-population, which extends to Kermadec Islands. The total New Zealand population size of bottlenose dolphin was estimated as 1576 (95% c.i.: 1081 to 2318) individuals. The total annual potential fatalities were estimated as 9.3 (95% c.i.: 1.1 to 36.0), with most fatalities estimated to occur in either trawl or set-net fisheries. There were a total of three observed captures in the dataset: one bottlenose dolphin caught on a trawl targeting John dory in the Northland-Hauraki area, and two bottlenose dolphin caught during surface longlining in the Bay of Plenty area.

The resulting risk to bottlenose dolphin was 0.53 (95% c.i.: 0.05 to 2.22). Although the mean (and median) values were similar to the risk ratio of Hector's and Māui dolphins, the risk ratio was highly skewed, with the credible interval extending well above one. Up to five people answered the Delphi question about the distribution of bottlenose dolphin, and the uncertainty in the distribution between the regional sub-populations was high. For example, the mean estimate of the proportion of the bottlenose dolphin sub-population in inshore Northland waters was 26.0%, but the 95% c.i. was 2.9% to 52.9% (see Appendix E). A further limitation of the Delphi survey for bottlenose dolphin was that the regions used in the survey were at a broad spatial scale: the inshore regions extended offshore to either 100 m water depth, or to 12 nautical miles (22.2 km). The Cook Strait region included both Marlborough Sounds and broader Cook Strait. Developing a quantitative model of the distribution and population structure of bottlenose dolphin throughout the New Zealand region would improve the estimation of the overlap and the annual potential fatalities, and thereby improve the estimation of the risk. This research is currently underway as a separate project (Ben Sharp, MPI, pers. comm.).

In addition, coastal bottlenose dolphin populations overlapped with inshore fisheries that have low observer coverage. Increased observer effort in these fisheries would also help improve the estimation of risk to this species. Both increased observer coverage and improved spatial information of the distribution and population structure of bottlenose dolphin would be required to allow estimation of the risk to different regional sub-populations of this species.

4.6 New Zealand fur seal

The mean risk index for New Zealand fur seal was 0.31 (95% c.i.: 0.13 to 0.64), with the range entirely below one. There have been no recent systematic counts of New Zealand fur seal since a population survey carried out between 1971 and 1974 (Wilson 1981). This early survey estimated the total population as 39 000 (range 30 000 to 50 000) individuals. The mean population estimate from the Delphi survey was 126 945 (95% c.i.: 64 620 to 220 998) individuals. The uncertainty in the estimated risk would be reduced by an improved estimate of the current population size of this species in New Zealand.

The estimated annual potential fatalities of New Zealand fur seal were 949 (95% c.i.: 611 to 1402). This estimate was the highest number of annual potential fatalities of all New Zealand marine mammal species. The estimated fatalities of New Zealand fur seal were in trawl, set-net and surface-longline fisheries.

4.7 New Zealand sea lion

The largest breeding colony of New Zealand sea lion is on Auckland Islands; this breeding population declined by around 40% between the late 1990s and 2010, and appears to have stabilised thereafter (e.g., Chilvers & Meyer 2017). In contrast, the breeding population at Campbell Island has shown an increase, albeit from a low base (e.g., Roberts et al. 2014). Extensive research has been carried out on evaluating the threats to New Zealand sea lion, including detailed demographic modelling, and an evaluation of a wide range of potential threats (Roberts & Doonan 2016). The broad conclusion from this research was that fisheries captures on their own were insufficient to explain the decline in sea lion populations and that the population at Auckland Islands faces multiple threats, including disease.

The mean APF of New Zealand sea lion were 25.8 (95% c.i.: 13.5 to 43.0). Most of the mean estimated annual potential fatalities were in trawl fisheries (24.5; 95% c.i.: 13.0 to 41.0), with some fatalities also estimated in set-net fisheries (1.2; 95% c.i.: 0.0 to 6.0). The estimates for trawl fisheries were derived from estimated captures in the recent bycatch assessment (Abraham & Berkenbusch 2017). The bycatch estimate was preferred as a basis for the estimation, as it took account of factors such as tow duration and distance from colony, that were not included in the risk assessment model (the broad polygons used in the risk assessment are a crude representation of spatial distribution for central place foragers such as sea lion). In Auckland Islands squid and Campbell Island southern blue whiting fisheries, trawls are fitted with SLEDs, which prevent sea lion from entering the cod end of the net, and allow them to escape.

The captures were adjusted to allow for cryptic mortalities, which were assumed to be the same as for marine mammals in other trawl fisheries (i.e., with the probability of an interaction being observable being uniformly distributed between 0.5 and 1, equivalent to a cryptic multiplier of 1.39 (95% c.i.: 1.013 to 1.950)). The estimate of fatalities also allowed for the survival of some of the animals released alive, with an estimated 12.2% (95% c.i.: 10.9 to 13.5%) of pinnipeds caught in trawls that were released alive (see Appendix F). Although the annual potential fatalities account for animals that are killed by fishing but not brought on board the vessel, they are different from the estimate of interactions that are included in the bycatch assessments (e.g., Abraham & Berkenbusch 2017). Interactions are the number of sea lion that would be caught if no SLEDs were used.

The estimated risk ratio for New Zealand sea lion was low (0.10; 95% c.i.: 0.05 to 0.19). The assessment of annual potential fatalities assumed that the cryptic mortalities for sea lion in SLEDs are the same as for marine mammals in other trawl fisheries (and are the same on tows with and without SLEDs). If information on cryptic mortalities associated with SLEDs became available, such as evidence of dead animals falling from the net, then it could be incorporated into the risk assessment.

New Zealand sea lion are managed under a Threat Management Plan with species-specific population recovery objectives that are different from the generic population recovery outcome used to define the PST across all species in this marine mammal risk assessment. The PST is specific to a defined population recovery outcome. For this reason, risk scores from the multi-species risk assessment cannot be used to inform performance against species-specific management objectives. Where species-specific population models and management objectives exist (as for New Zealand sea lion), the species-specific models are considered more useful for informing management. Nevertheless, this species was included in the present multi-species risk assessment to enable objective comparisons of relative risk across different species.

4.8 Other species

For beaked whales and whales, the estimated mean annual potential fatalities were all below one individual per year, with the exception of humpback whale, which had a mean of 1.4 (95% c.i.: 0.0 to 6.6) annual potential fatalities. For all of these species, the lower bound of the credible interval of the annual potential fatalities was zero. While the median and mean risk was generally low, the uncertain population sizes and distributions of these species mean that in some cases the risk was highly skewed. For sperm whale and Bryde's whale, the upper limit of the credible interval was above one. In many cases, the highest annual potential fatalities for beaked whales and whales were estimated to be from inshore trawl fisheries. As there have been fewer observations in inshore trawl fisheries than in deepwater trawling, the possible annual potential fatalities are more poorly constrained. Refining the distribution and population estimates of these species would help to clarify the risk. Overall, however, there was no strong evidence of a risk to these species from fisheries fatalities, based on current observer data.

The risk assessment assumed that, in longline fisheries, between 50 and 100% of all potentially fatal interactions with fishing gear were observable. Anecdotally, a beaked whale has been reported with a sliced rostrum, consistent with being cut by a longline (A. Van Helden, pers. comm.). If more information were available to allow a better estimate of the proportion of incidents that result in an observable capture, and on the fate of animals that interact with gear but are not captured, then this could be included in the estimation of the cryptic multiplier.

4.9 Refining the risk assessment

The current assessment developed estimates of annual potential fatalities for a wide range of New Zealand marine mammal taxa. This assessment reflects the broadest estimate of marine mammal bycatch and population level risk carried out across New Zealand fisheries to date. The risk assessment provides information for the development of policy to address and reduce commercial fisheries risk to marine mammals, allowing prioritisation of species at high risk.

To refine the assessment, improved information on the overlap between marine mammals and fisheries is required. For most species, the distribution information from the Delphi survey was uncertain, and was based on limited responses. Information on the distribution of marine mammals in New Zealand waters is available from sightings at sea, strandings, and research studies. Integrating this information through a quantitative approach is complex, given the heterogeneous and sporadic nature of the data, however work to model the distribution of New Zealand marine mammals is currently underway under a separate Ministry for Primary Industries contract. Increasing our understanding of distribution of marine mammals would allow for improved knowledge of the interactions of marine mammals with New Zealand fisheries. Furthermore, for some fisheries, most notably flatfish set-net fishing, spatial information was not available. Improving information on the distribution of this fishing effort would help inform the estimation of risk for marine mammals that utilise harbours and shallow water.

For many of the coastal species, the highest risk was associated with set-net fishing. Improved observation of set-net fishing (through human observers or video monitoring) would help improve estimates of fatalities and risk in set-net fisheries.

The output from the risk assessment was a risk ratio for the different taxa, reflecting both estimated fishery-related deaths and the population's inherent productivity. No specific modelling of marine mammal populations was carried out as part of this project, and, for most marine mammal species, there is no specific management framework for using these results. Having demonstrated the feasibility of carrying out an assessment across the broad range of marine mammal taxa, a next step would be consideration of how the assessment fits within a wider management framework. As part of this framework, supporting demographic modelling, specific to marine mammal populations should be carried out, developing a PST that is specifically calibrated for marine mammals.

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APPENDIX A: BAYESIAN MODEL

Model written in the BUGS language used to estimate the number of observable captures for each marine mammal (sub)species included in the risk assessment. This code works with Just Another Gibbs Sampler (JAGS) version 4.2.0 (Plummer 2016).

```
data {
    OVERLAP.OBSERVED <- observed[, slice]
    OVERLAP.EFFORT <- effort[, slice]
    N <- population[, slice]
    for (s in 1:N.SPECIES){
        POPULATION.CONSTRAINT[s] <- 0
    }
    YEARS <- 20
}

model {
    # Vulnerabilities
    sigma.leaf ~ dexp(0.2)
    for (d in 1:N.LEAF){
        r.leaf[1, d] ~ dnorm(0, pow(sigma.leaf, -2))      # Pelagic trawl, no sled
        r.leaf[2, d] <- r.leaf[1, d]                      # Pelagic trawl, sled
        r.leaf[3, d] ~ dnorm(0, pow(sigma.leaf, -2))      # Squid trawl, no sled
        r.leaf[4, d] <- r.leaf[3, d]                      # Squid trawl, sled
        for (f in 5:N.FISHERY){                           # Other fisheries
            r.leaf[f, d] ~ dnorm(0, pow(sigma.leaf, -2))
        }
    }

    for (g in 1:N.GROUP){
        q.fishery.group[1, g]  ~ dnorm(0, 1/100)          # Pelagic trawl, no sled
        q.fishery.group[2, g] <- q.fishery.group[1, g]    # Pelagic trawl, sled
        q.fishery.group[3, g]  ~ dnorm(0, 1/100)          # Squid trawl, no sled
        q.fishery.group[4, g] <- q.fishery.group[3, g]    # Squid trawl, sled
        for (f in 5:N.FISHERY){                           # Other fisheries
            q.fishery.group[f, g] ~ dnorm(0, 1/100)
        }
    }

    # SLED effect
    p.sled ~ dunif(1E-10, 1)

    for (i in 1:N.ROW) {
        q[i] <- exp(q.fishery.group[FISHERY[i], GROUP[i]] + r.leaf[FISHERY[i], LEAF[i]]) *
            ifelse(SLED.ROWS[i]==1, p.sled, 1)
    }

    # Probabilities of identifying species of each group
    for (g in 1:N.GROUP) {
        p.identified[g] ~ dunif(1E-10, 1-1E-10)
    }

    # Unidentified whales
    p.whale[1] <- 0
    p.whale[2] <- 0
    for (g in 3:N.GROUP){
        p.whale[g] ~ dunif(0, 1) #Whale groups
    }

    # Cryptic multiplier
    for (m in 1:N.METHOD){
        for (c in 1:N.CLASS){
            p.observable[m, c] ~ dunif(ifelse(m==3, 1.0/3.0, 1.0/2.0), 1)
            cryptic.multiplier[m, c] <- 1.0/p.observable[m, c]
```

```
    }
}

# Live probability
for (m in 1:N.METHOD){
    for (c in 1:N.CLASS){
        p.live[m, c] ~ dbeta(1, 3) # Opinionated
    }
}

# Survival probability
for (m in 1:N.METHOD){
    for (c in 1:N.CLASS){
        p.survive[m, c] ~ dbeta(1, 1) # Uniform
    }
}

# Fit to observed captures
for (i in 1:N.ROW) {
    mu.obs[i] <- p.observable[METHOD[FISHERY[i]], CLASS[GROUP[i]]] * q[i] * OVERLAP.OBSERVED[i]
    mu.obs.species[i] <- p.identified[GROUP[i]] * mu.obs[i]
    mu.obs.species.dead[i] <- max(1E-10,
        (1 - p.live[METHOD[FISHERY[i]], CLASS[GROUP[i]]]) * mu.obs.species[i])
    mu.obs.species.alive[i] <- max(1E-10,
             p.live[METHOD[FISHERY[i]], CLASS[GROUP[i]]]  * mu.obs.species[i])

    DEAD[i] ~ dpois(mu.obs.species.dead[i])
    obs.dead[i] ~ dpois(mu.obs.species.dead[i])
    loglik.dead[i] <- logdensity.pois(DEAD[i], mu.obs.species.dead[i])
    LIVE[i] ~ dpois(mu.obs.species.alive[i])
    obs.alive[i] ~ dpois(mu.obs.species.alive[i])
    loglik.alive[i] <- logdensity.pois(LIVE[i], mu.obs.species.alive[i])
}

for (f in 1:N.FISHERY){

    # Fit to observed captures, identified to the group level
    for (g in 1:N.GROUP) {
        mu.obs.unident[f, g] <- (1 - p.identified[g]) * sum(mu.obs[START.FG[f, g]:END.FG[f, g]])

        mu.obs.unident.whale[f, g] <-  p.whale[g]    * mu.obs.unident[f, g]
        mu.obs.unident.whale.dead[f, g] <-
            max(1E-10, (1 - p.live[METHOD[f], CLASS[g]])* mu.obs.unident.whale[f, g])
        mu.obs.unident.whale.alive[f, g] <-
            max(1E-10,      p.live[METHOD[f], CLASS[g]] * mu.obs.unident.whale[f, g])

        mu.obs.unident.z[f, g] <- (1 - p.whale[g]) * mu.obs.unident[f, g]
        mu.obs.unident.z.dead[f, g] <-
            max(1E-10, (1 - p.live[METHOD[f], CLASS[g]])* mu.obs.unident.z[f, g])
        mu.obs.unident.z.alive[f, g] <-
            max(1E-10,     p.live[METHOD[f], CLASS[g]] * mu.obs.unident.z[f, g])

        DEAD.GROUP[f, g]      ~ dpois(mu.obs.unident.z.dead[f, g])
        obs.dead.group[f, g] ~ dpois(mu.obs.unident.z.dead[f, g])
        loglik.dead.group[f, g] <- logdensity.pois(DEAD.GROUP[f, g], mu.obs.unident.z.dead[f, g])
        LIVE.GROUP[f, g] ~ dpois(mu.obs.unident.z.alive[f, g])
        obs.alive.group[f, g] ~ dpois(mu.obs.unident.z.alive[f, g])
        loglik.alive.group[f, g] <- logdensity.pois(LIVE.GROUP[f, g], mu.obs.unident.z.alive[f, g])
    }

    # Fit to observed captures, of unidentified whales
    DEAD.WHALE[f] ~ dpois(sum(mu.obs.unident.whale.dead[f, ]))
    obs.dead.whale[f] ~ dpois(sum(mu.obs.unident.whale.dead[f, ]))
```

```
        loglik.dead.whale[f] <- logdensity.pois(DEAD.WHALE[f], sum(mu.obs.unident.whale.dead[f, ]))
        LIVE.WHALE[f] ~ dpois(sum(mu.obs.unident.whale.alive[f, ]))
        obs.alive.whale[f] ~ dpois(sum(mu.obs.unident.whale.dead[f, ]))
        loglik.alive.whale[f] <- logdensity.pois(LIVE.WHALE[f], sum(mu.obs.unident.whale.alive[f, ]))
    }

    # Estimate all captures
    for (i in 1:N.ROW){
        apfs.years[i] ~ dpois(max(1E-10, YEARS *
            (1 - p.survive[METHOD[FISHERY[i]], CLASS[GROUP[i]]] *
                p.live[METHOD[FISHERY[i]], CLASS[GROUP[i]]]) *
            q[i] * OVERLAP.EFFORT[i]))
        apfs[i] <- apfs.years[i]/YEARS
    }

    for (s in 1:N.SPECIES){
        apf.species[s] <- sum(apfs[SP.ROWS[START.SP[s]:END.SP[s]]])
        POPULATION.CONSTRAINT[s] ~ dinterval(apf.species[s],  0.2 * N[s])
    }
}
```

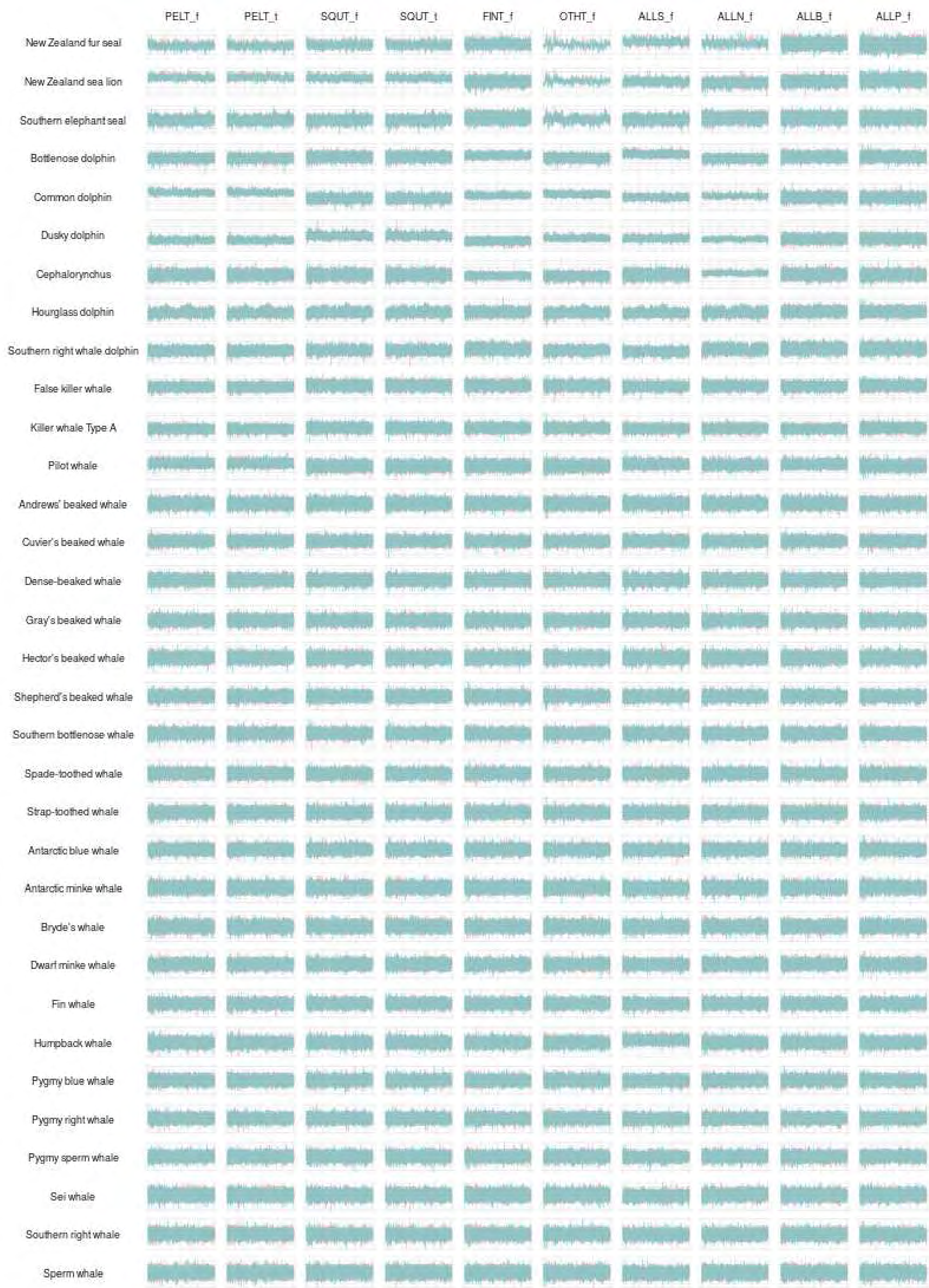


Figure A-1: Trace plots of the Markov chain Monte Carlo (MCMC) chains of the final model, for the effect of each of the combinations of fishery group and species group. PELT: pelagic trawl; SQUT: squid trawl; FINT: inshore trawl; OTHT: other trawl; ALLS: surface longline; ALLB: bottom longline; ALLN: set net; ALLP: purse seine.

APPENDIX B: ANALYSIS OF SIMULATED SURVEY RESPONSES

Simulations were carried out to explore how the model of the Delphi survey data produced a consensus distribution from individual responses. The model was tested using simulated population size data. For the first simulation, we sequentially added answers to illustrate how the method finds a consensus distribution, from a single expert answer to having six independent expert answers. The remaining three simulations were designed to illustrate three separate scenarios, each with eight experts answering: i) a scenario in which all experts expressed high uncertainty in their answers; ii) a scenario with two opposing groups, i.e., participating experts gave opposing answers (i.e., some experts suggested a low population size, whereas a second group of experts was convinced that the population size is considerable higher); a third scenario iii) opposed a single expert with high certainty against a number of experts with low certainty, but who answered in opposition to the first expert.

With only a single expert answer, the consensus prediction was centred on this expert's answer, but displayed wider distributions due to the vaguely informative priors (Figure B-2). When more experts were added, the predictive distribution became more centred on the mean response, but still showed considerable uncertainty, so the range of the posterior predictive distribution still contained the individual answers (as long as they were relatively certain).

For the three more extreme simulation scenarios, the hierarchical framework still provided reasonable answers that reflected the range of expert opinions (Figure B-3). Under scenario i), all of the experts had high uncertainty in their answers (orange densities), but the posterior predictive distribution (blue density) became centred around their mean answer, and had markedly lower uncertainty. Under scenario ii), two groups of experts gave opposing answers. The posterior predictive distribution was skewed toward the group with more experts, with wide distributions representing considerable uncertainty due to the opposing answers. The third scenario iii) showed a single dissenting, yet strong (i.e., certain) expert opinion opposing a number of experts whose answer reflected considerable uncertainty. This scenario was an extreme case of scenario ii), and the posterior prediction showed considerable uncertainty that spanned the range of answers.

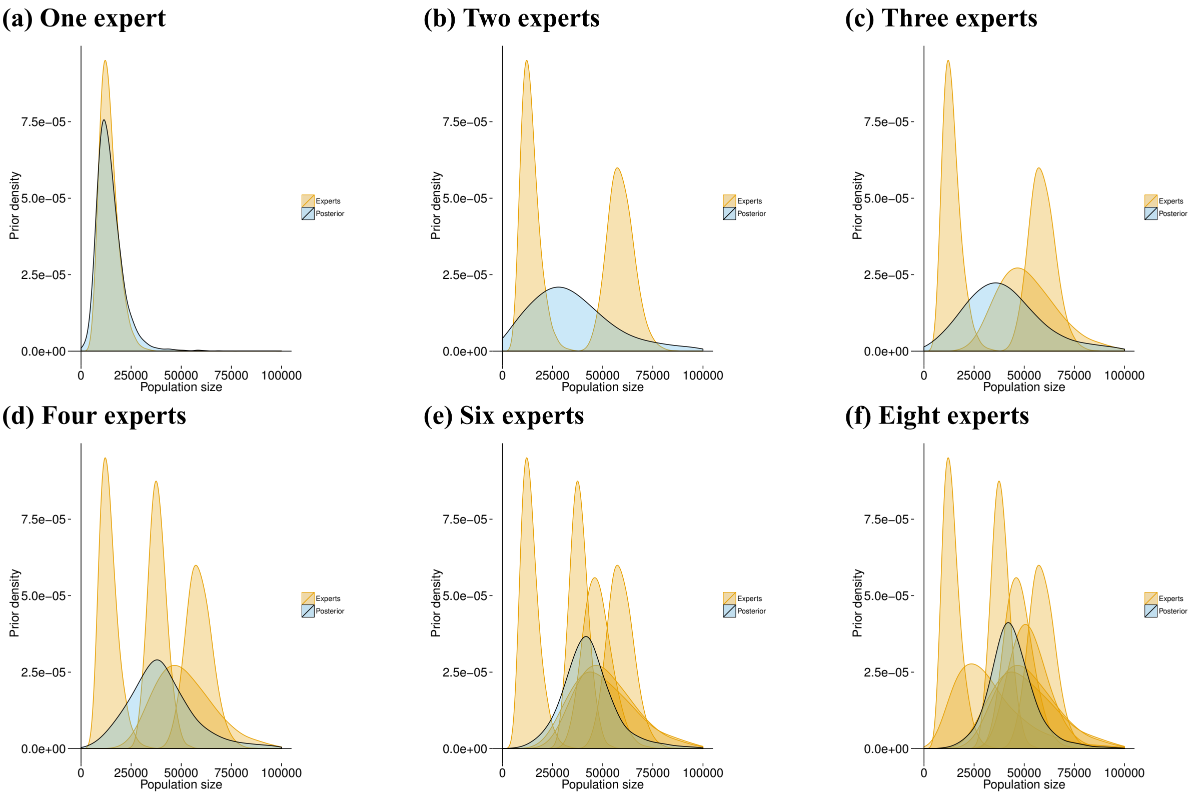


Figure B-2: Change of the estimated posterior consensus distribution (blue density) as more expert opinions (orange densities) were added to the model, with examples including a single expert (a) and up to eight expert opinions (f).

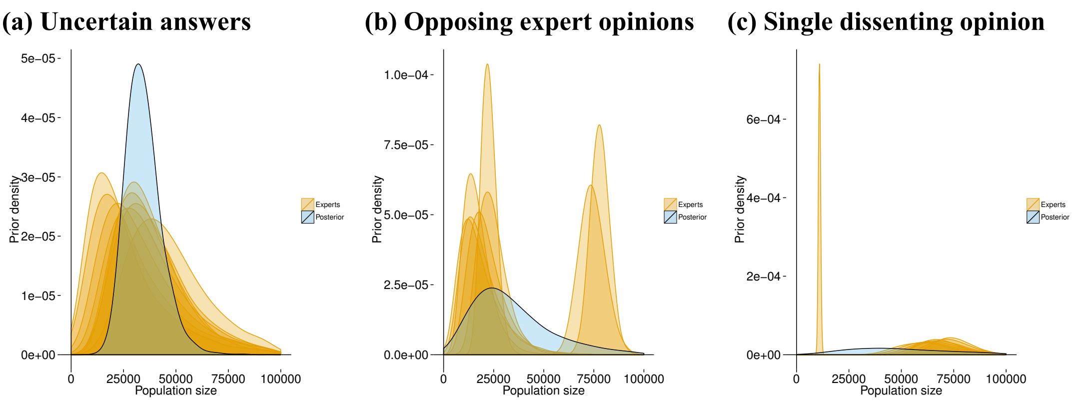
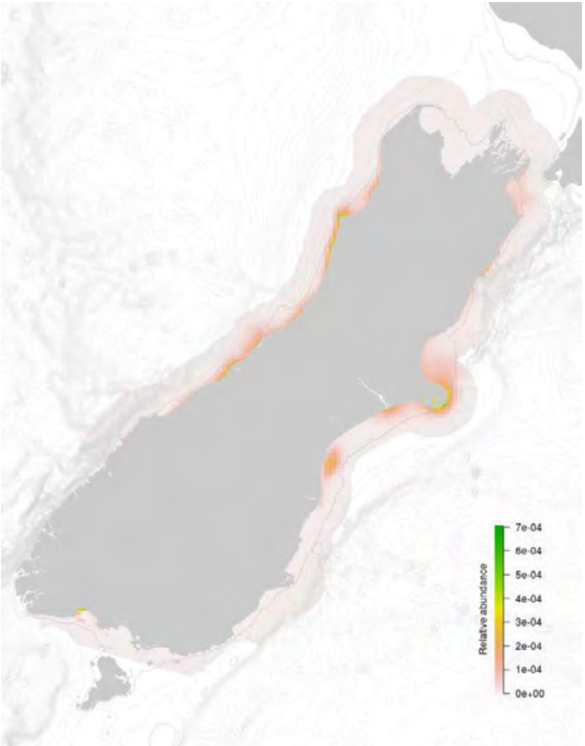


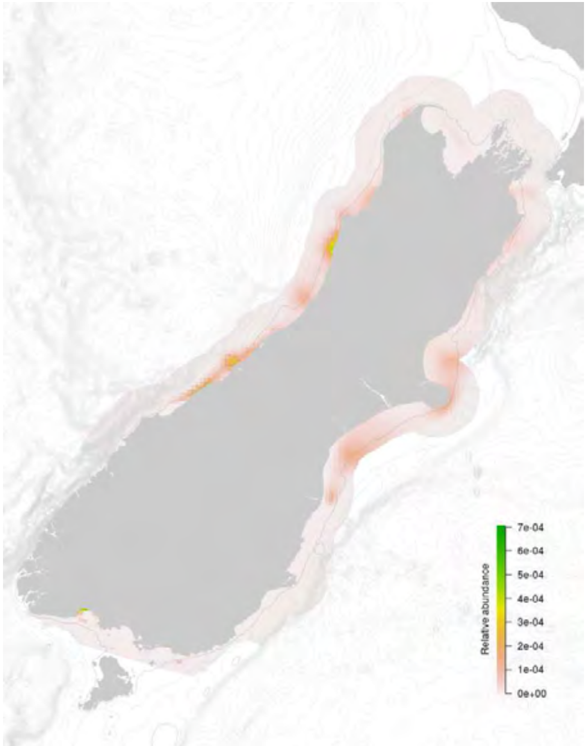
Figure B-3: Three extreme simulation scenarios, based on differences in the answers by eight experts, showing the posterior predictive distribution (blue density) and uncertainty (orange density). Scenarios included (a) all of the experts giving answers with high uncertainty, (b) two groups of experts with opposing answers, and (c) a single dissenting, yet strong (i.e., certain) expert opinion opposing a number of experts whose answer reflected considerable uncertainty.

APPENDIX C: HECTOR’S AND MĀUI DOLPHIN DISTRIBUTIONS AND OVERLAP

(a) Hector’s dolphin, summer distribution



(b) Hector’s dolphin, winter distribution



(c) Māui dolphin annual distribution

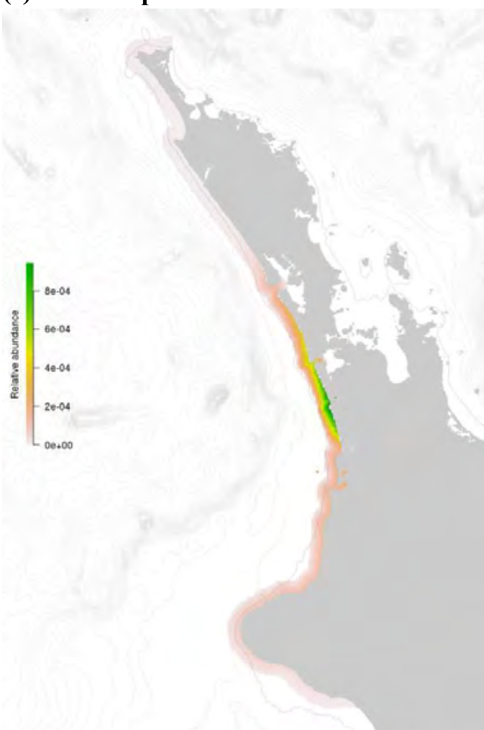
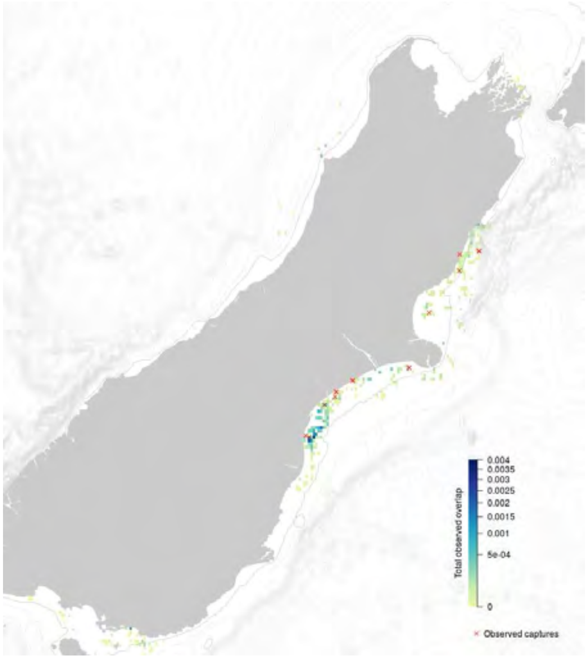
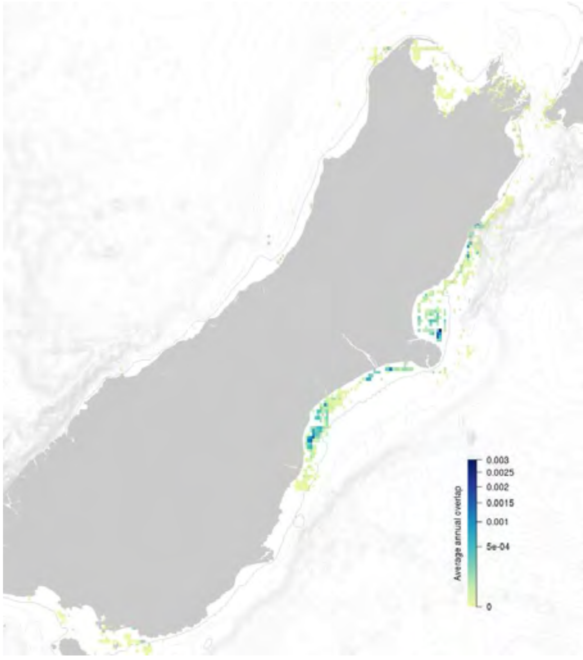


Figure C-4: Distributions of Hector’s (a, b) and Māui dolphins (c). The distribution of Hector’s dolphin is based on recent survey data (MacKenzie & Clement 2014, 2016), the distribution of Māui dolphin is from a recent risk assessment (Currey et al. 2012). Maps show the mean relative abundance normalised so that it integrates to one over the domain. The resolution of the distributions is 5 km (a, b) and 1.852 km (1 nautical mile; c).

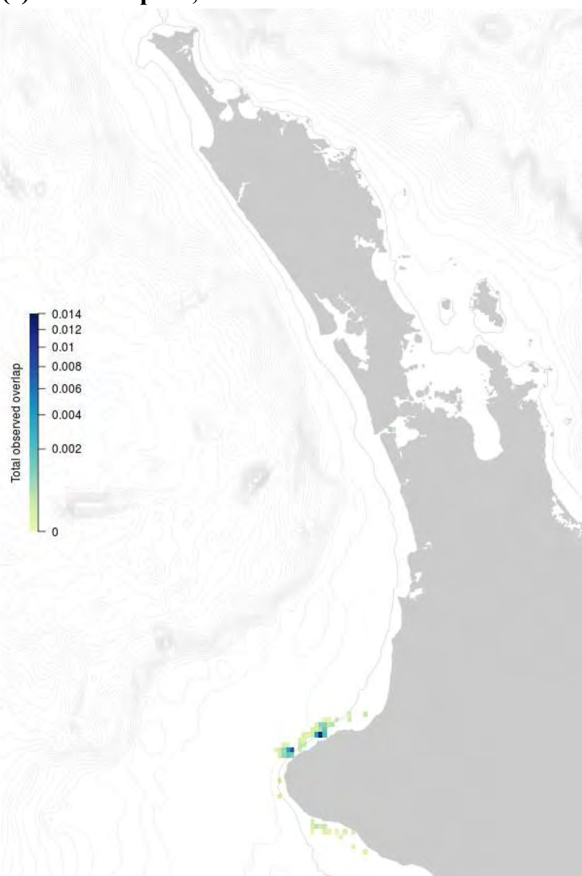
(a) Hector's dolphin, observed set-net effort



(b) Hector's dolphin, all set-net effort



(c) Māui dolphin, observed set-net effort



(d) Māui dolphin, all set-net effort

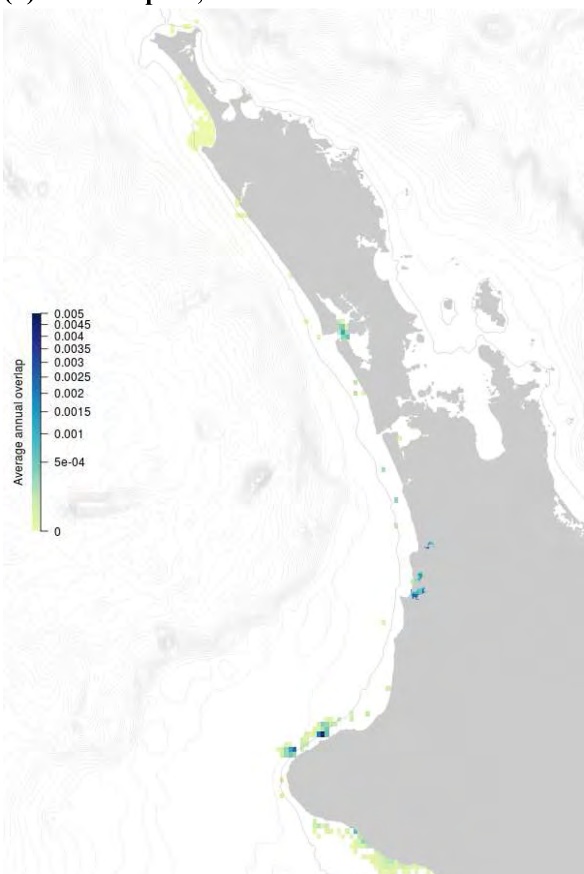
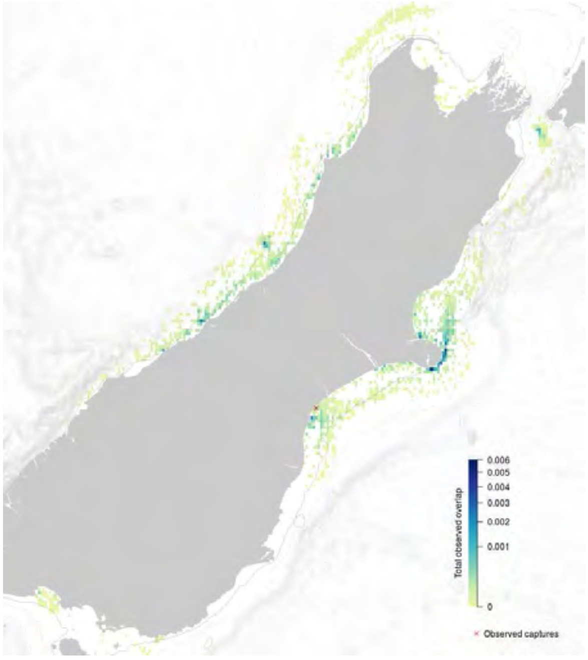
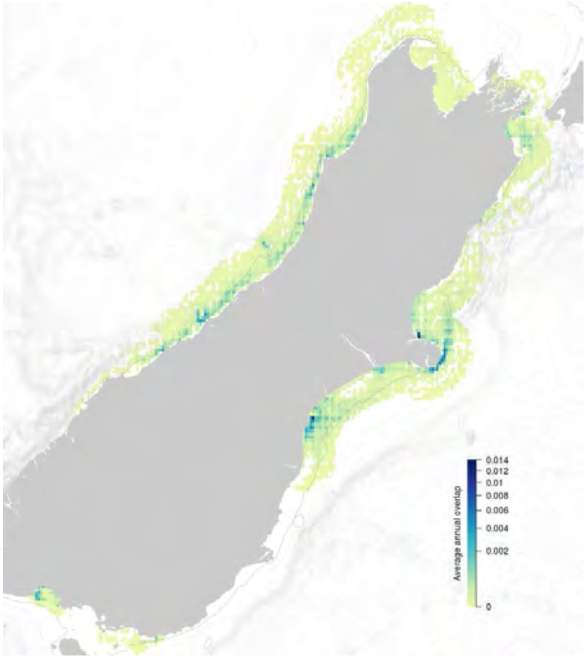


Figure C-5: Overlap between the distributions of Hector's (a, b) and Māui dolphins (c, d) and set-net fisheries. Shown is the overlap with observed fishing effort (a, c) and with annual average fishing effort over the period 2012–13 to 2014–15 (b, d). Locations of observed captures are indicated by red crosses (a). Contour lines are at 100 m intervals. The resolution of the overlaps is 5 km (a, b) and 1.852 km (1 nautical mile; c, d).

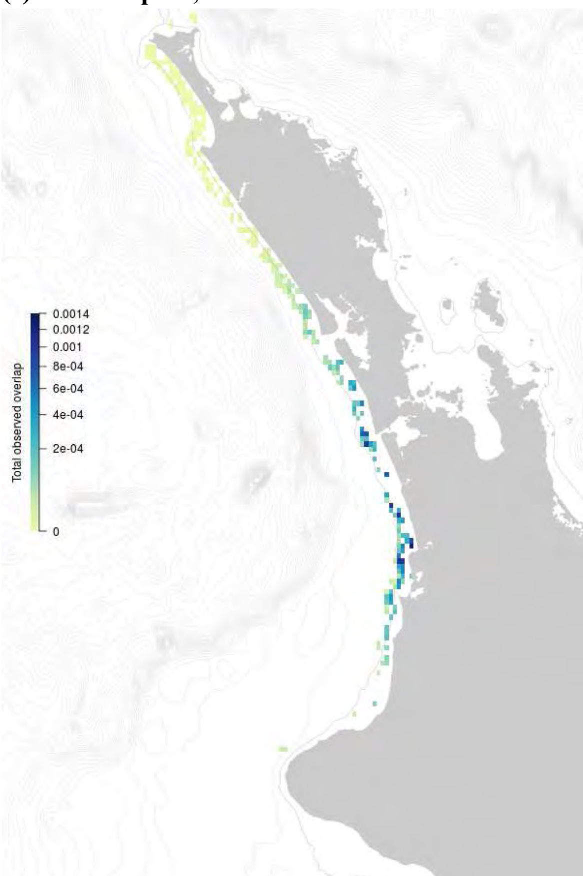
(a) Hector's dolphin, observed trawl effort



(b) Hector's dolphin, all trawl effort



(c) Māui dolphin, observed trawl effort



(d) Māui dolphin, all trawl effort

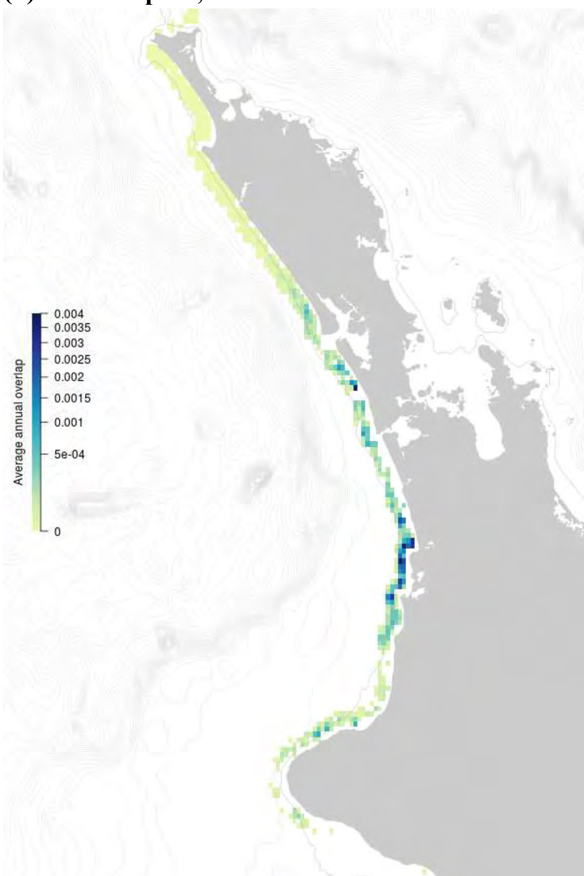


Figure C-6: Overlap between the distributions of Hector's (a, b) and Māui dolphins (c, d) and trawl fisheries. Shown is the overlap with observed fishing effort (a, c) and with annual average fishing effort over the period 2012–13 to 2014–15 (b, d). The location of the observed capture is indicated by a red cross (a). Contour lines are at 100 m intervals. The resolution of the overlaps is 5 km (a, b) and 1.852 km (1 nautical mile; c, d).

APPENDIX D: AGGREGATED DATA

The estimation of captures in the risk assessment relies on the assumption that the number of captures, C, of a species, s, in a fishery group, g, is given by a draw from a Poisson distribution:

$$C_{sg} \sim \text{Poisson}(p_{\text{observable}} q_{sg} \theta_{sg}), \tag{D-1}$$

where the mean of the Poisson distribution is given by the product of the probability that a capture incident is observable, $p_{\text{observable}}$, the vulnerability, q, and the overlap, θ, between the species and the fishery. The vulnerability is estimated by fitting this model to aggregated data, where the overlap and the captures have been summed within species and fisheries-group strata. It follows from the properties of a Poisson distribution, that the sum of Poisson variables has the same distribution as a Poisson whose mean is the sum of the means:

$$\sum_i \text{Poisson}(\mu_i) \sim \text{Poisson}(\sum_i \mu_i), \tag{D-2}$$

where i indicates a number of observations, each with mean μ_i. This relationship allows the model to be aggregated into strata, rather than requiring the estimation of the vulnerability to be carried out on event level data.

We tested the effect of aggregation on the estimation of the vulnerability by carrying out estimation on simple datasets. Datasets were generated that had 100 captures from 100 fishing events, with a total overlap across all the events of 100. The data were aggregated in different ways, and the overlap and the captures were distributed across the strata in different ways, to test whether the model estimated the same vulnerability in each case. The vulnerability was estimated using a Bayesian model, with the same core structure as was used in the risk assessment, but with captures from a single species and fishery group (so that only a single vulnerability was estimated):

```
model {
    p.observable ~ dunif(1/2, 1)
    q ~ dunif(0, 1E6)
    for (i in 1:N) {
        captures[i] ~ dpois(max(1E-10, p.observable*q*overlap[i]))
    }
}
```

Note that the maximum function is needed to ensure that the Poisson still returns an answer, even if the mean value becomes close to zero (a Poisson with a mean of zero causes an error).

In most cases, the mean and standard deviation of the estimated vulnerability is independent of either the aggregation or the distribution of the data between strata. Even extreme cases (such as all the captures being in one stratum and nearly all of the overlap being in another) give the same result as a single aggregated stratum. The estimation of the vulnerability is not sensitive to the overlap at the location of each capture event. As expected, the vulnerability is close to the ratio of the total captures to the total overlap and the total number of captures.

The exception however, is when captures occur in strata that have zero overlap. In this case, the captures in those strata are effectively ignored by the model, and so the vulnerability is reduced. This does not happen if there is very small non-zero overlap in those strata (in this case an overlap of 10^{-8} was sufficient for the captures to be included in the estimation). By aggregating the data, captures that occur in places where the overlap is zero will count towards the estimated vulnerability. In the context of the risk assessment, this is a preferable treatment as captures occurring in areas of zero overlap indicate incorrect assumptions about the overlap, and should not be discounted.

Table D-1: Estimation of vulnerability from test data, with different allocation of captures and overlap between strata. In each case, the total captures was 100 and the total overlap was 100. For each test case, the table gives the number of strata, the maximum (Max.) and minimum (Min.) of overlap and captures across the strata, and the mean and standard deviation (s.d.) of the posterior distribution of the vulnerability.

Test	N	Overlap		Captures		Vulnerability	
		Max.	Min.	Max.	Min.	Mean	s.d.
Aggregated	1	100	100	100	100	1.916	0.223
Ten strata with the same overlap and captures	10	10	10	10	10	1.962	0.194
Hundred strata, same overlap, random captures	100	1	1	4	0	1.979	0.194
Hundred strata, random overlap, random captures	100	1.87	0.00776	5	0	1.950	0.194
All captures in one stratum	10	10	10	100	0	1.975	0.196
Most overlap in one stratum	10	100	10^{-8}	10	10	1.918	0.193
All overlap in one stratum	10	100	0	10	10	0.206	0.065
Most overlap in one stratum, all captures in same stratum	10	91	1	91	1	1.885	0.239
Most overlap in one stratum, all captures in different stratum	10	91	1	91	1	1.892	0.213

APPENDIX E: DELPHI SURVEY RESULTS

E.1 Andrews' beaked whale

Table E-2: Demographic parameters of Andrews' beaked whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	1		20	12.82	17.35	20	23.03	29.74
	2	1	0	20	13.00	17.30	20	22.99	29.52
R_{max} (%)	1	0							
	2	1	0	4.09	2	2.88	3.77	5	8.47

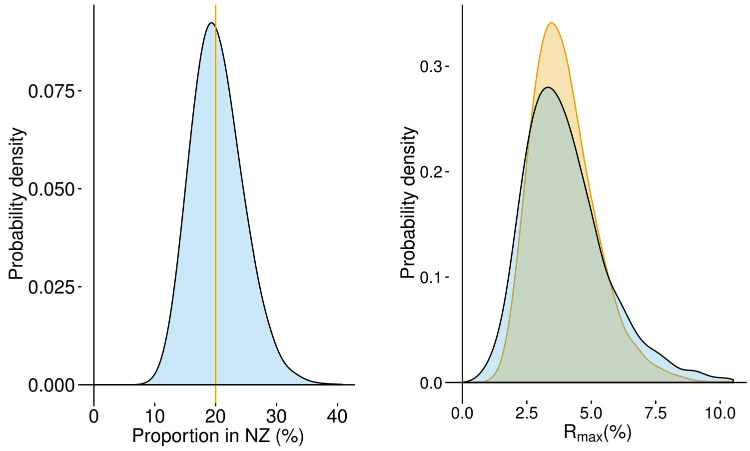


Figure E-7: Probability distributions of demographic parameters of Andrews' beaked whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

E.2 Antarctic blue whale

Table E-3: Demographic parameters of Antarctic blue whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	2		2.35	1.29	1.86	2.26	2.73	3.93
	2	2	1	1.45	0.90	1.21	1.42	1.65	2.25
Population (number)	1	2		69	18	48	61	76	130
	2	2	1	67	28	48	62	79	134
R_{max} (%)	1	2		4.34	1.48	2.84	3.90	5.34	9.62
	2	3	0	4.03	2.00	3.11	3.81	4.71	7.11

Table E-4: Distribution of Antarctic blue whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	2	1.3	0.4	0.9	1.1	1.4	3.8
	Bay of Plenty	2	0.9	0.2	0.6	0.8	1.0	2.2
	Chatham Rise	2	9.5	2.0	6.8	9.5	11.3	19.8
	East Coast North Island	2	11.4	3.1	8.6	10.8	13.0	24.8
	East Coast South Island	2	3.4	1.0	2.4	2.9	3.8	9.0
	Fiordland	2	11.4	3.6	8.5	10.5	12.8	26.4
	Kermadec Islands	1	12.5	1.5	8.2	13.1	16.0	25.9
	Northland and Hauraki	1	4.9	1.3	3.5	4.4	5.4	11.9
	Stewart Snares Shelf	2	3.7	1.0	2.6	3.2	4.1	9.2
	Subantarctic	2	21.9	5.3	17.0	22.4	26.2	40.4
	Taranaki	2	1.9	0.6	1.1	1.4	2.0	6.6
	West Coast North Island	1	7.4	1.9	5.4	7.1	8.5	16.4
	West Coast South Island	2	4.9	1.4	3.6	4.4	5.5	11.8
Inshore	Bay of Plenty	1	0.7	0.2	0.3	0.4	0.6	3.4
	Cook Strait	1	0.2	0.0	0.1	0.2	0.3	0.6
	East Coast South Island	1	0.6	0.1	0.4	0.6	0.7	1.7
	Fiordland	1	0.4	0.1	0.2	0.2	0.4	1.9
	Northland and Hauraki	1	0.9	0.2	0.4	0.5	0.8	3.6
	Taranaki	2	1.5	0.3	0.7	0.9	1.3	6.7
	West Coast South Island	1	0.6	0.2	0.3	0.4	0.6	2.4

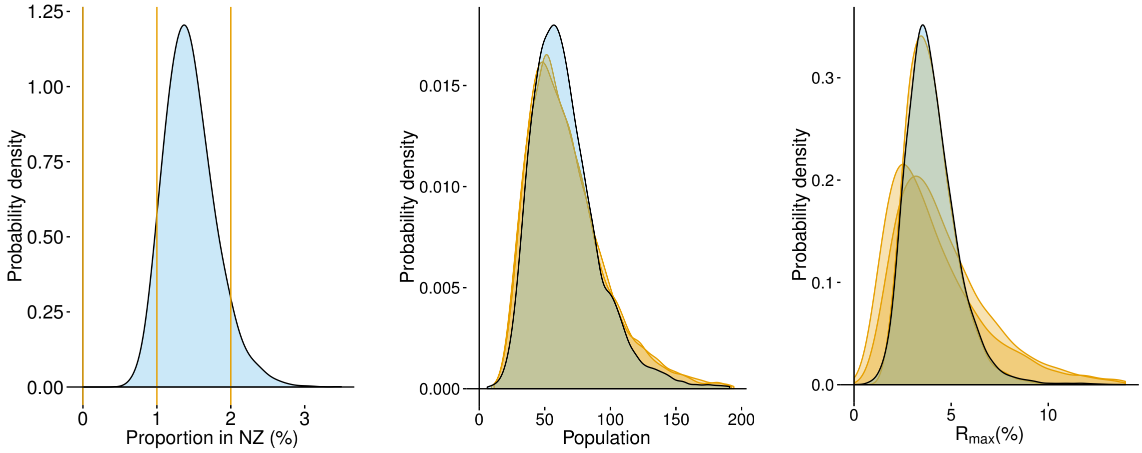


Figure E-8: Probability distributions of demographic parameters of Antarctic blue whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

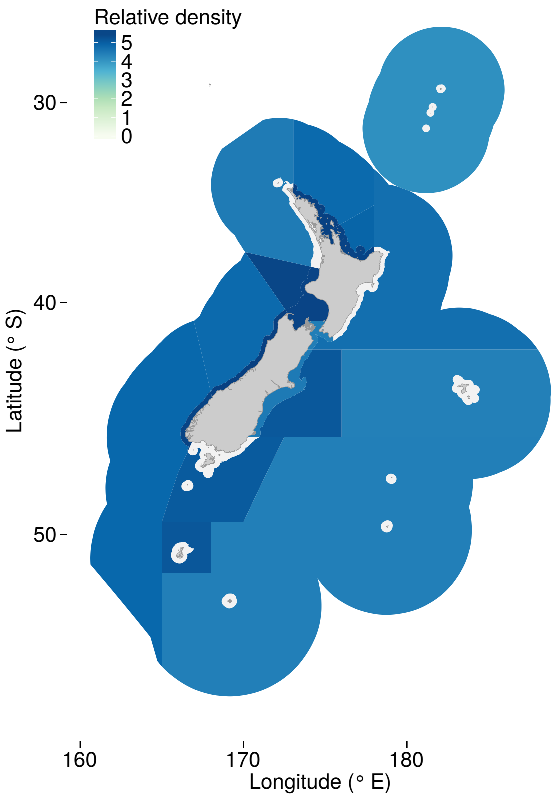


Figure E-9: Distribution of Antarctic blue whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.3 Antarctic minke whale

Table E-5: Demographic parameters of Antarctic minke whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	2		2.35	1.29	1.87	2.26	2.72	3.92
	2	2	0	2.35	1.28	1.87	2.25	2.73	3.95
Population (number)	1	2		293	75	162	240	344	761
	2	2	2	312	97	194	273	381	761
R_{max} (%)	1	0							
	2	1	0	4.13	1.63	2.90	3.79	4.94	8.52

Table E-6: Distribution of Antarctic minke whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	2	2.2	0.5	1.1	1.3	1.9	10.1
	Bay of Plenty	1	0.8	0.0	0.5	0.8	1.0	2.1
	Chatham Rise	2	10.7	1.5	7.5	10.9	13.1	21.4
	East Coast North Island	2	11.0	1.4	7.7	11.3	13.6	22.5
	East Coast South Island	2	3.7	0.8	2.6	3.3	4.1	9.3
	Fiordland	2	14.4	4.0	10.6	12.9	16.0	35.8
	Northland and Hauraki	1	5.0	0.0	3.4	4.8	5.8	12.4
	Stewart Snares Shelf	2	4.7	1.2	3.1	3.8	5.0	13.6
	Subantarctic	2	29.0	8.0	24.1	28.9	33.4	52.4
	Taranaki	1	1.5	0.0	0.9	1.3	1.6	3.6
	West Coast North Island	1	8.6	0.0	5.9	8.4	10.2	21.6
	West Coast South Island	1	5.4	1.0	3.9	5.1	6.1	13.0
Inshore	Bay of Plenty	1	0.4	0.0	0.3	0.4	0.5	1.1
	Cook Strait	1	0.3	0.0	0.2	0.2	0.3	0.7
	East Coast North Island	1	0.6	0.0	0.3	0.5	0.6	1.4
	Northland and Hauraki	1	0.6	0.0	0.4	0.5	0.6	1.4
	Taranaki	1	1.0	0.0	0.6	0.8	1.0	2.4

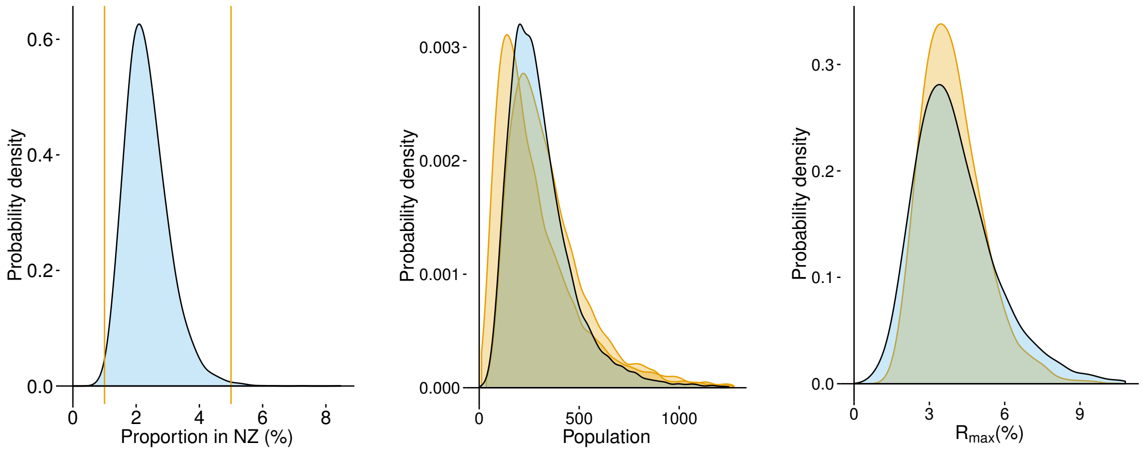


Figure E-10: Probability distributions of demographic parameters of Antarctic minke whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

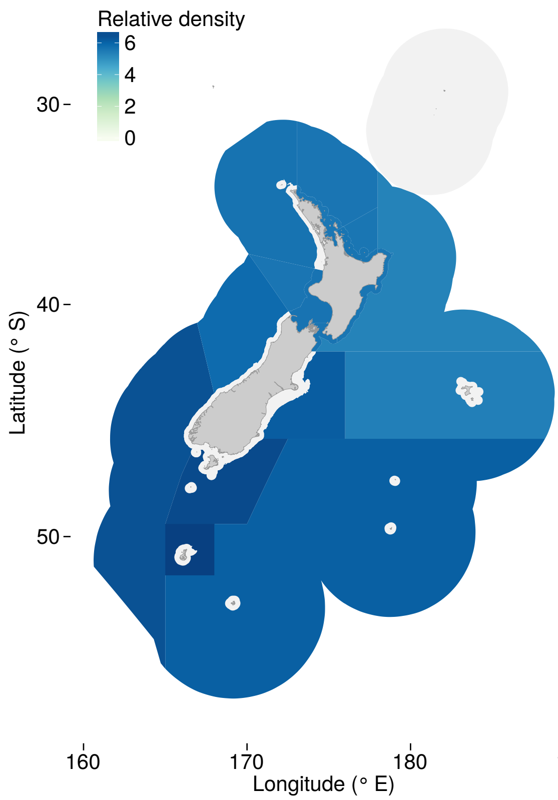


Figure E-11: Distribution of Antarctic minke whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.4 Bottlenose dolphin

Table E-7: Demographic parameters of bottlenose dolphin. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	4		0.23	0.15	0.20	0.23	0.26	0.34
	2	4	0	0.23	0.15	0.20	0.23	0.26	0.34
Population (number)	1	5		1 501	916	1 276	1 450	1 657	2 390
	2	5	4	1 640	1 080	1 415	1 597	1 807	2 468
R_{max} (%)	1	0							
	2	1	0	5.24	2.33	3.92	4.93	6.17	10.01

Table E-8: Distribution of bottlenose dolphin, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Bay of Plenty	4	2.9	0.2	1.3	2.2	3.5	9.5
	Chatham Rise	1	2.4	0.0	0.0	0.0	0.2	31.3
	East Coast North Island	2	2.1	0.0	0.0	0.0	0.2	27.1
	East Coast South Island	1	0.0	0.0	0.0	0.0	0.0	0.0
	Kermadec Islands	3	6.5	0.0	0.2	1.0	4.3	63.6
	Northland and Hauraki	3	4.0	0.2	1.8	3.0	4.8	13.9
	Stewart Snares Shelf	2	1.0	0.0	0.0	0.0	0.1	5.8
	Taranaki	2	0.0	0.0	0.0	0.0	0.0	0.0
Inshore	Bay of Plenty	5	3.9	0.3	1.9	3.1	4.8	11.2
	Chatham Rise	2	0.5	0.0	0.0	0.0	0.0	2.2
	Cook Strait	4	17.1	1.6	10.7	16.0	21.9	38.9
	East Coast North Island	4	1.7	0.1	0.8	1.3	2.0	5.3
	East Coast South Island	4	2.3	0.1	0.9	1.6	2.8	8.4
	Fiordland	5	16.6	1.6	10.4	15.5	21.6	38.3
	Kermadec Islands	2	1.3	0.0	0.0	0.1	0.4	11.9
	Northland and Hauraki	5	26.0	2.9	17.7	25.4	33.7	52.9
	Stewart Snares Shelf	4	5.1	0.4	2.8	4.4	6.4	13.8
	Taranaki	5	2.4	0.1	1.0	1.7	2.8	8.8
	West Coast North Island	5	2.1	0.2	1.1	1.7	2.5	6.3
	West Coast South Island	3	2.1	0.2	1.0	1.7	2.5	6.7

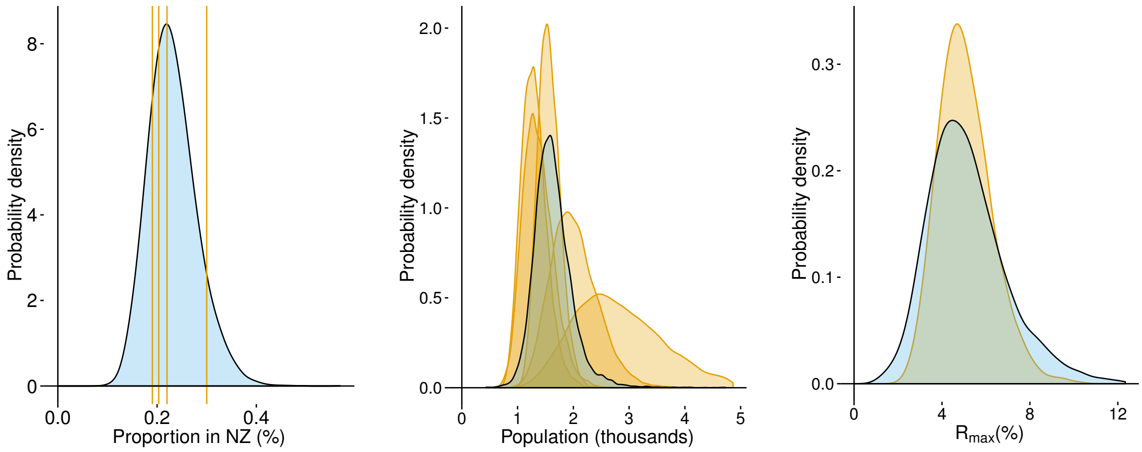


Figure E-12: Probability distributions of demographic parameters of bottlenose dolphin. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

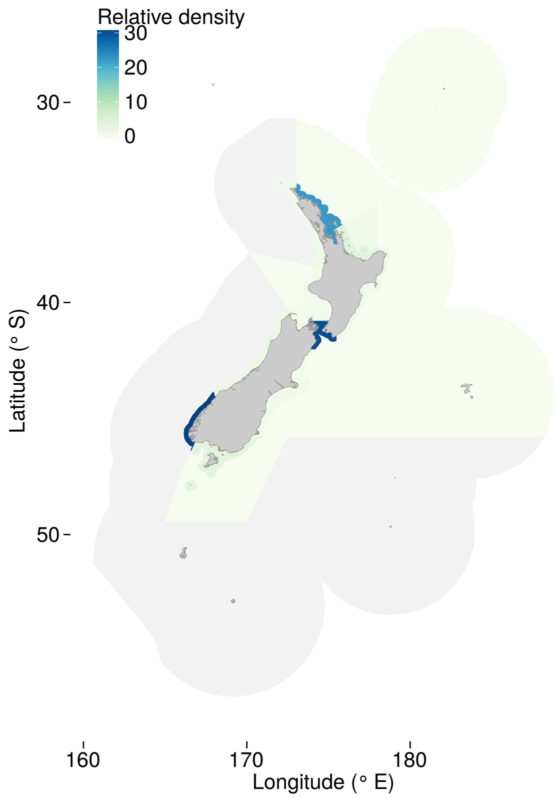


Figure E-13: Distribution of bottlenose dolphin in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.5 Bryde's whale

Table E-9: Demographic parameters of Bryde's whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	4		2.58	1.43	2.05	2.48	3.02	4.28
	2	4	0	2.59	1.41	2.06	2.51	3.02	4.33
Population (number)	1	6		153	60	115	148	180	291
	2	7	1	151	67	117	146	177	266
R_{max} (%)	1	2		4.87	2.20	3.59	4.55	5.76	9.28
	2	3	0	4.35	2.35	3.47	4.19	5.01	7.28

Table E-10: Distribution of Bryde's whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Bay of Plenty	7	2.4	0.0	0.2	0.6	1.8	17.7
	Chatham Rise	1	0.1	0.0	0.0	0.0	0.0	0.1
	East Coast North Island	2	0.0	0.0	0.0	0.0	0.0	0.0
	East Coast South Island	1	0.0	0.0	0.0	0.0	0.0	0.0
	Kermadec Islands	2	0.0	0.0	0.0	0.0	0.0	0.0
	Northland and Hauraki	8	5.8	0.0	0.5	1.7	5.3	42.1
	Taranaki	3	0.1	0.0	0.0	0.0	0.0	0.3
	West Coast North Island	4	0.3	0.0	0.0	0.0	0.0	0.8
	West Coast South Island	2	0.1	0.0	0.0	0.0	0.0	0.1
Inshore	Bay of Plenty	8	10.5	3.1	7.2	9.7	12.9	22.3
	Cook Strait	3	0.1	0.0	0.0	0.0	0.0	0.3
	East Coast North Island	3	0.2	0.0	0.0	0.0	0.0	0.4
	East Coast South Island	1	0.0	0.0	0.0	0.0	0.0	0.0
	Northland and Hauraki	8	79.7	34.0	76.7	83.9	88.1	93.5
	Taranaki	3	0.3	0.0	0.0	0.0	0.0	0.6
	West Coast North Island	4	0.3	0.0	0.0	0.0	0.0	1.3
	West Coast South Island	3	0.2	0.0	0.0	0.0	0.0	0.3

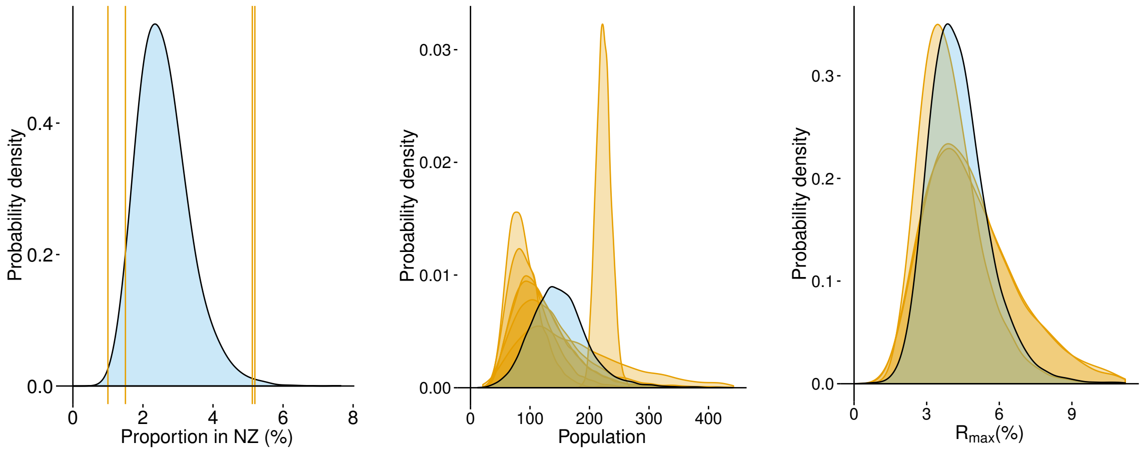


Figure E-14: Probability distributions of demographic parameters of Bryde's whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

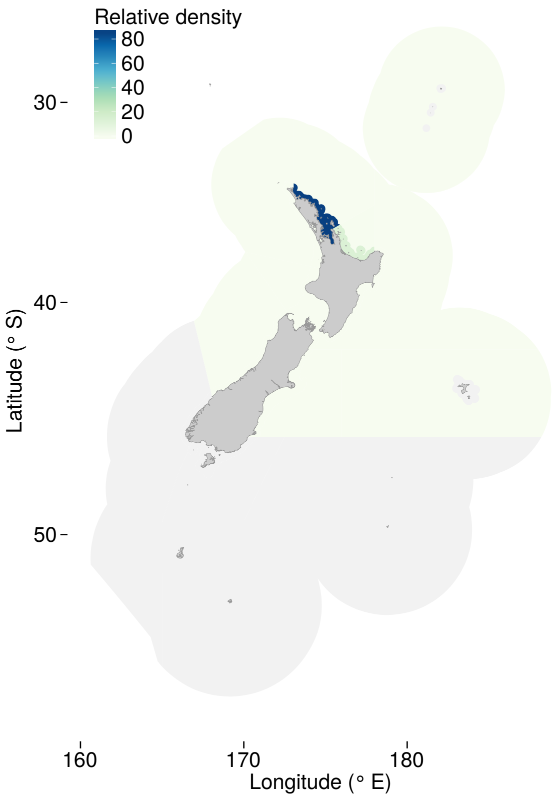


Figure E-15: Distribution of Bryde's whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.6 Common dolphin

Table E-11: Demographic parameters of common dolphin. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	2		1.63	0.96	1.34	1.58	1.87	2.56
	2	2	0	1.63	0.98	1.34	1.58	1.87	2.57
Population (number)	1	2		19 427	8 728	14 188	17 884	22 677	37 919
	2	2	1	19 051	8 658	14 057	17 634	22 083	35 367
R_{max} (%)	1	1		2.55	0.83	1.63	2.27	3.10	5.92
	2	2	0	4.03	1.87	3.13	3.84	4.68	7.21

Table E-12: Distribution of common dolphin, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	1	1.1	0.0	0.0	0.1	0.6	8.4
	Bay of Plenty	4	3.7	0.4	1.9	3.2	4.8	10.5
	Chatham Rise	2	5.9	0.0	0.4	1.6	5.4	43.3
	East Coast North Island	4	3.7	0.4	1.9	3.1	4.7	10.6
	East Coast South Island	3	2.8	0.0	0.1	0.6	2.2	22.8
	Fiordland	3	4.8	0.0	0.3	1.0	4.0	37.4
	Kermadec Islands	1	8.2	0.0	0.5	2.1	8.3	55.8
	Northland and Hauraki	4	4.9	0.5	2.6	4.2	6.3	13.4
	Stewart Snares Shelf	3	2.4	0.0	0.2	0.5	1.8	17.9
	Subantarctic	1	11.7	0.0	0.7	3.5	13.9	69.2
	Taranaki	4	2.2	0.1	0.8	1.5	2.6	8.7
	West Coast North Island	4	7.1	0.6	3.2	5.5	8.9	23.6
	West Coast South Island	4	6.2	0.5	2.7	4.8	7.8	20.2
Inshore	Auckland Islands	1	0.2	0.0	0.0	0.0	0.1	1.1
	Bay of Plenty	5	6.1	0.6	3.3	5.4	8.1	16.1
	Campbell Island	1	0.1	0.0	0.0	0.0	0.1	0.6
	Cook Strait	4	2.4	0.1	1.0	1.8	3.1	8.3
	East Coast North Island	3	3.4	0.4	1.8	3.0	4.5	9.0
	East Coast South Island	4	2.7	0.2	1.1	2.1	3.4	9.2
	Fiordland	3	0.3	0.0	0.0	0.0	0.2	1.8
	Northland and Hauraki	5	11.5	1.0	6.0	10.3	15.5	29.4
	Stewart Snares Shelf	4	1.6	0.1	0.6	1.1	1.9	5.7
	Taranaki	4	4.4	0.4	2.2	3.8	5.8	12.5
	West Coast North Island	3	0.7	0.0	0.0	0.1	0.4	5.1
	West Coast South Island	4	1.7	0.0	0.4	0.9	1.9	7.8

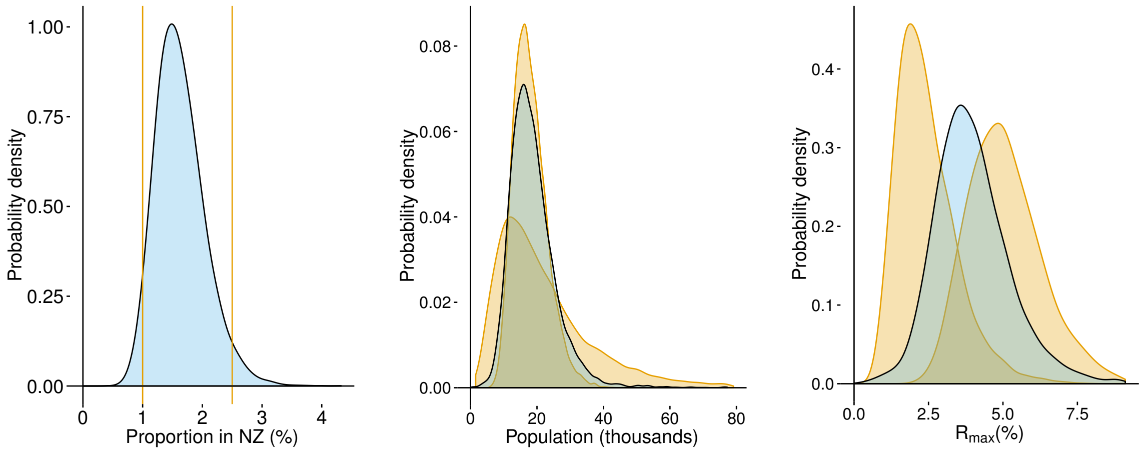


Figure E-16: Probability distributions of demographic parameters of common dolphin. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

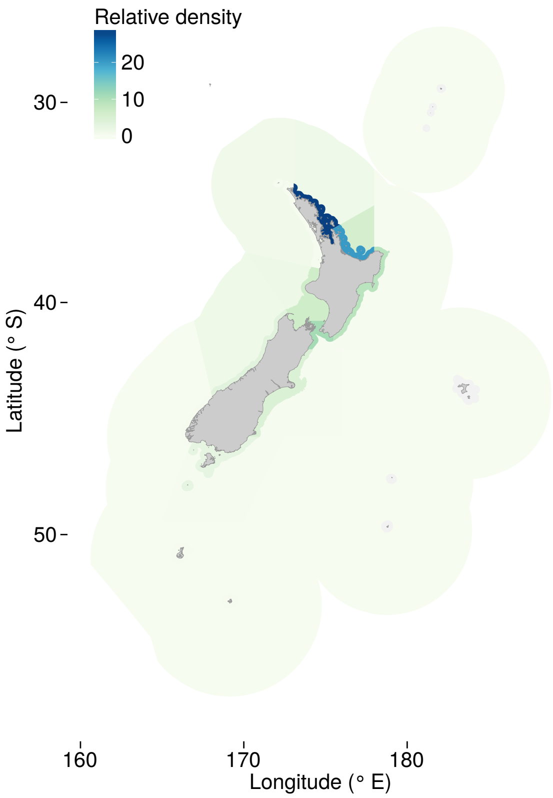


Figure E-17: Distribution of common dolphin in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.7 Cuvier's beaked whale

Table E-13: Demographic parameters of Cuvier's beaked whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	1		10.22	6.22	8.49	9.97	11.65	15.62
	2	1	0	10.26	6.25	8.55	10.01	11.70	15.73
Population (number)	1	1		5136	1 653	3 267	4 485	6 223	12 293
	2	1	0	5 056	1 622	3 223	4 435	6 173	12 124
R_{max} (%)	1	0							
	2	1	0	4.09	1.62	2.86	3.74	4.86	8.73

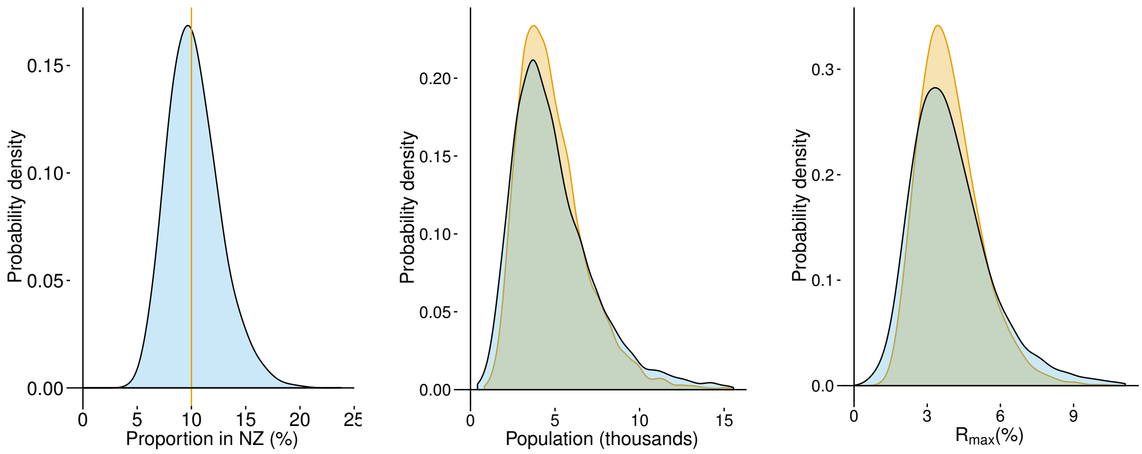


Figure E-18: Probability distributions of demographic parameters of Cuvier's beaked whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

E.8 Dusky dolphin

Table E-14: Demographic parameters of dusky dolphin. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	3		43.37	30.83	39.00	43.25	47.65	56.30
	2	3	0	43.51	31.26	39.07	43.46	47.89	56.53
Population (number)	1	3		25 109	11 045	19 130	23 331	28 588	51 360
	2	3	2	19 673	12 041	16 346	18 721	21 582	32 995
R_{max} (%)	1	1		4.22	1.51	2.80	3.81	5.12	9.32
	2	2	0	4.75	2.46	3.73	4.54	5.49	8.22

Table E-15: Distribution of dusky dolphin, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	2	2.7	0.0	0.0	0.1	0.5	32.5
	Bay of Plenty	1	0.0	0.0	0.0	0.0	0.0	0.0
	Chatham Rise	3	10.4	0.3	4.1	8.0	13.2	36.6
	East Coast North Island	1	4.4	0.0	0.0	0.1	0.9	56.3
	East Coast South Island	4	8.8	0.2	3.1	6.4	11.4	32.1
	Fiordland	2	5.6	0.0	0.0	0.2	1.7	69.8
	Stewart Snares Shelf	3	5.1	0.1	1.9	3.7	6.3	18.2
	Subantarctic	3	4.3	0.1	1.2	2.6	4.8	19.4
	Taranaki	2	2.8	0.0	0.0	0.1	0.6	35.1
	West Coast South Island	2	2.9	0.0	0.0	0.1	0.5	35.9
Inshore	Auckland Islands	1	1.4	0.0	0.0	0.0	0.2	12.4
	Bay of Plenty	1	0.0	0.0	0.0	0.0	0.0	0.0
	Cook Strait	4	8.0	0.1	2.7	5.7	10.4	29.9
	East Coast North Island	2	1.1	0.0	0.0	0.0	0.2	8.4
	East Coast South Island	6	27.9	0.9	15.5	27.4	38.9	63.2
	Fiordland	2	1.3	0.0	0.0	0.0	0.2	10.8
	Stewart Snares Shelf	4	7.2	0.2	3.1	5.7	9.3	23.8
	Taranaki	4	3.5	0.0	0.0	0.1	0.9	42.9
	West Coast South Island	4	2.6	0.0	0.7	1.5	3.0	11.5

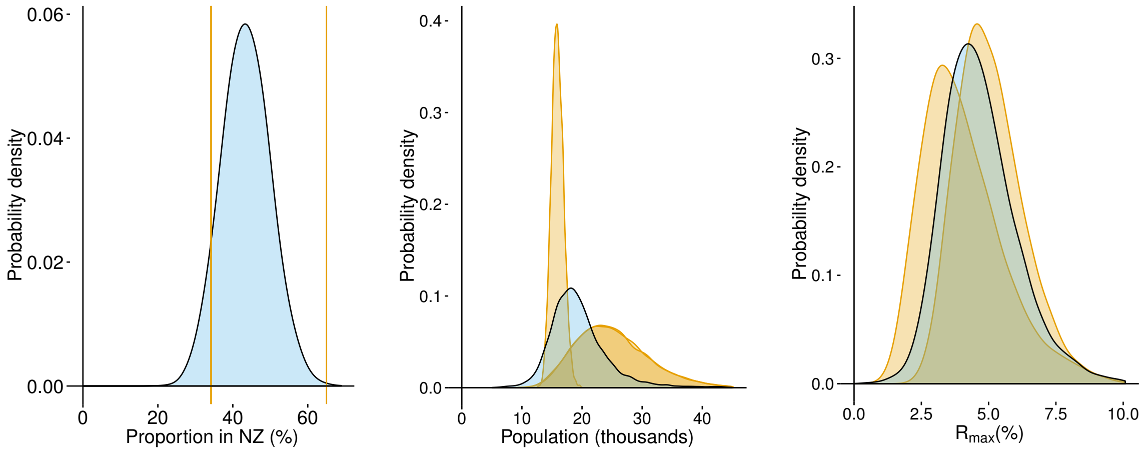


Figure E-19: Probability distributions of demographic parameters of dusky dolphin. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

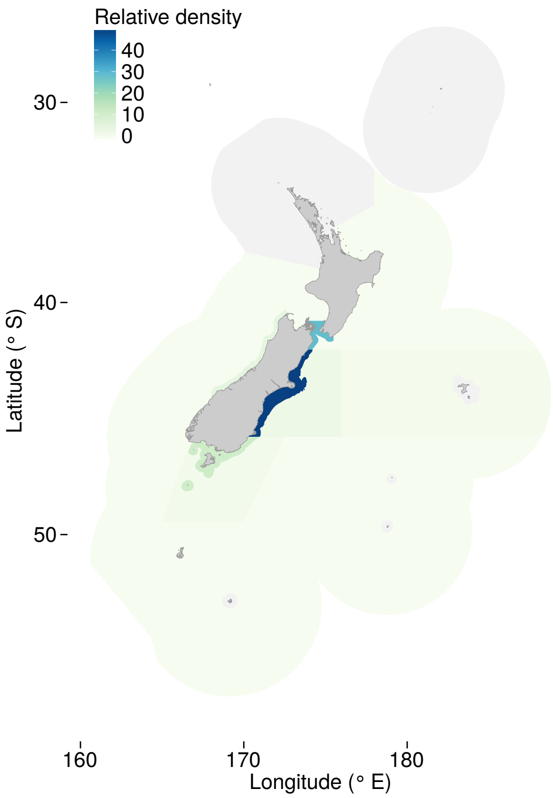


Figure E-20: Distribution of dusky dolphin in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.9 Dwarf minke whale

Table E-16: Demographic parameters of dwarf minke whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	2		3.26	1.97	2.69	3.17	3.73	5.04
	2	2	0	3.25	1.96	2.70	3.17	3.71	5.06
Population (number)	1	2		160	58	109	143	188	331
	2	2	1	140	53	95	126	166	299
R_{max} (%)	1	0							
	2	1	0	4.13	1.57	2.88	3.80	4.95	8.54

Table E-17: Distribution of dwarf minke whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Bay of Plenty	2	9.7	0.0	1.6	4.7	11.3	56.2
	East Coast North Island	2	12.3	0.1	2.1	6.2	14.8	69.7
	Kermadec Islands	1	12.8	0.1	2.2	6.1	14.6	73.3
	Northland and Hauraki	2	17.7	0.1	3.7	10.6	24.3	78.8
	Taranaki	1	0.6	0.0	0.0	0.0	0.0	2.9
	West Coast North Island	2	17.9	0.1	4.1	11.2	23.9	76.2
Inshore	Bay of Plenty	2	9.3	0.0	1.4	4.4	10.9	53.6
	Cook Strait	1	0.1	0.0	0.0	0.0	0.0	0.3
	East Coast North Island	1	0.3	0.0	0.0	0.0	0.0	0.8
	Northland and Hauraki	2	9.5	0.0	1.5	4.4	11.3	58.1
	Taranaki	1	0.5	0.0	0.0	0.0	0.0	1.5
	West Coast North Island	1	9.3	0.0	1.5	4.6	10.8	52.4

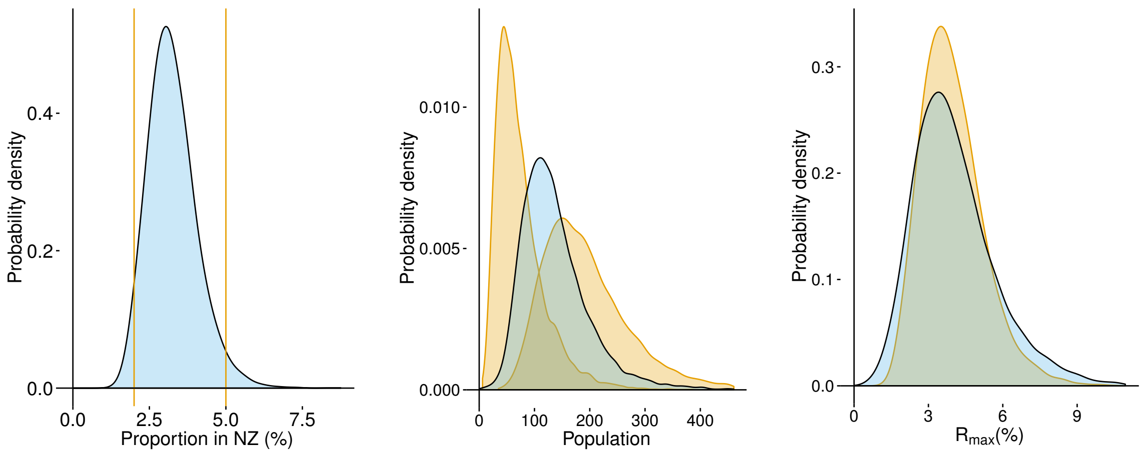


Figure E-21: Probability distributions of demographic parameters of dwarf minke whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

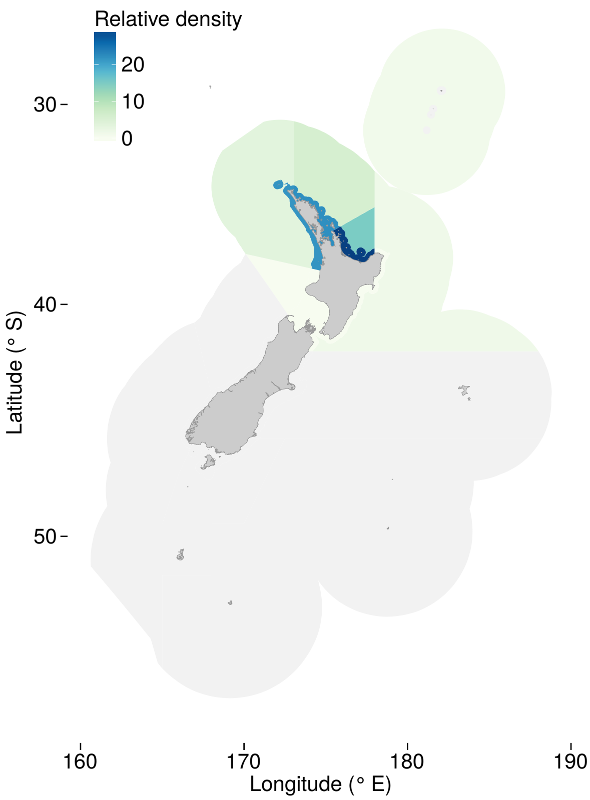


Figure E-22: Distribution of dwarf minke whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.10 False killer whale

Table E-18: Demographic parameters of false killer whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	3		1.23	0.57	0.90	1.15	1.46	2.35
	2	3	1	0.88	0.47	0.70	0.85	1.03	1.51
Population (number)	1	4		394	178	287	361	460	779
	2	5	2	361	175	272	337	420	674
R_{max} (%)	1	0							
	2	1	0	4.10	1.61	2.90	3.78	4.91	8.34

Table E-19: Distribution of false killer whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	1	0.4	0.0	0.0	0.0	0.0	1.8
	Bay of Plenty	4	5.8	0.4	3.5	5.5	7.5	13.9
	Chatham Rise	4	5.3	0.3	2.9	4.6	6.8	13.9
	East Coast North Island	4	6.9	0.5	4.1	6.4	8.9	16.4
	East Coast South Island	2	2.1	0.0	0.0	0.1	0.7	20.6
	Fiordland	1	2.0	0.0	0.0	0.0	0.2	22.8
	Kermadec Islands	2	8.9	0.0	0.2	1.1	6.1	77.7
	Northland and Hauraki	4	14.5	1.0	9.0	14.0	19.0	32.8
	Stewart Snares Shelf	3	1.8	0.0	0.0	0.1	0.5	16.4
	Subantarctic	2	4.0	0.0	0.1	0.2	1.3	47.9
	Taranaki	3	3.4	0.2	1.4	2.6	4.2	12.1
	West Coast North Island	3	10.6	0.6	5.5	9.1	13.9	30.4
	West Coast South Island	1	1.5	0.0	0.0	0.0	0.2	14.5
Inshore	Antipodes Islands	0	0.0	0.0	0.0	0.0	0.0	0.0
	Auckland Islands	0	0.0	0.0	0.0	0.0	0.0	0.0
	Bay of Plenty	5	5.5	0.3	3.3	5.2	7.1	13.2
	Campbell Island	0	0.0	0.0	0.0	0.0	0.0	0.0
	Chatham Rise	1	0.4	0.0	0.0	0.0	0.1	2.3
	Cook Strait	3	1.8	0.0	0.1	0.2	0.8	14.9
	East Coast North Island	3	1.9	0.0	0.1	0.3	1.1	16.4
	East Coast South Island	3	1.4	0.0	0.0	0.1	0.4	11.9
	Fiordland	1	0.3	0.0	0.0	0.0	0.0	1.1
	Kermadec Islands	1	0.4	0.0	0.0	0.0	0.0	2.3
	Northland and Hauraki	6	12.0	0.7	6.5	10.9	15.9	30.9
	Stewart Snares Shelf	0	0.0	0.0	0.0	0.0	0.0	0.0
	Taranaki	4	5.1	0.3	3.0	4.7	6.7	13.1
	West Coast North Island	4	3.7	0.2	1.9	3.2	4.8	10.7
	West Coast South Island	1	0.3	0.0	0.0	0.0	0.0	1.6
	Bounty Islands	0	0.0	0.0	0.0	0.0	0.0	0.0

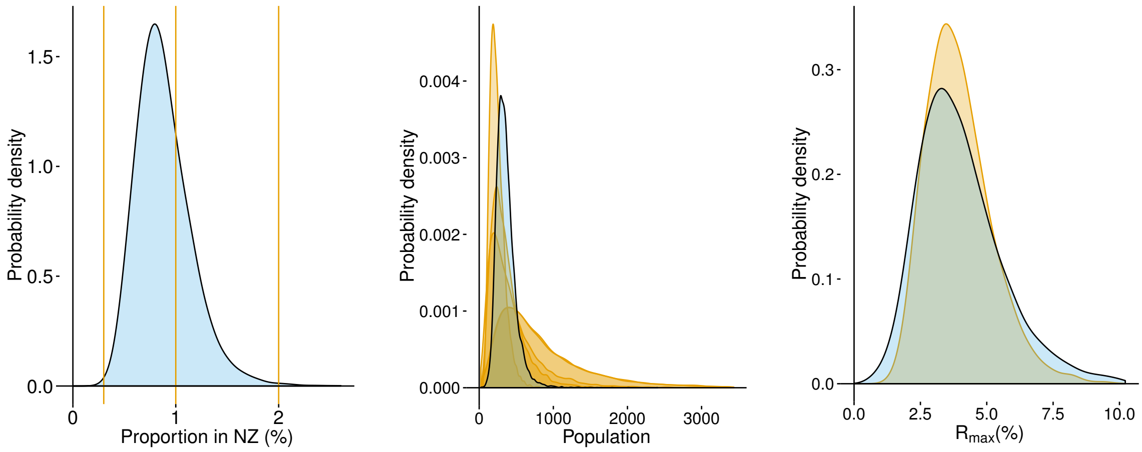


Figure E-23: Probability distributions of demographic parameters of false killer whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

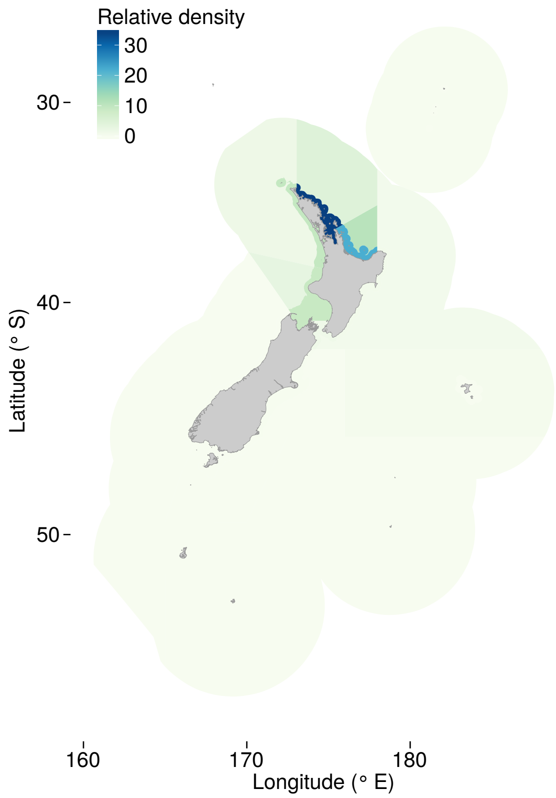


Figure E-24: Distribution of false killer whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.11 Fin whale

Table E-20: Demographic parameters of fin whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	3		1.54	0.92	1.27	1.50	1.76	2.43
	2	3	0	1.54	0.92	1.26	1.49	1.76	2.43
Population (number)	1	2		87	26	52	74	105	217
	2	2	1	84	26	51	72	102	203
R_{max} (%)	1	1		2.56	0.81	1.62	2.25	3.10	6.09
	2	2	1	3.79	2.00	3.00	3.61	4.35	6.53

Table E-21: Distribution of fin whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	2	1.9	0.2	0.9	1.2	1.9	7.4
	Bay of Plenty	2	2.7	0.2	0.7	1.1	2.6	15.4
	Chatham Rise	2	8.7	0.5	4.0	8.1	11.1	25.9
	East Coast North Island	2	9.7	0.5	4.8	8.9	11.8	29.4
	East Coast South Island	1	3.2	0.2	1.6	2.6	3.5	11.1
	Fiordland	1	10.0	0.7	5.4	9.0	11.9	29.5
	Kermadec Islands	1	10.7	0.1	1.9	10.6	15.9	33.3
	Northland and Hauraki	2	5.9	0.5	3.3	4.6	6.5	21.0
	Stewart Snares Shelf	1	5.0	0.5	2.5	3.4	5.3	19.4
	Subantarctic	2	16.9	0.5	6.5	16.7	24.5	43.7
	Taranaki	2	2.2	0.2	1.0	1.4	2.2	8.2
	West Coast North Island	2	7.7	0.0	2.4	6.6	9.2	31.3
	West Coast South Island	1	4.4	0.2	2.1	3.8	5.1	14.1
Inshore	Bay of Plenty	1	0.4	0.0	0.1	0.3	0.4	1.4
	Cook Strait	1	0.3	0.0	0.0	0.2	0.2	1.0
	Northland and Hauraki	2	6.8	0.2	0.5	0.7	4.0	54.1
	Taranaki	2	1.4	0.1	0.7	0.9	1.4	6.0
	West Coast North Island	1	2.1	0.2	0.5	0.8	2.0	12.1

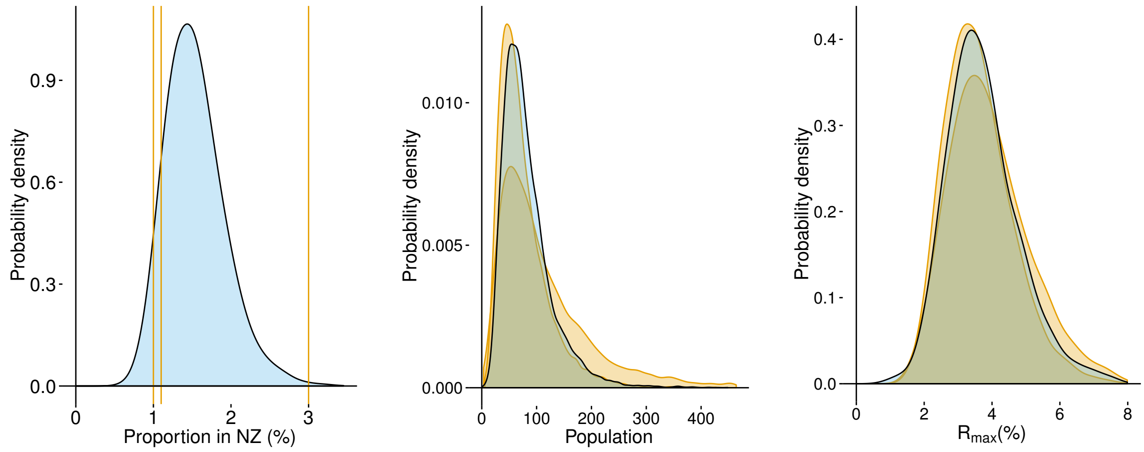


Figure E-25: Probability distributions of demographic parameters of fin whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

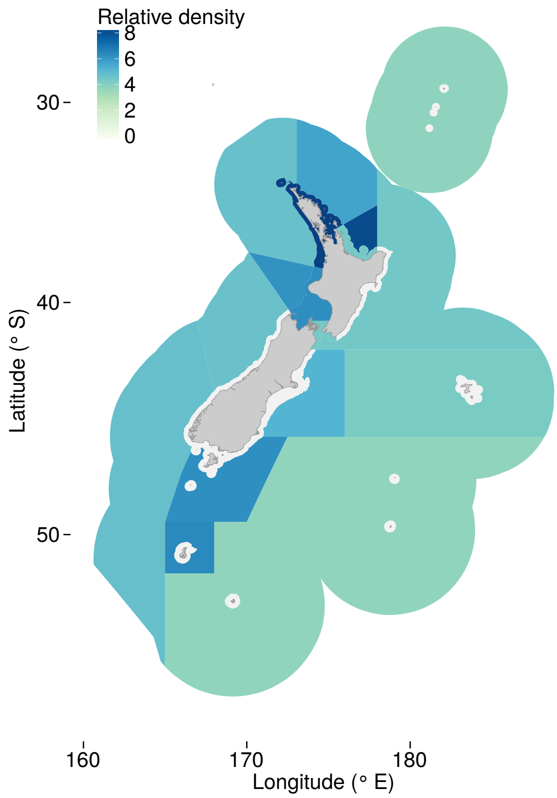


Figure E-26: Distribution of fin whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.12 Gray's beaked whale

Table E-22: Demographic parameters of Gray's beaked whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	2		17.60	11.87	15.33	17.33	19.62	24.83
	2	2	0	17.64	11.81	15.30	17.42	19.72	24.75
Population (number)	1	1		3 232	456	1 314	2 265	3 893	10 832
	2	1	0	3 174	447	1 302	2 221	3 812	11 346
R_{max} (%)	1	0							
	2	1	0	4.10	1.64	2.88	3.74	4.90	8.51

Table E-23: Distribution of Gray's beaked whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	1	1.9	0.4	1.0	1.3	1.8	7.2
	Bay of Plenty	2	1.6	0.3	0.7	0.9	1.4	6.8
	Chatham Rise	2	12.6	2.4	9.2	11.5	14.1	30.2
	East Coast North Island	2	10.4	1.0	6.9	10.5	12.8	23.2
	East Coast South Island	2	2.9	0.4	2.0	2.7	3.3	6.9
	Fiordland	1	10.0	1.0	6.8	10.0	12.2	22.3
	Kermadec Islands	1	15.0	2.0	10.9	15.2	18.0	31.4
	Northland and Hauraki	1	4.6	0.0	2.8	4.4	5.5	12.6
	Stewart Snares Shelf	1	4.0	0.7	2.7	3.4	4.3	11.3
	Subantarctic	1	28.0	6.8	22.6	27.2	32.2	55.8
	West Coast South Island	1	4.6	0.5	3.1	4.4	5.4	10.8
Inshore	Bay of Plenty	1	0.4	0.0	0.2	0.3	0.4	1.0
	Cook Strait	1	0.8	0.1	0.2	0.3	0.4	4.6
	East Coast North Island	1	0.5	0.0	0.3	0.4	0.5	1.3
	East Coast South Island	1	1.0	0.2	0.6	0.7	1.0	3.2
	Northland and Hauraki	1	0.5	0.0	0.3	0.5	0.6	1.4
	Stewart Snares Shelf	1	1.1	0.2	0.5	0.7	1.0	4.1

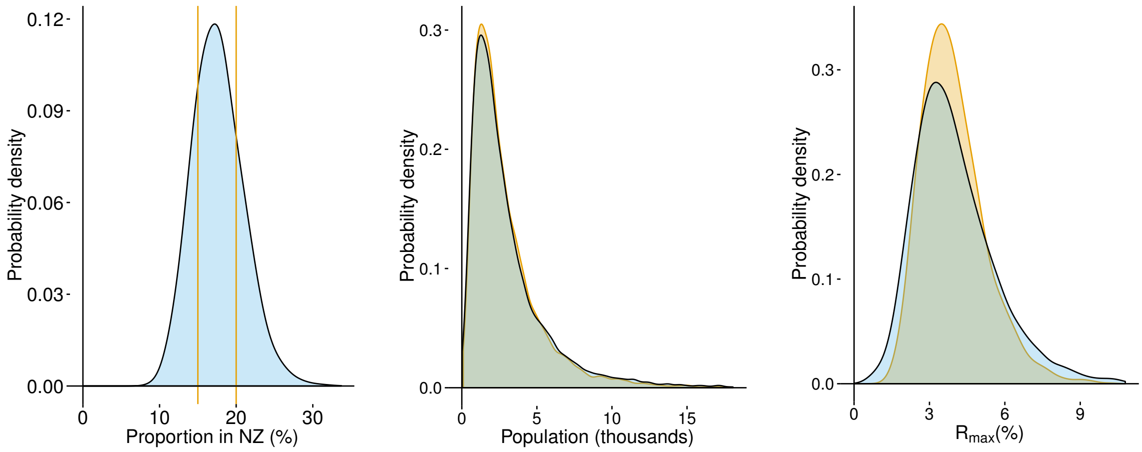


Figure E-27: Probability distributions of demographic parameters of Gray's beaked whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

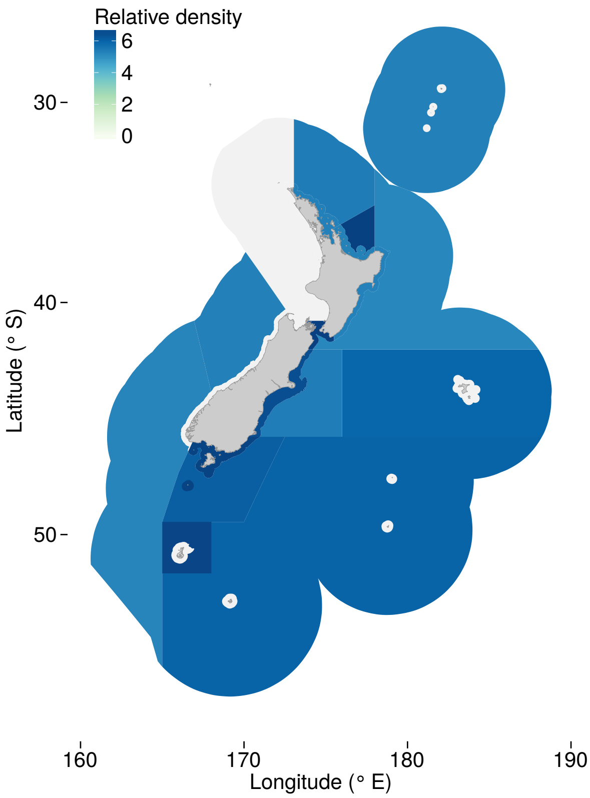


Figure E-28: Distribution of Gray's beaked whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.13 Hector's beaked whale

Table E-24: Demographic parameters of Hector's beaked whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
R_{max} (%)	1	0							
	2	1	0	4.12	1.59	3	3.77	4.95	9

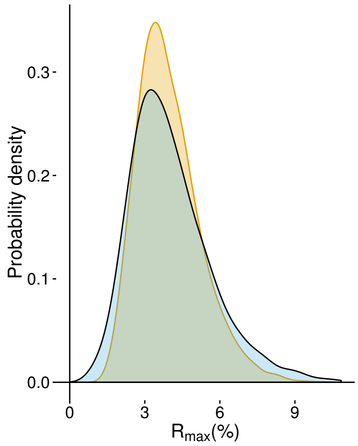


Figure E-29: Probability distributions of demographic parameters of Hector's beaked whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

E.14 Hector's dolphin

Table E-25: Demographic parameters of Hector's dolphin. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	11		100.00	100.00	100.00	100.00	100.00	100.00
	2	12	0	100.00	100.00	100.00	100.00	100.00	100.00
Population (number)	1	10		10 389	4 581	7 800	9 707	12 113	20 294
	2	10	2	9 926	4 334	7 353	9 306	11 620	19 274
R_{max} (%)	1	6		2.49	1.68	2.17	2.44	2.75	3.53
	2	7	1	2.56	1.76	2.25	2.52	2.81	3.62

Table E-26: Distribution of Hector's dolphin, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	East Coast North Island	1	0.0	0.0	0.0	0.0	0.0	0.0
	East Coast South Island	1	0.0	0.0	0.0	0.0	0.0	0.0
	Fiordland	2	0.0	0.0	0.0	0.0	0.0	0.0
	Stewart Snares Shelf	1	0.0	0.0	0.0	0.0	0.0	0.0
	Taranaki	1	0.0	0.0	0.0	0.0	0.0	0.0
	West Coast North Island	1	0.0	0.0	0.0	0.0	0.0	0.0
	West Coast South Island	2	0.0	0.0	0.0	0.0	0.0	0.0
Inshore	Cook Strait	9	10.1	5.6	8.2	9.8	11.7	16.5
	East Coast South Island	10	37.5	23.2	32.3	37.3	42.3	53.3
	Fiordland	5	0.2	0.0	0.0	0.0	0.1	1.1
	Stewart Snares Shelf	10	10.1	5.6	8.3	9.8	11.6	16.2
	Taranaki	10	2.7	0.8	1.7	2.4	3.3	6.6
	West Coast North Island	3	0.0	0.0	0.0	0.0	0.0	0.1
	West Coast South Island	10	39.3	24.4	33.9	39.0	44.5	55.8

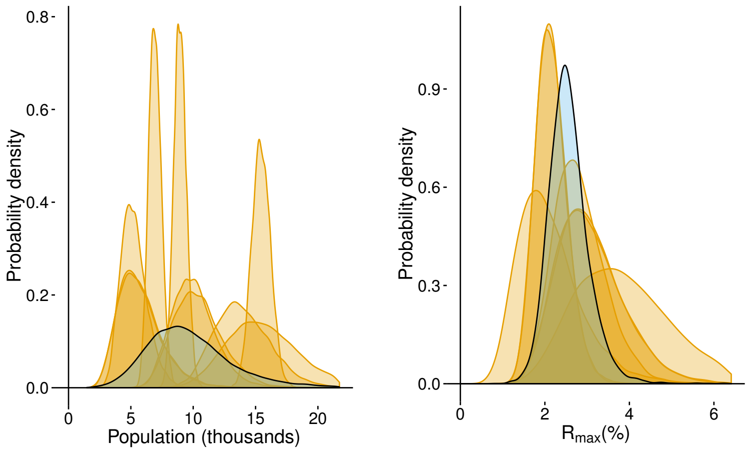


Figure E-30: Probability distributions of demographic parameters of Hector's dolphin. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

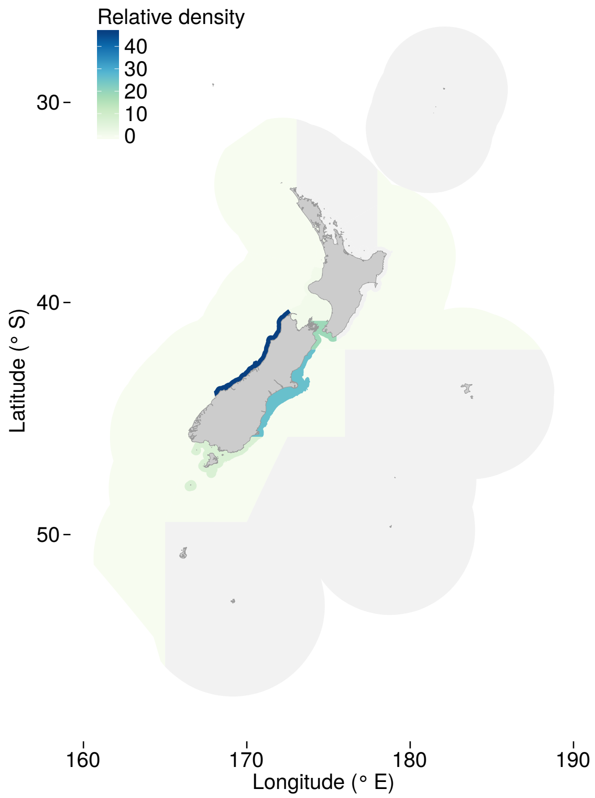


Figure E-31: Distribution of Hector's dolphin in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.15 Hourglass dolphin

Table E-27: Demographic parameters of hourglass dolphin. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	1		10.24	6.18	8.53	9.99	11.69	15.66
	2	1	0	10.26	6.19	8.53	9.98	11.69	15.70
Population (number)	1	2		4 461	13	61	96	162	2 082
	2	2	1	2 629	10	63	101	170	2 341
R_{max} (%)	1	0							
	2	1	0	4.12	1.60	2.90	3.77	4.91	8.61

Table E-28: Distribution of hourglass dolphin, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	2	2.4	0.9	1.7	2.0	2.6	6.4
	Chatham Rise	2	17.7	4.4	14.0	18.1	21.0	32.3
	East Coast South Island	2	5.4	1.8	4.2	5.1	6.1	11.2
	Fiordland	1	20.3	7.6	16.5	19.6	22.9	37.3
	Stewart Snares Shelf	2	6.6	2.5	5.0	5.9	7.2	14.9
	Subantarctic	2	46.2	23.5	41.6	46.4	51.1	67.9
Inshore	East Coast South Island	1	1.4	0.3	0.9	1.1	1.4	3.1

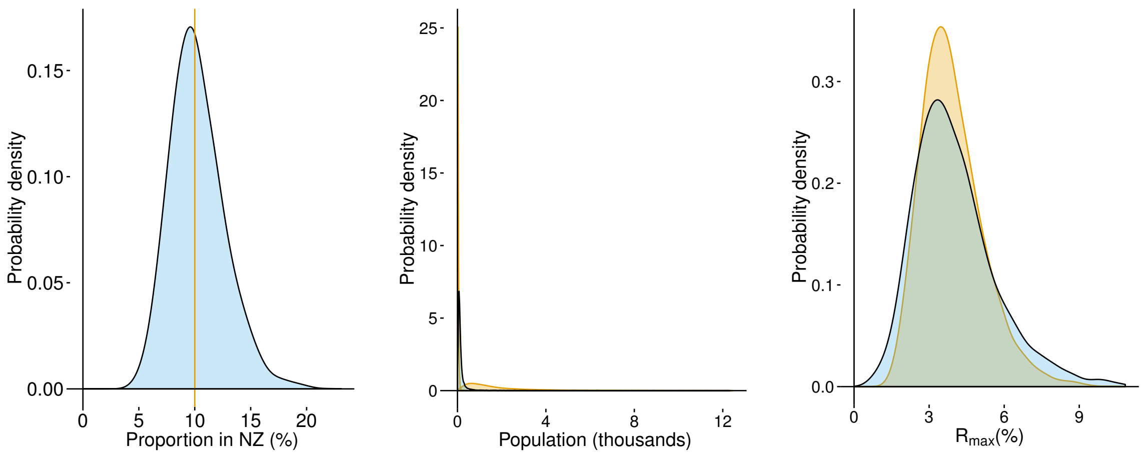


Figure E-32: Probability distributions of demographic parameters of hourglass dolphin. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

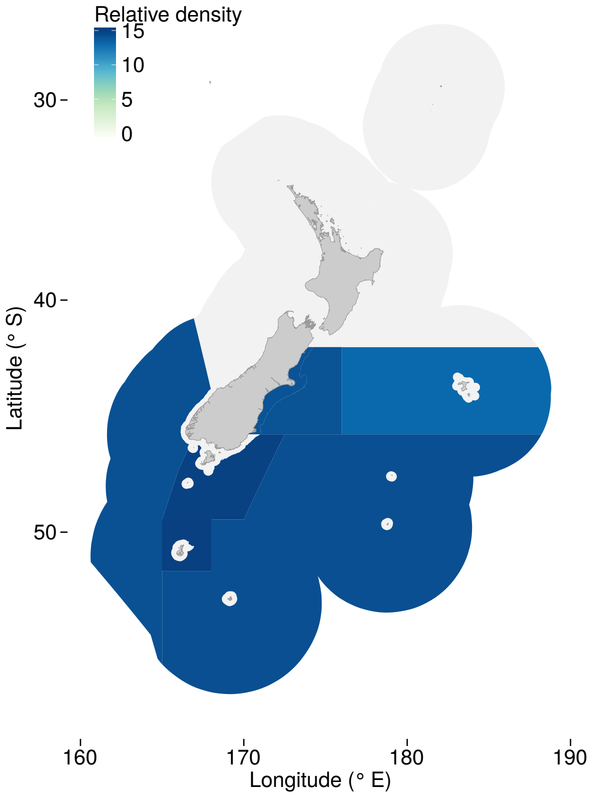


Figure E-33: Distribution of hourglass dolphin in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.16 Humpback whale

Table E-29: Demographic parameters of humpback whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	4		0.36	0.16	0.26	0.34	0.44	0.72
	2	4	1	0.61	0.39	0.52	0.60	0.69	0.92
Population (number)	1	4		1 449	33	242	544	1 178	7 783
	2	4	2	4 317	4	75	172	351	6 101
R_{max} (%)	1	3		9.39	5.24	8.02	9.22	10.55	14.16
	2	4	1	8.75	5.13	7.57	8.63	9.80	12.80

Table E-30: Distribution of humpback whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	2	3.6	0.0	0.6	1.5	3.3	21.4
	Bay of Plenty	4	3.2	0.1	1.5	2.6	4.0	9.9
	Chatham Rise	1	2.5	0.0	0.0	0.0	0.1	33.3
	East Coast North Island	3	5.5	0.1	1.7	3.5	6.4	23.1
	East Coast South Island	3	6.7	0.1	1.2	3.2	6.9	41.2
	Fiordland	2	2.6	0.0	0.0	0.0	0.1	35.1
	Kermadec Islands	4	8.2	0.1	2.3	5.0	9.7	38.3
	Northland and Hauraki	3	3.6	0.1	1.2	2.4	4.1	15.3
	Stewart Snares Shelf	3	4.3	0.0	0.7	1.6	3.7	30.4
	Subantarctic	1	4.5	0.0	0.0	0.0	0.2	69.5
	Taranaki	3	2.0	0.0	0.0	0.0	0.3	22.8
	West Coast North Island	2	3.9	0.0	0.0	0.1	0.9	52.3
	West Coast South Island	1	1.2	0.0	0.0	0.0	0.0	11.0
Inshore	Bay of Plenty	5	6.0	0.2	2.8	5.2	8.0	17.6
	Cook Strait	4	6.0	0.2	2.9	5.2	7.9	17.3
	East Coast North Island	5	5.9	0.1	2.1	4.4	7.5	20.7
	East Coast South Island	5	3.2	0.1	1.1	2.3	4.0	12.1
	Fiordland	4	4.8	0.2	2.3	4.0	6.3	13.3
	Northland and Hauraki	5	6.0	0.2	2.9	5.2	7.9	16.8
	Stewart Snares Shelf	5	2.5	0.1	1.0	1.9	3.1	8.9
	Taranaki	5	7.7	0.3	3.5	6.3	10.1	23.5
	West Coast North Island	5	3.2	0.1	1.1	2.2	3.9	12.1
	West Coast South Island	4	3.1	0.1	1.1	2.2	3.7	12.4

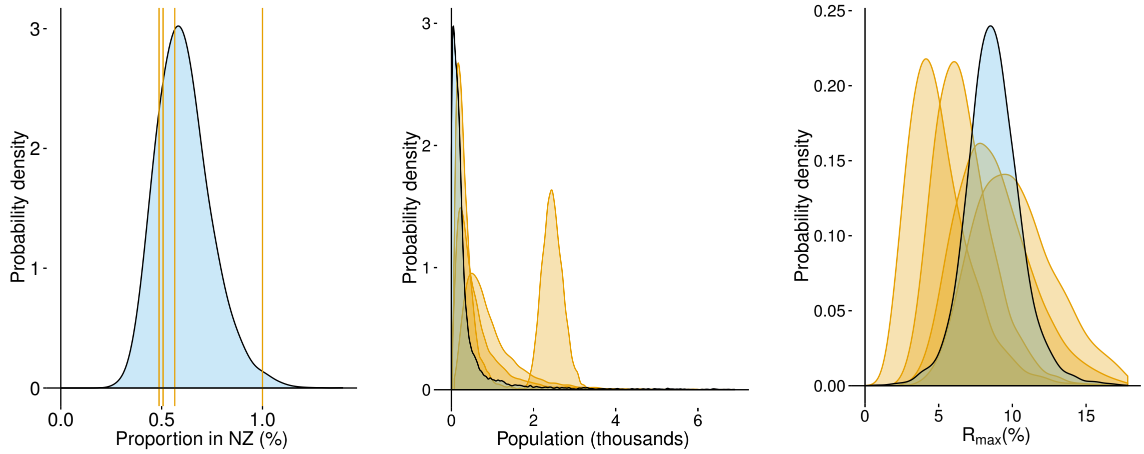


Figure E-34: Probability distributions of demographic parameters of humpback whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

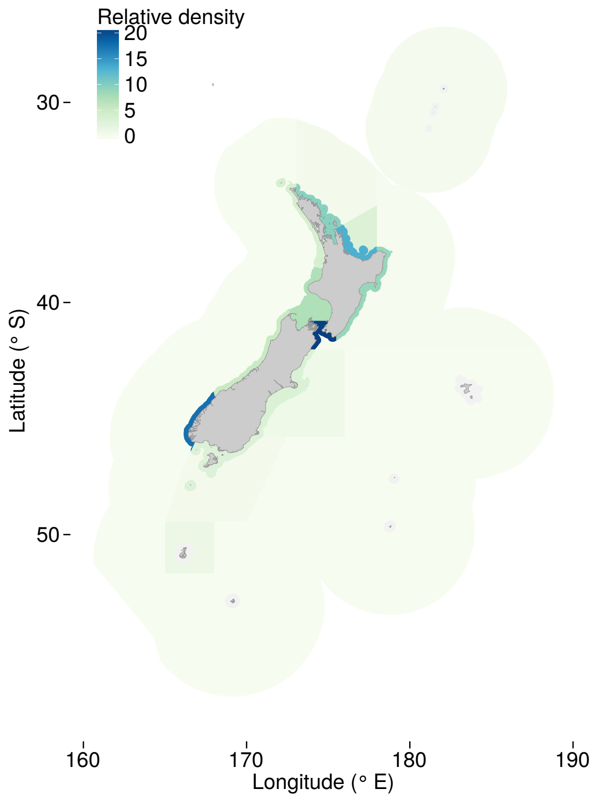


Figure E-35: Distribution of humpback whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.17 Killer whale

Table E-31: Demographic parameters of killer whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	4		1.10	0.60	0.87	1.05	1.27	1.87
	2	4	1	0.98	0.56	0.80	0.95	1.13	1.56
Population (number)	1	5		253	125	203	242	287	455
	2	5	1	240	118	196	232	273	419
R_{max} (%)	1	1		1.88	0.80	1.36	1.73	2.22	3.77
	2	2	0	2.62	1.22	1.99	2.44	3.01	4.94

Table E-32: Distribution of killer whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	1	1.4	0.1	0.5	0.9	1.6	6.5
	Bay of Plenty	2	1.8	0.3	0.9	1.4	2.2	5.8
	Chatham Rise	2	5.6	0.7	2.4	4.0	6.5	21.2
	East Coast North Island	2	3.2	0.4	1.3	2.1	3.6	13.2
	East Coast South Island	2	3.3	0.5	1.5	2.5	4.0	11.0
	Fiordland	1	12.3	1.1	5.0	8.8	15.6	45.8
	Northland and Hauraki	2	3.8	0.6	1.7	2.8	4.4	13.1
	Stewart Snares Shelf	1	4.1	0.3	1.3	2.5	4.6	18.3
	Subantarctic	1	12.7	1.2	4.4	8.1	15.3	55.6
	Taranaki	2	1.7	0.2	0.8	1.2	2.0	5.4
	West Coast North Island	2	3.6	0.4	1.3	2.3	4.0	15.1
	West Coast South Island	2	2.3	0.3	0.9	1.5	2.6	8.9
Inshore	Auckland Islands	1	0.7	0.0	0.2	0.5	0.9	3.3
	Bay of Plenty	5	5.2	0.3	2.4	4.4	7.0	15.1
	Chatham Rise	1	2.7	0.1	0.7	1.7	3.4	11.6
	Cook Strait	5	4.0	0.2	1.7	3.2	5.4	12.3
	East Coast North Island	5	4.5	0.4	2.1	3.7	6.0	13.2
	East Coast South Island	6	4.8	0.4	2.3	4.0	6.2	14.0
	Fiordland	5	1.6	0.2	0.8	1.3	2.1	4.9
	Northland and Hauraki	5	7.8	1.1	4.5	7.0	10.3	19.2
	Stewart Snares Shelf	5	3.7	0.4	1.8	3.0	4.8	10.8
	Taranaki	5	3.9	0.4	2.0	3.2	4.9	11.4
	West Coast North Island	5	3.1	0.2	1.3	2.3	4.0	10.0
	West Coast South Island	6	2.3	0.2	1.1	1.9	2.9	6.8

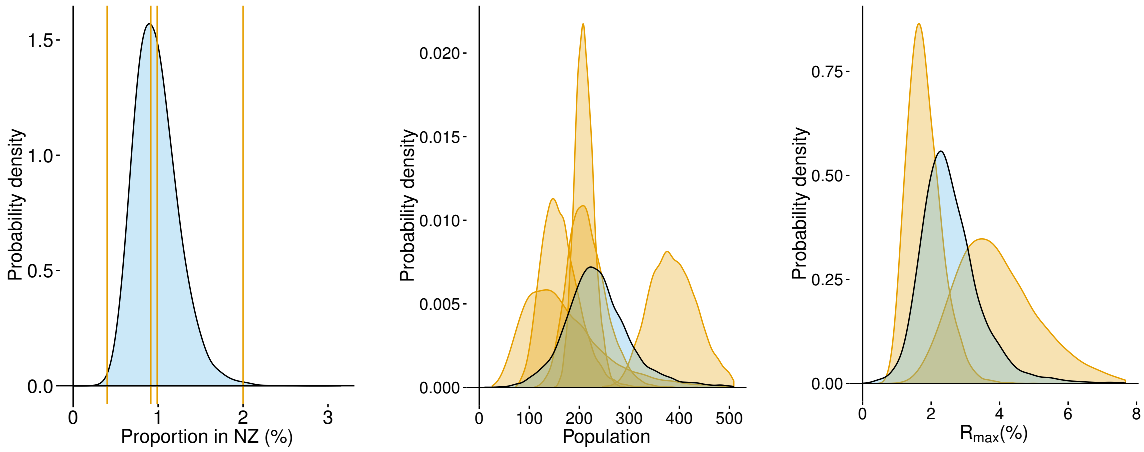


Figure E-36: Probability distributions of demographic parameters of killer whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

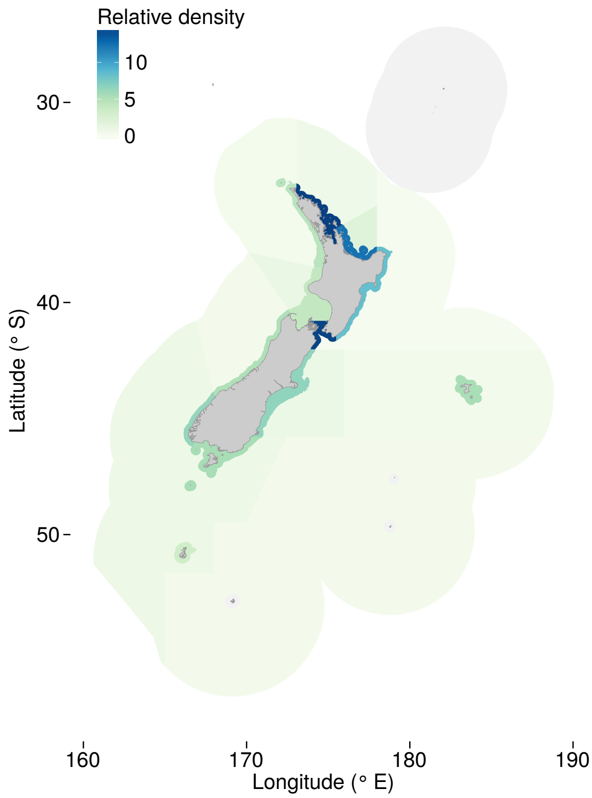


Figure E-37: Distribution of killer whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.18 Long-finned pilot whale

Table E-33: Demographic parameters of long-finned pilot whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	2		6.56	4.01	5.47	6.39	7.47	10.05
	2	2	1	4.58	2.90	3.87	4.47	5.17	6.87
Population (number)	1	2		3 641	536	1 417	1 937	2 690	12 604
	2	2	2	3 807	955	2 137	3 159	4 649	10 115
R_{max} (%)	1	0							
	2	1	0	4.09	1.63	2.87	3.77	4.88	8.57

Table E-34: Distribution of long-finned pilot whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	2	1.7	0.2	0.7	1.2	2.1	6.2
	Bay of Plenty	2	1.9	0.2	0.7	1.3	2.4	7.5
	Chatham Rise	2	12.2	1.5	6.1	10.5	15.7	35.6
	East Coast North Island	3	6.4	0.7	2.8	4.9	8.6	18.9
	East Coast South Island	2	5.4	0.6	2.4	4.0	6.7	19.0
	Fiordland	2	12.1	1.6	6.1	10.3	15.2	36.9
	Northland and Hauraki	2	6.5	0.2	1.8	4.0	7.4	31.7
	Stewart Snares Shelf	2	3.1	0.5	1.7	2.7	3.9	8.8
	Subantarctic	2	18.4	2.4	9.1	16.1	25.3	48.4
	Taranaki	2	2.1	0.1	0.5	1.1	2.1	10.9
	West Coast North Island	2	10.8	0.4	3.4	7.3	12.9	47.1
	West Coast South Island	2	6.7	0.7	3.2	5.3	8.3	21.8
Inshore	Bay of Plenty	2	0.3	0.0	0.1	0.3	0.4	1.2
	Cook Strait	2	1.7	0.1	0.4	1.0	2.3	7.0
	East Coast North Island	1	0.8	0.0	0.2	0.4	0.8	4.6
	East Coast South Island	2	1.1	0.1	0.5	0.8	1.4	4.0
	Fiordland	2	0.9	0.1	0.3	0.7	1.3	3.1
	Northland and Hauraki	2	0.8	0.0	0.2	0.4	0.8	4.4
	Stewart Snares Shelf	2	1.3	0.2	0.7	1.1	1.7	4.1
	Taranaki	4	3.7	0.4	1.3	2.8	5.1	11.9
	West Coast North Island	2	0.9	0.0	0.2	0.5	0.9	4.3
	West Coast South Island	1	0.9	0.1	0.3	0.6	1.1	3.3

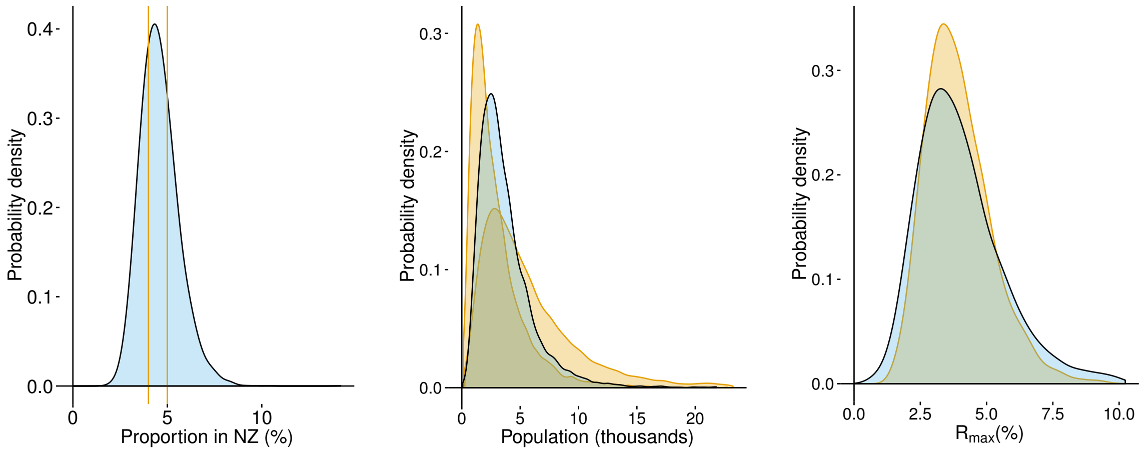


Figure E-38: Probability distributions of demographic parameters of long-finned pilot whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

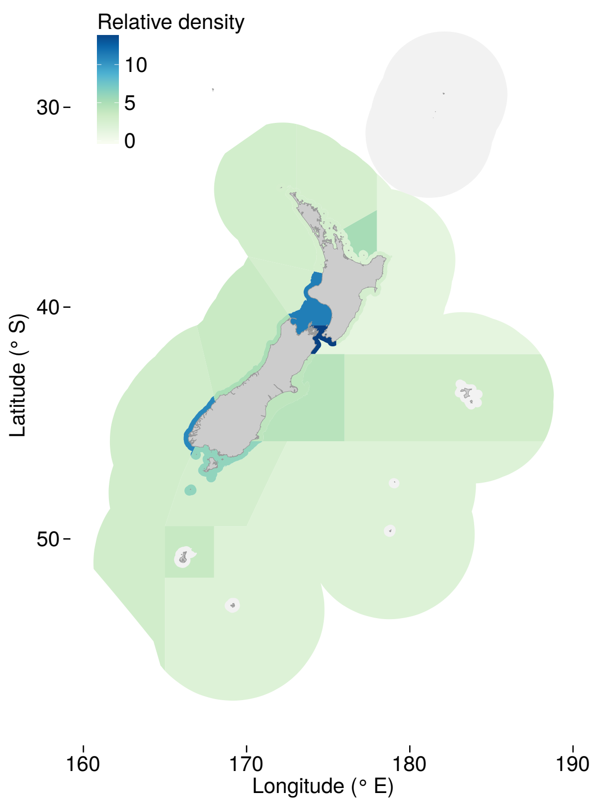


Figure E-39: Distribution of long-finned pilot whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.19 Māui dolphin

Table E-35: Demographic parameters of Māui dolphin. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	8		100.00	100.00	100.00	100.00	100.00	100.00
	2	10	0	100.00	100.00	100.00	100.00	100.00	100.00
Population (number)	1	8		67	48	60	66	73	92
	2	8	1	66	47	59	65	72	90
R_{max} (%)	1	4		2.13	1.38	1.83	2.09	2.39	3.13
	2	5	0	2.31	1.53	1.99	2.26	2.56	3.38

Table E-36: Distribution of Māui dolphin, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Bay of Plenty	1	0.0	0.0	0.0	0.0	0.0	0.0
	Cook Strait	2	0.1	0.0	0.0	0.0	0.0	0.2
	East Coast North Island	2	0.0	0.0	0.0	0.0	0.0	0.1
	Taranaki	9	12.8	6.6	10.1	12.3	14.9	21.9
	West Coast North Island	9	87.1	77.9	85.0	87.6	89.8	93.4

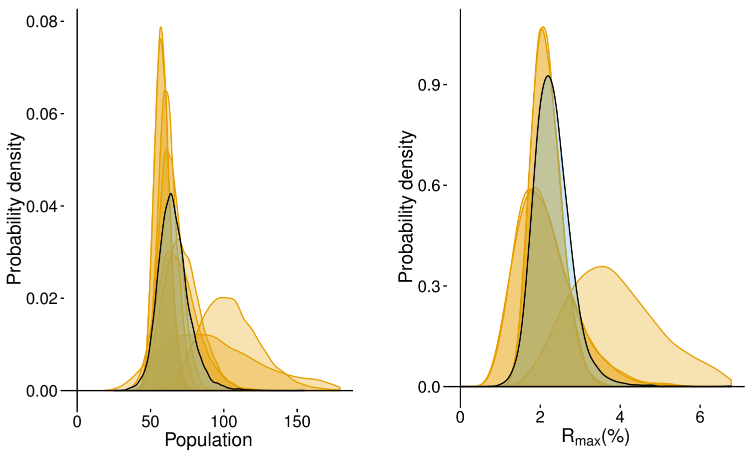


Figure E-40: Probability distributions of demographic parameters of Māui dolphin. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

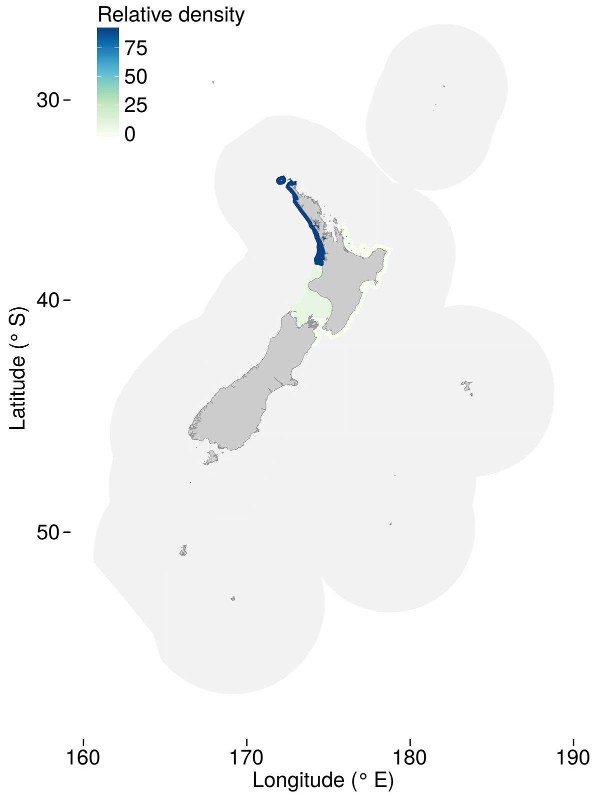


Figure E-41: Distribution of Māui dolphin in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.20 New Zealand fur seal

Table E-37: Demographic parameters of New Zealand fur seal. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	6		59.47	48.68	55.81	59.54	63.22	69.73
	2	7	2	58.10	47.23	54.54	58.18	61.81	68.59
Population (number)	1	6		126 757	61 883	99 837	120 326	144 967	233 271
	2	9	2	12 6833	71 970	104 550	122 361	143 680	206 123
R_{max} (%)	1	5		10.38	6.41	8.97	10.18	11.54	15.31
	2	7	1	10.68	7.16	9.47	10.55	11.76	14.76

Table E-38: Distribution of New Zealand fur seal, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	6	2.5	0.0	0.0	0.1	0.4	29.0
	Chatham Rise	5	5.6	0.0	0.0	0.2	1.6	69.1
	East Coast North Island	4	1.4	0.0	0.0	0.0	0.1	13.4
	East Coast South Island	7	3.5	0.0	0.0	0.1	0.6	48.2
	Fiordland	6	5.1	0.0	0.0	0.1	1.1	71.2
	Kermadec Islands	1	0.2	0.0	0.0	0.0	0.0	0.1
	Stewart Snares Shelf	7	3.9	0.0	0.0	0.1	0.8	52.4
	Subantarctic	7	8.6	0.0	0.0	0.4	3.5	87.7
	Taranaki	3	0.0	0.0	0.0	0.0	0.0	0.0
	West Coast South Island	6	4.5	0.0	0.0	0.1	1.1	58.8
Inshore	Antipodes Islands	2	0.7	0.0	0.0	0.0	0.1	4.3
	Auckland Islands	5	1.1	0.0	0.0	0.0	0.1	8.4
	Bay of Plenty	3	1.9	0.0	0.5	1.1	2.2	8.7
	Campbell Island	3	0.6	0.0	0.0	0.0	0.1	4.3
	Chatham Rise	7	4.7	0.0	1.0	2.7	5.6	21.9
	Cook Strait	8	4.2	0.0	0.9	2.5	5.1	18.1
	East Coast North Island	5	2.0	0.0	0.4	1.1	2.3	8.3
	East Coast South Island	8	14.0	0.1	4.1	10.7	20.0	48.3
	Fiordland	6	7.1	0.1	1.9	4.9	9.3	27.6
	Northland and Hauraki	2	1.9	0.0	0.4	1.1	2.2	8.9
	Stewart Snares Shelf	7	8.0	0.1	2.3	5.8	10.8	29.7
	Taranaki	7	4.5	0.0	1.2	3.0	5.8	18.4
	West Coast North Island	2	2.0	0.0	0.5	1.1	2.3	9.1
	West Coast South Island	6	9.1	0.1	2.7	6.7	12.3	34.4
	Bounty Islands	4	2.7	0.0	0.7	1.8	3.6	10.8

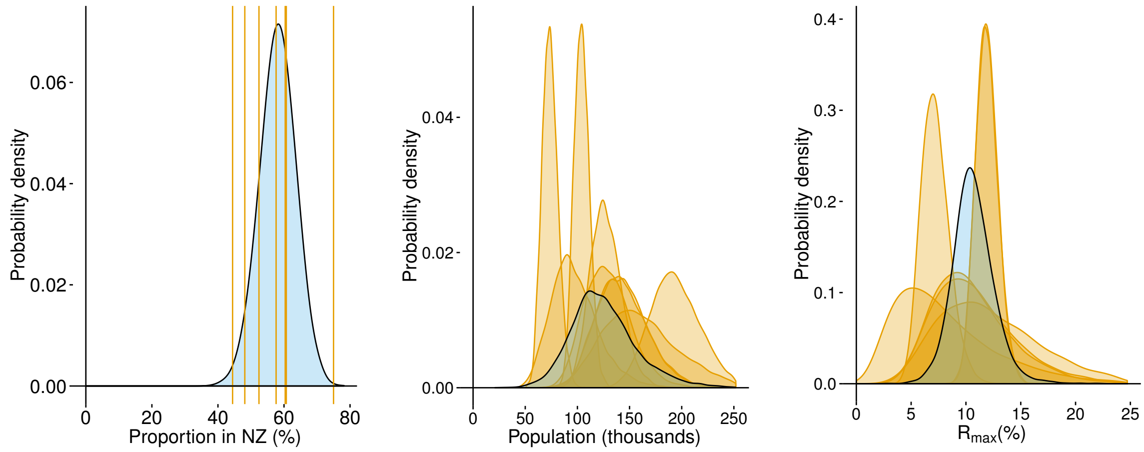


Figure E-42: Probability distributions of demographic parameters of New Zealand fur seal. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

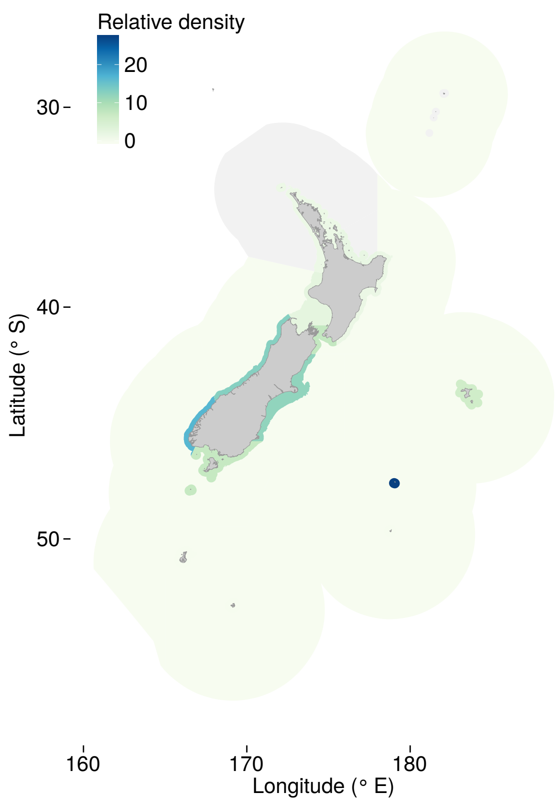


Figure E-43: Distribution of New Zealand fur seal in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.21 New Zealand sea lion

Table E-39: Demographic parameters of New Zealand sea lion. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	9		100.00	100.00	100.00	100.00	100.00	100.00
	2	12	0	100.00	100.00	100.00	100.00	100.00	100.00
Population (number)	1	8		11 654	8 917	10 600	11 553	12 598	14 954
	2	10	1	11 160	8 558	10 145	11 062	12 056	14 379
R_{max} (%)	1	4		9.68	6.62	8.58	9.57	10.62	13.48
	2	5	0	9.19	6.49	8.20	9.08	10.06	12.53

Table E-40: Distribution of New Zealand sea lion, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	8	4.1	0.0	0.1	0.3	1.5	46.5
	Fiordland	2	0.0	0.0	0.0	0.0	0.0	0.0
	Stewart Snares Shelf	7	2.5	0.0	0.0	0.1	0.4	28.6
	Subantarctic	7	0.9	0.0	0.0	0.0	0.0	4.0
Inshore	Antipodes Islands	1	0.0	0.0	0.0	0.0	0.0	0.0
	Auckland Islands	8	63.6	14.7	56.9	67.2	74.6	86.5
	Campbell Island	6	22.4	3.7	15.2	21.1	28.5	46.9
	East Coast South Island	7	1.3	0.0	0.0	0.0	0.2	9.6
	Stewart Snares Shelf	13	5.4	0.7	2.9	4.5	6.8	15.1

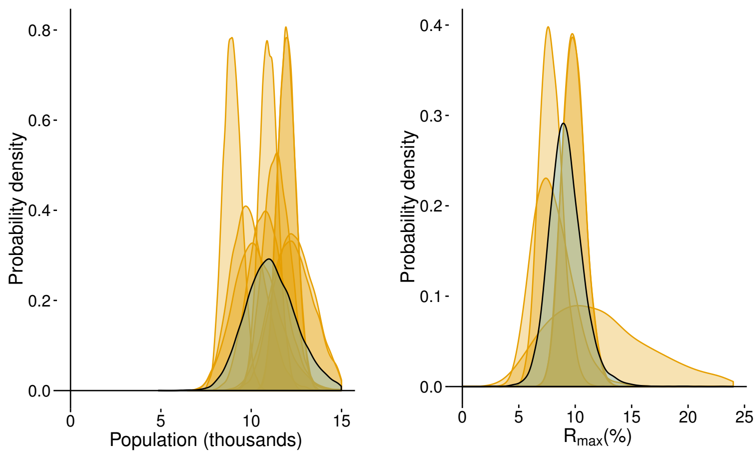


Figure E-44: Probability distributions of demographic parameters of New Zealand sea lion. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

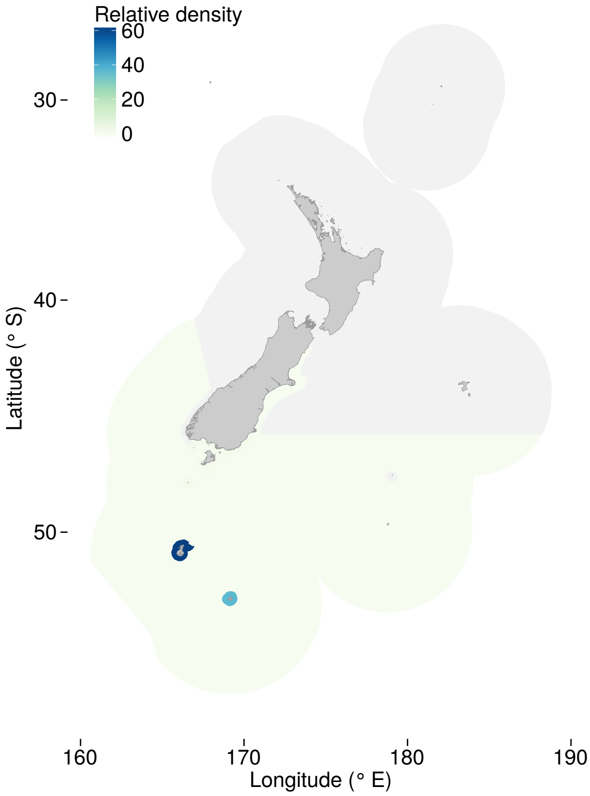


Figure E-45: Distribution of New Zealand sea lion in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.22 Pygmy blue whale

Table E-41: Demographic parameters of pygmy blue whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	4		4.96	2.39	3.75	4.72	5.87	8.95
	2	4	2	4.63	2.43	3.62	4.44	5.44	8.00
Population (number)	1	3		192	97	148	181	223	344
	2	3	1	202	111	161	192	230	337
R_{max} (%)	1	3		4.40	1.97	3.23	4.10	5.22	8.39
	2	4	0	4.12	2.20	3.27	3.94	4.78	7.00

Table E-42: Distribution of pygmy blue whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	2	1.6	0.0	0.1	0.4	1.3	10.1
	Bay of Plenty	3	1.1	0.1	0.5	0.8	1.3	3.6
	Chatham Rise	2	9.2	0.0	0.9	3.6	11.0	53.3
	East Coast North Island	3	7.1	0.4	2.0	4.1	8.1	34.1
	East Coast South Island	3	4.4	0.0	0.4	1.4	4.3	28.8
	Fiordland	3	5.0	0.4	1.8	3.3	5.9	20.9
	Kermadec Islands	2	10.8	0.1	1.4	4.6	13.6	57.4
	Northland and Hauraki	3	2.5	0.3	1.0	1.8	3.0	9.4
	Stewart Snares Shelf	3	4.3	0.3	1.3	2.6	5.2	19.4
	Subantarctic	3	7.0	0.5	2.2	4.1	8.0	33.1
	Taranaki	4	4.7	0.3	1.6	3.2	5.9	18.4
	West Coast North Island	3	2.8	0.2	0.9	1.6	3.0	13.1
	West Coast South Island	4	4.9	0.3	1.5	3.0	5.7	21.9
Inshore	Bay of Plenty	2	0.9	0.1	0.4	0.7	1.1	3.1
	Cook Strait	3	4.5	0.1	0.6	2.2	5.8	22.8
	East Coast North Island	1	0.7	0.0	0.0	0.1	0.4	4.6
	East Coast South Island	3	6.2	0.4	2.5	4.9	8.3	19.7
	Fiordland	1	0.4	0.0	0.1	0.2	0.5	1.9
	Northland and Hauraki	3	4.0	0.3	1.6	3.0	5.2	13.6
	Stewart Snares Shelf	1	0.7	0.0	0.2	0.3	0.7	3.2
	Taranaki	4	10.9	0.9	4.8	9.0	14.8	31.8
	West Coast North Island	1	1.0	0.0	0.3	0.5	1.0	4.3
	West Coast South Island	2	5.4	0.1	1.0	3.0	7.1	24.5

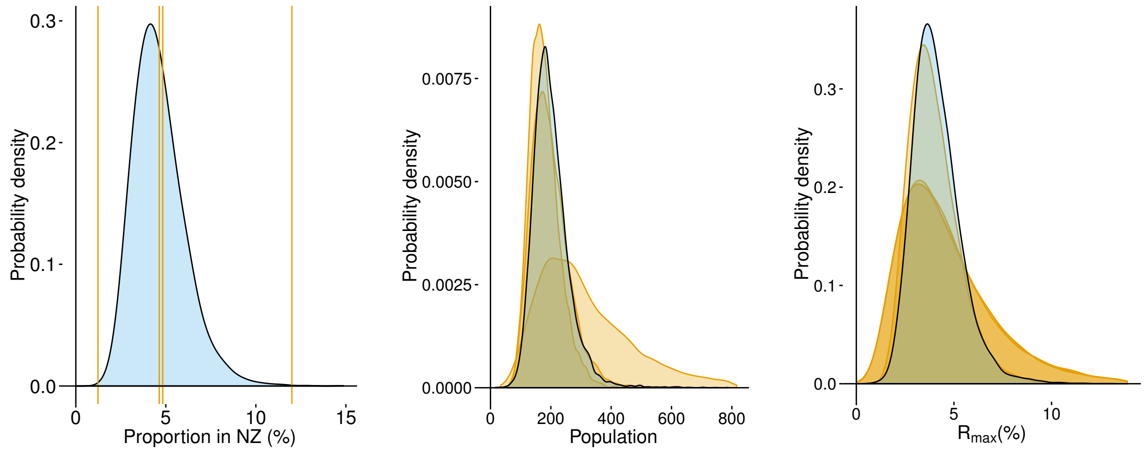


Figure E-46: Probability distributions of demographic parameters of pygmy blue whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

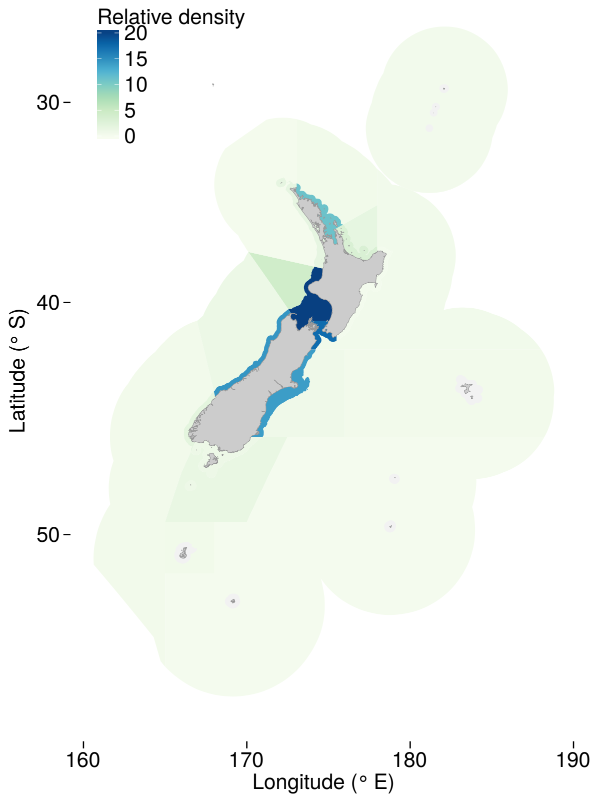


Figure E-47: Distribution of pygmy blue whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.23 Pygmy sperm whale

Table E-43: Demographic parameters of pygmy sperm whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	1		5.14	3.06	4.24	4.99	5.89	8.04
	2	1	0	5.19	3.07	4.25	5.02	5.94	8.28
Population (number)	1	2		151	35	72	102	148	318
	2	2	2	181	51	103	151	222	472
R_{max} (%)	1	1		4.12	1.56	2.90	3.78	4.91	8.47
	2	2	0	3.94	2.00	3.09	3.76	4.57	6.84

Table E-44: Distribution of pygmy sperm whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	1	1.2	0.1	0.4	0.8	1.4	5.0
	Bay of Plenty	2	10.3	0.3	2.3	7.5	15.2	35.8
	Chatham Rise	2	11.0	1.0	4.5	8.2	13.9	38.6
	East Coast North Island	2	11.7	2.1	6.3	10.0	14.7	32.6
	East Coast South Island	1	6.5	0.5	2.5	4.6	8.3	23.7
	Fiordland	1	5.2	0.3	1.4	3.1	6.4	22.0
	Kermadec Islands	1	11.1	1.0	4.4	8.1	14.3	40.2
	Northland and Hauraki	2	3.3	0.3	1.1	2.1	3.9	14.0
	Stewart Snares Shelf	1	5.6	0.4	2.2	3.9	6.9	21.0
	Subantarctic	1	13.4	1.2	4.9	9.3	17.5	49.1
	Taranaki	2	1.3	0.1	0.5	0.8	1.5	5.7
	West Coast North Island	1	3.6	0.2	0.9	1.8	4.2	18.6
	West Coast South Island	1	2.6	0.2	0.7	1.5	3.0	11.5
Inshore	Bay of Plenty	2	3.2	0.2	1.0	2.4	4.4	11.2
	Cook Strait	2	1.6	0.0	0.3	0.8	2.0	7.9
	East Coast North Island	2	2.3	0.2	0.8	1.6	3.0	8.3
	East Coast South Island	1	2.6	0.1	0.7	1.6	3.1	10.8
	Northland and Hauraki	1	0.5	0.0	0.0	0.2	0.4	2.5
	Stewart Snares Shelf	1	1.8	0.1	0.6	1.1	2.1	7.5
	Taranaki	2	1.1	0.1	0.4	0.7	1.2	4.3

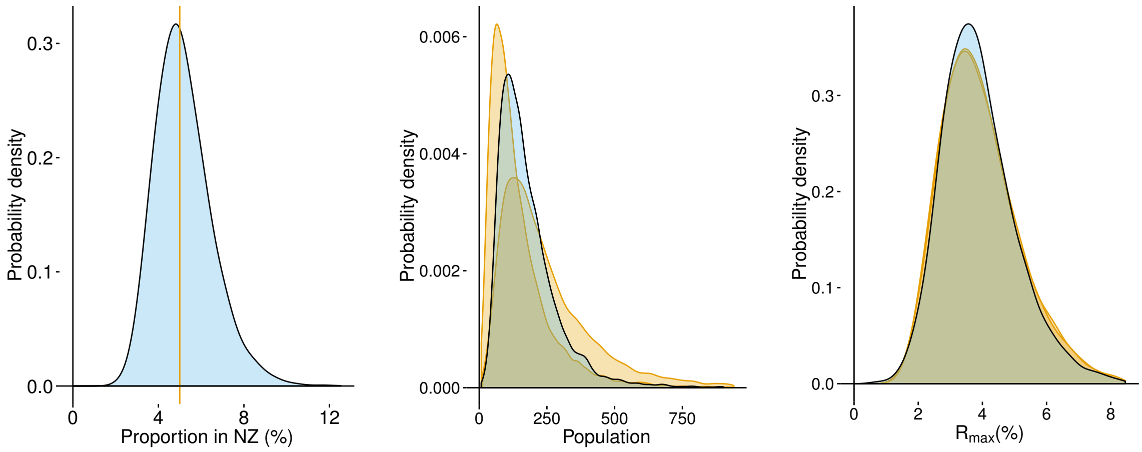


Figure E-48: Probability distributions of demographic parameters of pygmy sperm whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

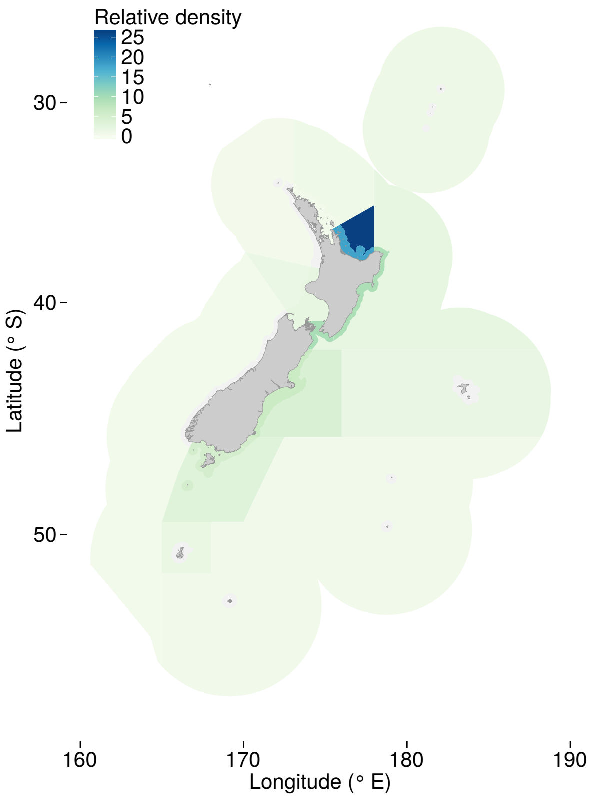


Figure E-49: Distribution of pygmy sperm whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.24 Sei whale

Table E-45: Demographic parameters of sei whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	1		2.07	1.20	1.68	2.01	2.38	3.32
	2	1	0	2.06	1.20	1.69	2.00	2.36	3.29
Population (number)	1	2		1 154	10	73	120	208	2 323
	2	2	1	1 035	7	76	129	221	2 719
R_{max} (%)	1	1		2.63	1.29	2.04	2.50	3.06	4.71
	2	2	0	3.02	1.63	2.43	2.89	3.42	5.17

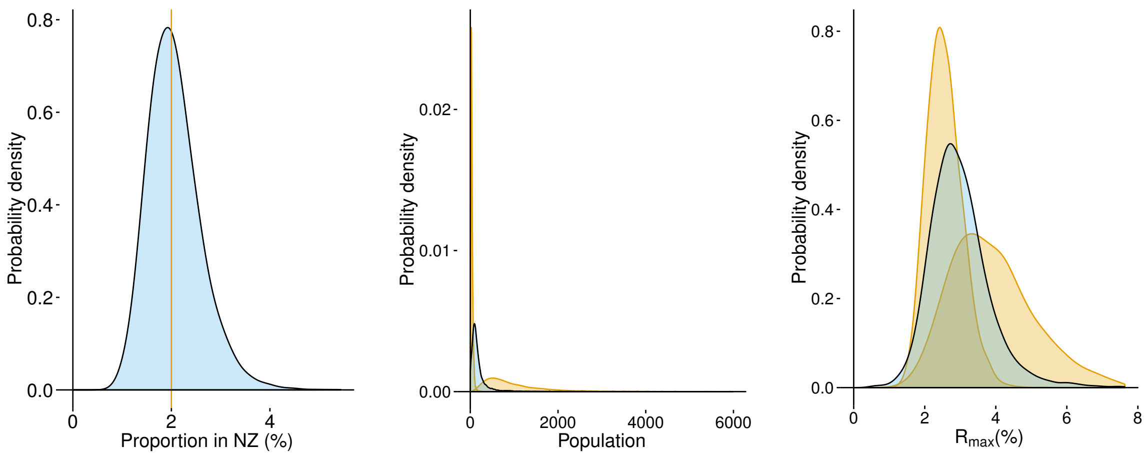


Figure E-50: Probability distributions of demographic parameters of sei whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

E.25 Shepherd's beaked whale

Table E-46: Demographic parameters of Shepherd's beaked whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate ($R_{\max}$). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
$R_{\max}$ (%)	1	0							
	2	1	0	4.09	1.62	3	3.73	4.91	8

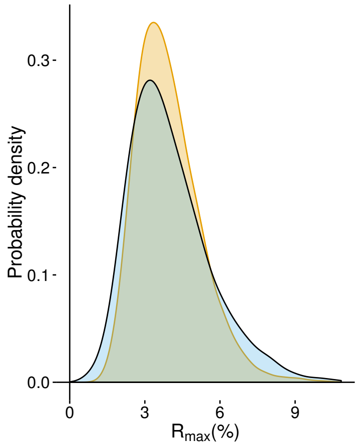


Figure E-51: Probability distributions of demographic parameters of Shepherd's beaked whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

E.26 Short-finned pilot whale

Table E-47: Demographic parameters of short-finned pilot whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	2		3.97	2.46	3.35	3.88	4.51	5.96
	2	2	0	3.97	2.49	3.33	3.88	4.49	5.93
Population (number)	1	2		2 149	300	762	993	1 407	8 022
	2	2	2	1 485	569	1 016	1 344	1 800	3 151
R_{max} (%)	1	0							
	2	1	0	4.15	1.59	2.90	3.82	4.97	8.62

Table E-48: Distribution of short-finned pilot whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Bay of Plenty	2	1.6	0.5	1.1	1.3	1.7	4.7
	Chatham Rise	2	15.3	4.3	11.8	15.4	18.1	28.6
	East Coast North Island	2	17.6	6.1	14.0	17.3	20.2	33.7
	East Coast South Island	2	4.6	1.4	3.4	4.3	5.2	10.2
	Kermadec Islands	1	25.0	9.8	20.5	24.5	28.5	44.5
	Northland and Hauraki	2	8.3	2.9	6.1	7.4	9.3	19.3
	Taranaki	2	1.8	0.4	1.3	1.8	2.1	3.9
	West Coast North Island	2	11.8	3.6	9.1	11.6	13.7	23.0
	West Coast South Island	1	7.1	1.3	5.1	6.7	8.2	16.8
Inshore	Bay of Plenty	2	0.9	0.3	0.5	0.7	1.0	2.8
	Cook Strait	1	0.4	0.1	0.2	0.3	0.4	0.8
	East Coast North Island	2	0.9	0.3	0.6	0.8	1.0	2.1
	East Coast South Island	1	0.9	0.1	0.7	0.9	1.1	2.2
	Northland and Hauraki	2	1.2	0.4	0.7	0.9	1.3	3.3
	Taranaki	1	1.2	0.2	0.8	1.2	1.4	2.8
	West Coast North Island	2	0.9	0.3	0.6	0.8	1.0	1.9
	West Coast South Island	1	0.6	0.1	0.4	0.5	0.6	1.3

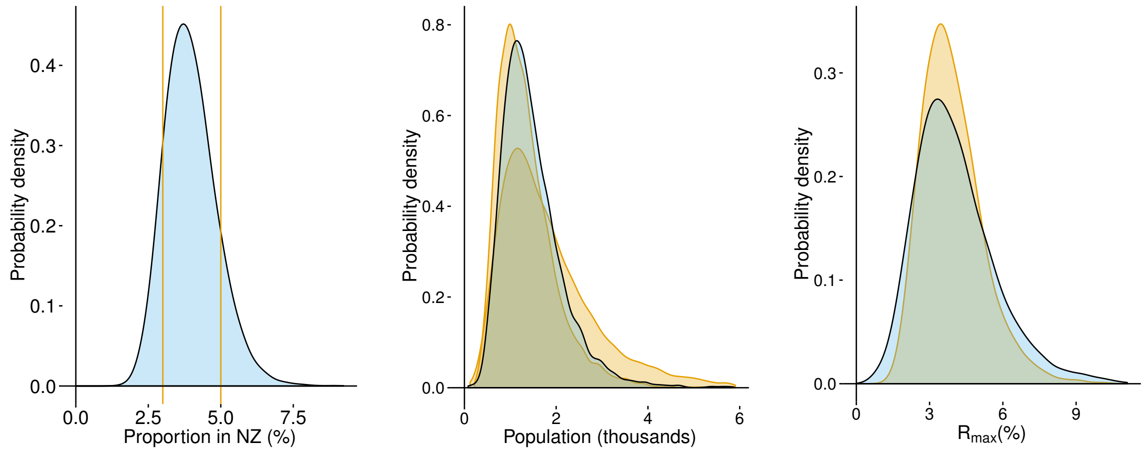


Figure E-52: Probability distributions of demographic parameters of short-finned pilot whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

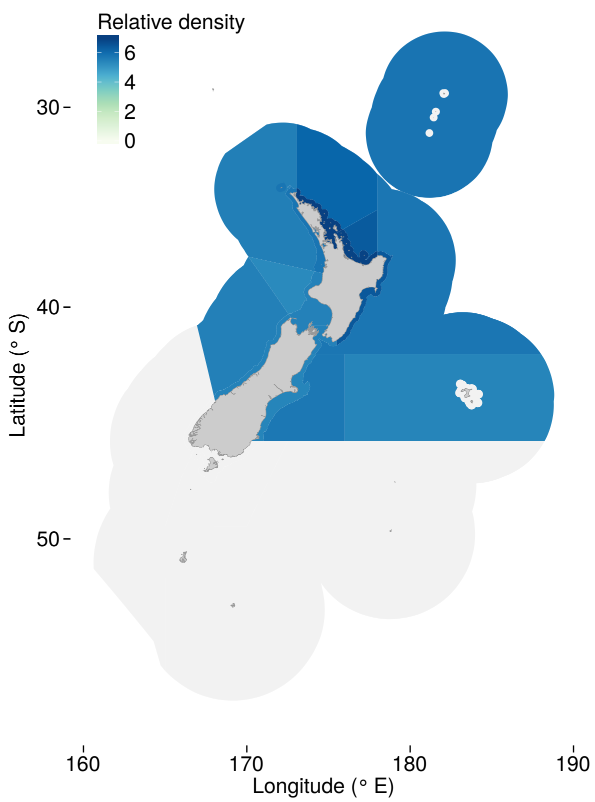


Figure E-53: Distribution of short-finned pilot whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.27 Southern elephant seal

Table E-49: Demographic parameters of southern elephant seal. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	3		0.09	0.01	0.03	0.06	0.11	0.36
	2	3	1	0.29	0.03	0.09	0.18	0.35	1.22
Population (number)	1	3		271	143	225	262	304	446
	2	3	1	267	141	219	257	301	451
R_{max} (%)	1	0							
	2	1	0	12.58	9.02	11.05	12.46	14.01	16.77

Table E-50: Distribution of southern elephant seal, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	3	4.9	0.1	1.5	3.0	6.0	22.8
	Chatham Rise	2	14.0	0.3	4.3	10.2	19.1	52.0
	Fiordland	1	11.1	0.2	2.7	6.5	15.4	48.2
	Stewart Snares Shelf	3	3.6	0.0	0.6	1.6	4.2	17.7
	Subantarctic	3	37.4	1.8	21.4	37.9	51.6	78.5
Inshore	Antipodes Islands	1	1.1	0.0	0.0	0.1	0.3	8.2
	Auckland Islands	5	2.6	0.1	0.7	1.8	3.5	10.2
	Campbell Island	4	7.7	0.1	0.4	2.7	10.8	38.7
	Chatham Rise	1	3.4	0.0	0.1	0.5	1.7	32.5
	East Coast South Island	3	5.2	0.0	0.3	1.1	3.2	47.2
	Stewart Snares Shelf	2	5.2	0.0	0.3	1.0	3.1	49.3
	West Coast South Island	1	3.8	0.0	0.2	0.7	2.0	35.9

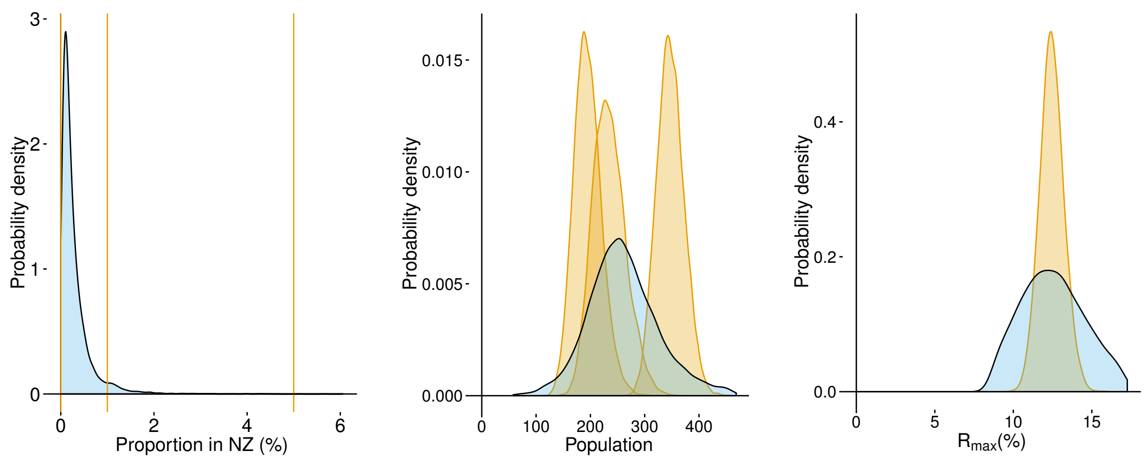


Figure E-54: Probability distributions of demographic parameters of southern elephant seal. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

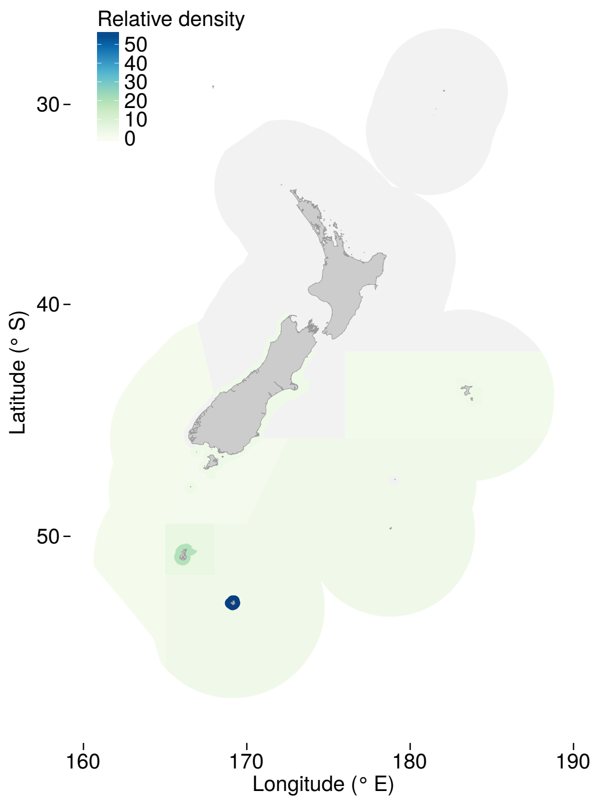


Figure E-55: Distribution of southern elephant seal in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.28 Southern right whale

Table E-51: Demographic parameters of southern right whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	6		16.49	11.26	14.38	16.27	18.34	23.05
	2	7	1	15.60	10.88	13.72	15.39	17.31	21.44
Population (number)	1	6		2 194	1 618	1 972	2 174	2 385	2 909
	2	7	1	2 162	1 620	1 952	2 144	2 346	2 820
R_{max} (%)	1	5		7.11	4.91	6.33	7.03	7.79	9.74
	2	6	0	6.81	4.56	6.05	6.75	7.48	9.41

Table E-52: Distribution of southern right whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	6	10.5	0.3	4.5	8.7	14.0	33.4
	Chatham Rise	2	6.7	0.0	0.0	0.3	2.5	79.9
	East Coast South Island	2	0.5	0.0	0.0	0.0	0.0	1.6
	Fiordland	3	5.4	0.0	0.0	0.1	1.2	73.4
	Kermadec Islands	1	5.9	0.0	0.0	0.2	1.7	74.4
	Northland and Hauraki	1	0.1	0.0	0.0	0.0	0.0	0.0
	Stewart Snares Shelf	6	2.9	0.1	0.8	1.7	3.3	13.2
	Subantarctic	5	7.1	0.0	0.4	1.5	5.8	60.2
Inshore	Auckland Islands	7	44.4	1.5	30.8	47.9	60.5	76.0
	Bay of Plenty	6	1.4	0.0	0.1	0.4	1.1	9.1
	Campbell Island	7	3.0	0.0	0.1	0.6	2.2	22.8
	Cook Strait	6	1.3	0.0	0.0	0.2	0.6	10.3
	East Coast North Island	5	0.6	0.0	0.0	0.1	0.3	4.2
	East Coast South Island	9	1.1	0.0	0.1	0.2	0.6	7.2
	Fiordland	6	0.3	0.0	0.0	0.0	0.1	1.6
	Kermadec Islands	1	0.0	0.0	0.0	0.0	0.0	0.0
	Northland and Hauraki	7	1.0	0.0	0.1	0.2	0.6	6.9
	Stewart Snares Shelf	8	5.8	0.2	3.5	5.6	7.9	13.6
	Taranaki	5	1.2	0.0	0.0	0.2	0.6	10.2
	West Coast North Island	3	0.4	0.0	0.0	0.0	0.0	2.0
	West Coast South Island	5	0.3	0.0	0.0	0.0	0.1	1.8

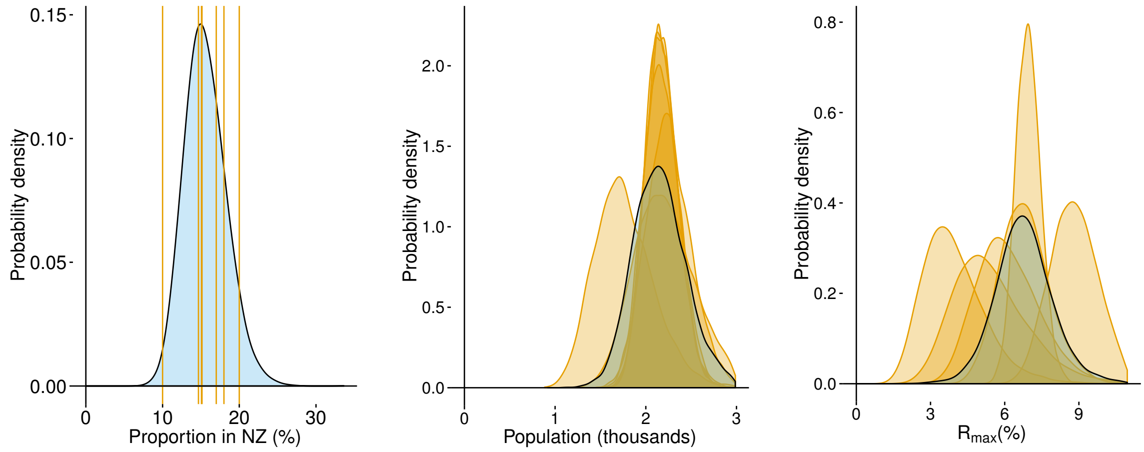


Figure E-56: Probability distributions of demographic parameters of southern right whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

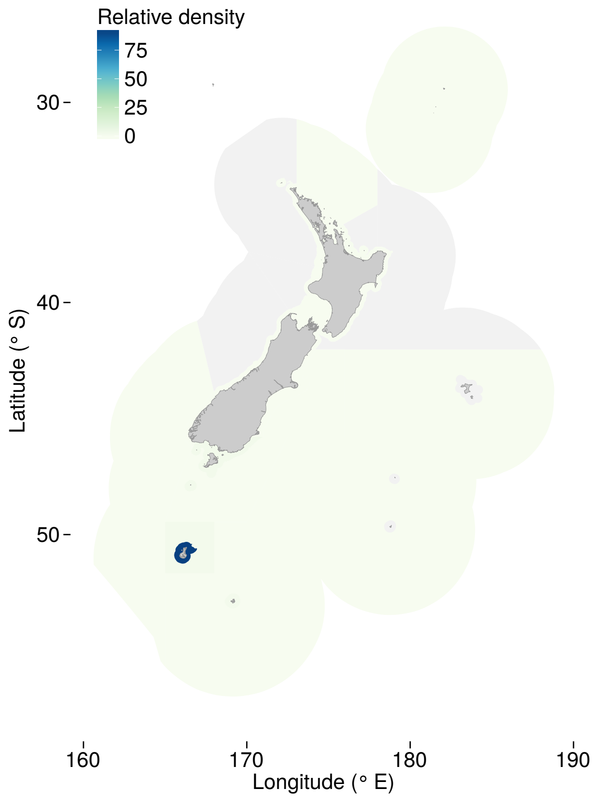


Figure E-57: Distribution of southern right whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.29 Southern right whale dolphin

Table E-53: Demographic parameters of southern right whale dolphin. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate ($R_{\max}$). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Population (number)	1	1		3 251	846	1842	2 688	3 935	8 834
	2	1	0	3 311	844	1 851	2 733	4 027	8 944
$R_{\max}$ (%)	1	0							
	2	1	0	4.10	2	2.89	3.77	5	8.50

Table E-54: Distribution of southern right whale dolphin, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	East Coast South Island	1	7.6	1.3	5.2	6.6	8.0	22.8
	Fiordland	1	24.7	6.7	19.9	24.4	28.5	46.6
	Stewart Snares Shelf	1	8.2	2.2	6.0	7.3	9.1	20.3
	Subantarctic	1	57.6	26.7	53.2	58.8	63.8	79.8
Inshore	East Coast South Island	1	1.8	0.3	1.1	1.4	1.8	5.3

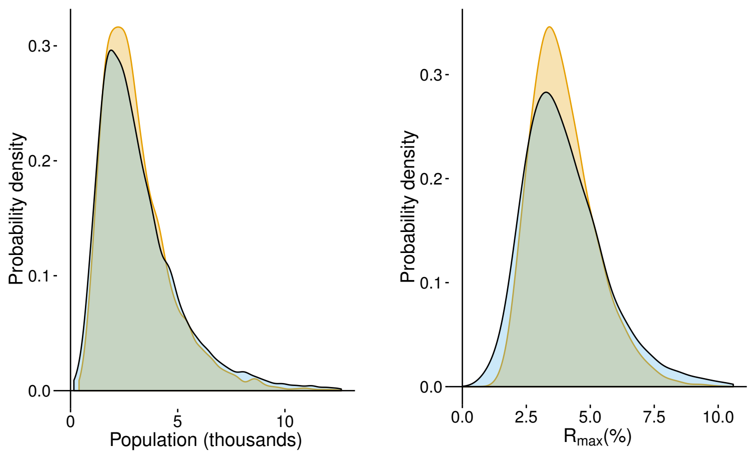


Figure E-58: Probability distributions of demographic parameters of southern right whale dolphin. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

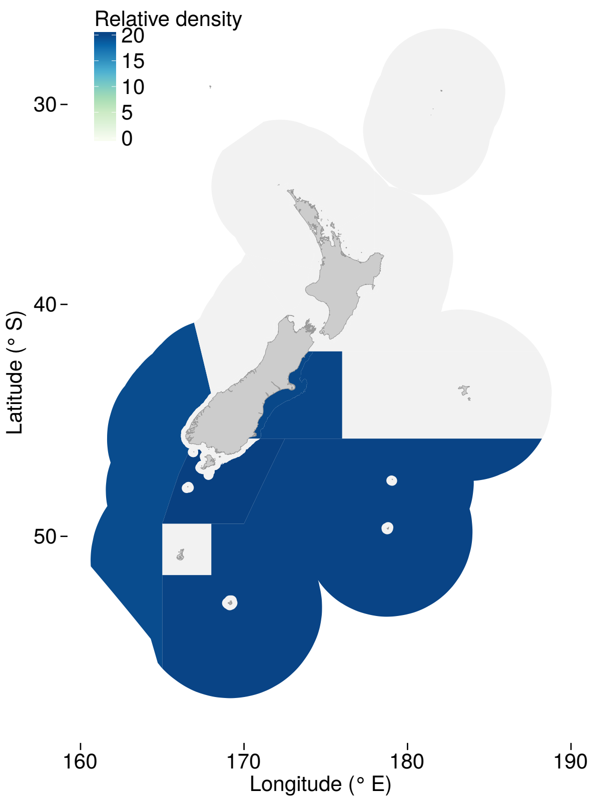


Figure E-59: Distribution of southern right whale dolphin in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.30 Spade-toothed whale

Table E-55: Demographic parameters of spade-toothed whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
R_{max} (%)	1	0							
	2	1	0	4.09	1.59	3	3.74	4.91	9

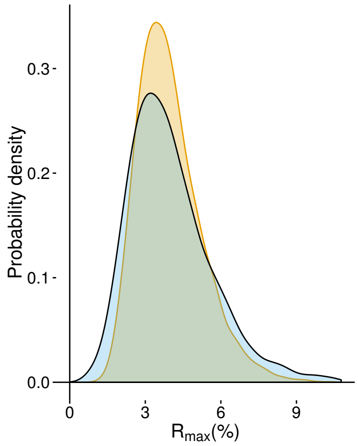


Figure E-60: Probability distributions of demographic parameters of spade-toothed whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

E.31 Sperm whale

Table E-56: Demographic parameters of sperm whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	4		1.64	0.72	1.17	1.53	1.97	3.23
	2	4	1	1.93	0.91	1.43	1.82	2.30	3.60
Population (number)	1	4		285	153	226	268	319	502
	2	4	1	242	139	196	233	275	401
R_{max} (%)	1	4		1.22	0.56	0.93	1.11	1.36	2.45
	2	5	0	1.75	0.46	1.06	1.44	2.00	4.79

Table E-57: Distribution of sperm whale, following the second round of responses. For each area, the table gives the number of people who answered the question, and a summary (mean, 2.5, 25, 50, 75 and 97.5 percentiles) of the estimated proportion of the New Zealand population within that area.

	Region	Answers	Mean	Percentiles				
				2.5%	25%	50%	75%	97.5%
Deep water	Auckland Islands	3	1.6	0.0	0.0	0.1	0.5	13.6
	Bay of Plenty	5	2.6	0.2	1.2	2.1	3.2	8.0
	Chatham Rise	4	6.3	0.0	0.2	0.9	4.3	53.9
	East Coast North Island	5	5.7	0.3	2.3	4.2	6.9	21.5
	East Coast South Island	5	7.3	0.5	3.6	6.3	9.5	20.3
	Fiordland	5	4.9	0.3	2.5	4.2	6.3	13.8
	Kermadec Islands	4	7.0	0.0	0.2	1.0	4.8	63.3
	Northland and Hauraki	5	2.4	0.1	1.0	1.7	2.9	8.1
	Stewart Snares Shelf	5	4.0	0.2	1.5	2.8	4.7	15.3
	Subantarctic	4	10.0	0.0	0.2	1.1	7.8	83.6
	Taranaki	5	2.6	0.1	0.8	1.6	3.0	11.4
	West Coast North Island	5	8.7	0.5	4.4	7.4	11.4	24.7
	West Coast South Island	5	3.8	0.2	1.3	2.6	4.4	15.9
Inshore	Bay of Plenty	2	1.0	0.0	0.0	0.0	0.2	7.5
	Chatham Rise	1	0.9	0.0	0.0	0.0	0.2	7.2
	Cook Strait	5	8.2	0.4	3.9	7.0	11.0	23.6
	East Coast North Island	2	0.9	0.0	0.0	0.1	0.3	7.5
	East Coast South Island	6	16.7	0.9	8.7	15.3	22.8	42.8
	Fiordland	2	0.7	0.0	0.0	0.1	0.3	5.0
	Northland and Hauraki	1	0.1	0.0	0.0	0.0	0.0	0.1
	Stewart Snares Shelf	1	0.1	0.0	0.0	0.0	0.0	0.2
	Taranaki	4	3.4	0.2	1.6	2.8	4.4	10.3
	West Coast North Island	2	0.5	0.0	0.0	0.0	0.1	3.0
	West Coast South Island	1	0.8	0.0	0.0	0.0	0.2	5.9

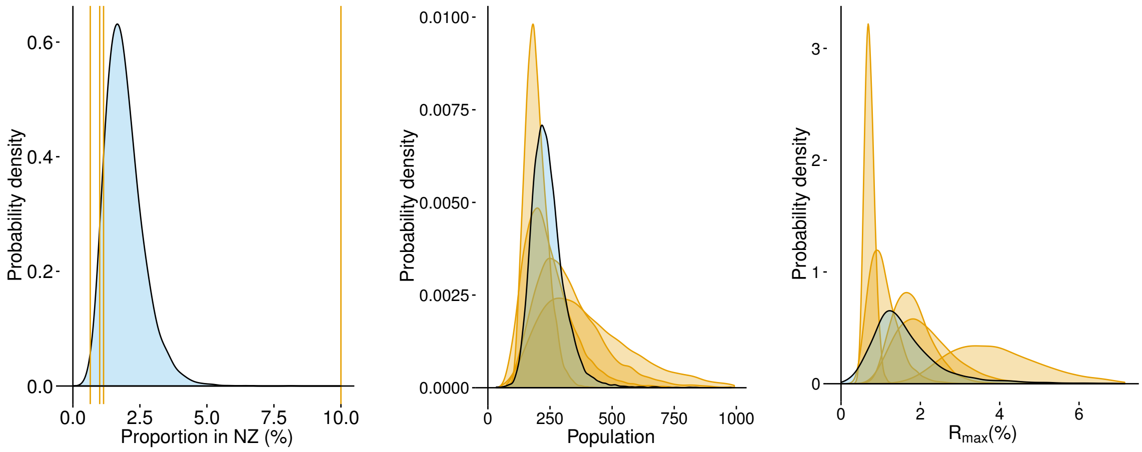


Figure E-61: Probability distributions of demographic parameters of sperm whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

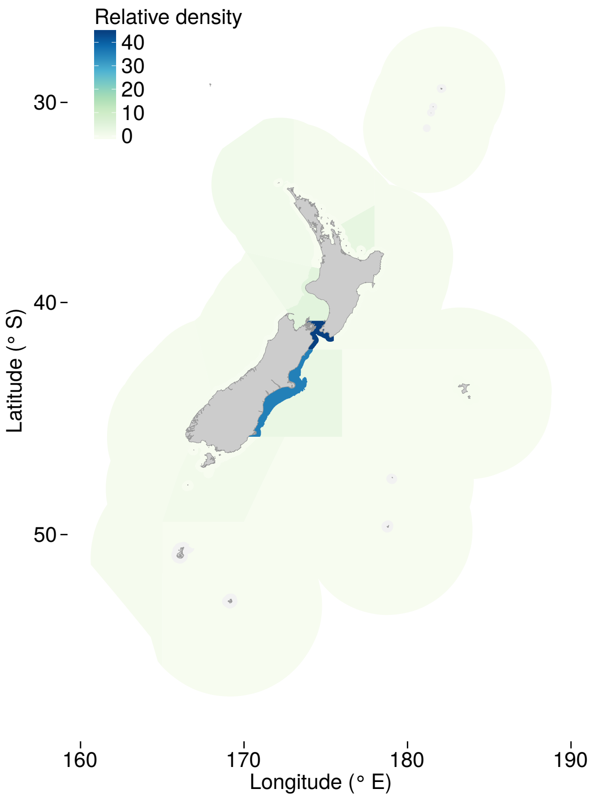


Figure E-62: Distribution of sperm whale in New Zealand waters. The intensity of the colour indicates the relative density (proportional to the number of animals per unit area) within each region. The density is the mean of the posterior distribution of the consensus estimate, derived from expert answers following the second round of the survey.

E.32 Strap-toothed whale

Table E-58: Demographic parameters of strap-toothed whale. The parameters are the percentage of the global population that is in New Zealand waters, the size of the New Zealand population, and the maximum annual population growth rate (R_{max}). For each parameter and round, the table gives the number of answers, the number of answers that were changed between round one and round two, and summary statistics of the consensus distribution (mean, 2.5, 25, 50, 75 and 97.5 percentiles).

Parameter	Round	Answers	Changes	Mean	Percentiles				
					2.5%	25%	50%	75%	97.5%
Proportion in NZ (%)	1	1		10.27	6.28	8.56	10.05	11.75	15.67
	2	1	0	10.22	6.19	8.50	9.97	11.65	15.67
Population (number)	1	1		3 170	449	1 328	2 260	3 840	10 839
	2	1	0	3 177	452	1 309	2 233	3 812	11 396
R_{max} (%)	1	0							
	2	1	0	4.09	1.59	2.86	3.74	4.90	8.44

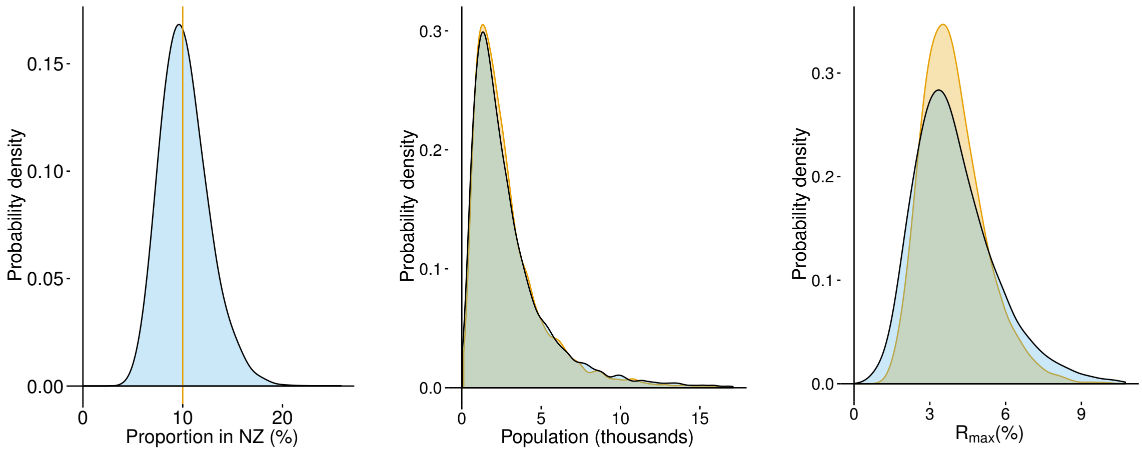


Figure E-63: Probability distributions of demographic parameters of strap-toothed whale. The posterior distribution of the consensus estimate is in blue, and the individual expert estimates are in orange.

APPENDIX F: MODEL PARAMETERS

Table F-59: Summary of the posterior distribution of the model parameters. For each parameter, the table gives the mean, median and 95% credible interval of the posterior distribution.

Description	Parameter	Group (or class)	Fishery (or method)	Posterior		
				Mean	Median	95% c.i.
Fishery–species-group vulnerability	q_{zg}	Pinnipeds	Pelagic trawl	1.674	0.855	0.065–8.381
			Pelagic trawl (SLED)	1.674	0.855	0.065–8.381
			Squid trawl	0.822	0.387	0.031–4.276
			Squid trawl (SLED)	0.822	0.387	0.031–4.276
			Inshore trawl	0.006	0.002	0.000–0.033
			Other trawl	1.308	0.407	0.014–10.281
			Surface longline	1.916	0.832	0.059–10.169
			Set net	0.050	0.016	0.001–0.312
			Bottom longline	0.001	0.000	0.000–0.005
			Purse seine	0.028	0.004	0.000–0.179
		Small dolphins	Pelagic trawl	0.074	0.039	0.003–0.350
			Pelagic trawl (SLED)	0.074	0.039	0.003–0.350
			Squid trawl	0.014	0.005	0.000–0.080
			Squid trawl (SLED)	0.014	0.005	0.000–0.080
			Inshore trawl	0.006	0.003	0.000–0.027
			Other trawl	0.006	0.003	0.000–0.024
			Surface longline	0.174	0.100	0.012–0.773
			Set net	0.042	0.026	0.003–0.183
			Bottom longline	0.000	0.000	0.000–0.001
			Purse seine	0.002	0.000	0.000–0.015
		Large dolphins	Pelagic trawl	0.272	0.096	0.003–1.538
			Pelagic trawl (SLED)	0.272	0.096	0.003–1.538
			Squid trawl	0.019	0.000	0.000–0.109
			Squid trawl (SLED)	0.019	0.000	0.000–0.109
			Inshore trawl	0.003	0.000	0.000–0.027
			Other trawl	0.001	0.000	0.000–0.010
			Surface longline	0.513	0.167	0.005–2.995
			Set net	0.067	0.012	0.000–0.444
			Bottom longline	0.024	0.008	0.000–0.137
			Purse seine	0.019	0.000	0.000–0.147
		Beaked whales	Pelagic trawl	0.001	0.000	0.000–0.009
			Pelagic trawl (SLED)	0.001	0.000	0.000–0.009
			Squid trawl	0.001	0.000	0.000–0.005
			Squid trawl (SLED)	0.001	0.000	0.000–0.005
			Inshore trawl	0.002	0.000	0.000–0.014
			Other trawl	0.000	0.000	0.000–0.001
			Surface longline	0.042	0.025	0.002–0.194
			Set net	0.003	0.000	0.000–0.023
			Bottom longline	0.000	0.000	0.000–0.002
			Purse seine	0.009	0.000	0.000–0.086
		Whales	Pelagic trawl	0.001	0.000	0.000–0.012
			Pelagic trawl (SLED)	0.001	0.000	0.000–0.012
			Squid trawl	0.002	0.000	0.000–0.015
			Squid trawl (SLED)	0.002	0.000	0.000–0.015
			Inshore trawl	0.001	0.000	0.000–0.006
			Other trawl	0.000	0.000	0.000–0.003
			Surface longline	0.060	0.024	0.000–0.343
			Set net	0.002	0.000	0.000–0.016
			Bottom longline	0.000	0.000	0.000–0.003
			Purse seine	0.004	0.000	0.000–0.037
Prob. capture is identified	$p_{\text{identified}}$	Pinnipeds		0.999	0.999	0.998–1.000
		Small dolphins		0.992	0.993	0.978–0.999
		Large dolphins		0.914	0.925	0.776–0.989
		Beaked whales		0.144	0.107	0.004–0.472
		Whales		0.581	0.595	0.106–0.981
Prob. incident is observable	$p_{\text{observable}}$	Pinnipeds	Trawl	0.741	0.736	0.511–0.986
		Dolphins	Trawl	0.743	0.739	0.512–0.987
		Whales	Trawl	0.713	0.694	0.508–0.981
			Surface longline	0.752	0.753	0.512–0.987
			Surface longline	0.750	0.750	0.513–0.987
			Surface longline	0.749	0.746	0.512–0.987

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Description	Parameter	Group (or class)	Fishery (or method)	Posterior		
				Mean	Median	95% c.i.
			Set net	0.667	0.668	0.350–0.984
			Set net	0.665	0.663	0.350–0.984
			Set net	0.654	0.647	0.348–0.982
			Bottom longline	0.746	0.744	0.513–0.987
			Bottom longline	0.746	0.745	0.512–0.987
			Bottom longline	0.741	0.736	0.510–0.985
			Purse seine	0.749	0.749	0.512–0.987
			Purse seine	0.746	0.745	0.511–0.987
			Purse seine	0.740	0.736	0.511–0.987
Prob. of live release	p_{alive}	Pinnipeds	Trawl	0.122	0.122	0.109–0.135
		Dolphins	Trawl	0.013	0.012	0.003–0.032
		Whales	Trawl	0.050	0.036	0.001–0.178
			Surface longline	0.940	0.940	0.921–0.956
			Surface longline	0.668	0.678	0.389–0.890
			Surface longline	0.787	0.800	0.548–0.949
			Set net	0.093	0.087	0.026–0.196
			Set net	0.128	0.120	0.037–0.264
			Set net	0.401	0.387	0.069–0.811
			Bottom longline	0.252	0.232	0.036–0.581
			Bottom longline	0.250	0.206	0.008–0.713
			Bottom longline	0.285	0.264	0.044–0.641
			Purse seine	0.199	0.159	0.006–0.603
			Purse seine	0.250	0.206	0.009–0.703
			Purse seine	0.248	0.206	0.008–0.705
Prob. unidentified capture is a whale	p_{whale}	Pinnipeds		0.000	0.000	0.000–0.000
		Small dolphins		0.000	0.000	0.000–0.000
		Large dolphins		0.357	0.322	0.014–0.861
		Beaked whales		0.431	0.433	0.053–0.796
		Whales		0.581	0.618	0.040–0.984
SLED effect	p_{sled}			0.559	0.495	0.297–0.993
Survival probability	p_{survival}	Pinnipeds	Trawl	0.497	0.495	0.025–0.974
		Dolphins	Trawl	0.502	0.504	0.026–0.976
		Whales	Trawl	0.501	0.501	0.025–0.975
			Surface longline	0.503	0.501	0.024–0.977
			Surface longline	0.501	0.502	0.025–0.976
			Surface longline	0.505	0.508	0.025–0.976
			Set net	0.500	0.502	0.026–0.976
			Set net	0.503	0.509	0.025–0.974
			Set net	0.498	0.499	0.023–0.975
			Bottom longline	0.505	0.509	0.026–0.977
			Bottom longline	0.500	0.504	0.024–0.974
			Bottom longline	0.498	0.497	0.026–0.974
			Purse seine	0.501	0.501	0.026–0.974
			Purse seine	0.498	0.500	0.027–0.976
			Purse seine	0.499	0.495	0.024–0.975
Vulnerablity random effect	r_{lg}	Andrews' beaked whale	Pelagic trawl	6.420	0.987	0.030–32.987
			Pelagic trawl (SLED)	6.420	0.987	0.030–32.987
			Squid trawl	5.752	1.006	0.030–29.879
			Squid trawl (SLED)	5.752	1.006	0.030–29.879
			Inshore trawl	5.339	0.967	0.030–30.904
			Other trawl	5.173	0.975	0.029–33.766
			Surface longline	5.373	0.985	0.029–34.376
			Set net	5.816	0.967	0.031–32.220
			Bottom longline	6.307	0.977	0.029–31.976
			Purse seine	5.138	0.974	0.028–31.373
		Antarctic blue whale	Pelagic trawl	5.750	0.979	0.029–33.031
			Pelagic trawl (SLED)	5.750	0.979	0.029–33.031
			Squid trawl	6.453	1.008	0.030–32.677
			Squid trawl (SLED)	6.453	1.008	0.030–32.677
			Inshore trawl	6.762	1.009	0.028–34.499
			Other trawl	5.387	0.979	0.029–29.542
			Surface longline	4.379	0.943	0.029–26.773
			Set net	5.998	1.005	0.028–32.699
			Bottom longline	5.897	0.988	0.030–33.226
			Purse seine	7.532	1.002	0.031–33.221
		Antarctic minke whale	Pelagic trawl	5.906	0.964	0.030–33.221
			Pelagic trawl (SLED)	5.906	0.964	0.030–33.221

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Description	Parameter	Group (or class)	Fishery (or method)	Posterior		
				Mean	Median	95% c.i.
			Squid trawl	5.999	0.968	0.029–32.647
			Squid trawl (SLED)	5.999	0.968	0.029–32.647
			Inshore trawl	6.076	0.999	0.029–33.812
			Other trawl	5.518	0.992	0.029–29.890
			Surface longline	4.062	0.900	0.028–24.792
			Set net	6.336	0.991	0.028–32.304
			Bottom longline	5.622	0.960	0.028–31.120
			Purse seine	5.576	0.986	0.031–33.688
		Bottlenose dolphin	Pelagic trawl	1.500	0.522	0.020–8.876
			Pelagic trawl (SLED)	1.500	0.522	0.020–8.876
			Squid trawl	4.184	0.920	0.028–25.664
			Squid trawl (SLED)	4.184	0.920	0.028–25.664
			Inshore trawl	8.345	3.256	0.235–48.319
			Other trawl	1.568	0.559	0.020–9.438
			Surface longline	19.760	7.389	0.665–107.187
			Set net	1.003	0.434	0.016–5.443
			Bottom longline	4.999	0.978	0.030–29.391
			Purse seine	7.463	0.972	0.029–28.905
		Bryde’s whale	Pelagic trawl	6.259	0.996	0.029–32.946
			Pelagic trawl (SLED)	6.259	0.996	0.029–32.946
			Squid trawl	6.557	1.016	0.030–34.191
			Squid trawl (SLED)	6.557	1.016	0.030–34.191
			Inshore trawl	5.370	0.965	0.029–28.450
			Other trawl	6.029	0.978	0.029–32.862
			Surface longline	5.295	0.961	0.031–27.406
			Set net	6.124	1.004	0.031–33.729
			Bottom longline	5.343	0.993	0.029–33.717
			Purse seine	5.094	0.975	0.028–30.272
		Cephalorynchus	Pelagic trawl	5.008	0.972	0.031–27.422
			Pelagic trawl (SLED)	5.008	0.972	0.031–27.422
			Squid trawl	5.687	1.003	0.030–33.056
			Squid trawl (SLED)	5.687	1.003	0.030–33.056
			Inshore trawl	0.921	0.485	0.043–4.522
			Other trawl	1.272	0.515	0.020–6.936
			Surface longline	5.482	0.995	0.030–31.621
			Set net	5.358	3.053	0.460–23.427
			Bottom longline	6.034	0.990	0.031–30.686
			Purse seine	9.888	0.954	0.029–30.821
		Common dolphin	Pelagic trawl	72.906	26.578	3.208–415.739
			Pelagic trawl (SLED)	72.906	26.578	3.208–415.739
			Squid trawl	1.657	0.480	0.015–9.617
			Squid trawl (SLED)	1.657	0.480	0.015–9.617
			Inshore trawl	7.292	3.208	0.379–40.121
			Other trawl	14.709	7.038	0.916–77.721
			Surface longline	1.654	0.806	0.084–8.341
			Set net	5.205	2.180	0.272–23.013
			Bottom longline	8.675	0.865	0.028–25.451
			Purse seine	4.152	0.821	0.026–23.439
		Cuvier’s beaked whale	Pelagic trawl	5.560	0.983	0.029–30.330
			Pelagic trawl (SLED)	5.560	0.983	0.029–30.330
			Squid trawl	5.238	0.947	0.029–27.714
			Squid trawl (SLED)	5.238	0.947	0.029–27.714
			Inshore trawl	4.760	0.940	0.030–28.781
			Other trawl	4.671	0.945	0.028–27.373
			Surface longline	5.455	0.973	0.029–33.791
			Set net	4.519	0.974	0.029–28.760
			Bottom longline	5.727	0.934	0.030–28.311
			Purse seine	4.927	0.951	0.028–29.882
		Dense-beaked whale	Pelagic trawl	4.918	0.938	0.029–31.483
			Pelagic trawl (SLED)	4.918	0.938	0.029–31.483
			Squid trawl	5.129	0.975	0.030–32.165
			Squid trawl (SLED)	5.129	0.975	0.030–32.165
			Inshore trawl	5.781	0.960	0.029–31.886
			Other trawl	6.123	0.941	0.028–27.907
			Surface longline	6.441	0.993	0.027–32.638
			Set net	5.522	0.976	0.030–33.066
			Bottom longline	5.204	0.955	0.028–29.988
			Purse seine	5.619	0.992	0.031–32.692
		Dusky dolphin	Pelagic trawl	0.915	0.311	0.028–4.177
			Pelagic trawl (SLED)	0.915	0.311	0.028–4.177

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Description	Parameter	Group (or class)	Fishery (or method)	Posterior		
				Mean	Median	95% c.i.
			Squid trawl	157.597	6.599	0.454–188.916
			Squid trawl (SLED)	157.597	6.599	0.454–188.916
			Inshore trawl	0.502	0.235	0.011–2.617
			Other trawl	3.408	1.406	0.176–18.023
			Surface longline	2.758	1.233	0.098–14.548
			Set net	1.167	0.649	0.084–5.344
			Bottom longline	3.928	0.841	0.027–23.652
			Purse seine	5.071	0.954	0.028–29.470
		Dwarf minke whale	Pelagic trawl	6.208	0.975	0.030–32.391
			Pelagic trawl (SLED)	6.208	0.975	0.030–32.391
			Squid trawl	7.058	0.998	0.030–36.039
			Squid trawl (SLED)	7.058	0.998	0.030–36.039
			Inshore trawl	5.477	0.974	0.028–30.975
			Other trawl	6.463	0.979	0.030–32.785
			Surface longline	4.304	0.962	0.029–27.672
			Set net	6.058	1.006	0.029–37.578
			Bottom longline	5.947	0.990	0.032–33.323
			Purse seine	6.699	0.978	0.029–31.890
		False killer whale	Pelagic trawl	1.364	0.453	0.017–7.993
			Pelagic trawl (SLED)	1.364	0.453	0.017–7.993
			Squid trawl	5.561	1.000	0.033–34.027
			Squid trawl (SLED)	5.561	1.000	0.033–34.027
			Inshore trawl	5.332	0.935	0.028–28.239
			Other trawl	5.542	0.983	0.031–29.077
			Surface longline	2.282	0.653	0.023–12.561
			Set net	3.099	0.814	0.024–19.768
			Bottom longline	2.253	0.671	0.022–13.808
			Purse seine	4.732	0.940	0.028–27.004
		Fin whale	Pelagic trawl	5.332	0.980	0.029–33.068
			Pelagic trawl (SLED)	5.332	0.980	0.029–33.068
			Squid trawl	5.730	0.993	0.032–30.400
			Squid trawl (SLED)	5.730	0.993	0.032–30.400
			Inshore trawl	7.384	0.980	0.029–32.734
			Other trawl	6.663	1.001	0.030–31.826
			Surface longline	4.368	0.959	0.029–26.629
			Set net	6.023	1.005	0.030–34.037
			Bottom longline	5.457	0.977	0.028–31.649
			Purse seine	5.693	1.000	0.029–31.302
		Gray's beaked whale	Pelagic trawl	5.132	0.959	0.028–28.746
			Pelagic trawl (SLED)	5.132	0.959	0.028–28.746
			Squid trawl	5.066	0.925	0.028–27.464
			Squid trawl (SLED)	5.066	0.925	0.028–27.464
			Inshore trawl	5.191	0.939	0.029–28.520
			Other trawl	4.581	0.973	0.030–28.463
			Surface longline	6.414	1.005	0.029–34.850
			Set net	6.655	0.901	0.029–26.222
			Bottom longline	5.631	0.913	0.029–26.454
			Purse seine	5.559	0.984	0.029–30.765
		Hector's beaked whale	Pelagic trawl	4.941	0.977	0.030–28.751
			Pelagic trawl (SLED)	4.941	0.977	0.030–28.751
			Squid trawl	4.924	0.968	0.028–30.716
			Squid trawl (SLED)	4.924	0.968	0.028–30.716
			Inshore trawl	5.139	0.985	0.028–29.828
			Other trawl	5.113	0.988	0.028–30.544
			Surface longline	6.106	0.980	0.028–31.879
			Set net	5.093	0.967	0.030–29.466
			Bottom longline	5.297	0.950	0.028–30.348
			Purse seine	6.423	0.991	0.030–31.065
		Hourglass dolphin	Pelagic trawl	2.622	0.587	0.018–14.813
			Pelagic trawl (SLED)	2.622	0.587	0.018–14.813
			Squid trawl	3.158	0.682	0.022–16.814
			Squid trawl (SLED)	3.158	0.682	0.022–16.814
			Inshore trawl	8.211	0.841	0.024–21.553
			Other trawl	2.471	0.674	0.021–15.028
			Surface longline	2.249	0.551	0.019–12.418
			Set net	3.233	0.670	0.021–19.233
			Bottom longline	5.226	0.986	0.029–32.828
			Purse seine	7.995	0.983	0.030–33.790
		Humpback whale	Pelagic trawl	4.575	0.882	0.027–24.837
			Pelagic trawl (SLED)	4.575	0.882	0.027–24.837

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Description	Parameter	Group (or class)	Fishery (or method)	Posterior		
				Mean	Median	95% c.i.
			Squid trawl	5.627	0.964	0.028–29.973
			Squid trawl (SLED)	5.627	0.964	0.028–29.973
			Inshore trawl	5.513	0.858	0.027–24.177
			Other trawl	4.143	0.877	0.027–25.500
			Surface longline	14.838	3.431	0.227–93.350
			Set net	4.771	0.868	0.026–26.124
			Bottom longline	4.345	0.890	0.028–23.857
			Purse seine	4.232	0.882	0.029–24.316
		Killer whale	Pelagic trawl	1.894	0.588	0.021–11.011
			Pelagic trawl (SLED)	1.894	0.588	0.021–11.011
			Squid trawl	5.592	0.957	0.030–31.023
			Squid trawl (SLED)	5.592	0.957	0.030–31.023
			Inshore trawl	4.862	0.959	0.028–27.565
			Other trawl	19.285	0.984	0.027–29.193
			Surface longline	2.765	0.761	0.024–17.395
			Set net	3.113	0.808	0.026–18.649
			Bottom longline	1.997	0.640	0.022–12.227
			Purse seine	5.457	0.949	0.028–28.799
		New Zealand fur seal	Pelagic trawl	1.486	0.604	0.060–7.109
			Pelagic trawl (SLED)	1.486	0.604	0.060–7.109
			Squid trawl	2.501	0.962	0.082–15.011
			Squid trawl (SLED)	2.501	0.962	0.082–15.011
			Inshore trawl	6.226	1.485	0.089–36.678
			Other trawl	10.294	1.140	0.040–29.836
			Surface longline	12.507	5.715	0.528–67.313
			Set net	11.313	2.346	0.134–76.897
			Bottom longline	6.197	1.472	0.088–35.592
			Purse seine	5.067	0.890	0.032–27.492
		New Zealand sea lion	Pelagic trawl	12.563	5.275	0.514–70.196
			Pelagic trawl (SLED)	12.563	5.275	0.514–70.196
			Squid trawl	8.284	3.681	0.362–43.720
			Squid trawl (SLED)	8.284	3.681	0.362–43.720
			Inshore trawl	1.753	0.574	0.020–10.491
			Other trawl	4.000	0.507	0.025–22.657
			Surface longline	1.050	0.411	0.031–5.954
			Set net	0.776	0.261	0.009–3.996
			Bottom longline	1.795	0.578	0.020–10.616
			Purse seine	5.070	0.971	0.029–29.358
		Pilot whale	Pelagic trawl	17.228	3.492	0.239–88.698
			Pelagic trawl (SLED)	17.228	3.492	0.239–88.698
			Squid trawl	3.824	0.787	0.022–23.722
			Squid trawl (SLED)	3.824	0.787	0.022–23.722
			Inshore trawl	4.281	0.804	0.025–24.340
			Other trawl	4.452	0.774	0.022–23.524
			Surface longline	9.593	1.926	0.114–50.245
			Set net	7.135	1.376	0.072–40.159
			Bottom longline	9.152	2.074	0.138–52.509
			Purse seine	4.972	0.840	0.026–24.373
		Pygmy blue whale	Pelagic trawl	4.848	0.964	0.028–28.499
			Pelagic trawl (SLED)	4.848	0.964	0.028–28.499
			Squid trawl	7.761	0.992	0.031–33.239
			Squid trawl (SLED)	7.761	0.992	0.031–33.239
			Inshore trawl	5.439	1.005	0.028–30.752
			Other trawl	6.370	1.011	0.030–33.634
			Surface longline	3.879	0.928	0.030–24.282
			Set net	5.168	0.966	0.029–32.107
			Bottom longline	7.366	0.969	0.031–33.368
			Purse seine	5.518	1.007	0.031–33.167
		Pygmy right whale	Pelagic trawl	5.226	0.983	0.031–31.083
			Pelagic trawl (SLED)	5.226	0.983	0.031–31.083
			Squid trawl	7.267	0.982	0.029–34.495
			Squid trawl (SLED)	7.267	0.982	0.029–34.495
			Inshore trawl	5.898	1.006	0.032–31.404
			Other trawl	6.220	0.988	0.031–34.204
			Surface longline	4.269	0.935	0.031–28.273
			Set net	5.650	0.995	0.029–32.877
			Bottom longline	5.383	0.987	0.029–32.137
			Purse seine	5.877	1.016	0.030–31.278
		Pygmy sperm whale	Pelagic trawl	5.996	1.013	0.028–32.411
			Pelagic trawl (SLED)	5.996	1.013	0.028–32.411

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Description	Parameter	Group (or class)	Fishery (or method)	Posterior		
				Mean	Median	95% c.i.
			Squid trawl	6.202	0.990	0.028–34.634
			Squid trawl (SLED)	6.202	0.990	0.028–34.634
			Inshore trawl	6.560	0.982	0.030–31.865
			Other trawl	5.624	0.982	0.028–30.958
			Surface longline	4.019	0.884	0.028–24.056
			Set net	5.905	1.009	0.029–33.617
			Bottom longline	5.753	0.968	0.028–32.382
			Purse seine	5.283	1.016	0.029–33.379
		Sei whale	Pelagic trawl	5.284	0.968	0.030–31.373
			Pelagic trawl (SLED)	5.284	0.968	0.030–31.373
			Squid trawl	4.636	0.946	0.029–29.027
			Squid trawl (SLED)	4.636	0.946	0.029–29.027
			Inshore trawl	5.504	1.016	0.032–30.500
			Other trawl	5.908	0.980	0.028–30.109
			Surface longline	2.384	0.657	0.022–13.063
			Set net	5.777	0.983	0.030–34.302
			Bottom longline	5.175	0.982	0.029–30.642
			Purse seine	5.819	1.004	0.028–32.418
		Shepherd’s beaked whale	Pelagic trawl	5.446	0.984	0.030–32.709
			Pelagic trawl (SLED)	5.446	0.984	0.030–32.709
			Squid trawl	5.662	0.983	0.030–30.880
			Squid trawl (SLED)	5.662	0.983	0.030–30.880
			Inshore trawl	7.751	0.938	0.030–30.702
			Other trawl	5.888	0.986	0.028–31.244
			Surface longline	5.176	0.989	0.028–32.567
			Set net	6.106	0.958	0.027–32.356
			Bottom longline	5.249	0.951	0.029–28.985
			Purse seine	5.122	0.980	0.028–30.342
		Southern bottlenose whale	Pelagic trawl	5.441	0.994	0.031–30.987
			Pelagic trawl (SLED)	5.441	0.994	0.031–30.987
			Squid trawl	6.314	0.970	0.030–32.266
			Squid trawl (SLED)	6.314	0.970	0.030–32.266
			Inshore trawl	5.315	0.967	0.030–31.590
			Other trawl	5.349	0.952	0.028–31.507
			Surface longline	5.428	0.992	0.028–31.182
			Set net	5.328	1.000	0.029–29.728
			Bottom longline	5.304	0.962	0.028–30.595
			Purse seine	5.402	0.992	0.029–31.848
		Southern elephant seal	Pelagic trawl	1.213	0.341	0.014–5.706
			Pelagic trawl (SLED)	1.213	0.341	0.014–5.706
			Squid trawl	0.936	0.307	0.011–5.104
			Squid trawl (SLED)	0.936	0.307	0.011–5.104
			Inshore trawl	4.464	0.963	0.029–27.945
			Other trawl	3.106	0.481	0.016–15.817
			Surface longline	1.269	0.447	0.017–7.113
			Set net	3.560	0.884	0.027–22.088
			Bottom longline	4.840	0.954	0.026–28.420
			Purse seine	5.040	0.972	0.027–29.593
		Southern right whale	Pelagic trawl	5.447	0.985	0.029–31.592
			Pelagic trawl (SLED)	5.447	0.985	0.029–31.592
			Squid trawl	4.665	0.860	0.027–24.229
			Squid trawl (SLED)	4.665	0.860	0.027–24.229
			Inshore trawl	4.879	0.936	0.027–29.551
			Other trawl	5.722	0.972	0.029–30.125
			Surface longline	3.956	0.907	0.028–22.584
			Set net	4.821	0.955	0.028–28.922
			Bottom longline	5.006	0.932	0.030–30.490
			Purse seine	5.747	0.965	0.029–32.292
		Southern right whale dolphin	Pelagic trawl	0.959	0.381	0.016–5.223
			Pelagic trawl (SLED)	0.959	0.381	0.016–5.223
			Squid trawl	1.481	0.458	0.017–8.677
			Squid trawl (SLED)	1.481	0.458	0.017–8.677
			Inshore trawl	4.396	0.913	0.027–26.862
			Other trawl	1.260	0.479	0.019–7.259
			Surface longline	0.583	0.236	0.010–3.308
			Set net	3.235	0.780	0.023–20.483
			Bottom longline	5.108	0.996	0.030–31.474
			Purse seine	6.375	1.016	0.029–34.857
		Spade-toothed whale	Pelagic trawl	8.178	0.997	0.031–31.726
			Pelagic trawl (SLED)	8.178	0.997	0.031–31.726

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Description	Parameter	Group (or class)	Fishery (or method)	Posterior		
				Mean	Median	95% c.i.
			Squid trawl	5.294	1.015	0.029–31.603
			Squid trawl (SLED)	5.294	1.015	0.029–31.603
			Inshore trawl	6.829	0.990	0.029–31.984
			Other trawl	5.806	0.954	0.030–29.066
			Surface longline	6.091	0.958	0.030–33.097
			Set net	5.599	0.962	0.027–29.779
			Bottom longline	8.518	0.998	0.029–30.425
			Purse seine	5.770	0.962	0.030–30.946
		Sperm whale	Pelagic trawl	5.511	0.960	0.030–29.537
			Pelagic trawl (SLED)	5.511	0.960	0.030–29.537
			Squid trawl	5.579	1.009	0.028–33.877
			Squid trawl (SLED)	5.579	1.009	0.028–33.877
			Inshore trawl	5.255	0.994	0.029–32.397
			Other trawl	5.864	0.992	0.029–32.408
			Surface longline	3.758	0.889	0.026–21.712
			Set net	5.085	0.963	0.028–31.144
			Bottom longline	5.364	0.991	0.027–31.856
			Purse seine	5.361	0.989	0.030–32.464
		Strap-toothed whale	Pelagic trawl	5.046	0.939	0.030–29.804
			Pelagic trawl (SLED)	5.046	0.939	0.030–29.804
			Squid trawl	6.073	0.969	0.029–29.464
			Squid trawl (SLED)	6.073	0.969	0.029–29.464
			Inshore trawl	6.325	0.978	0.028–30.472
			Other trawl	7.215	0.961	0.029–28.811
			Surface longline	5.188	0.996	0.028–30.568
			Set net	5.866	0.990	0.029–29.378
			Bottom longline	5.286	0.967	0.026–29.962
			Purse seine	6.608	0.960	0.029–31.378
Vulnerablity random effect s.d.	σ_{leaf}			1.730	1.688	1.122–2.573