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Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13

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This report presents an assessment of the risk of fisheries-related mortalities to 70 species and sub-species of seabirds that are breeding in New Zealand. The risk assessment considered all fishing by commercial trawl, bottom-longline, surface-longline and set-net methods within the outer boundary of New Zealand's Exclusive Economic Zone. It built on a previous seabird risk assessment that was carried out in 2013, and a subsequent workshop held by the Ministry for Primary Industries that involved a range of seabird specialists. The workshop was aimed at identifying the limitations of the risk assessment and at updating relevant data, with the outcomes including recommendations for species demographic data, at-sea seabird distributions, and species and fisheries groupings used in the assessment.

This update of the previous seabird risk assessment followed the recommendations, and included two additional years of data, the 2011–12 and 2012–13 fishing years. Risk was defined as the ratio of annual potential fatalities (an estimate of the number of birds killed in fisheries each year) to the Potential Biological Removal (PBR; a measure of the reproductive capacity of the populations). The estimation of the PBR included a calibration factor, ρ, to adjust the calculation of the maximum growth rate and total population size, and to ensure that the population goals are met in the presence of environmental stochasticity. The appropriate value for ρ (ranging between between 0.17 and 0.61) depends on the species type. In addition, the PBR generally includes a recovery factor f that protects against errors in the demographic estimates used to calculate it. Here, the recovery factor f was set to 1, guided by the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (NPOA). The PBR with the calibration factor, and with a recovery factor of one, is referred to as PBR_ρ. The estimation of annual potential fatalities was based on data of seabird captures recorded by government fisheries observers and of fishing effort in trawl, bottom- and surface-longline, and set-net fisheries. A risk ratio larger than one indicates that the fishing-related fatalities in commercial fisheries exceed PBR_ρ, and the population will be at risk of not being able to remain above half its carrying capacity.

In total, there were 16 200 (95% c.i.: 12 600–21 000) estimated annual potential seabird fatalities across the four fishing methods in the seven-year period from 2006–07 to 2012–13. The highest number of annual potential fatalities were in trawl fisheries with 11 500 (95% c.i.: 8040–16 300) estimated annual potential fatalities. In comparison, there were a total of 2920 (95% c.i.: 2300–3700) annual potential fatalities in bottom-longline fisheries. Seabird fatalities in surface-longline fisheries were lower, with a total of 1420 (95% c.i.: 1150–1740) annual potential fatalities of all seabirds. There were fewer estimated fatalities in set-net fisheries, with a total of 294 (95% c.i.: 203–414) annual potential fatalities of all species. These estimates of annual potential fatalities depended on assumptions that were made about the extent of cryptic mortalities (birds that are killed by the fishing activity but not brought on-board the fishing vessel or included in captures reported by fisheries observers).

Following the risk categories in the NPOA, seven species were considered to be at "Very high risk", including black petrel, Salvin's albatross, southern Buller's albatross, flesh-footed shearwater, Gibson's albatross, New Zealand white-capped albatross, and northern Buller's albatross. The risk ratio of black petrel was especially large, with a median of 11.34 (95% c.i.: 6.85–19.81), due to the combination of a high number of estimated annual potential fatalities (mean 1130; 95% c.i.: 840–1490), and a low PBR_ρ (mean 100; 95% c.i.: 60–147).

Four species were considered to be at "High risk", including Chatham Island albatross, Antipodean albatross, Westland petrel, and Campbell black-browed albatross. Eight species were at "Medium risk", and another ten species were at "Low risk". Among the 70 considered species, 41 species had "Negligible risk" suggesting that commercial fisheries in New Zealand waters are unlikely to significantly impact the populations of these species.

Changes in the risk ranking from the previous assessment (which was corrected for some errors in the implementation) were primarily due to updated demographic data and to changes in the way seabird species and fisheries were grouped for estimating the annual potential fatalities. Chatham Island albatross was previously considered to be at “Very High” risk, but was found to be at “High risk” in the current assessment. This decrease was due to assessing small-vessel bottom-longline fishing targeting ling separately to other small-vessel fisheries that targeted this species. Gibson’s albatross was at “High” risk in the previous assessment, but was found to be at “Very High” risk here. This increase in the risk ranking was due to assessing wandering and royal albatrosses separately. Other changes included Campbell black-browed albatross moving into the “High risk” category, northern royal albatross moving from “High risk” to “Medium risk”, Stewart Island shag moving from “Low risk” to “Medium risk”, and Snares Cape petrel moving from “High risk” to “Low risk”. These changes were due to updates in the demographic parameters, changing the definition of Cape petrel to exclude Antarctic Cape petrel, and changing the grouping of the seabird species.

This seabird risk assessment allowed an assessment of the impacts of a wide range of commercial fishing on New Zealand seabirds. Risk was quantified, placing the estimated annual potential fatalities in a population context. The relative stability in the assessment, given the changes that were made since the previous assessment, indicated that the methodology is maturing. Over time, it will allow for fisheries-related changes in the risk to be assessed. Possible improvements include a better specification of cryptic mortality. Poor knowledge of cryptic mortality restricts understanding of the impacts of fisheries on seabird populations. Other improvements include increased observer coverage in small-vessel fisheries that currently have limited observer data. As the risk assessment requires adequate observer data, increasing observer coverage in these fisheries would reduce the uncertainty associated with the current estimates of risk. The assessment could also be extended to include broader impacts, such as seabird captures in recreational fisheries, and in global fisheries.

1. INTRODUCTION

Seabirds are among the most threatened bird groups globally, being subject to a number of threats including invasive species, climate change, ocean pollution, and habitat degradation (Croxall et al. 2012). Incidental captures in fisheries also represent a significant threat, as seabirds are killed during commercial fishing by getting caught in nets, getting hooked, or through other interactions with fishing gear. They may also be indirectly affected by commercial fishing through depletion of their prey. New Zealand is globally significant for seabirds, with around 25% of the world's seabird species breeding in New Zealand, and New Zealand waters support a higher seabird diversity than any other region (Karpouzi et al. 2007). Several studies have recently been carried out to assess the risk of commercial fisheries to seabirds that breed in the New Zealand region (Waugh et al. 2009, Rowe 2010, Dillingham & Fletcher 2011, Richard et al. 2011, Richard & Abraham 2013c). These studies have focused on the identification of species whose populations may be adversely affected by fishing-related mortalities.

This report presents an updated risk assessment that was carried out for most of the seabird species that breed in the New Zealand region, involving 70 species. In New Zealand, the key policy for managing the impact of commercial fisheries on seabirds is the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (NPOA; Ministry for Primary Industries 2013). The risk assessment is a primary input into the NPOA, allowing for monitoring of progress towards this goal.

A recently developed method for quantifying the risk to seabird populations from fishing compared the Potential Biological Removal (PBR; Wade 1998) to an estimate of fishing-related mortalities (Sharp et al. 2011). The PBR index was developed under the United States Marine Mammal Protection Act to assess the maximum level of human-induced mortality that a population can incur, while being able to stay above half its carrying capacity in the long term (Wade 1998). For seabirds, the PBR may be estimated from simple demographic parameters (Dillingham & Fletcher 2011). Richard & Abraham (2013a) recently showed that when calculating the PBR from data available for seabirds, the PBR is typically overestimated. They recommended that an additional calibration factor, ρ, is included in the calculation of the PBR. The calibration factor is required to adjust the estimated PBR, so that populations experiencing annual human-caused mortality at or below the PBR level will meet the management criterion of being able to remain above half the carrying capacity. In the Richard & Abraham (2013a) application of the PBR methods, the calibration factor varied between 0.17 and 0.61, depending on the seabird species. Although the calculation of the PBR generally requires the specification of the recovery factor, f (Dillingham & Fletcher 2011, Richard et al. 2011), we followed the approach used for the NPOA (Ministry for Primary Industries 2013) of setting $f = 1$. We refer to the PBR calculated with the calibration factor (ρ), and with $f = 1$, as PBR_ρ.

The assessment followed the risk assessment framework initially developed by Sharp et al. (2011). The risk ratio (RR) is expressed as the ratio of the annual potential fatalities (APF) to PBR_ρ:

$$\mathrm{RR} = \mathrm{APF}/\mathrm{PBR}_\rho, \tag{1}$$

where the fatalities are from trawl, longline, and set-net fisheries within New Zealand's Exclusive Economic Zone (EEZ). The estimate of APF includes cryptic mortalities, i.e., birds that are killed by the fishing activity but not brought on-board the fishing vessel or included in captures reported by fisheries observers. The term "potential fatalities" is used to indicate the inherent uncertainty associated with estimating these cryptic fatalities, and the uncertainties associated with estimating fatalities from observed captures.

In accordance with the NPOA, the risk of fisheries to seabirds was categorised according to the median and the upper limit of the 95% credible interval of the risk ratio RR:

- Very high risk: median risk ratio above 1 or an upper 95% credible limit above 2,
- High risk: median above 0.3 or an upper 95% credible limit above 1,
- Medium risk: median above 0.1 or an upper 95% credible limit above 0.3,

- Low risk: upper 95% credible limit above 0.1,
- Negligible risk: upper 95% credible limit less than 0.1.

The NPOA sets out a five-year plan for reducing risk to seabird populations, to be achieved by 30 June 2018. Over this period, the NPOA requires that "species currently categorised as at very high or high risk from fishing move to a lower category of risk" (Ministry for Primary Industries 2013).

The most recent seabird risk assessment was carried out by Richard & Abraham (2013c). Following this assessment, a workshop with seabird specialists was held in November 2013 to identify the limitations of the risk assessment, and improve the data and methods used (Walker et al. 2015). The workshop resulted in recommendations for the species demographic data and at-sea distributions, and for species and fisheries groupings, but there were no modifications to the estimation method of the potential fatalities and risk ranking used in the risk assessment. The current assessment was based on these updated data, and the main changes were:

1. Data on fishing effort and observed captures included two more fishing years, and vulnerability was estimated using data for the period between 2006–07 and 2012–13.
2. Annual potential fatalities were estimated using data between the 2010–11 and 2012–13 fishing years to reflect the current level and spatial distribution of fishing effort.
3. An error in the data on fishing effort was corrected; this error had previously caused the proportion of fishing effort that was observed to be overestimated in inshore trawl fisheries.
4. One capture previously identified as Kermadec storm petrel was changed to New Zealand white-faced storm petrel. Captures identified as southern Cape petrel were removed, as only the subspecies Snares Cape petrel breeds in New Zealand.
5. The PBR_ρ was calculated using the lower quartile of the distribution of the number of annual breeding pairs. It was inadvertently calculated using the distribution of the whole population in Richard & Abraham (2013c).
6. The population size was changed for 11 species; it was decreased for Antipodean albatross, Gibson's albatross, and Westland petrel, and increased for Salvin's albatross, New Zealand white-capped albatross, black petrel, grey petrel, flesh-footed shearwater, pied shag, Stewart Island shag, and little black shag.
7. The annual survival rate was increased for New Zealand white-capped albatross, Westland petrel, black petrel, and flesh-footed shearwater.
8. The proportion of adults breeding was decreased for grey petrel and New Zealand white-capped albatross, and increased for pied shag.
9. The breeding season was altered for 54 species.
10. Royal albatrosses were separated from Antipodean and Gibson's albatrosses for the estimation of vulnerability; the grouping of shag species was amended depending on whether they forage in groups or solitarily.
11. Surface-longline fishing targeting swordfish was assessed as a distinct fishery, and the small-vessel bottom-longline fishery targeting ling was also assessed as a separate fishery.
12. The at-sea distribution was changed for black petrel, Salvin's albatross, Gibson's albatross, New Zealand white-capped albatross, yellow-eyed penguin, flesh-footed shearwater, Westland petrel, New Zealand storm petrel, and Kermadec storm petrel.

13. A parameter was introduced to describe the proportion of birds that remain in New Zealand waters during the non-breeding season, instead of treating birds as either present or absent during the non-breeding season.

This risk assessment is accompanied by supplementary information that provides detailed information on the demographic parameters and at-sea distribution used for the 70 seabird species included in the assessment (Richard & Abraham 2015). Due to the size of the supplementary information, it is produced as a separate document.

2. METHODS

The methodology for calculating PBR_ρ and estimating the number of APF for each species followed the methods used in Richard & Abraham (2013c). The following sections have been reproduced from Richard & Abraham (2013c), and were updated where necessary (for details of the updates to the input data and the methods, see Subsection 2.4).

2.1 Potential Biological Removal

The PBR_ρ was estimated using the following expression (Richard & Abraham 2013a):

$$\text{PBR} = \frac{1}{2}\rho r_{\text{max}}^{NL} N_{\text{min}}^{G} f, \tag{2}$$

where ρ is a calibration factor (between 0.17 and 0.61, depending on species type); r_{max}^{NL} is an estimate of the maximum growth rate, under optimal conditions (calculated following Niel & Lebreton (2005)); N_{min}^{G} is an estimate of the population size, calculated from a conservative estimate of the number of breeding pairs $N_{\text{BP}_{\text{min}}}$ (Gilbert 2009); and the recovery factor f is here set to $f = 1$.

The methods for calculating PBR_ρ are detailed in Richard & Abraham (2013a). The calculation of r_{max}^{NL} and N_{min}^{G} requires estimates of the adult survival, S_A; the age at first reproduction, A; the proportion of adults breeding in a year, P_B; and the number of breeding pairs $N_{\text{BP}_{\text{min}}}$. The growth rate is estimated by solving the following expressions (Niel & Lebreton 2005):

$$\lambda_{\text{max}}^{NL} = \exp\left[\left(A + \frac{S_A}{\lambda_{\text{max}}^{NL} - S_A}\right)^{-1}\right] \tag{3}$$

$$r_{\text{max}}^{NL} = \lambda_{\text{max}}^{NL} - 1, \tag{4}$$

and the total population size may be estimated as follows (Gilbert 2009, Richard et al. 2011):

$$N_{\text{min}}^{G} = \frac{2N_{\text{BP}_{\text{min}}}}{P_B} S_A^{1-A}. \tag{5}$$

When calculating PBR_ρ, uncertainty in the input parameters is carried through the calculation, so that the uncertainty in the risk ratio may also be calculated.

The calibration factor, ρ, is necessary to correct the approximations in the calculation of the maximum growth rate and total population size, and to ensure that the population goals are met in the presence of environmental stochasticity. The appropriate value for ρ depends on the species type (Tables 1, 2). The factor ρ was calibrated in Richard & Abraham (2013a) by using the total population size, but assuming a perfect knowledge of the demographic parameters. To ensure that the population size used in calculating PBR_ρ is conservative, the lower quartile of the distribution of breeding pairs was used ($N_{\text{BP}_{\text{min}}}$).

The recovery factor f was set to 1 in this assessment to categorise the risk according to the NPOA (Ministry for Primary Industries 2013).

Table 1: Assignment of species to the species types (see Richard & Abraham 2013a) that were used to select a value for the correction factor ρ in the approximation of the Potential Biological Removal.

Species	Species type
Gibson's albatross	Antipodean albatross
Antipodean albatross	Antipodean albatross
Southern royal albatross	Antipodean albatross
Northern royal albatross	Antipodean albatross
Campbell black-browed albatross	Grey-headed albatross
New Zealand white-capped albatross	Grey-headed albatross
Salvin's albatross	Grey-headed albatross
Chatham Island albatross	Grey-headed albatross
Grey-headed albatross	Grey-headed albatross
Southern Buller's albatross	Grey-headed albatross
Northern Buller's albatross	Grey-headed albatross
Light-mantled sooty albatross	Antipodean albatross
Northern giant petrel	Giant petrel
Grey petrel	Black petrel
Black petrel	Black petrel
Westland petrel	Black petrel
White-chinned petrel	Black petrel
Flesh-footed shearwater	Flesh-footed shearwater
Wedge-tailed shearwater	Flesh-footed shearwater
Buller's shearwater	Flesh-footed shearwater
Sooty shearwater	Flesh-footed shearwater
Fluttering shearwater	Flesh-footed shearwater
Hutton's shearwater	Flesh-footed shearwater
Little shearwater	Fairy prion
Snares Cape petrel	Fairy prion
Fairy prion	Fairy prion
Antarctic prion	Fairy prion
Broad-billed prion	Fairy prion
Pycroft's petrel	Fairy prion
Cook's petrel	Fairy prion
Chatham petrel	Fairy prion
Mottled petrel	Fairy prion
White-naped petrel	Flesh-footed shearwater
Kermadec petrel	Flesh-footed shearwater
Grey-faced petrel	Flesh-footed shearwater
Chatham Island taiko	Flesh-footed shearwater
White-headed petrel	Flesh-footed shearwater
Soft-plumaged petrel	Fairy prion
Common diving petrel	Common diving petrel
South Georgian diving petrel	Common diving petrel
New Zealand white-faced storm petrel	Storm petrel
White-bellied storm petrel	Storm petrel
Black-bellied storm petrel	Storm petrel
Kermadec storm petrel	Storm petrel
New Zealand storm petrel	Storm petrel
Yellow-eyed penguin	Yellow-eyed penguin
Northern little penguin	Erect-crested penguin
White-flippered little penguin	Erect-crested penguin
Southern little penguin	Erect-crested penguin
Chatham Island little penguin	Erect-crested penguin
Eastern rockhopper penguin	Erect-crested penguin
Fiordland crested penguin	Erect-crested penguin
Snares crested penguin	Erect-crested penguin
Erect-crested penguin	Erect-crested penguin
Australasian gannet	Shag
Masked booby	Shag
Pied shag	Shag
Little black shag	Shag
New Zealand king shag	Shag
Stewart Island shag	Shag
Chatham Island shag	Shag
Bounty Island shag	Shag
Auckland Island shag	Shag
Campbell Island shag	Shag
Spotted shag	Shag
Pitt Island shag	Shag
Subantarctic skua	Shag
Southern black-backed gull	Caspian tern
Caspian tern	Caspian tern
White tern	Caspian tern

Table 2: Values for the calibration factor, ρ, for different species types, used for correcting the approximate calculation of the Potential Biological Removal (Richard & Abraham 2013a). (See Table 1 for the assignment of species to each species type.)

Species type	ρ
Antipodean albatross	0.37
Grey-headed albatross	0.43
Giant petrel	0.34
Black petrel	0.33
Flesh-footed shearwater	0.41
Fairy prion	0.32
Common diving petrel	0.17
Storm petrel	0.30
Erect-crested penguin	0.50
Yellow-eyed penguin	0.55
Shag	0.57
Caspian tern	0.61

The number of annual breeding pairs, the proportion of adults breeding in any given year, the annual adult survival rate, and the age at first reproduction for the seabird species concerned were obtained from the literature. The main sources of information were in the primary literature; published books on seabirds; grey literature; and trusted resources on the Internet, such as Birdlife International (http://www.birdlife.org/datazone/species) and the Agreement on the Conservation of Albatrosses and Petrels (ACAP; http://www.acap.aq). Where demographic estimates were not available, values from proxy species were used instead.

The chosen demographic parameters for the 70 species included in this risk assessment are detailed in the supplementary information, including their associated uncertainty (if any), reference to their origin, and whether proxy species were used (Richard & Abraham 2015). A summary of the distributions for the input demographic parameters is presented in Table A-1 of the appendix, and the derived values are presented in Table A-2. The values of $N_{\mathrm{BP}_{\min}}$, $N^{G}_{\min}$, $r^{NL}_{\max}$, and ρ used to calculate PBR$_\rho$ for each species are presented in Table A-3.

The seabird taxonomy followed the recommendations of the Ornithological Society of New Zealand (Ornithological Society of New Zealand checklist committee 2010).

2.1.1 Uncertainties

Every estimate contains some level of uncertainty, which is often large. As seabird data are collected from colonies that are often remote and difficult to access, regular monitoring of a sufficient proportion of the total population is rare. Estimates in the literature are sometimes reported with their uncertainty, but this important information is frequently missing.

To explicitly account for the uncertainty in all parameters, PBR$_\rho$ was calculated from samples of distributions of the parameters. This approach allowed for uncertainty in the risk ratio to be derived. For this purpose, every demographic estimate was assigned a standard deviation (s.d.), or a range when necessary, to match the uncertainties typically reported in the literature.

We assigned an index of quality (poor, medium, or high) to each estimate when possible, based on the methodology used and the size of the sample from which the estimate was calculated. For example, the quality of estimates of survival rates was considered high when capture-mark-recapture modelling was used on a sample size of over 100 individuals. In contrast, the quality was qualified as poor, when the sample size was less than 50 individuals, with the survival estimate considered to be simply the ratio of banded birds returning alive to the breeding site to the total number of banded birds. When details of the methodology were not provided, e.g., when estimates were reported by a source and not the original publication of the study, we used the quality assessment of the citing source when possible, which was mostly for estimates from ACAP. When quality assessment could not be made, the quality was assumed to be poor. In general, survival estimates were net estimates (including fisheries mortality), while for the calculation of r_{max}, they are assumed to be survival under optimal conditions.

When no uncertainty was reported in the literature, survival estimates were given a standard deviation of 0.01, 0.02, or 0.03 for estimates of good, medium, or poor quality, respectively. Estimates from capture-mark-recapture analysis are sometimes reported as a confidence interval. In this case, the mean was derived by calculating the logit of the mean (the average of the logit of the lower and upper limits of the confidence interval), which was then back-transformed. The standard deviation of the logit of the mean was calculated by dividing the difference between the logit of the upper limit and the logit of the lower limit, divided by 2×1.96. The standard deviation of the mean was then calculated using the delta method:

$$\text{s.d.}(\bar{S}) = \frac{\text{s.d.}(\text{logit}(\bar{S}))}{\bar{S}(1-\bar{S})} \tag{6}$$

Age at first reproduction and the number of breeding pairs were reported in the literature either as a minimum value only, or only as a mean. For age at first reproduction, when only a minimum was reported, the maximum was derived by multiplying the minimum by $5/3$, and when only a maximum was reported, the minimum was derived by multiplying the maximum by $3/5$. When the minimum and the mean only were reported, the maximum was defined as the difference between twice the mean and the minimum. Similarly, when the maximum and the mean only were reported, the minimum was defined as the difference between twice the mean and the maximum. When only the mean was reported, it was multiplied by $3/4$ to get the minimum, and by $5/4$ to get the maximum.

For the number of breeding pairs, when only the minimum value was reported in the literature, it was multiplied by 3 to obtain a maximum value. The minimum was also reduced to 70% of its reported value to consider the possibility of a population decline since the value was derived (e.g., a reported minimum of 10 000 pairs was treated as between 7000 and 30 000 pairs). When only the maximum number of breeding pairs was reported, it was divided by 5 to get the minimum value, and it was multiplied by 1.2 to allow for a population increase. Calculation of the maximum and minimum values when only the mean and either the minimum or the maximum were reported followed the approach used for age at first reproduction. When only the mean value was reported, a log-normal distribution was assumed, with a standard deviation set to 0.1, 0.2, or 0.3 for estimates of good, medium, or poor quality, respectively. When the uncertainty of the proportion of adults breeding in any given year was not reported, a standard deviation of 0.05 was used.

Whereas only one estimate of the number of breeding pairs was chosen during the grooming process, estimates of similar quality and similar age for adult survival and age at first reproduction were kept. When multiple estimates were available for the same parameter, the following rules were applied to combine them: for multiple pairs of minima and maxima (e.g., age at first reproduction of Fiordland crested penguin), the minimum and the maximum of the union of these ranges were taken; for multiple means and standard deviations (e.g., survival rate of northern giant petrel), pairs of minima and maxima were created by taking the lower and upper limits of the confidence intervals (c.i.), defined as the mean $\pm$ 1.96 s.d., and by applying the previous rule.

The distributions of the parameters used for calculating PBR_ρ are presented in the appendix (Table A-1). A sample of 4000 values was calculated for each parameter and each species. For estimates whose range was defined by the mean and the standard deviation, the sample was drawn from a normal distribution for the age at first reproduction, from a log-normal distribution for the number of breeding pairs, and from a normal distribution on the logit scale for the adult annual survival and the proportion of adults breeding in any given year. When only a minimum and a maximum were obtained, the age at first reproduction, the annual adult survival rate, and the proportion of adults breeding in a given year were assumed to be distributed uniformly between the minimum and the maximum, and the distribution of the number of breeding pairs was assumed to be uniform on the log scale between the minimum and the maximum.

2.2 Annual potential fatalities

2.2.1 Species distribution

Seabird spatial distribution maps were used for estimation of seabird captures. The maps were discretised with a resolution of one thirtieth of degree of latitude and longitude, extending from 57°S to 23°S and from 160°E to 170°W. A single annual-average distribution was derived for species that breed throughout the year (albatrosses of the genus *Diomedea*, and white-capped albatross), for species whose distribution was expected to be similar during the breeding and non-breeding seasons (shags, gulls, terns, and skua), and for species for which available information was insufficient to distinguish the breeding and non-breeding distributions (*Fregetta* and masked booby). For the remaining species, two distribution maps were generated, with one map each for the breeding and non-breeding periods. Nevertheless, for black petrel, three maps were used for the breeding season, following recent research assessing the at-sea distribution of this species, including maps for the pre-egg laying stage, the incubation stage, and the guard and chick rearing stage (Abraham et al. 2015).

For seabird species with different seasonal distributions (except for black petrel), two distribution layers were created, one for breeding birds and one for non-breeders. The density of breeders was assumed to decrease exponentially away from colonies. The location and size of colonies, and the exponential rate of decrease, were obtained from the literature (see Richard et al. 2011).

The distribution of non-breeders was derived from existing maps published by NABIS (National Aquatic Biodiversity Information System) and Birdlife International. Annual distribution maps from NABIS contain three layers of seabird density: the hot spot layer, and the 90% and the 100% of the population presence layers. In some cases, other sources of information, including at-sea observations, observer data, telemetry, and main colony positions, were also considered. The maps were intended to indicate annual average distributions, and do not provide information on seasonal changes in distribution, such as would occur during annual migrations, or at different stages of the breeding cycle. These maps were converted into density maps by assigning a bird density to each layer. Following the choices used previously (Waugh et al. 2009, Richard et al. 2011), the hot spot layer was assigned a value of 0.5, the 90%-presence layer a value of 0.4, and the 100%-presence layer a value of 0.1. The resulting maps were then normalised, so that the density summed to one across the region of the maps. Maps from Birdlife International are single-layer range maps, representing the range of a species at a global scale. Depending on the species, these maps were derived from at-sea observations, observer data, or telemetry (GLS, GPS, Argos, and radio tracking). In these maps, the density of birds is equal to one within the species' range and equal to zero outside it. These maps were clipped to the latitude and longitude range used for the distributions, and normalised.

The distributions of breeders and non-breeders were normalised so the density summed to unity over the entire region. The distribution during the breeding season was obtained by adding the density of breeders and non-breeders, each multiplied by their relative population size. The latter was calculated from the ratios of the total population to the number of breeding pairs (N/N_{BP}; Table 3), estimated in Richard & Abraham (2013a).

The number of breeders and non-breeders was a function of the number of annual breeding pairs using the following relationships:

$$\begin{aligned} N_{\mathrm{B}} &= 2N_{\mathrm{BP}}, \\ N_{\mathrm{NB}} &= N^G - 2N_{\mathrm{BP}}, \end{aligned}$$

where N^G is the total population size (see Equation 5), N_{BP} the number of annual breeding pairs, N_{B} the number of breeders, and N_{NB} the number of non-breeders.

Table 3: Ratio of the total population N^G to the number of breeding pairs N_{BP} for various species types, based on the simulations of seabird population dynamics (Richard & Abraham 2013a).

Species type	N^G/N_{BP}
Biennial breeding albatrosses	8.5
Partially biennial albatrosses	8.0
Annual breeding albatrosses	7.5
Biennial breeding petrels	6.0
Diving petrels	3.5
Other Procellariiformes	5.0
Two-egg clutch size or more	5.0

For distributions outside the breeding season, the normalised density of non-breeders was multiplied by the total population size and by the proportion of the population remaining in New Zealand waters during the non-breeding season (see 2.4.6).

2.2.2 Estimation of observable captures

The total number of captures was estimated using data of seabird captures reported by Ministry for Primary Industries (MPI) observers. When observers are on-board commercial fishing vessels, they record captures of protected species, including seabirds and marine mammals. The capture events are entered into a database maintained by the National Institute of Water and Atmospheric Research (NIWA) on behalf of MPI. These data are currently housed in the Centralised Observer Database (COD). Extraction and grooming of fisheries and seabird capture data followed the methods described by Abraham et al. (2013), with data encompassing the period from 2006–07 to 2012–13. Non-fishing related captures, such as birds colliding with the superstructure of the vessels or landing on the deck, were identified by the capture method code and observer comments, and were excluded from the data set.

In addition to the observer data, the estimation of total captures required fishing effort data. Records of all fishing events made during commercial bottom-longline, surface-longline, trawl, and set-net fishing were obtained, covering the period from 2006–07 to 2012–13. Data were extracted from the *warehou* database (Ministry for Primary Industries 2012), and included target species, vessel characteristics, location, time, and date. Fishing effort was defined as the number of tows for trawl fisheries, the number of line sets for bottom- and surface-longline fisheries, and the net length (in metres) for set-net fisheries.

Fishing effort was assigned to fishery groups based on fisher-reported information (Table 4), as in previous assessments (Waugh et al. 2009, Richard et al. 2011, Richard & Abraham 2013c). Fishery groups were assigned on the basis of the target species of each fishing event, the size of the vessel, and, for trawl fishing targeting middle-depth species, whether the vessel was a processor or a fresher type; and if it was a processor type, whether or not it had a meal plant on board (as in Richard & Abraham 2013c). The target species groups followed groupings defined in assessments of protected species captures (e.g., Abraham et al. 2010b), with the exception that trawl fishing targeting hoki, hake, and ling was included with trawl fishing targeting other middle-depth species. In addition, set-net fishing was also included here.

The risk assessment was carried out for 70 distinct seabird species or populations (Table 5). As in Richard & Abraham (2013c), seabirds were aggregated into species groups to improve the estimation of potential fatalities for species with small populations. Grouping species assumed that the species within the same group interacted similarly with fisheries. For shearwaters, *Procellaria* petrels, and albatrosses, different species groupings were used for set-net fisheries compared with other fisheries. Captures of these species were not frequently observed in set-net fisheries, and grouping them into broader groups helped to better constrain the estimated captures. The different groups used for set-net fisheries were: small albatrosses and giant petrel (*Thalassarche* and *Macronectes* species); great albatrosses (*Diomedea* and *Phoebetria*

Table 4: Fishery groups used for the assignment of fishing effort (SBW, southern blue whiting; SQU, squid; SCI, scampi; SNA, snapper).

Method	Fishery group	Description
Trawl	Small inshore	Targeting inshore species (other than flatfish), or targeting middle-depth species (principally hoki, hake, or ling) on vessels less than 28 m length.
	SBW	Targeting southern blue whiting.
	SCI	Targeting scampi.
	Mackerel	Targeting mackerel (primarily jack mackerel species).
	SQU	Targeting squid.
	Flatfish	Targeting flatfish species.
	Large trawler (no meal plant)	Targeting middle-depth species, vessel longer than 28 m, with freezer but without meal plant.
	Large trawler (with meal plant)	Targeting middle-depth species, vessel longer than 28 m, with freezer and meal plant.
	Large fresher	Targeting middle-depth species, vessel longer than 28 m, with no processing on board, and so no freezer.
	Deepwater	Targeting deepwater species (principally orange roughy or oreos).
Bottom longline (BLL)	Bluenose	Targeting bluenose, and vessel less than 34 m length.
	SNA	Targeting snapper, and vessel less than 34 m length.
	Ling	Targeting ling, and vessel less than 34 m length.
	Small	Not targeting snapper, bluenose, or ling, and vessel less than 34 m length.
	Large	Vessel 34 m or longer.
Surface longline (SLL)	Swordfish	Targeting swordfish, and vessel less than 45 m length.
	Small	Not targeting swordfish, and vessel less than 45 m length.
	Large	Vessel 45 m or longer.
Set net	Set net	All set-net fishing.

species); *Procellaria* petrels (*Procellaria* species); and shearwaters (*Puffinus* species).

Vulnerability to capture was a function of both the species group and the fishery type. Some species have a tendency to be more attracted to fishing vessels than others, and some fisheries are more likely than others to catch birds, due to risk factors such as discharge management and the mitigation measures deployed. A model including these two components of vulnerability (plus an intercept) allowed the estimation of vulnerability in poorly-observed fisheries and for rare species to be informed by the vulnerability from better observed fisheries, or from common species. To reflect differences in operations relating to fishing gear types, and in the different units of fishing effort, a separate model was fitted for each method (trawl, bottom longline, surface longline, and set net).

For trawl, surface-longline, and bottom-longline methods, the model of observable captures for each fishing method was defined as:

$$C_{gs} \sim \text{Poisson}(\mu_{gs}) \tag{7}$$

$$\mu_{gs} = v_0 v_g v_s O_{gs} \epsilon_{gs}, \tag{8}$$

where C_{gs} is the number of annual observable captures of the species group s in the fishery group g, μ_{gs} is the mean number of observable captures of species group s in the fishery group g, v_g is the overall vulnerability of seabirds in the fishery group g (reflecting that some fisheries tend to attract more birds than others), v_s is the vulnerability of the species group, s (reflecting that some birds have a tendency to be more attracted to fishing vessels than others). The overlap O_{gs} between the species group s and the fishery group g, is the product of the fishing effort and the bird density at each fishing event, summed over all fishing events, and ϵ_{gs} the error associated with the combination of species group, s, and the fishing group, g. The intercept, v_0, is taken as the vulnerability of white-chinned petrel in deepwater

Table 5: Species considered in the assessment of risk of commercial fisheries to seabirds breeding in New Zealand, and their grouping in the models for estimating their vulnerability in set nets and in other fisheries (trawling and longlining).

		Modelled species groups	
Common name	Scientific name	Set net fisheries	Other fisheries
Gibson's albatross	*Diomedea antipodensis gibsoni*	Great albatrosses	Wandering albatrosses
Antipodean albatross	*Diomedea antipodensis antipodensis*	Great albatrosses	Wandering albatrosses
Southern royal albatross	*Diomedea epomophora*	Great albatrosses	Royal albatrosses
Northern royal albatross	*Diomedea sanfordi*	Great albatrosses	Royal albatrosses
Campbell black-browed albatross	*Thalassarche impavida*	Small albatrosses and giant petrel	Campbell black-browed albatross
New Zealand white-capped albatross	*Thalassarche cauta steadi*	Small albatrosses and giant petrel	White-capped albatross
Salvin's albatross	*Thalassarche salvini*	Small albatrosses and giant petrel	Salvin's albatross
Chatham Island albatross	*Thalassarche eremita*	Small albatrosses and giant petrel	Chatham albatross
Grey-headed albatross	*Thalassarche chrysostoma*	Small albatrosses and giant petrel	Grey-headed albatross
Southern Buller's albatross	*Thalassarche bulleri bulleri*	Small albatrosses and giant petrel	Buller's albatrosses
Northern Buller's albatross	*Thalassarche bulleri platei*	Small albatrosses and giant petrel	Buller's albatrosses
Light-mantled sooty albatross	*Phoebetria palpebrata*	Great albatrosses	Light-mantled sooty albatross
Northern giant petrel	*Macronectes halli*	Small albatrosses and giant petrel	Giant petrel
Grey petrel	*Procellaria cinerea*	Procellaria petrels	Grey petrel
Black petrel	*Procellaria parkinsoni*	Procellaria petrels	Black petrel
Westland petrel	*Procellaria westlandica*	Procellaria petrels	Westland petrel
White-chinned petrel	*Procellaria aequinoctialis*	Procellaria petrels	White-chinned petrel
Flesh-footed shearwater	*Puffinus carneipes*	Shearwaters	Flesh-footed shearwater
Wedge-tailed shearwater	*Puffinus pacificus*	Shearwaters	Shearwaters
Buller's shearwater	*Puffinus bulleri*	Shearwaters	Shearwaters
Sooty shearwater	*Puffinus griseus*	Shearwaters	Sooty shearwater
Fluttering shearwater	*Puffinus gavia*	Shearwaters	Shearwaters
Hutton's shearwater	*Puffinus huttoni*	Shearwaters	Shearwaters
Little shearwater	*Puffinus assimilis*	Shearwaters	Shearwaters
Snares Cape petrel	*Daption capense australe*	Cape petrel	Cape petrel
Fairy prion	*Pachyptila turtur*	Prions	Prions
Antarctic prion	*Pachyptila desolata*	Prions	Prions
Broad-billed prion	*Pachyptila vittata*	Prions	Prions
Pycroft's petrel	*Pterodroma pycrofti*	Pterodroma petrels	Pterodroma petrels
Cook's petrel	*Pterodroma cookii*	Pterodroma petrels	Pterodroma petrels
Chatham petrel	*Pterodroma axillaris*	Pterodroma petrels	Pterodroma petrels
Mottled petrel	*Pterodroma inexpectata*	Pterodroma petrels	Pterodroma petrels
White-naped petrel	*Pterodroma cervicalis*	Pterodroma petrels	Pterodroma petrels
Kermadec petrel	*Pterodroma neglecta*	Pterodroma petrels	Pterodroma petrels
Grey-faced petrel	*Pterodroma macroptera gouldi*	Pterodroma petrels	Pterodroma petrels
Chatham Island taiko	*Pterodroma magentae*	Pterodroma petrels	Pterodroma petrels
White-headed petrel	*Pterodroma lessonii*	Pterodroma petrels	Pterodroma petrels
Soft-plumaged petrel	*Pterodroma mollis*	Pterodroma petrels	Pterodroma petrels
Common diving petrel	*Pelecanoides urinatrix*	Diving petrels	Diving petrels
South Georgian diving petrel	*Pelecanoides georgicus*	Diving petrels	Diving petrels
New Zealand white-faced storm petrel	*Pelagodroma marina maoriana*	Storm petrels	Storm petrels
White-bellied storm petrel	*Fregetta grallaria grallaria*	Storm petrels	Storm petrels
Black-bellied storm petrel	*Fregetta tropica*	Storm petrels	Storm petrels
Kermadec storm petrel	*Pelagodroma albiclunis*	Storm petrels	Storm petrels
New Zealand storm petrel	*Pealeornis maoriana*	Storm petrels	Storm petrels
Yellow-eyed penguin	*Megadyptes antipodes*	Yellow-eyed penguin	Yellow-eyed penguin
Northern little penguin	*Eudyptula minor f. iredalei*	Blue penguins	Blue penguins
White-flippered little penguin	*Eudyptula minor f. albosignata*	Blue penguins	Blue penguins
Southern little penguin	*Eudyptula minor f. minor*	Blue penguins	Blue penguins
Chatham Island little penguin	*Eudyptula minor f. chathamensis*	Blue penguins	Blue penguins
Eastern rockhopper penguin	*Eudyptes chrysocome filholi*	Crested penguins	Crested penguins
Fiordland crested penguin	*Eudyptes pachyrhynchus*	Crested penguins	Crested penguins
Snares crested penguin	*Eudyptes robustus*	Crested penguins	Crested penguins
Erect-crested penguin	*Eudyptes sclateri*	Crested penguins	Crested penguins
Australasian gannet	*Morus serrator*	Boobies and gannets	Boobies and gannets
Masked booby	*Sula dactylatra*	Boobies and gannets	Boobies and gannets
Pied shag	*Phalacrocorax varius varius*	Solitary shags	Solitary shags
Little black shag	*Phalacrocorax sulcirostris*	Solitary shags	Solitary shags
New Zealand king shag	*Leucocarbo carunculatus*	Solitary shags	Solitary shags
Stewart Island shag	*Leucocarbo chalconotus*	Group foraging shags	Group foraging shags
Chatham Island shag	*Leucocarbo onslowi*	Group foraging shags	Group foraging shags
Bounty Island shag	*Leucocarbo ranfurlyi*	Group foraging shags	Group foraging shags
Auckland Island shag	*Leucocarbo colensoi*	Group foraging shags	Group foraging shags
Campbell Island shag	*Leucocarbo campbelli*	Group foraging shags	Group foraging shags
Spotted shag	*Stictocarbo punctatus*	Group foraging shags	Group foraging shags
Pitt Island shag	*Stictocarbo featherstoni*	Solitary shags	Solitary shags
Subantarctic skua	*Catharacta antarctica lonnbergi*	Gulls, terns and skua	Gulls, terns & skua
Southern black-backed gull	*Larus dominicanus dominicanus*	Gulls, terns and skua	Gulls, terns & skua
Caspian tern	*Hydroprogne caspia*	Gulls, terns and skua	Gulls, terns & skua
White tern	*Gygis alba candida*	Gulls, terns and skua	Gulls, terns & skua

trawl fisheries for the trawl model, in large bottom-longline fisheries for the bottom-longline model, and in large surface-longline fisheries for the surface-longline model. The vulnerabilities v_s and v_g were fixed to 1 for this species and these fisheries taken as base cases. Vulnerabilities in other groups (species or fisheries) were expressed relative to these base cases.

The error, ϵ_{gs}, was defined as a random effect following a log-normal distribution with mean one and a gamma-distributed standard error, with a prior of rate and shape 0.001. The vulnerabilities v_g and v_s had a log-normal prior, with a mean 0 and standard deviation of 16 on the normal scale. These priors were defined to be vague, and re-running the models with different values showed that the impact of these choices on the posterior distribution of the parameters was minimal.

Because set-net fisheries were aggregated into a single fishery group, the mean number of captures in the model was

$$C_s \sim \text{Poisson}(\mu_s), \tag{9}$$

$$\mu_s = v_s O_s. \tag{10}$$

The vulnerability, v_s, had a uniformly distributed prior, with range 0 to 0.1, after verification that changing this upper bound had a minimal influence on the parameters' posterior distributions.

For each combination of species group and fishery group, the observed fishing events were aggregated by summing the observed captures and by summing the overlap over all fishing events. The model, run for each fishing method, was coded in the BUGS language (Spiegelhalter et al. 2003), and fitted using Markov Chain Monte Carlo (MCMC) methods with the software JAGS (Plummer 2005). Two chains were used, with a burn-in period of one million iterations, and the posterior samples taken from 800 000 iterations, thinned by sampling every 400 values.

The models were assessed by visually examining the trace of the MCMC chains for convergence and mixing. The vulnerabilities were taken as samples of 4000 values from the posterior distribution of the model's parameters. The number of observable captures was estimated in non-observed fishing events. This number represents the number of captures that would have been observed if observers had been present on all fishing vessels. The number of observable captures in the non-observed fishing events was calculated by applying the fitted models in Equations 7–10 to the non-observed overlap for each fishing method. The total annual number of observable captures was then obtained by adding the captures in observed fishing events to the estimated number of observable captures in the non-observed fishing events; this sum was then divided the number of years covered by the data, to get the average annual number of observable captures.

The data used for estimating the observable captures, i.e., the number of observed captures of each species and the proportion of overlap observed between the different species and fisheries, are summarised in the appendix (Table A-4). The proportion of overlap observed for each species was calculated as the ratio of the total overlap at the observed fishing events (the product of the seabird density and the fishing effort, summed over the fishing events) to the total overlap at all fishing events. In many cases, the proportion of the overlap observed was low (less than 10%).

2.2.3 Potential seabird fatalities

Observer records of seabird captures may under-represent the total number of fishing-related seabird mortalities, as seabirds involved in fatal interactions with commercial fisheries may not necessarily be captured by fishers or recorded by observers. In longline fisheries, birds can become hooked during sets, but may not be retained when gear is hauled, so that they are not brought on-board the fishing vessel (Brothers et al. 2010). In trawl fisheries, birds may get caught in nets, but may also be fatally injured by the impact with trawl warps while flying ("aerial warp strike", *sensu* Sharp et al. 2011), or become entangled by warps on the water and subsequently drown ("surface warp strike"; Watkins et al. 2008). These cryptic mortalities are not included in the number of observable captures, so that estimates based on observable captures are potentially underestimates of the total number of fatalities.

There is limited information available to help quantify cryptic mortalities. For surface-longline fisheries, a 15-year study counted the number of seabirds that were caught when lines were set, and found that only half of the bodies, 85 of a total 176, were retrieved during line hauling (Brothers et al. 2010). For trawl fisheries, Watkins et al. (2008) provide data on the number of warp strikes and subsequent fatalities, based on 190 hours of dedicated observations in the South African deepwater hake fishery in 2004 and 2005. Abraham (2010) provide estimates of the number of warp strikes per observed capture, using 7266 observations of warp strikes recorded in New Zealand trawl fisheries between the 2004–2005 and 2008–2009 fishing years.

From the values provided in these studies, cryptic mortality multipliers were calculated. These multipliers give the number of potential fatalities as a multiple of the number of observable captures, and varied between 1.3 and 8.2, depending on the species type (a summary of the cryptic mortality multipliers depending on the fishing method and species type is presented in Table 6). The calculations of the multipliers followed Richard & Abraham (2013c), but were updated with two more years of capture data since the previous assessment (see Appendix B). These multipliers include some uncertainty, limited to statistical uncertainty from the underlying data sources; however, the uncertainty associated with extrapolating from results obtained in different fisheries, and in different jurisdictions was not considered.

There are no data available for cryptic mortality in bottom-longline fisheries, and we assumed the same cryptic mortality in both surface- and bottom-longline fisheries. In trawl fisheries, the amount of cryptic mortality due to interactions with nets was based on expert knowledge, agreed at a New Zealand National Plan of Action Risk Assessment workshop (held in February 2009). Because no data exist on cryptic mortality in set-net fisheries to allow for the estimation of a multiplier, the number of annual potential fatalities was assumed to be equal to the estimated number of observable captures in these fisheries (i.e., a cryptic multiplier of one).

Table 6: Mean and 95% credible interval (c.i.) of the number of potential seabird fatalities per observed capture in longline and trawl fisheries for each species type (Large: albatrosses, giant petrels, skuas; small fast-flying: large petrels and shearwaters; small slow-flying: small petrels, prions, storm petrels, diving petrels, small shearwaters; small diving: shags, penguins, gannets and boobies).

Fishery	Species type	Mean	95% c.i.
Bottom & surface longline	All	2.09	1.80–2.46
Trawl	Large	8.20	5.41–11.96
	Small fast-flying	3.42	1.85–6.69
	Small slow-flying	2.98	1.68–5.73
	Small diving	1.30	1.10–1.71

2.3 Sensitivity

To understand the relative importance of different sources of uncertainty in the risk ratio, a sensitivity analysis was carried out. For a range of input parameters, the sensitivity of uncertainty in the risk ratio was determined by setting the value of the parameter to its mean value. The resulting reduction in the 95% credible interval of the risk ratio was then determined. Using this method, the sensitivity to the uncertainty was determined for the following parameters: proportion of breeders (P_B); age at first breeding (A); adult survival (S_A); number of breeding pairs (N_{BP}); cryptic mortality multiplier; observable captures in set-net fisheries; observable captures in surface-longline fisheries; observable captures in bottom-longline fisheries; and observable captures in trawl fisheries.

2.4 Updates from the previous risk assessment

2.4.1 Updates to the data

The range of fisheries and observer data used for estimating the vulnerability was extended from the period between 2006–07 and 2010–11 to the period from 2006–07 to 2012–13 (see data summary in Table 7).

As part of the update, data from the previous years were revised, and this revision revealed a significant error in the previous risk assessment that was corrected in the current study. The error occurred during the data preparation for the previous risk assessment, when the fishing method of an observed trip in November 2009 was correctly changed from set net to trawl without also assigning the correct effort to the latter fishing method. This error meant that observer coverage in inshore trawl fisheries was overestimated. Specifically, there was an incorrect key in COD for the vessel concerned, so that the fishing trip was matched to set netting instead of trawling. Following confirmation from Department of Conservation and MPI that it was a trawl trip, the method for this trip was manually changed in the data set, but the effort data were not corrected. For this reason, a fishing effort of 2000 tows was incorrectly included in the observer data (it was originally entered in COD as 2000 m of net; in COD, net length and number of tows are recorded in the same field). This overestimation of effort resulted in a correspondingly low bias of the vulnerability values for inshore trawl fisheries. This error was corrected in the data preparation for the current risk assessment.

To ensure that there were no other similar errors, a range check was applied to the data (Table 8). There was no anomaly apparent, in the order of magnitude of effort and in the comparison of observed versus unobserved effort.

Small differences persisted in the maximum effort between the observed and non-observed fishing effort. This discrepancy was due to the use of Catch Effort and Landing Return (CELR) forms by skippers on small vessels for reporting their fishing effort. On these forms, several fishing events may occasionally be aggregated, and the differences reflect a sampling effect, as the fishing effort by small vessels is seldom observed. For example, in the small-vessel bottom-longline fisheries, among the 3303 fishing events recorded on CELR forms, only five events were observed. More observations in these fisheries would lead to a higher probability that a form contains a high number of fishing events.

2.4.2 Changes in demographic parameters

Following the workshop in November 2013 (Walker et al. 2015), a number of changes were made to the demographic parameters used in the previous risk assessment by Richard & Abraham (2013c).

The population size was changed for 11 species, reflecting recent surveys. The number of annual breeding pairs was reduced from 6292 to 3320 for Antipodean albatross (G. Elliot, pers. comm.), and from between 4826 and 7417 annual breeding pairs to a mean of 4792 annual breeding pairs for Gibson's albatross (Elliott & Walker 2014, Baker & Jensz 2014). The number of annual breeding pairs was increased for Salvin's albatross, from a mean of 31 947 (Agreement on the Conservation of Albatrosses and Petrels (ACAP) 2010) to between 33 000 and 41 000 annual breeding pairs (Baker et al. 2014b); for grey petrel from between 32 000 and 73 000 to a mean of 50 000 annual breeding pairs (Walker et al. 2015); for flesh-footed shearwater from between 6689 and 10 540 to a mean of 10 000 annual breeding pairs (Walker et al. 2015); for Stewart Island shag from between 1800 and 2000 to between 2075 and 2482 annual breeding pairs (Lalas & Perriman 2012); for little black shag from between 400 and 800 annual breeding pairs to a mean of 1500 annual breeding pairs (Walker et al. 2015); and for pied shag from a minimum of 652 to a mean of 6400 annual breeding pairs (Bell 2013).

For white-capped albatross, Baker et al. (2013) provided data of the breeding population from annual aerial surveys between 2006 and 2013. The distribution of the overall mean breeding population size of this species was obtained from these eight surveys using a bootstrap procedure, resulting in a mean number of 95 700 (95% c.i.: 85 400–106 000) annual breeding pairs, an increase from the mean of 77 000

Table 7: Summary of data used in the current risk assessment, including fishing effort, observer effort, and observer coverage by fishery group for the period between 2006–07 and 2012–13 (BLL, bottom longlining; SLL, surface longlining; SBW, southern blue whiting). Effort data included the number of tows (trawl fisheries), the number of sets (longline fisheries), and kilometres of net (set-net fisheries), and are not comparable between methods.

Method	Fishery group	Effort	Observed	Coverage (%)
Trawl	Small inshore	276 762	3 913	1.4
	SBW	6 663	3 133	47.0
	Scampi	31 684	2 901	9.2
	Mackerel	16 060	7 269	45.3
	Squid	28 165	10 011	35.5
	Flatfish	131 475	1 459	1.1
	Large processor	30 760	7 306	23.8
	Large meal	54 455	15 106	27.7
	Large fresher	14 297	1 326	9.3
	Deepwater	37 169	12 025	32.4
BLL	Bluenose	24 877	218	0.9
	Snapper	42 760	529	1.2
	Small ling	21 429	454	2.1
	Small	24 646	246	1.0
	Large	12 504	1 736	13.9
SLL	Small tuna	15 830	948	6.0
	Small swordfish	1 261	139	11.0
	Large	1 415	1 166	82.4
Set net	Set net	151 911	2 490	1.6

Table 8: Range check applied to fisheries data used in the risk assessment, giving the maximum effort recorded by a vessel during a fishing record, for each fishery group, after data grooming. The table gives the maximum effort on observed and unobserved fishing, with trawl and longline effort being recorded in tows and sets, respectively, and set net effort being recorded in metres of net.

Method	Fishery group	Max. observed effort	Max. unobserved effort
Trawl	Small inshore	6	9
	SBW	1	1
	Scampi	1	1
	Mackerel	1	1
	Squid	1	7
	Flatfish	7	9
	Large processor	1	1
	Large meal	1	1
	Large fresher	1	1
	Deepwater	1	7
BLL	Bluenose	4	8
	Snapper	1	10
	Small ling	4	10
	Small	3	10
	Large	1	1
SLL	Small tuna	1	2
	Small swordfish	1	1
	Large	1	1
SN	Set net	8000	8100

annual breeding pairs used in the previous assessment. The quality of the population size estimate for Westland petrel was changed from medium to good, decreasing the uncertainty and lowering the upper end of the estimate, as suggested during the risk assessment workshop (Walker et al. 2015).

There were also changes to the black petrel population estimates (see following section).

The annual survival rate was updated for three species. It was increased for Westland petrel from between 88.4 and 93.3% to between 90 and 97%, using white-chinned petrel as a proxy species (Dillingham & Fletcher 2008), as the previous estimate was considered too low for representing the survival rate in optimum conditions. Similarly, annual survival was increased for flesh-footed shearwater from 92 to 94%, and for black petrel from 90.32 to 95% (Walker et al. 2015).

Additionally, for grey petrel, the proportion of adults breeding was decreased from the default value for annual breeders of 90 to 80% (Walker et al. 2015); it was increased from 90 to 100% for pied shag to reflect that the estimated population size (Bell 2013) was already corrected for the proportion of adults breeding.

There were no updates to the estimate of age at first reproduction from the previous risk assessment by Richard & Abraham (2013c).

The breeding season was altered for 54 species, including 15 species based on expert judgement (G. Taylor, Department of Conservation), to better reflect when the birds are present around colonies. For the remaining 39 species, the breeding seasons were updated using information from New Zealand Birds Online (http://nzbirdsonline.org.nz/).

2.4.3 Black petrel population

The size of the black petrel population was estimated by synthesising data from three sources. First, counts at the Great Barrier Island (Mt Hobson, Hirakimata) colony were used to provide a lower estimate of the black petrel population. From the survey of the colony, it was estimated that there were "2954 ± 167 breeding adults (i.e., approximately 1500 breeding pairs)" (Bell et al. 2013a). As the survey was of a 35-ha area, and there were black petrel known to breed outside this area, the survey data were considered to be a lower estimate. Using a multiplier of 4.7, for the ratio between the number of breeding pairs and the total population (Richard & Abraham 2013a), a lower bound for the population size was considered to be 6952 black petrel.

An alternate estimate was obtained by counting black petrel during the non-breeding season off the coast of South America, using data from 15 cruises between 1980 and 1995 (Spear et al. 2005). By using a Generalised Additive Model (GAM), the counts were used to derive a mean estimate of 37 950 black petrel (95% c.i.: 28 268–49 806) during the austral autumn/winter season. This value may have been an overestimate as black petrel may have been attracted to the vessels. In addition, estimating the abundance by integrating over a distribution derived from a GAM may also have led to inflated estimates (if the GAM predicted abundant black petrel away from the data).

A third source of data were records of banded birds. Of the 48 black petrel caught in fisheries that were necropsied, four birds were banded. From an estimate of the number of banded birds that were alive when the captures occurred, an estimate of the total black petrel population was derived. Based on the count data, we constructed a prior for the black petrel population as a log-normal distribution with a mean of $\log(6952)$, and a standard deviation (on the log scale) of 3. The resulting prior was truncated to between 6952 and 37 950 individuals. With this prior for the black petrel population, N, a Bayesian model was used to predict whether or not a necropsied bird was banded (b_i), and to derive a posterior distribution for N:

$$b_i \sim \text{Bernouilli}(n_{y_i}/N), \tag{11}$$

where i runs from 1 to the number of necropsied birds, y_i is the year in which the bird was caught, and n_{y_i} is the number of adult banded birds that were alive during that year. The number of banded birds increased from around 800 individuals in 2000, and then stabilised at between 1500 and 1600 individuals from 2007 onwards (Bell et al. 2014). The prior distribution had a mean of 11 655 (95% c.i.: 7080–24 424), while the posterior distribution had a mean of 12 828 (95% c.i.: 7410–23 801). The prior and the banding data were broadly consistent; however, fitting to the banding data increased the median of the distribution, and decreased the range. From the posterior distribution, the number of breeding pairs was estimated by dividing by the ratio 4.7. The resulting estimate was a mean number of black petrel breeding pairs of 2750 (95% c.i.: 1600–5120), and this distribution was used in the risk assessment. The credible interval ranged from between 1.1 and 3.4 times the number of breeding pairs that were counted at the Mt Hobson (Hirakimata) colony.

2.4.4 Changes in species and fishery groups

The risk to royal albatrosses was previously found to be high, despite a low number of observed captures. This finding was likely to have been a consequence of a single vulnerability to capture, estimated for all great albatrosses, i.e., royal and wandering albatrosses (Antipodean and Gibson's albatrosses), with the latter frequently observed caught in fisheries. Following the recommendations of the expert review workshop (Walker et al. 2015), the vulnerability was estimated separately for royal and wandering albatrosses.

Shag species were grouped according to their foraging behaviour, depending on whether they were solitary or group foragers. However, the previous allocation of species to each group was deemed inaccurate (Walker et al. 2015), and it was amended, grouping spotted shag and all *Leucocarbo* species other than New Zealand king shag as group foragers. The remaining shag species were grouped as solitary foragers.

Additionally, in the previous assessment, the two subspecies of Cape petrel found in New Zealand waters were not differentiated, and the observed captures were merged together. Only the Snares Cape petrel (*Daption capense australe*) breeds in the New Zealand region, as the southern subspecies (*Daption capense capense*) breeds on mainland Antarctica, the Antarctic Peninsula, and Antarctic and subantarctic islands outside of New Zealand (Sagar 2013). Any captures that were explicitly identified (either at necropsy, by observers, or by imputation) as being the southern subspecies were excluded from the analysis. Any captures that were not identified to the subspecies level (or whose identification could not be imputed to the subspecies level) were retained.

The fishery effect on vulnerability was previously constrained to be the same for all small-vessel surface-longline fisheries (vessels less than 45 m long); however, as recommended by the expert review workshop, swordfish fisheries were assessed separately from other small-vessel surface-longline fisheries.

Similarly, all small-vessel bottom-longline fisheries (vessels less than 34 m long), other than those targeting snapper or bluenose, were previously grouped together. This fishery group is diverse, with a wide range of gear configurations and operational practices. Following the recommendations of the workshop, small-vessel bottom-longline fisheries targeting ling were assessed separately.

2.4.5 Changes to distribution maps

The at-sea distribution of nine species was changed from the previous assessment (Richard & Abraham 2013c) to incorporate recent studies and experts' opinion expressed during the workshop (Walker et al. 2015).

The distribution of black petrel was previously defined as a density decreasing with increasing distance from Great Barrier Island, where the main breeding colony is, with the outer boundary set at the NABIS 100% distribution layer. This definition resulted in a high overlap of black petrel with fisheries in Hauraki Gulf, whereas at-sea observations and Global Positioning System (GPS) tracking data suggest that black petrel tend to forage preferentially on the shelf break (Freeman et al. 2010). A recent project derived distribution maps for this species based on counts by government fisheries observers at the back of fishing vessels, counts from a seabird expert (C. Gaskin) during pelagic tours, and GPS tracking data (Abraham et al. 2015). The distribution maps were predicted to represent the density of black petrel as would be recorded by observers on-board fishing vessels. The distributions, therefore, directly represent the density of birds behind the vessels. This density changed with the fishing method and the breeding season, which was divided into three periods: the pre-egg laying stage (October–November), the incubation stage (December–January), and the chick rearing stage (February–May).

A single distribution map was obtained for each breeding period by taking for each map cell the average black petrel density among the different fishing methods, weighted by the respective number of fishing events. For this reason, the bird density was undefined outside the area where fishing vessels operate, although this effect did not impact on the estimation of APF. To be comparable, the distribution maps were subsequently standardised as for other species. Moreover, tracking data (Bell et al. 2014) indicated that all black petrel migrate to South America during the non-breeding season (June–September), and this species' density within New Zealand's EEZ was assumed to be zero during that period.

The distribution of Salvin's albatross was amended to reflect the high capture rate off the east coast of South Island and on Chatham Rise (Abraham & Thompson 2012a). This "hot spot" off the South Island east coast was enlarged to encompass the area of high capture density, the radius from the colony was doubled from 1500 km to 3000 km. Furthermore, the distance from the colony was taken as the minimum distance over sea to represent the longer distance to the West Coast, rather than a Euclidean distance as previously used. The latter was calculated using the cost distance function in GRASS GIS (Neteler et al. 2012).

For Gibson's albatross, the at-sea distribution was amended to consider new tracking data. A kernel-smoothed density was computed from the GPS points presented in Elliott & Walker (2013), using the "density.ppp" function from the "spatstat" R library (Baddeley & Turner 2005). The mean of the standard deviation of the latitudes and longitudes, divided by seven, was used as the standard deviation of the isotropic Gaussian smoothing kernel. This approach resulted in a smooth distribution that did not over-fit the individual GPS points. This distribution was used for the breeding portion of the population, and the distribution of the non-breeding portion was considered to be uniform over the New Zealand region. The merging of both distributions followed the same process as for other species (as described in Section 2.2.1).

Changes to the distribution of New Zealand white-capped albatross were made by increasing their density on the South Island west coast, overlaying a new hot spot in the area of high captures with the original hot spot layer from NABIS.

Ellenberg & Mattern (2012) provided a distribution of yellow-eyed penguin foraging ranges. This distribution consists of a non-breeding distribution restricted by the 150-m depth contour, an incubation and post-guard distribution with a maximum foraging range of 50 km from the colonies, and a similar chick-guard distribution but with a maximum range of 20 km. These areas were treated as if they were the 100%, 90%, and hot spot NABIS layers, respectively. No distribution was provided for the sub-antarctic populations in the Auckland and Campbell islands, but we applied the same rules found for the mainland to these islands (150-m depth contour, and maximum radius of 50 and 20 km from the colonies). The distribution during the non-breeding season was considered a uniform density within the non-breeding layer.

The distribution of flesh-footed shearwater was modified following recommendations made during the workshop, which suggested that this shearwater was unlikely to occur further south than Banks Peninsula (Walker et al. 2015). We, therefore, set the southern limit to the south of the Chatham Rise, and followed the shape of the 90% NABIS layer on the western side of South Island, with the southern limit being further north. The hot spot around North Island was enlarged, as tracking of flesh-footed shearwater indicated that the area of intense foraging extends further offshore than the original NABIS layer area suggested (Waugh et al. 2014).

For Westland petrel, the at-sea distribution was changed to better reflect the findings of Landers et al. (2011). From the kernel density of each of the eight tracked birds of the study, we devised a distribution that attempted to capture the common area between them, while keeping some of the features of the

NABIS layers. The distribution was enlarged around the colony near Punakaiki, on the South Island west coast, and the NABIS hot spot was extended further north (up to the Taranaki region), and further east and south off the east coast (to Banks Peninsula).

Since the last assessment, the breeding ground of New Zealand storm petrel, re-discovered in 2003, was found to be on Little Barrier Island. Whereas the density was previously uniformly distributed across the New Zealand area, a new distribution was derived. This distribution was centred on Little Barrier Island, with a maximum radius of 800 km, clipped within a horizontal band with the northern limit just below Kermadec Islands, and a southern limit just south of Cook Strait to the east, and just north of South Island to the west.

The southerly extent of the distribution of Kermadec storm petrel was restricted to 33° S, following the recommendations of the workshop (Walker et al. 2015).

2.4.6 Non-breeding population

In the previous assessment, the seabird populations during the non-breeding season were assumed to either stay entirely in New Zealand waters, or to migrate entirely away from New Zealand. The species that were assumed to migrate were black petrel, Westland petrel, white-chinned petrel, flesh-footed shearwater, wedge-tailed shearwater, Buller's shearwater, sooty shearwater, Hutton's shearwater, Pycroft's petrel, Cook's petrel, Chatham petrel, mottled petrel, white-naped petrel, Chatham Island taiko, and New Zealand white-faced storm petrel. Nevertheless, some species only partially migrate, or expand their foraging range, leading to a lower density during that season. For this assessment, the proportion of the population staying in New Zealand during the non-breeding season was considered for each species (G. Taylor, Department of Conservation, unpubl. data). The most likely value was used to scale the population within New Zealand waters during the non-breeding season compared with the population during the breeding season. Twenty of the values were expressed as an upper limit, e.g. < 5%, and half of the upper limit was used in these cases.

The density of birds in the non-breeding distribution was then multiplied by this proportion to obtain the density of birds at the location of fishing events during that period.

2.4.7 Consequences of updates

To clarify the impact of the updates on the previous estimates of risk by Richard & Abraham (2013c), the changes were grouped by type, and the risk estimation process was repeated sequentially on each group of updates, as follows:

1. The assessment was first re-run on the same years as in Richard & Abraham (2013c), i.e., on fishing and capture data for the period between 2006–07 and 2010–11. This step sought to reproduce the previous assessment, and to identify any errors in the calculation of the risk ratio or as a consequence of changes in the data.
2. The vulnerability was estimated on the fishing effort and capture data between 2006–07 and 2012–13, but with the calculation of APF made on the data between 2006–07 and 2010–11. Changes in risk ranking reflected the change in vulnerability due to the addition of two more years of data on fishing effort.
3. The APFs were then calculated on the fishing and capture data between the fishing years 2010–11 and 2012–13, so that the estimated risk ranking reflected the current fishing effort and spatial distribution. In particular, changes in distribution due to recent regulation of inshore set-net fisheries will be accounted for (Ministry for Primary Industries 2008).
4. The demographic parameters were then updated to assess their impact on the estimation of risk.
5. The updates on species and fishery groups were applied.

6. The updates on distribution maps were then applied.

2.4.8 Additional sensitivity analyses

To estimate the overlap of black petrel with fisheries, Abraham et al. (2015) fitted a model to at-sea count and tracking data of black petrel. Two approaches were used to predict the at-sea distribution of black petrel. The first approach (used in the current risk assessment) related the counts to environmental variables, the second approach related them to the geographic coordinates. Nevertheless, the difference in the predictive skill of the two approaches was small. As a sensitivity analysis, the calculation of risk was repeated on the predictions from the model including the geographic coordinates only, to test the sensitivity of the results to the choice of distribution map.

During January 2010, 27 black petrels were observed caught by a small bottom-longline vessel targeting bluenose and hapuka in the Bay of Plenty and the east coast of North Island. To test the sensitivity of the risk to this single large capture event, the risk calculations were repeated after treating this trip as unobserved, i.e., without including these captures while still considering the fishing effort.

Similarly, 37 seabird captures were observed during a single fishing trip on Chatham Rise in 2007, on a small bottom-longline vessel targeting ling. These captures included 12 Chatham Island albatross, compared with a total of only 21 individuals of this species that have been observed caught in all fisheries between 2006–2007 and 2012–13. The sensitivity of the risk to this fishing trip was also assessed, by re-running the calculations while treating this trip as unobserved.

Another large capture event occurred in February 2009 off the east coast of South Island by an inshore trawl vessel, during which 31 spotted shags were observed caught. Given the low observer coverage in this fishery, and the low number of observed captures (35 captures between 2006–07 and 2012–13), the risk of spotted shag and other group foragers may be very sensitive to this large capture event. A sensitivity analysis was carried out, by treating this trip as unobserved, and repeating the risk calculations, to quantify the impact of this single event.

Another fishing trip by a small surface-longline vessel off Kermadec Islands caught 58 seabirds in November 2006 while targeting swordfish. The observer recorded that 32 of these captures were fatal involving unidentified albatross. Unidentified birds were not included in the risk assessment. Consultation with experts suggested that these captures were likely to be of Gibson’s or Antipodean albatross, as three and ten individuals, respectively were observed caught alive during the same trip. The risk was re-calculated by assigning these captures to Gibson’s albatross, to test for the sensitivity of the risk to these captures.

All seabird captures, live or dead, were considered in the current assessment (except deck captures and captures that occurred during research trips; see section 2.2.2). A sensitivity analysis was carried out to assess how sensitive the risk ratios were to the removal of live captures or the removal of birds that were uninjured. Observers not only record the live status of each capture, but also the injury status, using a combination of 21 different codes describing the possible types of injuries. All birds captured and recorded with codes indicating an injury were defined as injured except when the bird was recorded as “disoriented or uncoordinated”. The risk calculations were re-run twice, once with only captures recorded as fatal, and once also with the captures of birds recorded as injured captures.

A total of 412 captures of Buller’s albatross were observed between 2006–07 and 2012–13, and all necropsied birds were identified as southern Buller’s albatross. Nevertheless, distinguishing the two species is challenging, and some of the observed captures were considered to be most likely of northern Buller’s albatross. In particular, it was agreed that observed captures in the northern part of New Zealand’s EEZ were likely to be northern Buller’s albatross. Moreover, captures in October and November were probably not southern Buller’s albatross, as tracking studies showed that this species forages off the coast of South America during this period (Sagar & Weimerskirch 1996).

In the current assessment, the assignment of captures to the respective species was irrelevant as both species were pooled for the estimation of vulnerability. Nevertheless, a sensitivity analysis was carried out to evaluate the potential impact of estimating a separate vulnerability for each species. For this purpose, two strategies were tested to re-assign some captures of southern Buller's albatross to northern Buller's albatross. First, we re-assigned the 23 Buller's albatross captures north of 40°S, and captures recorded in October and November (2 captures) to northern Buller's albatross. Second, a further 12 captures east of 180°, around Chatham Islands, were re-assigned to northern Buller's albatross. For both strategies, the vulnerability was estimated for both species separately, and the risk re-calculated.

Because of the method used to estimate vulnerability, the estimation of APF was not expected to be sensitive to population size, although the species component of vulnerability was expected to scale to variations in population size. The sensitivity of APF to population size could be relevant for black petrel, as the at-sea distribution of this species was not defined outside the area where fishing vessels operate (Abraham et al. 2015), leading to a concentrated bird density relatively to other species. The lack of sensitivity was tested by calculating APF twice, with a population size for black petrel artificially multiplied by 10, and divided by 10, and by comparing the resulting estimates with the base case.

To derive the at-sea distribution of black petrel, the bird density at the back of fishing vessels, which depended on the fishing method in the original data, was averaged across fishing methods by their respective effort in each map cell. Another approach for combining the black petrel distributions is to calculate the weighted average over the whole New Zealand region instead of each map cell. This approach was tested by repeating the risk calculations on this alternative distribution map to assess the sensitivity of the risk to the choice of approach.

3. RESULTS

3.1 Overall risk

Among the 70 seabird species for which the risk of fisheries was assessed, seven species were in the "Very high risk" category (Table 9, Figure 1). In order of decreasing median risk, these species were: black petrel, Salvin's albatross, southern Buller's albatross, flesh-footed shearwater, Gibson's albatross, New Zealand white-capped albatross, and northern Buller's albatross. There were four species in the "High risk" category: Chatham Island albatross, Antipodean albatross, Westland petrel, and Campbell black-browed albatross. There were seven species in the "Medium risk" category: Stewart Island shag, white-chinned petrel, northern giant petrel, northern royal albatross, spotted shag, Chatham petrel, and Chatham Island taiko, and the risk category of the mainland population of yellow-eyed penguin was also considered "Medium risk" when assigning all potential fatalities to this population. The risk of ten species was categorised as "Low risk" (southern royal albatross, Snares Cape petrel, grey petrel, yellow-eyed penguin, little black shag, light-mantled sooty albatross, Fiordland crested penguin, grey-headed albatross, New Zealand king shag, and New Zealand storm petrel), with the risk of the remaining 42 species categorised as "Negligible risk".

Black petrel was estimated to be the species most at risk from fisheries, with a median risk ratio of 11.34 (95% c.i.: 6.85–19.81). The PBR_ρ for this species had an estimated mean of 100 (95% c.i.: 60–147), whereas the mean number of APF was estimated to be 1130 (95% c.i.: 836–1490). Between the fishing years 2006–07 and 2012–13, there were 3 observed captures of this species in trawl fisheries, 60 in bottom-longline fisheries, and 11 in surface-longline fisheries.

The species second most at risk was Salvin's albatross, with a median risk ratio of 3.44 (95% c.i.: 1.82–6.50). The mean PBR_ρ was 1020 (95% c.i.: 638–1650), and the mean APF was 3480 (95% c.i.: 2250–5200). Between the fishing years 2006–07 and 2012–13, there were 190 observed captures in trawl fisheries, 25 in bottom-longline fisheries, and 7 in surface-longline fisheries.

The species third most at risk was southern Buller's albatross, with a median risk ratio of 1.82 (95% c.i.: 0.97–3.67). The mean PBR_ρ was 449 (95% c.i.: 246–701), and the mean APF was 791 (95% c.i.: 541–1160). Between the fishing years 2006–07 and 2012–13, there were 163 observed captures in trawl fisheries, 9 in bottom-longline fisheries, and 215 in surface-longline fisheries.

The species fourth most at risk was flesh-footed shearwater, with a median risk ratio of 1.50 (95% c.i.: 0.56–3.36). The mean PBR_ρ was 514 (95% c.i.: 233–1140), and the mean APF was 696 (95% c.i.: 478–995). Between the fishing years 2006–07 and 2012–13, there were 30 observed captures in trawl fisheries, 27 in bottom-longline fisheries, and 6 in surface-longline fisheries.

The species fifth most at risk was Gibson's albatross, with a median risk ratio of 1.26 (95% c.i.: 0.69–2.49). The mean PBR_ρ was 181 (95% c.i.: 98–281), and the mean APF was 222 (95% c.i.: 161–301). Between the fishing years 2006–07 and 2012–13, there was 1 observed capture in trawl fisheries, none in bottom-longline fisheries, and 26 in surface-longline fisheries.

The species sixth most at risk was New Zealand white-capped albatross, with a median risk ratio of 1.10 (95% c.i.: 0.59–1.97). The mean PBR_ρ was 4040 (95% c.i.: 2620–6320), and the mean APF was 4410 (95% c.i.: 2800–6620). Between the fishing years 2006–07 and 2012–13, there were 471 observed captures in trawl fisheries, 2 in bottom-longline fisheries, and 89 in surface-longline fisheries.

Finally, the seventh species in the "Very high risk" category was northern Buller's albatross, with a median risk ratio of 1.02 (95% c.i.: 0.58–2.00). The mean PBR_ρ was 540 (95% c.i.: 296–845), and the mean APF was 549 (95% c.i.: 409–723). There was no observed capture of northern Buller's albatross between the fishing years 2006–07 and 2012–13.

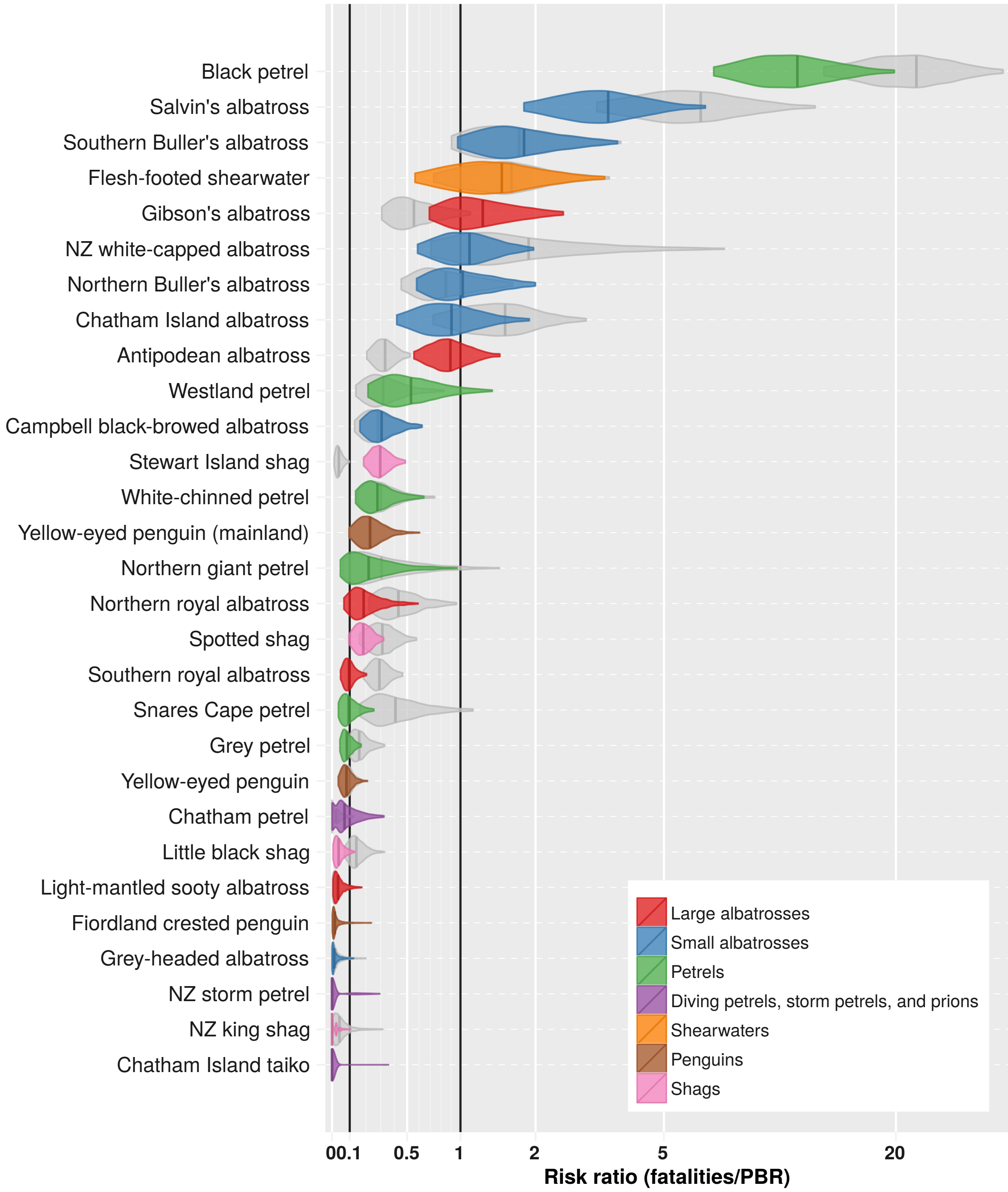
Large seabirds were found to be the most at risk, due to a combination of their low productivity (with a late age at first breeding, and a single egg produced every one or two years), and a propensity to interact with commercial fisheries. Of the eleven species in the "Very high risk" or "High risk" categories, eight were albatrosses, and most of the remaining species were *Procellaria* petrels or large shearwaters.

The risk categories were based on the median and 95% credible level of the risk. From the samples of the risk ratio, the probability that the risk is larger than one may be calculated (Table 9). For each of the birds in the "Very high risk" category, the probability that the risk ratio is larger than one (i.e., that the number of annual potential fatalities exceeded the PBR_ρ) was greater than 50%. For birds in the "High risk" category the probability that the risk ratio is larger than one ranged between 0.05% for Campbell black-browed albatross and around 40% for Chatham Island albatross. For northern giant petrel, the probability that the risk ratio exceeds one was around 2%, and for the mainland population of yellow-eyed penguin, assuming that all fatalities were of this population, the probability was just above 1%. For all other birds not in the "High risk" or "Very high risk" categories, the probability that the risk ratio exceeds one was less than 1%.

Table 9: Potential Biological Removal (PBR_ρ, i.e., with a recovery factor $f = 1$), total annual potential fatalities (APF) in trawl, longline, and set-net fisheries, risk ratio with $f = 1$ ($RR = APF/PBR_\rho$), and the probability that $APF > PBR_\rho$ with $f = 1$, $f = 0.5$, and $f = 0.1$ (P_1, $P_{0.5}$, and $P_{0.1}$ respectively) for seabird species in the current risk assessment. Species are ordered in decreasing order of the median risk ratio. The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800. Species names are coloured according to their risk category. Red: risk ratio with a median over 1 or upper 95% credible limit (u.c.l.) over 2; dark orange: median over 0.3 or u.c.l. over 1; light orange: median over 0.1 or u.c.l. over 0.3; yellow: u.c.l. over 0.1. PBR_ρ and APF values were rounded to three significant digits.

	PBR_ρ		APF		Risk ratio		P_1	$P_{0.5}$	$P_{0.1}$
	Mean	95% c.i.	Mean	95% c.i.	Median	95% c.i.			
Black petrel	100	60–147	1 130	836–1 490	11.34	6.85–19.81	100.00	100.00	100.00
Salvin's albatross	1 020	638–1 650	3 480	2 250–5 200	3.44	1.82–6.50	100.00	100.00	100.00
Southern Buller's albatross	449	246–701	791	541–1 160	1.82	0.97–3.67	96.88	100.00	100.00
Flesh-footed shearwater	514	233–1 140	696	478–995	1.50	0.56–3.36	80.53	98.25	100.00
Gibson's albatross	181	98–281	222	161–301	1.26	0.69–2.49	73.90	100.00	100.00
NZ white-capped albatross	4 040	2 620–6 320	4 410	2 800–6 620	1.10	0.59–1.97	61.15	99.33	100.00
Northern Buller's albatross	540	296–845	549	409–723	1.02	0.58–2.00	52.62	99.67	100.00
Chatham Island albatross	139	85–228	127	70–226	0.91	0.42–1.90	39.12	93.65	100.00
Antipodean albatross	136	98–187	122	85–175	0.89	0.56–1.47	32.33	99.15	100.00
Westland petrel	157	89–234	88	37–181	0.53	0.21–1.37	9.82	54.48	100.00
Campbell black-browed albatross	673	437–937	213	121–359	0.31	0.16–0.63	0.05	8.90	100.00
Stewart Island shag	301	244–369	91	58–139	0.30	0.19–0.49	0.00	1.90	100.00
White-chinned petrel	5 200	2 670–8 170	1 440	906–2 540	0.28	0.14–0.64	0.32	8.62	99.92
Yellow-eyed penguin (mainland)	164	113–231	44	17–91	0.23	0.10–0.60	1.15	62.83	97.03
Northern giant petrel	164	57–352	37	9–99	0.22	0.05–0.96	2.27	14.00	82.85
Northern royal albatross	259	134–423	52	20–119	0.19	0.07–0.59	0.28	4.30	88.95
Spotted shag	2 400	1 580–3 890	426	285–628	0.18	0.10–0.32	0.00	0.00	96.45
Southern royal albatross	387	280–530	37	18–70	0.10	0.05–0.20	0.00	0.00	44.75
Snares Cape petrel	564	231–1 110	50	26–89	0.09	0.03–0.25	0.00	0.02	44.62
Grey petrel	2 150	1 220–3 200	177	110–274	0.08	0.04–0.17	0.00	0.00	32.00
Yellow-eyed penguin	465	321–659	44	17–90	0.08	0.03–0.21	0.35	0.78	29.40
Chatham petrel	9	4–19	1	0–2	0.07	0.00–0.32	0.05	0.57	36.15
Little black shag	215	123–366	9	1–23	0.04	0.01–0.13	0.00	0.00	6.20
Light-mantled sooty albatross	236	167–315	11	1–40	0.03	0.01–0.17	0.00	0.12	9.07
Pied shag	830	671–1 010	31	5–79	0.03	0.01–0.10	0.00	0.00	2.17
Fiordland crested penguin	322	210–427	12	0–72	0.02	0.00–0.24	0.10	0.52	8.97
Australasian gannet	2 730	1 210–5 450	41	3–129	0.01	0.00–0.06	0.00	0.00	0.20
Grey-headed albatross	221	130–328	5	0–24	0.01	0.00–0.12	0.00	0.05	4.03
Fluttering shearwater	1 800	1 040–2 850	25	3–90	0.01	0.00–0.05	0.00	0.00	0.30
Grey-faced petrel	11 900	5 540–26 300	101	43–187	0.01	0.00–0.02	0.00	0.00	0.00
Cook's petrel	2 250	1 070–4 960	16	6–32	0.01	0.00–0.02	0.00	0.00	0.00
Soft-plumaged petrel	60	25–133	0	0–2	0.01	0.00–0.04	0.00	0.00	0.00
Pycroft's petrel	93	43–208	1	0–2	0.01	0.00–0.03	0.00	0.00	0.00
Sooty shearwater	230 000	93 500–410 000	1 350	745–2 600	0.01	0.00–0.02	0.00	0.00	0.00
Northern little penguin	1 020	799–1 310	7	1–22	0.01	0.00–0.02	0.00	0.00	0.00
Mottled petrel	13 800	6 370–29 800	46	17–89	0.00	0.00–0.01	0.00	0.00	0.00
White-flippered little penguin	324	231–426	1	0–5	0.00	0.00–0.02	0.00	0.00	0.00
Hutton's shearwater	4 880	3 060–7 040	18	5–49	0.00	0.00–0.01	0.00	0.00	0.00
Southern little penguin	1 020	793–1 310	3	0–11	0.00	0.00–0.01	0.00	0.00	0.00
White-headed petrel	12 300	5 390–25 300	14	5–27	0.00	0.00–0.00	0.00	0.00	0.00
Common diving petrel	26 600	17 300–38 900	34	9–103	0.00	0.00–0.00	0.00	0.00	0.00
Snares crested penguin	3 220	2 090–4 280	5	0–20	0.00	0.00–0.01	0.00	0.00	0.00
Buller's shearwater	9 730	4 580–19 400	10	1–33	0.00	0.00–0.00	0.00	0.00	0.00
Black-bellied storm petrel	3 440	2 150–5 560	2	0–7	0.00	0.00–0.00	0.00	0.00	0.00
NZ white-faced storm petrel	55 900	32 400–92 400	51	8–223	0.00	0.00–0.00	0.00	0.00	0.00
Chatham Island little penguin	1 020	794–1 310	2	0–18	0.00	0.00–0.02	0.00	0.00	0.00
Southern black-backed gull	197 000	129 000–294 000	94	27–214	0.00	0.00–0.00	0.00	0.00	0.00
Fairy prion	85 000	53 700–133 000	41	10–122	0.00	0.00–0.00	0.00	0.00	0.00
Little shearwater	5 700	3 690–8 100	2	0–8	0.00	0.00–0.00	0.00	0.00	0.00
Eastern rockhopper penguin	6 400	5 280–7 880	3	0–12	0.00	0.00–0.00	0.00	0.00	0.00
Antarctic prion	13 900	7 940–24 200	3	0–7	0.00	0.00–0.00	0.00	0.00	0.00
Broad-billed prion	69 800	41 000–110 000	14	2–66	0.00	0.00–0.00	0.00	0.00	0.00
Erect-crested penguin	12 100	9 990–14 900	1	0–3	0.00	0.00–0.00	0.00	0.00	0.00
Auckland Island shag	163	122–216	0	0–1	0.00	0.00–0.01	0.00	0.00	0.00
Bounty Island shag	13	10–17	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Subantarctic skua	30	19–44	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Caspian tern	135	79–201	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Chatham Island shag	45	35–56	0	0–2	0.00	0.00–0.04	0.00	0.00	0.55
Campbell Island shag	196	128–261	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
White-bellied storm petrel	44	24–74	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
White tern	15	12–19	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
South Georgian diving petrel	3	2–4	0	0–0	0.00	0.00–0.00	0.00	0.00	0.68
NZ king shag	15	12–18	0	0–2	0.00	0.00–0.11	0.00	0.08	2.77
Kerm. storm petrel	2	1–3	0	0–0	0.00	0.00–0.00	0.00	0.00	0.02
Masked booby	35	23–51	0	0–0	0.00	0.00–0.01	0.00	0.00	0.00
NZ storm petrel	2	1–4	0	0–0	0.00	0.00–0.29	0.00	0.45	15.70
Pitt Island shag	66	43–89	0	0–3	0.00	0.00–0.04	0.00	0.00	0.57
Chatham Island taiko	1	0–2	0	0–0	0.00	0.00–0.36	0.05	1.35	3.52
Wedge-tailed shearwater	3 900	2 580–5 460	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Kerm. petrel	298	140–666	0	0–1	0.00	0.00–0.00	0.00	0.00	0.00
White-naped petrel	2 000	863–4 590	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00

Figure 1: Risk ratio for different seabird species, based on data for the periods between 2006–07 and 2011–12, and between 2006–07 and 2012–13. The risk ratio is displayed on a logarithmic scale, with the threshold of the number of potential bird fatalities equalling the Potential Biological Removal (PBR_ρ) with the recovery factor at $f = 0.1$ and $f = 1$ indicated by the two vertical black lines, and the distribution of the risk ratios within their 95% credible interval indicated by the coloured shapes, including the median risk ratio (vertical line). Seabird species are listed in decreasing order of the median risk ratio. Species with a risk ratio of almost zero were not included (95% upper limit with $f = 1$ less than 0.1). The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800. The grey shapes indicate the risk ratios from the previous assessment (Richard & Abraham 2013c), corrected for errors, to show the change in risk since the 2010–11 fishing year.



3.2 Effect of updates

The progressive change in risk ratio for each species when applying the updates successively is shown for the 30 species that were identified as the most at risk in Figure 2 (for the effects of the updates on the risk ratio of all species see Appendix A, Table A-5).

When re-running the calculations using the same years as in Richard & Abraham (2013c), a number of changes occurred. First, a mistake was found in Richard & Abraham (2013c), in which the PBR_ρ was calculated using the total number of annual breeding pairs, instead of the lower quartile of the distribution ($N_{\mathrm{BP}_{\mathrm{min}}}$) as was stated in the methods. Correcting this error resulted in a general increase in the risk for all species (taking the lower quartile of the population size is inherently conservative). Another error during data preparation of the previous assessment led to over-counting the observer effort in the poorly-observed inshore trawl fishery (see subsection 2.4). Estimates of potential fatalities are large for New Zealand white-capped albatross and Salvin's albatross in this fishery, so that correcting this error led to a large increase in the estimate of APF for these species, with the overall risk increasing from a median of 0.8 to almost 2 for New Zealand white-capped albatross, and from 3 to over 6 for Salvin's albatross. Another change from the update was that the risk ratio of Kermadec storm petrel decreased to almost zero, following the re-assignment of an observed capture in a deepwater trawl off the Chatham Islands that was actually of New Zealand white-faced storm petrel.

Overall, these changes led to a change in risk category for 15 species, including an increase for Westland petrel, northern royal albatross, white-chinned petrel, northern giant petrel, spotted shag, little black shag, pied shag, New Zealand king shag, Chatham petrel, light-mantled sooty albatross, grey-headed albatross, Pitt Island shag, and Chatham Island shag, and a decrease only for Stewart Island shag and Kermadec storm petrel (Appendix A, Figure A-1). The change in risk ratio was, however, only significant for Salvin's albatross and Kermadec storm petrel.

The change in risk ratio resulting from a change in vulnerability was then assessed by expanding the number of years used for the calculation of vulnerability to include the fishing years 2011–12 and 2012–13, while calculating the APF based on the same five years as in Richard & Abraham (2013c). No significant variation in risk ratios occurred. Nevertheless, the risk category increased for southern royal albatross, from "Medium risk" to "High risk", caused by an additional six observed captures between 2011–12 and 2012–13, compared with four observed captures between 2006–07 and 2010–11. The risk category decreased for spotted shag from "High risk" to "Medium risk".

The effect of the change in fishing effort in recent years, assessed by calculating the APF using the fishing effort during the period 2010–11 to 2012–13, in comparison to 2006–07 to 2010–11, also did not lead to significant changes in risk ratio, but to a decrease in the risk category of three species; for white-chinned petrel and northern giant petrel, it decreased from "High risk" to "Medium risk", while for New Zealand king shag, it decreased from "Medium risk" to "Low risk".

Updating the demographic parameters led to an increase in risk category for northern giant petrel and Fiordland crested penguin, and to a decrease for grey petrel, pied shag, Pitt Island shag, and Chatham Island shag. None of the associated changes in risk ratio were significant.

The modification of the species and fishery groups led to the largest change in risk ratios, with a significant increase for Gibson's albatross, Antipodean albatross, and Stewart Island shag. It also led to a significant decrease in risk ratios for northern royal albatross, Snares Cape petrel, southern royal albatross, and little black shag. The significant change for wandering albatrosses was due to the disaggregation of royal albatrosses from the Antipodean and Gibson's albatrosses for the estimation of vulnerability. Royal albatrosses are rarely observed caught in surface-longline fisheries (3 observed captures between 2006–07 and 2012–13) compared with Gibson's and Antipodean albatrosses (54 observed captures), suggesting a different vulnerability to capture between these two groups. The decrease in the risk ratios for little black shag and for Stewart Island shag was caused by the re-allocation of shag species into solitary and group foraging types. The decrease in the risk ratio for Cape petrel was caused by the removal of captures identified as southern Cape petrel. The change in species and fishery groups led to an increase

Figure 2: Progressive changes to the estimated risk ratio (median and 95% credible interval) following data updates. Previous: previous assessment (Richard & Abraham 2013c); rerun: as previous assessment but with error corrections; vulnerability: updated fishing data, vulnerability estimated on seven years of data, annual potential fatalities (APF) on same five years of data as the previous assessment; effort: change in fishing effort, vulnerability estimated on seven years, APF on last three years; demography: updated demographic parameters; groups: updated species and fishery groups; maps: updated distribution maps. Shown are the 30 seabird species most at risk. (*continued on next page*)

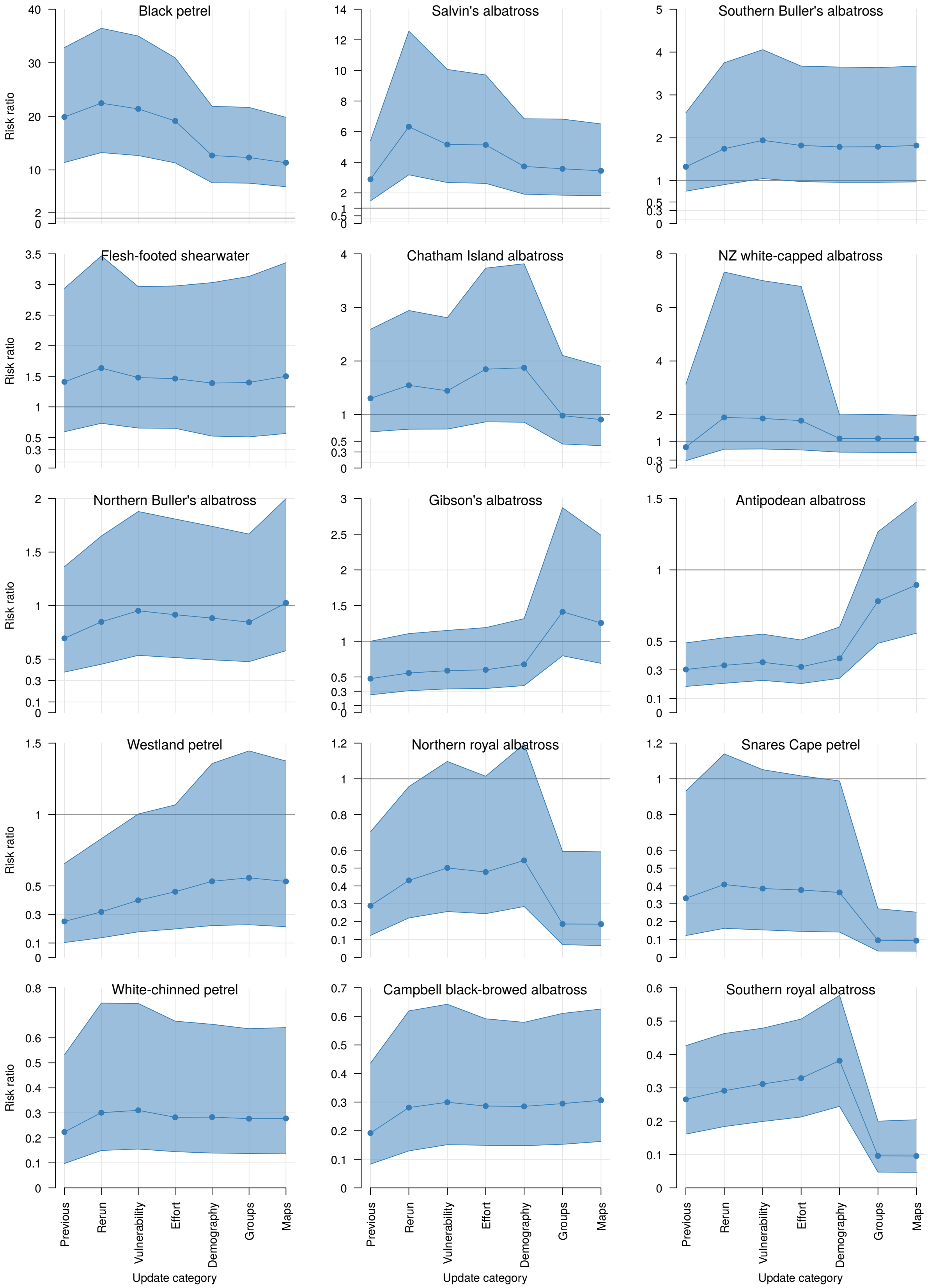


Figure 2: (*continued*)

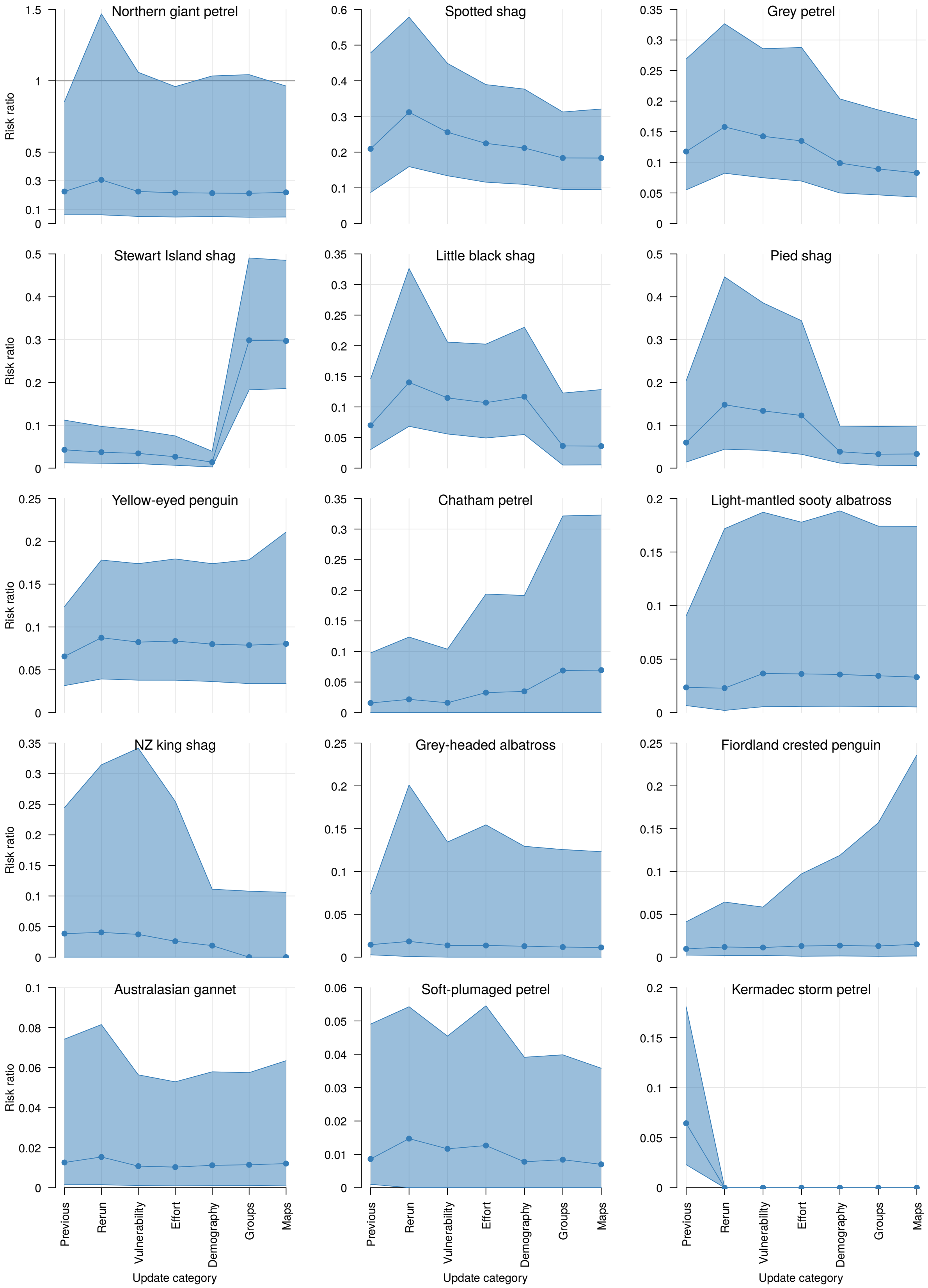


Table 10: Comparison of the risk ratio between the previous assessment (Richard & Abraham (2013c), after error correction) and the current, updated study. Included are all species whose risk (in this study) had an upper 95% credible limit greater than 0.1. Species names are coloured according to their risk category. Red: risk ratio with a median over 1 or upper 95% credible limit (u.c.l.) over 2; dark orange: median over 0.3 or u.c.l. over 1; light orange: median over 0.1 or u.c.l. over 0.3; yellow: u.c.l. over 0.1.

	Before updates		After updates	
	Median	95% c.i.	Median	95% c.i.
Black petrel	**22.46**	13.23–36.44	**11.34**	6.85–19.81
Salvin's albatross	**6.32**	3.18–12.57	**3.44**	1.82–6.50
Southern Buller's albatross	**1.74**	0.91–3.75	**1.82**	0.97–3.67
Flesh-footed shearwater	**1.63**	0.73–3.47	**1.5**	0.56–3.36
Chatham Island albatross	**1.55**	0.73–2.94	**0.91**	0.42–1.90
NZ white-capped albatross	**1.89**	0.71–7.32	**1.1**	0.59–1.97
Northern Buller's albatross	**0.85**	0.45–1.65	**1.02**	0.58–2.00
Gibson's albatross	**0.56**	0.31–1.11	**1.26**	0.69–2.49
Antipodean albatross	**0.33**	0.21–0.52	**0.89**	0.56–1.47
Westland petrel	**0.32**	0.14–0.83	**0.53**	0.21–1.37
Northern royal albatross	**0.43**	0.22–0.96	**0.19**	0.07–0.59
Snares Cape petrel	**0.41**	0.16–1.14	**0.09**	0.03–0.25
White-chinned petrel	**0.3**	0.15–0.74	**0.28**	0.14–0.64
Campbell black-browed albatross	**0.28**	0.13–0.62	**0.31**	0.16–0.63
Southern royal albatross	**0.29**	0.18–0.46	**0.1**	0.05–0.20
Northern giant petrel	**0.31**	0.06–1.47	**0.22**	0.05–0.96
Spotted shag	**0.31**	0.16–0.58	**0.18**	0.10–0.32
Grey petrel	**0.16**	0.08–0.33	**0.08**	0.04–0.17
Stewart Island shag	0.04	0.01–0.10	**0.3**	0.19–0.49
Little black shag	**0.14**	0.07–0.33	**0.04**	0.01–0.13
Yellow-eyed penguin	**0.09**	0.04–0.18	**0.08**	0.03–0.21
Chatham petrel	**0.02**	0.00–0.12	**0.07**	0.00–0.32
Light-mantled sooty albatross	**0.02**	0.00–0.17	**0.03**	0.01–0.17
NZ king shag	**0.04**	0.00–0.31	**0**	0.00–0.11
Grey-headed albatross	**0.02**	0.00–0.20	**0.01**	0.00–0.12
Fiordland crested penguin	0.01	0.00–0.06	**0.02**	0.00–0.24
NZ storm petrel	**0**	0.00–0.12	**0**	0.00–0.29
Chatham Island taiko	0	0.00–0.00	**0**	0.00–0.36

in risk category for Gibson's albatross, Chatham petrel, Stewart Island shag, and Chatham Island taiko, and to a decrease for northern royal albatross, Snares Cape petrel, southern royal albatross, little black shag, and New Zealand storm petrel.

No significant change in risk ratios occurred from updating the distribution maps. Nevertheless, small variations were sufficient to make the risk category change for five species, with an increase for northern Buller's albatross, Campbell black-browed albatross, and New Zealand storm petrel, and a decrease for Chatham Island albatross and northern giant petrel. The change in the risk category of Campbell black-browed albatross and northern giant petrel was due to very small variations, as their distribution maps were not changed (their vulnerability was changed by changes in the distribution of other species), but their risk ratios were at the boundary of two categories.

The comparison of risk ratios between the previous assessment by Richard & Abraham (2013c) (re-run, correcting for errors) and the present assessment (after applying all updates) revealed eight significant changes (see comparisons for the most at-risk species in Table 10, and comparisons of the PBR_{ρ}, APF, and risk ratios for all species in Appendix A, Tables A-6 to A-8; see Table A-9 and Figure A-1 for the risk ratio values following the error corrections in the previous assessment). These changes included a significant increase in risk ratio for Gibson's albatross, Antipodean albatross, and Stewart Island shag, and a significant decrease in risk ratio for black petrel, Snares Cape petrel, southern royal albatross, little black shag, and pied shag (Table 10). The overall change for Gibson's, Antipodean, and southern royal albatrosses, and for the three shag species was primarily due to changes in the seabird groups. The significant decrease in the risk ratio of black petrel was due to the higher estimate of population size used in the current iteration, whereas the decrease for Snares Cape petrel was due to the removal of observed captures identified as southern Cape petrel (*Daption capense capense*), which does not breed in New Zealand.

Overall, the risk category changed from the assessment using data from 2006–07 to 2010–11 for 20 species. The changes included an increase in the risk ratio for northern Buller's albatross, Gibson's albatross, Campbell black-browed albatross, Chatham petrel, Stewart Island shag, Chatham Island taiko, and Fiordland crested penguin species, and a decrease for Chatham Island albatross, northern royal albatross, white-chinned petrel, northern giant petrel, spotted shag, Snares Cape petrel, southern royal albatross, grey petrel, little black shag, New Zealand king shag, pied shag, Pitt Island shag, and Chatham Island shag species.

Among the species that were found at "Very high risk" in the previous assessment by Richard & Abraham (2013c), only the risk category of Chatham Island albatross was downgraded to "High risk". This decrease in risk ratio was primarily due to the disaggregation of the ling bottom-longline fishery from the small-vessel bottom-longline fishery group. In contrast, the "Very high risk" category currently includes Gibson's albatross and northern Buller's albatross, which were previously at "High risk". The increase in risk ratio of Gibson's albatross was due to a combination of updating the population size and calculating the vulnerability of wandering albatrosses separately from royal albatrosses. For northern Buller's albatross, the increased risk ratio was due to an increase in the observed capture rate of southern Buller's albatross in 2011–12 and 2012–13 (the two species were combined for the vulnerability estimation).

None of the major changes in the risk ratios from the previous assessment (Richard & Abraham 2013c) reflected a change in fishing practices, effort, or distribution. All significant deviations from the results of the previous assessment can be attributed to updates in the risk assessment methodology that were applied in the current assessment, i.e., updates to the data on species demography, species and fishery groups, and distribution maps, and to the correction of previous errors.

3.3 Annual potential fatalities by fishery

The current assessment involved estimates of the APF of seabirds across the different fisheries (see Appendix A, Tables A-10 to A-14). The mean number of APF of the 70 seabird species across the four assessed fishing methods was estimated to be 16 100 (95% c.i.: 12 500–20 900) birds per year (Table A-14). Trawl fisheries were associated with the highest number of potential fatalities, with the mean APF of 11 600 (95% c.i.: 8000–16 300) seabirds per year. The mean APF in bottom-longline fisheries was estimated at 2910 (95% c.i.: 2290–3680), and that of surface-longline fisheries at 1380 (95% c.i.: 1120–1710) seabirds per year. The estimated mean APF was the lowest for set-net fisheries, at 293 (95% c.i.: 202–416) birds per year.

The APF in trawl fisheries only were sufficiently high to cause the risk category to be "Very high risk" for New Zealand white-capped albatross, Salvin's albatross, and southern Buller's albatrosses. Among trawl fisheries, the estimated APF were highest in inshore trawl fisheries (Table A-10), with a mean of 4450 (95% c.i.: 2790–6670) seabirds per year, predominantly New Zealand white-capped albatross and Salvin's albatross. The APF of Salvin's albatross in inshore trawl fisheries alone were sufficient to cause the risk category of this species to be "Very high risk". Other trawl fisheries with a mean above 1000 APF included fisheries targeting squid, hoki, scampi, and middle-depth species. Annual potential fatalities in squid trawl fisheries were mostly of New Zealand white-capped albatross, white-chinned petrel, sooty shearwater, and southern Buller's albatross; in hoki trawl fisheries, mostly of New Zealand white-capped albatross, Salvin's albatross, and southern Buller's albatross; in scampi trawl fisheries, mostly of white-chinned petrel and Salvin's albatross; and in trawl fisheries targeting middle-depth species, mostly of New Zealand white-capped albatross and Salvin's albatross.

Among all bottom-longline fisheries, the fisheries targeting snapper had the highest estimated APF (Table A-11), with a mean of 746 (95% c.i.: 523–1010) birds annually, predominantly of black petrel and flesh-footed shearwater. The potential fatalities in these fisheries were sufficiently high to cause the risk category of black petrel to be "Very high risk". The number of potential fatalities in the small-vessel ling bottom-longline fisheries (vessels less than 34-m long) was estimated to be similar, with a mean of 694 (95% c.i.: 477–964) seabirds per year but mostly of Salvin's albatross. None of the APF in the small-vessel ling bottom longline fisheries caused the species risk category to be "Very high risk". Potential fatalities in the bottom-longline fisheries targeting each of snapper, bluenose, and hapuka, were individually sufficient to cause the risk of black petrel to be "Very high risk". Across all bottom-longline fisheries, the APF were sufficiently high to cause the risk category to be "Very high risk" for black petrel and flesh-footed shearwater.

The surface-longline fisheries with the highest APF were the fisheries targeting big eye tuna, and the small-vessel fleet targeting southern bluefin tuna (vessels less than 45-m long), with the mean APF estimated to be 686 (95% c.i.: 547–853), and 430 (95% c.i.: 338–541) seabirds annually, respectively (Table A-12). None of the different surface-longline fisheries were estimated to be associated with sufficient numbers of potential fatalities to cause the risk of any species to be "Very high risk". Nevertheless, across all surface-longline fisheries combined, the APF were sufficiently high to cause the risk category to be "Very high risk" for Gibson's albatross.

Set-net fisheries had relatively low APF, with the total mean APF of 293 (95% c.i.: 202–416) seabirds per year. Set-net fisheries targeting shark species had the highest estimated APF with a mean of 131 (95% c.i.: 92–178) birds per year, mostly of yellow-eyed penguin, Snares Cape petrel, and sooty shearwater (Table A-13). Across all set-net fisheries, none of the APF were sufficiently high to cause the risk category to be "Very high risk" for any of the species included in the current assessment.

3.4 Vulnerabilities

As part of the estimation of the total observable captures in trawl and longline fisheries, the vulnerability was estimated as the product of a constant, v_0, multiplied by a species-group vulnerability, v_s, and a fisheries-group vulnerability, v_g (see Equation 7). The species-group vulnerabilities had high uncertainty and varied widely between the different species and fisheries (Tables A-15 to A-17). The species vulnerability depends on the population and on the distribution of each species, so that comparing between species is difficult. Uncertainties in the estimated observable captures were lower than uncertainty on the estimated model parameters. In cases where there was little overlap between the species distribution and the fishing method (such as for yellow-eyed penguin in surface-longline fisheries), the calculation of the vulnerability was poorly constrained, resulting in high apparent vulnerability, but no estimated observable captures, and hence no actual risk. The vulnerability calculation for set-net fisheries was different, as there was only a single fishing group, resulting in a single vulnerability value for each species group (Table A-16).

Species vulnerabilities are relatively sensitive to population size estimates and, therefore, vary among species depending on the proportion of the population that forages within New Zealand's EEZ, regardless of the propensity of the species to get caught in fisheries. For illustration purposes, the effect of artificially modifying the population size on species vulnerabilities and APF was assessed by re-running the models twice, once with the black petrel population size divided by 10, and once by multiplying it by 10. The estimated species vulnerability directly corresponded with the variation in population size (Table 11), although the estimated APF remained constant. As a consequence of high uncertainties, of the problem of low overlap increasing apparent vulnerabilities, and their dependence on population and distribution estimates, direct comparisons of the species-group vulnerabilities are difficult to make and should be interpreted with caution.

The fisheries-group vulnerabilities had less uncertainty than the species-group vulnerabilities (Appendix A, Table A-17). For trawl fisheries, the fisheries-group vulnerabilities were estimated relative to deepwater trawl fisheries. The highest fisheries vulnerabilities were in a group of trawl fisheries that included southern blue whiting, large processor, scampi, large meal, and squid trawls, with mean vulnerability values between 6 and 9. A second group had mean vulnerabilities between 1 and 2 (deepwater, flatfish, mackerel, and small inshore trawl), and the large fresher trawl group had a mean vulnerability of 0.2. There was no apparent difference in vulnerability between large vessels with or without a meal plant, but large freshers, which do not discharge processing waste, had a markedly lower vulnerability.

In bottom-longline fisheries, the small-vessel group targeting species other than snapper, bluenose, and ling had the highest vulnerability, followed by the small-vessel ling and bluenose fisheries, whereas the snapper fishery group had the lowest vulnerability, although none of these differences were significant (Appendix A, Table A-17). The vulnerability associated with small-vessel surface-longline fisheries was similar between the group targeting swordfish and that targeting tuna and other species, and was estimated to be higher than that of the large-vessel group, although the difference was not significant.

3.5 Sensitivities

The sensitivity of the uncertainties in the risk ratio to the uncertainty in input parameters are shown for the most at risk species in Figure 3, and for all species in Appendix A (Table A-18; and see Tables A-19 to A-23 for the sensitivity of the risk ratio to different scenarios).

For about half of the species included in the current assessment, the uncertainty in the risk ratio was most sensitive to uncertainty in bottom-longline fatalities. For most species, this uncertainty was caused by the large uncertainty in the fatalities estimated for the small-vessel bottom-longline fisheries (Table A-11). The large uncertainty in these fisheries was caused by the low observer coverage in these fisheries. Accordingly, the risk ratio for these species could potentially be reduced by increasing the observer coverage.

For the species most at risk, however, uncertainty in the risk ratio was mainly sensitive to the adult survival rate and to fatalities in trawl fisheries (Figure 3). Adult survival rate affects the maximum growth rate and, therefore, the PBR_{ρ}, as well as the population multiplier used to calculate the total population size from the number of annual breeding pairs. The effect is especially pronounced when the survival rate is high, typical of larger seabirds, which tend to be most at risk. Large seabirds were also mostly killed in trawl fisheries, in part due to a high cryptic mortality multiplier in these fisheries. Uncertainty in the cryptic mortality caused uncertainty in the associated potential fatalities, which in turn affected uncertainty in the risk.

For all the species in the risk assessment, the sensitivity analysis allowed the source of uncertainty in the risk ratio to be explored (see Table A-18). This analysis may be used to prioritise further research, where reducing the uncertainty in the risk ratio would help resolve the risk status of the species. The sensitivity analysis helps to understand uncertainty in the risk ratio, but is not suited for identifying the most effective way of reducing the risk.

The sensitivity of the estimated risk ratios to some large capture events was also assessed (Table A-19). In poorly-observed fisheries, a single fishing event with a large number of observed captures may have a large impact on the vulnerability and, therefore, on the risk ratio of the associated species. There was a small bottom-longline vessel trip in 2010 that caught 27 black petrel while targeting bluenose and hapuka. When this trip was assessed as unobserved, i.e., effectively omitting the observed captures while still considering the associated fishing effort, the risk ratio of black petrel decreased from 11.34 (95% c.i.: 6.85–19.81) to 6.45 (95% c.i.: 3.76–11.61). This large decrease was not sufficient to change the risk category of black petrel, which remained at “Very high risk”.

In 2007, there was a trip during which 12 Chatham albatross were caught by a small bottom-longline vessel targeting ling on Chatham Rise. When this trip was assessed as unobserved, the risk ratio of Chatham albatross decreased from 0.91 (95% c.i.: 0.42–1.90) to 0.27 (95% c.i.: 0.09–0.89); this decrease was sufficient for the risk category to change from “High risk” to “Medium risk”. Similarly, the risk of group-foraging shags was sensitive to the capture of 31 spotted shags during a single event by an inshore

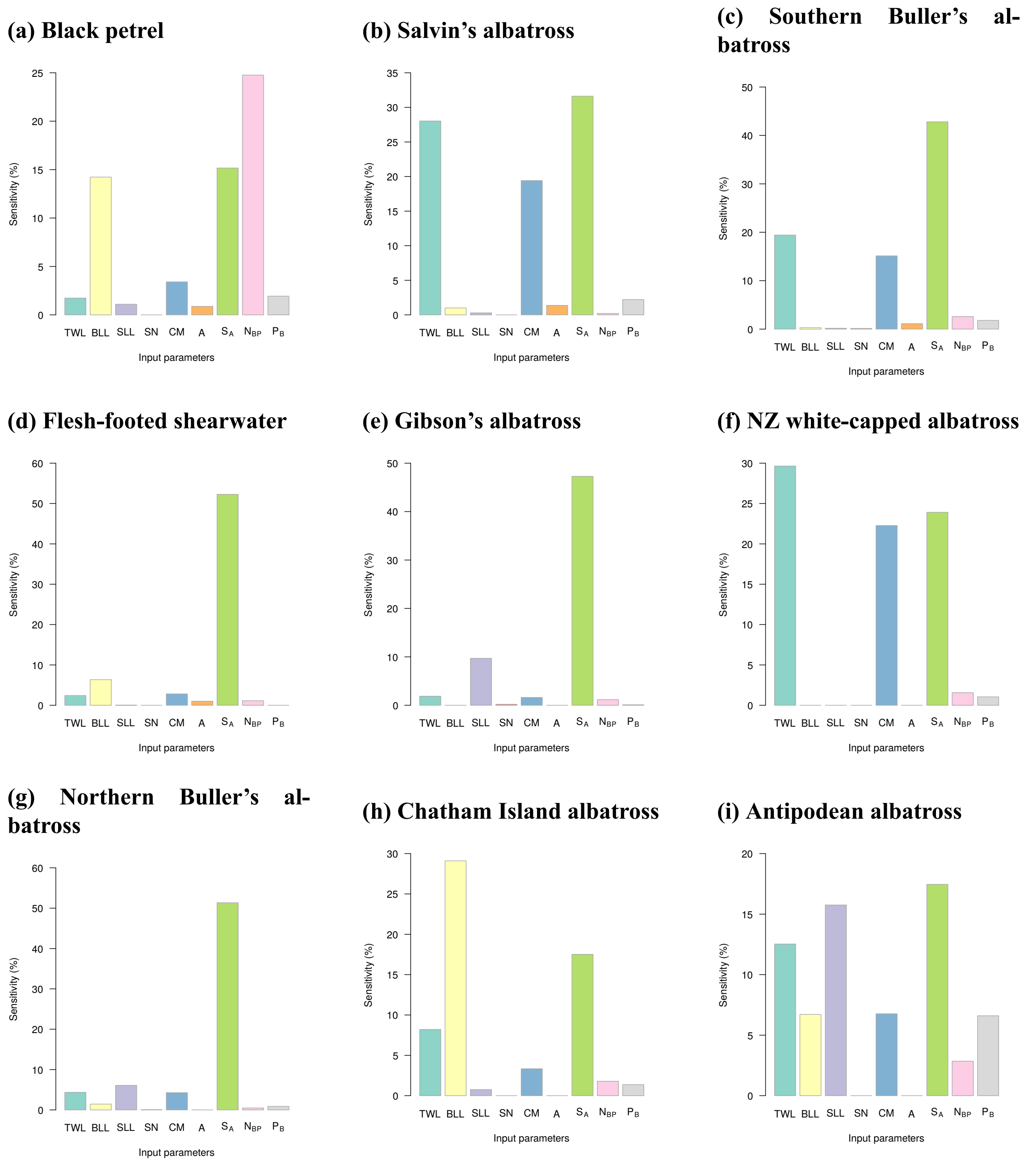


Figure 3: Sensitivity of the uncertainty in the risk ratio for the 12 seabird species with the highest risk ratio. For each seabird type, the sensitivity to the uncertainty in the following parameters was considered: annual potential fatalities in trawl, bottom-longline, surface-longline and set-net fisheries (TWL, BLL, SLL, SN, respectively); the cryptic multipliers (CM); age at first reproduction (A); adult survival (S_A); the number of annual breeding pairs (N_{BP}); and the proportion of adults breeding (P_{B}). Sensitivity is defined as the percentage of reduction in the 95% credible interval of the risk ratio that occurs when the parameter is set to its arithmetic mean (note the different scales).

trawl vessel in 2009. Assessing the associated trip as unobserved led to a decrease of the risk ratio to close to zero for Stewart Island and spotted shag. In 2006, a small surface-longline vessel caught 32 individuals of unidentified albatross while targeting swordfish. If these captures were assigned to be of Gibson's albatross, the risk ratio of this species, already categorised as "Very high risk", increased from 1.26 (95% c.i.: 0.69–2.49) to 1.76 (95% c.i.: 1.01–3.5).

The modelling of at-sea counts of black petrel by Abraham et al. (2015) provided two alternative distribution maps for this species. While the map used in the current study was predicted from a model relating the counts of black petrel to habitat variables, a related model used the latitude and longitude of the counts to predict the overlap of black petrel with fisheries. When using the alternative distribution from the model with the coordinates of the counts instead of habitat variables, the risk of black petrel slightly increased from 11.34 (95% c.i.: 6.85–19.81) to 12.29 (95% c.i.: 7.6–21.74), although this increase was not significant.

Similarly, Abraham et al. (2015) provided a black petrel distribution map for each fishing method, representing the number of birds around fishing vessels. Here, the distribution maps were combined for each breeding period by weighting the distributions by the respective number of fishing events of each fishing method in each map cell. An alternative method of combining the distributions was tested by weighting the distributions by the number of fishing events across the whole New Zealand region. This method led to small non-significant variations in species vulnerabilities and in APF (Table 12; Table A-23), showing that the results were not sensitive to the method for combining the distributions.

To assess the sensitivity of the risk to Buller's albatross to the decision of grouping the two species together, the risk calculations were re-run while considering two alternatives. First, vulnerability was estimated separately for both species, re-assigning the 23 observed captures of southern Buller's albatross north of 40°S, and those recorded in October and November (2 captures) to be northern Buller's albatross. The risk to southern Buller's albatross increased by 54% and that of northern Buller's albatross decreased by 68%, with the risk category of northern Buller's albatross changing from "Very high risk" to "High risk" (Table A-21). When a further 12 captures east of 180°, around Chatham Islands, were re-assigned to be northern Buller's albatross, the risk to southern Buller's albatross increased by 37% compared with the base case of grouping the two species together, and the risk to northern Buller's albatross decreased by 43%.

The risk ratios were also sensitive to the exclusion of captures of birds caught alive, and to the exclusion of captures of birds caught alive and also unharmed (Table A-20). When excluding the observed captures of birds caught alive and unharmed, the risk category of New Zealand white-capped albatross, Gibson's albatross, and northern Buller's albatross decreased from "Very high risk" to "High risk", and that of Campbell black-browed albatross from "High risk" to "Medium risk". The largest decrease in risk ratio, however, was of black petrel following the exclusion of birds captured unharmed, from a median 11.34 (95% c.i.: 6.85–19.81) to 8.41 (95% c.i.: 5.06–14.90). The decrease was also large for flesh-footed shearwater, with a 41% decrease, from a median risk ratio of 1.50 (95% c.i.: 0.56–3.36) to 0.87 (95% c.i.: 0.33–2.02). When further excluding all captures of birds recorded alive, the risk category of flesh-footed shearwater also changed from "Very high risk" to "High risk". However, the risk category of black petrel, Salvin's albatross, and southern Buller's albatross under this scenario remained "Very high risk", even with a large decrease in risk ratio for black petrel to a median of 4.64 (95% c.i.: 2.64–8.28).

3.6 Integrity of the calculations

When re-running the assessment, the errors found in the calculations used in the previous assessment by Richard & Abraham (2013c) affected both the calculation of PBR_ρ, and the estimates of APF. To be confident in the integrity of the current study, the PBR_ρ calculations were independently assessed. For this independent assessment, all input data (see Table A-1) were read using a parser, before repeating the PBR_ρ calculations to confirm that the PBR_ρ values (see Table 9) can be reproduced. In repeating the calculations, the mean value of PBR_ρ was calculated, by repeatedly drawing sets of 4000 samples from each of the distributions in Table A-1 to derive a distribution of mean PBR_ρ values. For each species,

Table 11: Sensitivity of the estimation of vulnerability and of the number of annual potential fatalities to the population size of black petrel. Population sizes included the base case, and the population size divided by 10 or multiplied by 10.

	Method	Trawl		BLL		SLL	
		Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Species vulnerability	Base case	10.5	0.7–47.3	887.5	33.6–4 783.5	7.4	0.6–33.6
	Population size / 10	85.1	5.3–387.3	6 939.4	214.9–41 652.8	60.2	5.5–277.6
	Population size × 10	1.1	0.1–4.6	137.9	3.9–895.1	0.9	0.1–4.5
Annual potential fatalities	Base case	45.0	5.7–151.3	1 001.0	731.3–1 335.7	81.5	39.0–141.3
	Population size / 10	44.0	5.3–146.3	1 001.1	725.3–1 336.0	81.4	37.7–142.7
	Population size × 10	46.6	5.7–153.0	1 000.2	725.0–1 335.1	82.1	39.0–141.3

Table 12: Sensitivity of the estimation of vulnerability and of the number of annual potential fatalities to the weighting method for creating a single at-sea distribution for black petrel. Base case: spatially-varying weighting of fisheries; simple weight: uniform weighting of fisheries across the whole distribution.

	Method	Trawl		BLL		SLL	
		Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Species vulnerability	Base case	10.5	0.7–47.3	887.5	33.6–4 783.5	7.4	0.6–33.6
	Simple weight	3.1	0.2–14.9	516.6	17.2–2 904.4	10.1	0.8–49.4
Annual potential fatalities	Base case	45.0	5.7–151.3	1 001.0	731.3–1 335.7	81.5	39.0–141.3
	Simple weight	50.6	5.7–167.7	1 104.6	802.7–1 476.7	60.9	29.7–104.0

it was confirmed that the mean value in Table 9 lay within the 95% credible interval of the resulting distribution. In addition, the code used for the calculations was reviewed, and the PBR_ρ calculations were independently assessed (Webber 2014).

In response to this review, the deviance from the four models used for estimating the vulnerability is shown in Appendix A (Figure A-2). All four models converged (the distribution of each of the two chains was similar), and there was no evidence of long auto-correlation in the chains.

Richard & Abraham (2013b) provide estimates of the number of observable captures of New Zealand white-capped albatross, southern Buller's albatross, Salvin's albatross, sooty shearwater, white-chinned petrel, and all birds, in trawl and longline fisheries. The estimation method in Richard & Abraham (2013b) does not rely on the at-sea distribution of the species. Instead, the models include covariates, such as time of day at setting and moon phase, to account for variation in the seabird capture rate. These models require a sufficient number of observed captures to be fitted, and can only provide estimates of the number of observable captures for a small number of species. The estimates are independent from those in the current study, and can be directly compared to the estimates of observable captures, i.e., the APF without cryptic mortality, in trawl and longline fisheries.

The means of annual observable captures in the current study were all above previous values (Richard & Abraham 2013b), except for southern Buller's albatross and white-chinned petrel, although the estimates of the latter species were very similar (Table 13). All the means of the present study fell within the 95% credible interval of Richard & Abraham (2013b), except for southern Buller's albatross. Estimates of observable captures for southern Buller's albatross in the current study were half those of Richard & Abraham (2013b). Here, for the estimation of vulnerability, northern and southern Buller's albatross were combined, to reflect that captures of southern Buller's albatross could sometimes be of northern Buller's albatross, due to the difficult identification of the two species. In Richard & Abraham (2013b), it was assumed that none of the observed captures of southern Buller's albatross were of northern Buller's albatross, hence leading to a higher estimate of observable captures for southern Buller's albatross.

Table 13: Estimates of annual observable captures in commercial fisheries in New Zealand waters for five seabird species and for all seabirds in 2011–12, as estimated in the present risk assessment and previously (Richard & Abraham 2013b).

	This study		Previous assessment	
Species	Mean	95% c.i.	Mean	95% c.i.
New Zealand white-capped albatross	631	523–757	519	401–659
Southern Buller's albatross	166	138–203	329	238–481
Salvin's albatross	579	460–710	557	323–939
Sooty shearwater	394	320–487	263	144–454
White-chinned petrel	494	442–557	497	346–693
All birds	4 289	3 964–4 635	3 856	3 247–4 577

The risk assessment used an estimate of the proportion of the population of each species that remains in the New Zealand region outside the breeding season. This proportion may be compared with the proportion of observed captures and estimated potential fatalities that occur outside the breeding season (Table A-24), to assess whether the seasonal variation in the captures is adequately represented.

4. DISCUSSION

4.1 Updating the risk assessment

The seabird risk assessment process underwent substantial development during the preparation of the previous assessment (Richard & Abraham 2013c), which was used as a key input into the NPOA (Ministry for Primary Industries 2013). This report updates the previous assessment by including two more years of fisheries' data and recommendations made at an expert review workshop (Walker et al. 2015). In addition, the present update corrected some errors that were found in the implementation of the previous assessment.

Despite the updates, there were only eight species that had substantial changes in their risk ratio, i.e., a mean value outside the range of the 95% credible level of the previous study (see Table 10 and Table A-8). For five of these species (Gibson's albatross, Antipodean albatross, southern royal albatross, Stewart Island shag, little black shag), the primary reason for the change was owing to changes in the way that the species were grouped during the calculation of the vulnerability. Wandering and royal albatrosses were separated, and the foraging groups of shags were changed. There was a significant decrease in the risk to black petrel, after using a higher population estimate based on additional data suggesting that the previous population estimate was too low (Spear et al. 2005). There was a decrease in the risk to pied shag, reflecting recent estimates of the pied shag population (Bell 2013). The risk ratio of Snares Cape petrel decreased markedly, due to captures of southern Cape petrel being excluded (this subspecies does not breed in New Zealand waters).

There were other changes to the risk ratios, however, the changes that were due to the addition of two more years of fishing data were relatively small. The risk assessment did not yet provide evidence for decreases in the risk categories due to lower seabird mortalities in fisheries.

4.2 Very high risk species

4.2.1 Black petrel

Black petrel was found to be the species the most at risk from commercial fisheries in New Zealand, with a median risk ratio of 11.34 (95% c.i.: 6.85–19.81), a net decrease in the risk ratio from 22.46 (95% c.i.: 13.23–36.44) (Richard & Abraham 2013c, with errors corrected). The mean PBR_ρ was estimated at 100 (95% c.i.: 60–147), and the mean APF of black petrel was estimated to be 1130 (95% c.i.: 836–1490) individuals per year, from 74 observed captures. The estimated APF of black petrel were mostly in small-vessel bottom-longline fisheries.

Although the estimated risk category of black petrel was "Very high risk", the population trend of black petrel is unclear. Data from random transect surveys of the main Great Barrier Island colony, conducted in 2004–05, 2009–10, and 2012–13 suggested an apparent population decline of 22% over the 5 years to 2009–10, followed by an apparent increase of 110% between 2009–10 and 2012–13 (Bell et al. 2013b). In contrast, the trend obtained from census grid data estimated a population growth rate between -2.3% and 2.5% per year, depending on juvenile annual survival. Assuming a juvenile annual survival rate of 88%, the population growth rate was estimated to be -1.1% per year (Bell et al. 2014).

The calculation of PBR_ρ included a correcting factor ρ to adjust the bias introduced by the approximations in the calculation of $r_{\max}$ and of the total population size from the number of annual breeding pairs (Richard & Abraham 2013a). Black petrel is the only species for which an estimate of the total population size was available, calculated from the proportion of banded birds in the observed captures at sea, in relation to the number of birds banded that were estimated to be alive. The number of annual breeding pairs was then back-calculated from the estimate of total population size to be treated in a similar way as other species. In the black petrel case, the correction of the calculation of the total population size was unnecessary. Nevertheless, because the corrections factor ρ also corrects for the calculation of $r_{\max}$, it was left in the PBR_ρ calculation. As a consequence, the PBR may be underestimated, and the risk ratio, therefore, overestimated. Nevertheless, correcting for this overestimation would not change the risk category of this species, as removing the ρ factor from the PBR calculation would still result in a median risk ratio of 3.40 (95% c.i.: 2.06–5.94).

One explanation for the apparent relative stability of the black petrel population, despite the high risk ratio, is that the population size is substantially underestimated. The population counts are made within a

35-ha study area, at the top of Mount Hobson (Hirakimata) on Great Barrier Island. In this analysis, these counts were used as a lower estimate of the population size, with an analysis of the capture of banded birds at sea providing another method for estimating the total population that is available to be caught. There were many assumptions needed to make this estimate, and it is possible that the population on Little Barrier Island is larger than expected, or that there are more breeding black petrel on Great Barrier Island, outside the study colony. Confirming the estimate of the entire black petrel population size will help to reduce uncertainty in the risk ratio, and may reduce the risk, if the population is larger than expected.

PBR_ρ was calibrated so that the population size remains above half the carrying capacity with a 95% probability, when the number of annual human-caused fatalities equal PBR_ρ. When it exceeds PBR_ρ, the population may still remain stable, although at a level below half the carrying capacity. Black petrel formerly bred throughout North Island and northwest Nelson, and are now restricted mainly to Great Barrier Island (Bell et al. 2013b), suggesting that the population may be already below half its carrying capacity.

Of the 74 observed captures of black petrel, 37 captures were recorded as alive, and 15 captures as unharmed. Consequently, the risk to black petrel was sensitive to the exclusion of live captures, with the risk ratio decreasing from a median of 11.34 (95% c.i.: 6.85–19.81) to 8.41 (95% c.i.: 5.06–14.90) when unharmed birds were excluded, and to 4.64 (95% c.i.: 2.64–8.28) when only fatal captures were considered. The risk was also sensitive to the removal of a fishing trip that caught 27 black petrel, with the risk ratio decreasing from 11.34 (95% c.i.: 6.85–19.81) to 6.45 (95% c.i.: 3.76–11.61).

4.2.2 Salvin's albatross

Salvin's albatross was estimated to be the second highest species at risk from commercial fisheries, with a median risk ratio of 3.44 (95% c.i.: 1.82–6.50). This value was a decrease from the estimate in the previous last assessment, when the median risk ratio was 6.32 (95% c.i.: 3.18–12.57) (Richard & Abraham 2013c, corrected for errors). Most of this decrease was due to changes in the demographic parameters, which included an increase in the estimated number of breeding pairs.

In this assessment, the mean PBR_ρ was estimated at 1020 (95% c.i.: 638–1650) and the mean APF at 3480 (95% c.i.: 2250–5200) individuals per year, from 222 observed captures, mainly in trawl fisheries. Of the estimated total APF of this species, over half were in inshore trawl fisheries, with observed captures occurring at the western, inshore end of Chatham Rise.

There is mixed evidence for changes in the population size of Salvin's albatross. Population surveys at Bounty Islands appeared to indicate that the annual number of breeding pairs of Salvin's albatross on Proclamation Island declined by an estimated 30% between 1997 and 2011, and by 13% between 2004 and 2011 on Depot Island (Sagar et al. 2015). Recent aerial surveys showed an increase (Baker et al. 2014b) between 2010 and 2013 (from 31 786 to 39 995 annual breeding pairs, across the Bounty Islands), and the count of annual breeding pairs at Proclamation Island doubled between the two surveys. This inter-annual variability in the number of annual breeding pairs, may confound the ability of discrete surveys to be used for estimating population changes. Between 2006 and 2012, the number of Salvin's albatross attending bird-watching vessels near Kaikoura decreased (Richard et al. 2014) (although the decrease was not significant, and may indicate a change in distribution rather than a population decline). The conservation status of this species changed in 2013 from "Nationally Vulnerable" to "Nationally Critical", according to the New Zealand Threat Classification System (Robertson et al. 2013).

4.2.3 Southern Buller's albatross

The third highest risk ratio was estimated to be of southern Buller's albatross, with a median risk ratio of 1.82 (95% c.i.: 0.97–3.67). The mean APF was estimated to be 791 (95% c.i.: 541–1160) individuals per year, from 387 observed captures, including 215 captures in surface-longline and 163 captures in trawl fisheries. The mean PBR_ρ was estimated to be 449 (95% c.i.: 246–701). The risk ratio ranking remained unchanged from the previous assessment (Richard & Abraham 2013c, corrected for errors).

Annual potential fatalities of southern Buller's albatross occurred in a range of fisheries. They were estimated to mostly occur in hoki and squid trawl fisheries, but also in small-vessel surface-longline fisheries targeting southern bluefin tuna, and the small-vessel bottom-longline fisheries targeting ling (see Appendix A, Tables A-10 to A-14).

The population of southern Buller's albatross, breeding on The Snares and Solander Islands, has sustained a long-term increase (Sagar & Stahl 2005). Nevertheless, an apparent decline in the annual survival rate of breeding birds and in the recruitment of known-age birds has been found on The Snares in recent years, with the potential to lead to a decline in overall abundance (Sagar 2014).

As in the previous risk assessment (Richard & Abraham 2013c), southern and northern Buller's albatross were grouped together for the estimation of vulnerability, since the identification of both species is difficult and a number of observed captures of southern Buller's albatross were likely to be of northern Buller's albatross. Nevertheless, no observed captures were identified to be of northern Buller's albatross, in contrast with the 412 observed captures of southern Buller's albatross, during the years used for the assessment. The risk to Buller's albatross was found to be relatively sensitive to the treatment of both species in the estimation of vulnerability. When the two species were split for the vulnerability estimation, with the re-assignment of 25 captures (north of 40°S or recorded in October and November) to be of northern Buller's albatross, the risk to southern Buller's albatross increased by 54%, while the risk to northern Buller's albatross decreased by 68%. With the further re-assignment of 12 captures around Chatham Islands to be of northern Buller's albatross, the difference in risk between the two species decreased but remained large compared with the base case of grouping them together. Improving ways to distinguish the two species such as the use of genetic markers during necropsy would greatly clarify the risk to both Buller's albatross species.

4.2.4 Flesh-footed shearwater

The updated risk ratio of flesh-footed shearwater is similar to that of the previous assessment (Richard & Abraham 2013c), with an estimated median of 1.50 (95% c.i.: 0.56–3.36), after a number of updates, including a higher population size, a higher adult annual survival rate, and a change in the at-sea distribution. The mean PBR_ρ for this species was estimated to be 514 (95% c.i.: 233–1140) and the mean APF to be 696 (95% c.i.: 478–995) individuals per year, from 64 observed captures, including 30 and 27 captures in trawl and bottom-longline fisheries, respectively.

Flesh-footed shearwater have recently been added to the Threatened categories, being classified as "Nationally Vulnerable" (Robertson et al. 2013). This classification followed a recent survey that found a considerable lower number of breeding pairs than expected, with approximately 10 000 pairs (Baker et al. 2010), from a previous estimate of between 25 000 to 50 000 pairs (Taylor 2000). A recent review concluded that flesh-footed shearwater populations in New Zealand are declining (Waugh et al. 2013); long-term monitoring of the population breeding on Lord Howe Island, eastern Australia, found that this population has been declining (Priddel et al. 2006). Demographic modelling of birds from two New Zealand sites concluded that the population at Lady Alice Island / Mauimua (in the Hen and Chickens' Group, Northland) was declining, while the population at Kauwahaia Island (Bethells Beach, West Auckland) was stable (Barbraud et al. 2014), this was considered consistent with the mortalities estimated by the risk assessment.

Some captures observed within New Zealand's EEZ might be of birds breeding outside New Zealand, which would lead to an overestimate of the number of APF. At the same time, this species is also caught in recreational fisheries (Miskelly et al. 2012), foraging in the north-eastern region of New Zealand, where there is considerable recreational fishing effort (Abraham et al. 2010a). Recreational fishing was not considered in this risk assessment. There is also evidence that flesh-footed shearwater are impacted by plastic ingestion (Barbraud et al. 2014, Buxton et al. 2013).

4.2.5 Gibson's albatross

Gibson's albatross were estimated in the previous assessment to be at "High risk" from commercial fisheries (Richard & Abraham 2013c). In the current assessment, their risk category increased to "Very high risk", and this species was estimated to be the fifth most at risk from commercial fisheries, with a median risk ratio of 1.26 (95% c.i.: 0.69–2.49). The mean PBR_ρ for this species was estimated to be 181 (95% c.i.: 98–281) and the mean APF to be 222 (95% c.i.: 161–301) birds per year.

The increase in risk ratio was due to the population size being revised downwards, and the disaggregation of royal albatrosses from Gibson's and Antipodean albatrosses for the estimation of vulnerability. Royal albatrosses do not get caught as often as the other albatross species included in the grouping, and removing them from the wandering albatrosses group led to an increase in vulnerability for Antipodean and Gibson's albatrosses. The disaggregation of the swordfish fishery from the small-vessel surface-longline fishery group may also have impacted the estimated APF.

Gibson's albatross have been well studied since 1991 on Adams Island, where approximately 95% of the species breeds. Monitoring of the population showed that during the period 2004–2006 there was a decrease in the number of breeding birds, in the annual survival and recruitment rates, and in nesting success. These changes may have been associated with an increase in the foraging range (Elliott & Walker 2014). In addition to captures within New Zealand waters, Gibson's albatross may also be caught in fisheries operating outside New Zealand's EEZ.

Although some signs of recovery have been observed in recent years (Elliott & Walker 2014), the conservation status of this species changed in 2013 from "Nationally Vulnerable" to "Nationally Critical", according to the New Zealand Threat Classification System (Robertson et al. 2013).

4.2.6 New Zealand white-capped albatross

The risk category of New Zealand white-capped albatross has not changed from the last assessment; however, the median risk ratio of 1.10 (95% c.i.: 0.59–1.97) was less than the risk ratio in the previous assessment of 1.89 (95% c.i.: 0.71–7.32) (Richard & Abraham 2013c, after correcting for errors). All of the updates in the current assessment led to a decrease in risk ratio (Figure 2); however, the most important change was in the demographic parameters, with the number of annual breeding pairs revised upwards, from a mean of 77 000 to a mean of 95 700 (95% c.i.: 85 400–106 000) breeding pairs, using a bootstrapped estimate from the recent aerial surveys of the population (Baker et al. 2014a). Additionally, the uncertainty in the annual survival rate was more constrained. This change in demographic parameters led to a decrease in the risk ratio from a median 1.77 (95% c.i.: 0.68–6.78) to 1.1 (95% c.i.: 0.59–1.99). The change in at-sea distribution and in fishing effort in recent years only led to a minor decrease in risk ratio.

The updated APF were estimated to be 4410 (95% c.i.: 2800–6620) individuals per year, from 562 observed captures, including 471 captures in trawl fisheries. The mean PBR_ρ was estimated to be 4040 (95% c.i.: 2620–6320). Around half of the estimated APF of white-capped albatross were predicted to occur in poorly-observed inshore trawl fisheries (2110 estimated APF), with around 400 or more estimated APF in each of squid, hoki and middle-depth trawl fisheries.

The New Zealand conservation status of New Zealand white-capped albatross is "Declining". The trend in the population size is unclear, as annual aerial surveys since 2006 have shown a highly variable number of annual breeding pairs for this biennially breeding species (Baker et al. 2014a).

White-capped albatross had very high capture rates in squid trawl fisheries. In the 1990–91 season, observers recorded capture rates of 27.9 white-capped albatross per 100 tows (Bartle 1991, Hilborn & Mangel 1997). With the prohibition on the use of net sonde cables, the introduction of mandatory warp mitigation, and with an emphasis on practices such as better offal management, the capture rate of white-capped albatross in this fishery reduced to 4.1 (95% c.i.: 2.4 to 6.4) white-capped albatrosses per 100 tows (Abraham & Thompson 2011). Despite this reduction in the capture rate, white-capped albatross continue to be caught in trawl nets, and there are still some warp-captures, even in fisheries that use warp mitigation (Abraham & Thompson 2012b).

4.2.7 Northern Buller's albatross

The risk ratio of northern Buller's albatross increased in the current assessment from a median value of 0.85 (95% c.i.: 0.45–1.65) in the previous assessment (Richard & Abraham 2013c, corrected for errors) to 1.02 (95% c.i.: 0.58–2.00), although there were no observed captures. Southern and northern Buller's albatross were grouped together for the estimation of vulnerability, and the increase in capture rate of southern Buller's albatross in 2011–12 and 2012–13 led to an increased vulnerability of Buller's albatross and, therefore, of northern Buller's albatross.

The number of APF was estimated to be a mean 549 (95% c.i.: 409–723) birds per year, mostly occurring in surface-longline fisheries targeting bigeye tuna, but also in surface-longline fisheries targeting southern bluefin tuna, and in hoki and scampi trawl fisheries.

The risk to northern Buller's albatross was sensitive to the treatment of both Buller's albatross species for the estimation of vulnerability, with the risk ratio decreasing to a median of 0.33 (95% c.i.: 0.17–0.71) and the risk category changing from "Very high risk" to "High risk" when vulnerability was estimated separately for both species. The latter included the re-assignment of 25 captures of southern Buller's albatross recorded north of 40°S and in October and November to be of northern Buller's albatross.

The distinction between southern and northern Buller's albatross is difficult and reliable techniques to identify both species accurately would greatly improve the estimation of their respective risk.

4.3 Other species

4.3.1 Chatham Island albatross

Chatham Island albatross was estimated to be in the "High risk" category, with a median risk ratio of 0.91 (95% c.i.: 0.42–1.90). This finding was different to the outcome of the previous assessment, in which the risk of this species was classified as "Very high risk", with a median risk ratio of 1.55 (95% c.i.: 0.73–2.94). The present decrease in the risk ratio was due to the disaggregation of the small-vessel, bottom-longline fishery targeting ling from the other small-vessel, bottom-longline fisheries.

There was an increase in the APF when it was calculated using the fishing effort between 2010–11 and 2012–13, compared with the APF for the period between 2006–07 and 2011–12. This finding suggests that there has been an increase in recent years in the fishing effort that overlaps with the distribution of this species.

The estimated risk ratio was sensitive to the 12 captures observed during a single trip by a small bottom-longline vessel in 2007 while targeting ling. When this trip was considered as unobserved, the risk ratio decreased to a median of 0.27 (95% c.i.: 0.09–0.89), and the risk category changed to "Medium risk" (Table A-19). Only 2.1% of the fishing effort was observed in this fishery between 2006–07 and 2011–12, and more observations are necessary for the risk to be clarified.

Based on surveys counting nest sites, the population of this species has appeared stable between 1999 and 2010 (IUCN 2012).

4.3.2 Royal albatrosses

In the present study, the risk of commercial fisheries to both northern and southern royal albatrosses was greatly reduced in comparison with the risk estimated in the previous assessment by Richard & Abraham (2013c). The risk ratio of southern royal albatross decreased from a median of 0.29 (95% c.i.: 0.18–0.46) to 0.10 (95% c.i.: 0.05–0.20), and for northern royal albatross from a median of 0.43 (95% c.i.: 0.22–

0.96) to 0.19 (95% c.i.: 0.07–0.59). This reduction in risk ratio led to a decrease in the risk category of southern royal albatross from “Medium risk” to “Low risk”, whereas the category of northern royal albatross decreased from “High risk” to “Medium risk”, after corrections were applied to Richard & Abraham (2013c). Both decreases in risk were due to the separation of royal albatrosses from wandering albatrosses for the estimation of vulnerability.

4.3.3 Shags

Stewart Island and spotted shag both had risk categorised as “Medium risk”. Both these species are group-foraging shags. The risk was primarily influenced by a high vulnerability in inshore trawl fisheries, which was caused by a single fishing event during which 31 spotted shags were observed caught. Considering this fishing event as unobserved reduced the risk to these species to close to zero (Table A-19). The high sensitivity of the risk to this capture event was due to poor observer coverage in inshore trawl fisheries, with only 1.4% of the effort observed between 2006–07 and 2012–13.

The vulnerability of group-foraging shag species is expected to be higher than that of solitary-foraging shags (Walker et al. 2015), and for trawl fisheries this expectation was confirmed. Stewart Island shag previously had a risk category of “Low risk”. The significant increase in the risk category was due to the change in the classification of this species, from solitary- to group-foraging. Nearly all of the estimated potential fatalities were in flatfish trawl fisheries, which had low observer coverage (0.3% in 2012–13), and there have been only observed captures of Stewart Island shag (in a set net targeting rig). Stewart Island shag is classified as “Nationally Vulnerable” (based on a moderate, stable population) according to the New Zealand Threat Classification System (Robertson et al. 2013).

Of the other eight shag species assessed during this study, two species (little black shag and New Zealand king shag) had a risk categorised as “Low risk”, while the other species had a risk categorised as “Negligible risk”. Relative to the risk calculated previously by Richard & Abraham (2013c), corrected for errors, the risk to both little black shag and New Zealand king shag decreased from “Medium risk” to “Low risk”. There was also a decrease in the risk to pied shag, although the risk category remained at “Negligible risk”. This decrease was primarily due to revisions to the population data, with the mean number of breeding pairs increasing from 626 to 6430, following a comprehensive review (Bell 2013).

4.4 The risk assessment calculation

The PBR represents the maximum human-caused mortalities that a population can sustain, while remaining above half its carrying capacity (Wade 1998, Richard & Abraham 2013a) (in the long term). The calculation of r_{max} and of the total population size was found to typically lead to overestimated PBR values when applied to seabirds (Richard & Abraham 2013a). For this reason, a correction factor ρ was introduced to ensure that the probability of the population falling below the carrying capacity was less than 5% when the human-caused mortality equalled the estimated PBRi_{ρ}.

The correction factor, ρ, does not correct for biases in the estimates of demographic parameters, and it was agreed in the Aquatic Environment Working Group of the Ministry for Primary Industries to retain the conservative estimate of population size N_{min} in the PBR_{ρ} calculation. The 20$^{\mathrm{th}}$ percentile of the log-normal distribution of population size was originally recommended by Wade (1998) for defining N_{min}. Nevertheless, in the approach taken here, all parameters were represented by a probability distribution, and N_{min} was calculated from the lower quartile of the number of annual breeding pairs. As a result, the mean of N_{min} was lower than the point estimate that would be derived using the 20$^{\mathrm{th}}$ percentile. (The difference between the mean of the number of breeding pairs, N_{BP}, and the lower-quartile of this distribution, $N_{\mathrm{BP}_{\mathrm{min}}}$, can be assessed in the appendix by comparing Tables A-2 and A-3.)

Survival rate was used both in the scaling of the number of annual breeding pairs to the total population size, and in the calculation of r_{max}. The former requires an estimate of survival of the species in its current context, i.e., including human-caused mortality, whereas the latter requires an estimate of survival in optimum conditions, i.e. not including human-caused mortality. In the present study, because of the high sensitivity of $r_{\max}$ to survival rate, a single survival rate was used, taken as the adult annual survival rate, intended to represent the estimate expected under optimum conditions. As a result, the use of survival rate in optimum conditions may lead to the total population size to be overestimated (Richard & Abraham 2013a). This overestimate could lead to an underestimate of the risk of commercial fisheries to seabird species.

The posterior distribution of APF in fisheries with low observer coverage will reflect the prior that was used, as the low number of observations may contain insufficient information to constrain the vulnerability. Information is shared between fisheries, allowing the vulnerability in poorly-observed fisheries to be influenced by well-observed fisheries (for example, the finding that there are few observed captures of light-mantled sooty albatross in well-observed trawl fisheries allows the model to be confident that there are few captures of light-mantled sooty albatross in inshore fisheries). This approach means, however, that the model may estimate a positive number of APF of a seabird species in a fishery, even though there have been no observed captures of that seabird species in that fishery.

In calculating the APF, observed captures of birds that are released alive were treated as if the bird died. This approach was taken because the survival of birds following their capture during fishing is unknown, and the risk to some species was found to be sensitive to the state of the seabirds at capture that is considered in the data (Table A-20). Deck captures (where a bird lands on the vessel, or where it flies into the superstructure of the vessel) are not recorded as fisheries-related captures. The calculation of APF does not consider the sex of the birds. In some cases, there is a sex-bias in the captured birds (i.e., for sooty shearwater, male birds are caught more frequently than female birds). No consideration has been given to this sex bias, and it is possible that the population impact of sex-biased captures is higher than if the captures were of similar numbers of males and females. Detailed population modelling would be needed to include the effects of sex bias on a population.

4.5 Future directions

PBR_ρ was used as an index of the impact of fisheries-related fatalities on the population of 70 species of seabirds that breed in New Zealand. PBR_ρ represents the maximum number of annual human-related fatalities that may occur with the population remaining above half its carrying capacity in the long term. Here, we compared PBR_ρ to the potential fatalities occurring in commercial trawl and longline fisheries within New Zealand's EEZ. Other fisheries impacts (such as ecosystem effects), and other potential human-caused fatalities (such as from pollution) were not considered in the current risk assessment.

Many New Zealand seabirds migrate outside the EEZ after the breeding season, and may interact with other fisheries that were not considered in the present study. For example, black petrel, Westland petrel, Buller's albatrosses, and Chatham Island albatross migrate to South American waters, while New Zealand white-capped albatross tend to migrate to South African waters. Outside New Zealand, these species may interact with numerous fisheries and the fatalities that result from these interactions were not included in the current assessment. Expanding the risk assessment to a global scale would allow a better understanding of the impacts of fisheries on New Zealand seabirds.

Seabirds may also be killed in non-commercial fisheries. A study using boat ramp surveys suggested that over 11 000 birds may be caught annually in the northeastern region of New Zealand alone, and potentially 40 000 throughout New Zealand (Abraham et al. 2010a). This estimate is higher than the number of APF in commercial trawl and longline fisheries. Petrels were reported as the group of seabirds that were caught the most frequently in recreational fisheries, followed by seagulls. Captures of albatrosses, shags, gannets, penguins and terns were also reported. The impact of these captures is unknown, but inspection of dead birds following the oil spill by the container vessel MV *Rena* found evidence of fatalities caused by recreational fishing (Miskelly et al. 2012). Given the indicated scale of these captures, and the potential overlap between recreational fisheries and seabirds that are at very high risk, a better assessment of fatalities in recreational fisheries is recommended.

Potential fatalities were calculated by multiplying the estimated number of observable captures by a multiplier to consider cryptic mortality. This multiplier was estimated from scarce data in South African trawl fisheries and in Australian longline fisheries. It is unclear how appropriate these data are to extrapolate to New Zealand fisheries. However, the multiplier has a large impact on the estimated potential fatalities (Table A-25), with a maximum mean of 8.2 for large seabirds in trawl fisheries. Further research on cryptic mortality of seabirds would clarify the risk of commercial fisheries to seabirds.

This assessment of the risk to seabirds from commercial fisheries depended on observer data as the primary source of information on seabird fatalities. Observer coverage in inshore and small-vessel trawl and longline fisheries remains low (typically less than 2%). Extending observer coverage, particularly in areas of high overlap with high risk species, would increase certainty in the results of the risk assessment. Inshore bottom-longline fisheries in north-eastern New Zealand, and inshore trawl fisheries in eastern South Island waters are fisheries where estimates of high risk are based on low observer coverage. Improving observer coverage in these fisheries will be necessary to be able to demonstrate progress towards the goals of the NPOA (Ministry for Primary Industries 2013).

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APPENDIX A

A.1 Potential Biological Removal parameters

Table A-1: Description of the distribution of the processed parameters used for the calculation of the Potential Biological Removal for 70 seabird species to assess the risk of commercial fisheries. S: adult annual survival rate; A: age at first reproduction; P_B: proportion of adults breeding; N_{BP}: annual breeding pairs. $\mathcal{U}$: uniform distribution; Log-$\mathcal{U}$: uniform distribution on the logarithmic scale; Logit-$\mathcal{N}$: normal distribution on the logit scale; Log-$\mathcal{N}$: normal distribution on the logarithmic scale. "Posterior distribution" indicates a distribution obtained from the posterior distribution of external studies (see Methods). μ, σ: mean and standard deviation on the natural scale (not transformed); s: standard deviation on the transformed scale (log or logit).

Species	S		A		P_B		N_{BP}	
Gibson's albatross	$\mathcal{U}$	0.938 – 0.985	$\mathcal{U}$	10.00 – 12.00	Logit-$\mathcal{N}$	μ=0.60; σ=0.05	Log-$\mathcal{N}$	μ= 4 792; s=0.1
Antipodean albatross	Logit-$\mathcal{N}$	μ=0.957; σ=0.007	$\mathcal{U}$	10.00 – 13.00	Logit-$\mathcal{N}$	μ=0.60; σ=0.05	Log-$\mathcal{N}$	μ= 3 320; s=0.1
Southern royal albatross	Logit-$\mathcal{N}$	μ=0.949; σ=0.008	$\mathcal{U}$	8.50 – 10.60	Logit-$\mathcal{N}$	μ=0.60; σ=0.05	Log-$\mathcal{N}$	μ= 7 886; s=0.1
Northern royal albatross	$\mathcal{U}$	0.908 – 0.969	$\mathcal{U}$	8.50 – 10.60	Logit-$\mathcal{N}$	μ=0.61; σ=0.05	Log-$\mathcal{N}$	μ= 5 832; s=0.3
Campbell black-browed albatross	Logit-$\mathcal{N}$	μ=0.945; σ=0.007	$\mathcal{U}$	6.00 – 13.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 21 000; s=0.3
NZ white-capped albatross	Logit-$\mathcal{N}$	μ=0.960; σ=0.010	$\mathcal{U}$	9.00 – 15.00	Logit-$\mathcal{N}$	μ=0.68; σ=0.05	-	Posterior distribution
Salvin's albatross	Logit-$\mathcal{N}$	μ=0.967; σ=0.010	$\mathcal{U}$	9.00 – 15.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	33 000 – 41 000
Chatham Island albatross	Logit-$\mathcal{N}$	μ=0.967; σ=0.010	$\mathcal{U}$	9.00 – 15.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 5 247; s=0.1
Grey-headed albatross	Logit-$\mathcal{N}$	μ=0.953; σ=0.009	$\mathcal{U}$	7.00 – 13.00	Logit-$\mathcal{N}$	μ=0.75; σ=0.05	Log-$\mathcal{N}$	μ= 6 600; s=0.3
Southern Buller's albatross	$\mathcal{U}$	0.930 – 0.980	$\mathcal{U}$	9.00 – 15.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 13 625; s=0.1
Northern Buller's albatross	$\mathcal{U}$	0.930 – 0.980	$\mathcal{U}$	9.00 – 15.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 16 346; s=0.1
Light-mantled sooty albatross	$\mathcal{U}$	0.960 – 0.980	$\mathcal{U}$	9.00 – 15.00	Logit-$\mathcal{N}$	μ=0.60; σ=0.05	Log-$\mathcal{U}$	6 770 – 6 900
Northern giant petrel	$\mathcal{U}$	0.808 – 0.965	$\mathcal{U}$	6.00 – 10.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 2 567; s=0.2
Grey petrel	$\mathcal{U}$	0.900 – 0.970	$\mathcal{U}$	5.00 – 9.00	Logit-$\mathcal{N}$	μ=0.80; σ=0.05	Log-$\mathcal{N}$	μ= 50 000; s=0.1
Black petrel	Logit-$\mathcal{N}$	μ=0.950; σ=0.010	$\mathcal{U}$	6.21 – 6.99	Logit-$\mathcal{N}$	μ=0.80; σ=0.05	-	Posterior distribution
Westland petrel	$\mathcal{U}$	0.900 – 0.970	$\mathcal{U}$	4.00 – 9.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 4 000; s=0.1
White-chinned petrel	$\mathcal{U}$	0.900 – 0.970	$\mathcal{U}$	4.00 – 9.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 168 725; s=0.3
Flesh-footed shearwater	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	4.00 – 9.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 10 000; s=0.1
Wedge-tailed shearwater	$\mathcal{U}$	0.889 – 0.958	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	52 500 – 60 000
Buller's shearwater	Logit-$\mathcal{N}$	μ=0.920; σ=0.030	$\mathcal{U}$	4.00 – 9.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 200 000; s=0.3
Sooty shearwater	$\mathcal{U}$	0.860 – 0.979	$\mathcal{U}$	5.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ=5 000 000; s=0.3
Fluttering shearwater	$\mathcal{U}$	0.889 – 0.958	$\mathcal{U}$	4.00 – 6.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	20 000 – 200 000
Hutton's shearwater	$\mathcal{U}$	0.889 – 0.958	$\mathcal{U}$	4.00 – 6.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 94 000; s=0.2
Little shearwater	$\mathcal{U}$	0.889 – 0.958	$\mathcal{U}$	4.00 – 6.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	100 000 – 220 000
Snares Cape petrel	$\mathcal{U}$	0.771 – 0.939	$\mathcal{U}$	3.00 – 8.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 8 420; s=0.3
Fairy prion	Logit-$\mathcal{N}$	μ=0.840; σ=0.030	$\mathcal{U}$	4.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	700 000 – 3 000 000
Antarctic prion	Logit-$\mathcal{N}$	μ=0.840; σ=0.030	$\mathcal{U}$	5.00 – 6.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	100 000 – 1 000 000
Broad-billed prion	Logit-$\mathcal{N}$	μ=0.840; σ=0.030	$\mathcal{U}$	4.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ=1 000 000; s=0.3
Pycroft's petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	2 000 – 3 000
Cook's petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	50 000 – 60 000
Chatham petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 250; s=0.2
Mottled petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	300 000 – 400 000
White-naped petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 50 000; s=0.3
Kermadec petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	5 000 – 7 000
Grey-faced petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	200 000 – 300 000
Chatham Island taiko	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 17; s=0.1
White-headed petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	4.00 – 7.00	Logit-$\mathcal{N}$	μ=0.60; σ=0.05	Log-$\mathcal{N}$	μ= 200 000; s=0.3
Soft-plumaged petrel	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	6.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	1 000 – 9 999
Common diving petrel	$\mathcal{U}$	0.750 – 0.870	$\mathcal{U}$	2.00 – 3.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	300 000 – 2 150 000
South Georgian diving petrel	$\mathcal{U}$	0.750 – 0.870	$\mathcal{U}$	2.00 – 3.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 64; s=0.3
NZ white-faced storm petrel	Logit-$\mathcal{N}$	μ=0.900; σ=0.030	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	700 000 – 3 000 000
White-bellied storm petrel	Logit-$\mathcal{N}$	μ=0.900; σ=0.030	$\mathcal{U}$	4.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 1 000; s=0.3
Black-bellied storm petrel	Logit-$\mathcal{N}$	μ=0.900; σ=0.030	$\mathcal{U}$	4.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	50 000 – 100 000
Kermadec storm petrel	Logit-$\mathcal{N}$	μ=0.900; σ=0.030	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	20 – 120
NZ storm petrel	Logit-$\mathcal{N}$	μ=0.900; σ=0.030	$\mathcal{U}$	4.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	20 – 1 000
Yellow-eyed penguin	Logit-$\mathcal{N}$	μ=0.870; σ=0.030	$\mathcal{U}$	2.00 – 3.00	Logit-$\mathcal{N}$	μ=0.60; σ=0.05	Log-$\mathcal{U}$	1 700 – 2 420
Northern little penguin	Logit-$\mathcal{N}$	μ=0.830; σ=0.020	$\mathcal{U}$	2.00 – 3.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	5 000 – 10 000
White-flippered little penguin	Logit-$\mathcal{N}$	μ=0.830; σ=0.020	$\mathcal{U}$	2.00 – 3.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 2 200; s=0.2
Southern little penguin	Logit-$\mathcal{N}$	μ=0.830; σ=0.020	$\mathcal{U}$	2.00 – 3.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	5 000 – 10 000
Chatham Island little penguin	Logit-$\mathcal{N}$	μ=0.830; σ=0.020	$\mathcal{U}$	2.00 – 3.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	5 000 – 10 000
Eastern rockhopper penguin	Logit-$\mathcal{N}$	μ=0.840; σ=0.011	$\mathcal{U}$	3.00 – 6.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	38 961 – 58 500
Fiordland crested penguin	Logit-$\mathcal{N}$	μ=0.840; σ=0.011	$\mathcal{U}$	3.00 – 6.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 3 000; s=0.3
Snares crested penguin	Logit-$\mathcal{N}$	μ=0.840; σ=0.011	$\mathcal{U}$	5.00 – 6.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 30 000; s=0.3
Erect-crested penguin	Logit-$\mathcal{N}$	μ=0.840; σ=0.011	$\mathcal{U}$	5.00 – 6.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	77 000 – 85 000
Australasian gannet	Logit-$\mathcal{N}$	μ=0.940; σ=0.030	$\mathcal{U}$	3.00 – 7.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 46 004; s=0.3
Masked booby	Logit-$\mathcal{N}$	μ=0.850; σ=0.030	$\mathcal{U}$	2.00 – 4.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 240; s=0.2
Pied shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	2.00 – 3.33	Logit-$\mathcal{N}$	μ=1.00; σ=0.00	Log-$\mathcal{N}$	μ= 6 400; s=0.1
Little black shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	1.00 – 3.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 1 500; s=0.3
NZ king shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	102 – 126
Stewart Island shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	2 075 – 2 482
Chatham Island shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 357; s=0.1
Bounty Island shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 120; s=0.2
Auckland Island shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	956 – 4 098
Campbell Island shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 2 000; s=0.3
Spotted shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	1.00 – 3.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	10 000 – 30 000
Pitt Island shag	$\mathcal{U}$	0.859 – 0.897	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 669; s=0.3
Subantarctic skua	$\mathcal{U}$	0.910 – 0.970	$\mathcal{U}$	7.62 – 8.44	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	450 – 470
Southern black-backed gull	Logit-$\mathcal{N}$	μ=0.810; σ=0.030	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	700 000 – 3 000 000
Caspian tern	$\mathcal{U}$	0.816 – 0.937	$\mathcal{U}$	2.00 – 4.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{N}$	μ= 1 000; s=0.2
White tern	$\mathcal{U}$	0.780 – 0.830	$\mathcal{U}$	3.00 – 5.00	Logit-$\mathcal{N}$	μ=0.90; σ=0.05	Log-$\mathcal{U}$	60 – 100

Table A-2: Summary of demographic parameters (mean and 95% credible interval) for each seabird species, used for the calculation of the Potential Biological Removal, including adult survival (S_A), age at first reproduction (A), the proportion of adults breeding (P_B), and the number of annual breeding pairs (N_{BP}), rounded to three significant digits. Species names were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

Species	S_A		A		P_B		N_{BP}	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	0.96	0.94–0.98	11.01	10.05–11.96	0.60	0.49–0.69	4 820	3 950–5 830
Antipodean albatross	0.96	0.94–0.97	11.48	10.07–12.91	0.60	0.50–0.69	3 340	2 720–4 020
Southern royal albatross	0.95	0.93–0.96	9.56	8.55–10.55	0.60	0.50–0.69	7 940	6 490–9 610
Northern royal albatross	0.94	0.91–0.97	9.56	8.56–10.55	0.61	0.51–0.70	6 080	3 250–10 500
Campbell black-browed albatross	0.94	0.93–0.96	9.49	6.19–12.83	0.89	0.75–0.96	21 900	11 700–37 300
New Zealand white-capped albatross	0.96	0.93–0.98	12.02	9.15–14.84	0.68	0.58–0.77	95 700	85 400–106 000
Salvin's albatross	0.97	0.94–0.98	12.02	9.16–14.82	0.89	0.76–0.96	36 800	33 200–40 800
Chatham Island albatross	0.97	0.94–0.98	11.99	9.13–14.86	0.89	0.76–0.96	5 280	4 320–6 420
Grey-headed albatross	0.95	0.93–0.97	10.00	7.16–12.86	0.75	0.64–0.83	6 920	3 680–11 600
Southern Buller's albatross	0.96	0.93–0.98	12.00	9.15–14.85	0.89	0.74–0.96	13 700	11 300–16 600
Northern Buller's albatross	0.96	0.93–0.98	12.00	9.16–14.85	0.89	0.76–0.96	16 400	13 500–19 800
Light-mantled sooty albatross	0.97	0.96–0.98	12.01	9.18–14.83	0.60	0.50–0.69	6 840	6 770–6 900
Northern giant petrel	0.89	0.81–0.96	8.02	6.10–9.90	0.89	0.75–0.96	2 620	1 730–3 770
Grey petrel	0.93	0.90–0.97	7.00	5.10–8.89	0.80	0.68–0.88	50 200	41 100–60 800
Black petrel	0.95	0.93–0.97	6.60	6.23–6.97	0.79	0.69–0.88	4 630	1 970–9 780
Westland petrel	0.93	0.90–0.97	6.48	4.14–8.89	0.89	0.76–0.96	4 020	3 270–4 870
White-chinned petrel	0.93	0.90–0.97	6.54	4.15–8.87	0.89	0.75–0.96	177 000	94 300–304 000
Flesh-footed shearwater	0.93	0.85–0.98	6.52	4.14–8.87	0.89	0.75–0.96	10 100	8 240–12 100
Wedge-tailed shearwater	0.92	0.89–0.96	4.02	3.06–4.96	0.89	0.75–0.96	56 200	52 700–59 800
Buller's shearwater	0.91	0.84–0.96	6.49	4.13–8.89	0.89	0.75–0.96	209 000	110 000–365 000
Sooty shearwater	0.92	0.86–0.98	5.98	5.05–6.95	0.89	0.75–0.96	5 260 000	2 780 000–9 130 000
Fluttering shearwater	0.92	0.89–0.96	5.00	4.05–5.95	0.89	0.76–0.96	79 400	21 200–190 000
Hutton's shearwater	0.92	0.89–0.96	5.00	4.06–5.95	0.89	0.75–0.96	96 000	63 800–140 000
Little shearwater	0.92	0.89–0.96	5.00	4.06–5.94	0.89	0.75–0.96	153 000	102 000–216 000
Snares Cape petrel	0.85	0.77–0.93	5.53	3.13–7.88	0.89	0.75–0.96	8 800	4 620–15 200
Fairy prion	0.84	0.77–0.89	4.50	4.02–4.97	0.89	0.75–0.97	1 590 000	728 000–2 890 000
Antarctic prion	0.84	0.77–0.89	5.50	5.02–5.98	0.89	0.76–0.96	391 000	107 000–940 000
Broad-billed prion	0.84	0.77–0.89	4.50	4.02–4.98	0.89	0.75–0.96	1 040 000	551 000–1 790 000
Pycroft's petrel	0.93	0.84–0.98	6.50	6.02–6.98	0.89	0.75–0.97	2 470	2 020–2 970
Cook's petrel	0.93	0.85–0.98	6.50	6.03–6.97	0.89	0.75–0.96	54 800	50 200–59 700
Chatham petrel	0.93	0.85–0.98	6.50	6.03–6.97	0.89	0.75–0.96	254	167–365
Mottled petrel	0.93	0.85–0.98	6.50	6.02–6.97	0.89	0.75–0.96	347 000	302 000–397 000
White-naped petrel	0.93	0.85–0.98	6.50	6.02–6.97	0.89	0.74–0.96	52 600	28 400–90 400
Kermadec petrel	0.93	0.85–0.98	6.50	6.02–6.98	0.89	0.75–0.96	5 940	5 040–6 940
Grey-faced petrel	0.93	0.85–0.98	6.50	6.03–6.97	0.89	0.75–0.97	247 000	202 000–297 000
Chatham Island taiko	0.93	0.84–0.98	6.51	6.03–6.97	0.89	0.75–0.96	17	14–21
White-headed petrel	0.93	0.85–0.98	5.50	4.07–6.93	0.60	0.50–0.69	208 000	112 000–353 000
Soft-plumaged petrel	0.93	0.85–0.98	6.49	6.02–6.97	0.89	0.75–0.96	3 880	1 070–9 430
Common diving petrel	0.81	0.75–0.87	2.50	2.03–2.97	0.89	0.75–0.96	949 000	316 000–2 050 000
South Georgian diving petrel	0.81	0.75–0.87	2.50	2.02–2.98	0.89	0.75–0.97	67	35–117
New Zealand white-faced storm petrel	0.90	0.83–0.95	3.99	3.04–4.95	0.89	0.76–0.96	1 580 000	726 000–2 870 000
White-bellied storm petrel	0.90	0.83–0.94	4.50	4.03–4.98	0.89	0.75–0.97	1 040	543–1 790
Black-bellied storm petrel	0.90	0.83–0.94	4.49	4.02–4.98	0.89	0.75–0.96	71 900	50 800–98 200
Kermadec storm petrel	0.90	0.82–0.95	4.01	3.06–4.95	0.89	0.74–0.96	57	21–116
New Zealand storm petrel	0.90	0.82–0.95	4.50	4.02–4.97	0.89	0.75–0.97	253	22–900
Yellow-eyed penguin	0.87	0.80–0.92	2.51	2.03–2.98	0.60	0.50–0.69	2 030	1 720–2 400
Northern little penguin	0.83	0.79–0.87	2.50	2.03–2.97	0.89	0.76–0.96	7 170	5 080–9 810
White-flippered little penguin	0.83	0.79–0.86	2.50	2.02–2.97	0.89	0.76–0.96	2 250	1 490–3 280
Southern little penguin	0.83	0.79–0.86	2.50	2.03–2.97	0.89	0.75–0.96	7 220	5 100–9 820
Chatham Island little penguin	0.83	0.79–0.87	2.50	2.02–2.97	0.89	0.75–0.96	7 190	5 080–9 800
Eastern rockhopper penguin	0.84	0.82–0.86	4.52	3.07–5.92	0.89	0.76–0.96	48 100	39 400–58 000
Fiordland crested penguin	0.84	0.82–0.86	4.52	3.08–5.93	0.89	0.76–0.96	3 150	1 660–5 470
Snares crested penguin	0.84	0.82–0.86	5.50	5.03–5.98	0.89	0.75–0.96	31 400	16 700–54 100
Erect-crested penguin	0.84	0.82–0.86	5.49	5.03–5.98	0.89	0.75–0.96	81 000	77 200–84 800
Australasian gannet	0.93	0.85–0.98	5.00	3.11–6.88	0.89	0.75–0.96	47 800	25 500–80 700
Masked booby	0.85	0.78–0.90	2.99	2.05–3.94	0.89	0.75–0.96	245	161–358
Pied shag	0.88	0.86–0.90	2.68	2.04–3.30	1.00	1.00–1.00	6 430	5 270–7 810
Little black shag	0.88	0.86–0.90	2.00	1.04–2.95	0.89	0.76–0.96	1 550	821–2 640
New Zealand king shag	0.88	0.86–0.90	4.00	3.05–4.95	0.89	0.75–0.96	113	103–125
Stewart Island shag	0.88	0.86–0.90	4.01	3.06–4.95	0.89	0.75–0.96	2 270	2 080–2 470
Chatham Island shag	0.88	0.86–0.90	4.00	3.05–4.96	0.89	0.75–0.96	358	292–434
Bounty Island shag	0.88	0.86–0.90	3.99	3.04–4.95	0.89	0.74–0.96	122	81–176
Auckland Island shag	0.88	0.86–0.90	4.01	3.04–4.95	0.89	0.76–0.96	2 160	989–3 950
Campbell Island shag	0.88	0.86–0.90	4.00	3.05–4.94	0.89	0.74–0.96	2 100	1 120–3 640
Spotted shag	0.88	0.86–0.90	1.99	1.05–2.95	0.89	0.75–0.96	18 000	10 300–29 100
Pitt Island shag	0.88	0.86–0.90	3.99	3.05–4.95	0.89	0.75–0.96	701	370–1 190
Subantarctic skua	0.94	0.91–0.97	8.03	7.64–8.42	0.89	0.75–0.97	460	450–469
Southern black-backed gull	0.81	0.74–0.86	4.00	3.05–4.95	0.89	0.75–0.96	1 570 000	726 000–2 900 000
Caspian tern	0.88	0.82–0.93	3.00	2.06–3.94	0.89	0.76–0.96	1 020	682–1 480
White tern	0.80	0.78–0.83	4.00	3.05–4.94	0.89	0.75–0.96	78	61–98

Table A-3: Summary of the input parameters to the calculation of the Potential Biological Removal (PBR_ρ) for seabird species breeding in New Zealand, including the lower quartile of the number of annual breeding pairs ($N_{BP_{min}}$), the conservative total population size N^G_{min} estimated from $N_{BP_{min}}$, the estimated maximum growth rate r^{NL}_{max} (mean and 95% credible interval), and the PBR_ρ calibration factor ρ. $N_{BP_{min}}$ and N^G_{min} were rounded to three significant digits. Species names were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

Species	Breeding pairs, $N_{BP_{min}}$		Population size, N^G_{min}		Growth rate, r^{NL}_{max}		ρ
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	
Gibson's albatross	4 230	3 730–4 470	21 300	15 400–29 100	0.045	0.032–0.055	0.37
Antipodean albatross	2 930	2 600–3 100	15 800	12 400–20 200	0.046	0.040–0.054	0.37
Southern royal albatross	6 960	6 140–7 360	37 000	28 800–47 600	0.056	0.048–0.064	0.37
Northern royal albatross	4 020	2 770–4 730	23 200	14 000–34 500	0.059	0.046–0.071	0.37
Campbell black-browed albatross	14 500	10 100–17 000	53 600	33 900–76 000	0.059	0.045–0.080	0.43
New Zealand white-capped albatross	89 000	82 800–92 100	425 000	319 000–605 000	0.044	0.034–0.057	0.43
Salvin's albatross	33 900	33 000–34 800	114 000	88 400–164 000	0.041	0.031–0.055	0.43
Chatham Island albatross	4 630	4 110–4 900	15 600	11 800–22 100	0.041	0.030–0.055	0.43
Grey-headed albatross	4 580	3 060–5 390	19 300	12 100–27 600	0.053	0.041–0.070	0.43
Southern Buller's albatross	12 000	10 600–12 700	45 800	31 800–67 600	0.045	0.032–0.060	0.43
Northern Buller's albatross	14 400	12 700–15 300	55 000	38 100–81 700	0.045	0.032–0.060	0.43
Light-mantled sooty albatross	6 790	6 770–6 800	32 100	25 700–40 600	0.039	0.031–0.049	0.37
Northern giant petrel	2 000	1 580–2 230	11 400	5 430–23 900	0.082	0.054–0.113	0.34
Grey petrel	44 100	38 900–46 600	169 000	123 000–238 000	0.077	0.054–0.105	0.33
Black petrel	2 480	1 660–3 030	8 410	5 430–11 200	0.072	0.061–0.084	0.33
Westland petrel	3 520	3 110–3 720	11 600	8 640–16 600	0.082	0.054–0.121	0.33
White-chinned petrel	117 000	80 000–137 000	388 000	242 000–588 000	0.082	0.054–0.121	0.33
Flesh-footed shearwater	8 830	7 800–9 340	30 400	21 000–55 200	0.081	0.049–0.128	0.41
Wedge-tailed shearwater	53 400	52 500–54 300	155 000	129 000–193 000	0.123	0.090–0.165	0.41
Buller's shearwater	138 000	95 300–162 000	526 000	309 000–936 000	0.090	0.059–0.136	0.41
Sooty shearwater	3 450 000	2 350 000–4 050 000	12 100 000	7 040 000–18 900 000	0.090	0.056–0.122	0.41
Fluttering shearwater	27 100	20 300–35 000	84 600	57 100–122 000	0.104	0.078–0.132	0.41
Hutton's shearwater	73 400	57 200–81 800	229 000	167 000–307 000	0.104	0.078–0.133	0.41
Little shearwater	110 000	101 000–121 000	346 000	271 000–450 000	0.104	0.079–0.132	0.32
Snares Cape petrel	5 820	3 990–6 850	29 000	14 100–63 800	0.126	0.077–0.208	0.32
Fairy prion	849 000	707 000–1 010 000	3 590 000	2 510 000–5 240 000	0.149	0.126–0.174	0.32
Antarctic prion	136 000	101 000–178 000	694 000	428 000–1 130 000	0.126	0.108–0.145	0.32
Broad-billed prion	691 000	473 000–812 000	2 940 000	1 840 000–4 310 000	0.149	0.126–0.176	0.32
Pycroft's petrel	2 100	2 000–2 210	7 180	5 150–12 300	0.079	0.052–0.109	0.32
Cook's petrel	51 100	50 100–52 300	174 000	126 000–290 000	0.079	0.052–0.109	0.32
Chatham petrel	194	153–217	661	436–1 100	0.079	0.051–0.108	0.32
Mottled petrel	311 000	301 000–322 000	1 060 000	760 000–1 770 000	0.079	0.052–0.109	0.32
White-naped petrel	34 800	24 200–40 900	119 000	71 600–213 000	0.079	0.052–0.109	0.41
Kermadec petrel	5 210	5 010–5 420	17 800	12 700–30 500	0.079	0.052–0.109	0.41
Grey-faced petrel	211 000	200 000–221 000	715 000	517 000–1 170 000	0.078	0.052–0.109	0.41
Chatham Island taiko	15	13–16	51	36–86	0.079	0.052–0.109	0.41
White-headed petrel	138 000	94 300–162 000	649 000	387 000–1 080 000	0.090	0.057–0.136	0.41
Soft-plumaged petrel	1 350	1 020–1 750	4 600	2 830–8 010	0.079	0.051–0.109	0.32
Common diving petrel	386 000	304 000–483 000	1 200 000	860 000–1 690 000	0.264	0.206–0.338	0.17
South Georgian diving petrel	44	30–52	138	89–187	0.265	0.207–0.338	0.17
New Zealand white-faced storm petrel	845 000	706 000–1 000 000	2 680 000	1 940 000–3 860 000	0.140	0.100–0.192	0.30
White-bellied storm petrel	688	469–809	2 310	1 450–3 330	0.126	0.096–0.157	0.30
Black-bellied storm petrel	54 500	50 200–59 000	182 000	141 000–252 000	0.125	0.097–0.156	0.30
Kermadec storm petrel	25	20–31	80	56–116	0.139	0.101–0.189	0.30
New Zealand storm petrel	34	20–52	113	61–193	0.126	0.096–0.158	0.30
Yellow-eyed penguin	1 780	1 700–1 850	7 430	6 060–9 380	0.226	0.172–0.296	0.55
Northern little penguin	5 450	5 020–5 900	16 400	13 600–20 400	0.254	0.207–0.312	0.50
White-flippered little penguin	1 720	1 350–1 920	5 160	3 830–6 630	0.254	0.208–0.315	0.50
Southern little penguin	5 460	5 020–5 920	16 400	13 500–20 400	0.253	0.207–0.312	0.50
Chatham Island little penguin	5 460	5 020–5 920	16 400	13 600–20 400	0.253	0.206–0.312	0.50
Eastern rockhopper penguin	41 000	39 100–43 000	174 000	127 000–238 000	0.152	0.117–0.205	0.50
Fiordland crested penguin	2 070	1 400–2 440	8 740	5 290–12 800	0.153	0.118–0.205	0.50
Snares crested penguin	20 700	14 200–24 300	103 000	67 100–137 000	0.126	0.115–0.138	0.50
Erect-crested penguin	78 000	77 000–78 900	387 000	324 000–479 000	0.126	0.115–0.138	0.50
Australasian gannet	31 700	21 800–37 200	96 200	60 100–154 000	0.099	0.058–0.162	0.57
Masked booby	187	146–209	595	422–823	0.211	0.152–0.298	0.57
Pied shag	5 640	4 990–5 970	14 100	12 100–16 000	0.209	0.168–0.263	0.57
Little black shag	1 030	706–1 220	2 660	1 760–3 520	0.290	0.186–0.506	0.57
New Zealand king shag	105	102–107	351	291–433	0.150	0.122–0.187	0.57
Stewart Island shag	2 120	2 080–2 170	7 120	5 860–8 810	0.150	0.121–0.187	0.57
Chatham Island shag	315	278–333	1 060	846–1 340	0.150	0.122–0.187	0.57
Bounty Island shag	93	73–104	313	228–409	0.150	0.122–0.188	0.57
Auckland Island shag	1 150	964–1 360	3 860	2 900–5 130	0.150	0.122–0.188	0.57
Campbell Island shag	1 380	946–1 620	4 620	3 090–6 230	0.150	0.122–0.187	0.57
Spotted shag	11 500	10 100–13 100	29 700	23 300–38 000	0.291	0.185–0.503	0.57
Pitt Island shag	463	316–546	1 550	1 010–2 070	0.150	0.122–0.187	0.57
Subantarctic skua	452	450–455	1 590	1 220–2 070	0.066	0.052–0.078	0.57
Southern black-backed gull	840 000	706 000–992 000	3 660 000	2 480 000–5 550 000	0.177	0.139–0.228	0.61
Caspian tern	780	615–872	2 310	1 650–3 150	0.192	0.129–0.280	0.61
White tern	64	60–68	280	212–374	0.179	0.145–0.225	0.61

A.2 Observed captures and effort

Table A-4: Number of observed seabird captures (C) and the proportion of overlap observed (P) with trawl, bottom-longline (BLL), surface-longline (SLL), and set-net fisheries between 2006–07 and 2012–13. Species names were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

Species	Trawl		BLL		SLL		Set net	
	C	P (%)	C	P (%)	C	P (%)	C	P (%)
Gibson's albatross	1	11.0	0	2.6	26	13.5	0	1.8
Antipodean albatross	0	10.3	0	3.3	28	9.3	0	2.1
Southern royal albatross	10	14.0	3	3.7	2	12.6	0	2.1
Northern royal albatross	0	8.7	0	3.1	1	10.5	0	3.1
Campbell black-browed albatross	9	15.2	4	6.1	18	11.8	0	3.4
NZ white-capped albatross	471	13.8	2	2.7	89	11.8	0	2.2
Salvin's albatross	190	10.8	25	2.4	7	6.5	0	2.5
Chatham Island albatross	8	15.8	13	3.6	0	3.9	0	2.1
Grey-headed albatross	0	12.5	0	3.1	0	12.2	0	2.4
Southern Buller's albatross	163	11.2	9	2.6	215	40.0	0	4.4
Northern Buller's albatross	2	10.2	0	1.5	22	4.6	0	1.3
Light-mantled sooty albatross	1	13.1	0	3.2	0	14.2	0	2.3
Northern giant petrel	5	14.3	0	3.6	0	12.4	0	1.9
Grey petrel	32	13.1	8	4.4	30	12.9	0	1.6
Black petrel	3	4.9	60	1.6	11	4.5	0	0.2
Westland petrel	11	8.9	1	1.6	5	7.4	3	1.6
White-chinned petrel	729	13.4	49	3.4	28	13.5	1	2.8
Flesh-footed shearwater	30	4.0	27	1.7	6	3.6	1	0.6
Wedge-tailed shearwater	0	55.2	0	0.0	0	29.8	0	0.0
Buller's shearwater	0	6.0	0	1.7	0	9.7	0	1.8
Sooty shearwater	608	11.5	14	2.5	2	11.0	8	5.2
Fluttering shearwater	0	1.9	1	0.3	0	10.7	1	0.0
Hutton's shearwater	0	4.8	0	2.0	0	3.7	0	6.1
Little shearwater	0	8.6	0	1.7	0	13.1	0	0.7
Snares Cape petrel	3	18.9	1	3.4	2	12.5	9	5.0
Fairy prion	7	5.0	0	0.7	0	12.7	0	1.1
Antarctic prion	1	27.0	0	3.8	0	8.3	0	2.7
Broad-billed prion	0	14.3	0	1.3	0	12.2	0	2.1
Pycroft's petrel	0	3.1	0	1.7	0	3.6	0	0.0
Cook's petrel	0	2.3	0	1.5	0	4.8	0	0.3
Chatham petrel	0	17.1	0	0.8	0	0.0	0	0.0
Mottled petrel	0	7.4	0	6.8	0	19.7	0	8.6
White-naped petrel	0	0.0	0	0.0	0	26.3	0	0.0
Kermadec petrel	0	7.3	0	1.8	0	10.9	0	1.4
Grey-faced petrel	0	4.9	6	1.4	3	7.5	0	0.7
Chatham Island taiko	0	21.4	0	2.3	0	0.0	0	0.0
White-headed petrel	0	19.8	0	5.0	0	12.7	0	2.6
Soft-plumaged petrel	0	10.1	0	2.9	0	11.0	0	2.3
Common diving petrel	7	6.1	0	4.5	0	8.4	0	6.8
South Georgian diving petrel	0	5.8	0	9.0	0	0.0	0	10.5
NZ white-faced storm petrel	2	13.8	0	0.7	0	6.3	0	1.1
White-bellied storm petrel	0	36.4	0	1.3	0	11.0	0	0.0
Black-bellied storm petrel	1	9.8	0	2.3	0	11.1	0	2.2
Kermadec storm petrel	0	100.0	0	0.0	0	14.3	0	0.0
NZ storm petrel	0	3.6	0	1.3	0	6.7	0	0.2
Yellow-eyed penguin	0	2.4	0	1.8	0	0.0	9	4.3
Northern little penguin	0	3.2	0	1.3	0	5.0	0	1.4
White-flippered little penguin	0	5.3	0	2.7	0	0.0	0	2.6
Southern little penguin	0	4.3	0	1.6	0	6.8	0	5.2
Chatham Island little penguin	0	16.5	0	1.3	0	0.0	0	0.0
Eastern rockhopper penguin	0	24.7	0	16.2	0	29.8	0	4.3
Fiordland crested penguin	0	4.7	0	0.5	0	10.7	1	8.0
Snares crested penguin	0	24.2	0	6.6	0	36.1	0	6.9
Erect-crested penguin	0	30.7	0	20.3	0	0.0	0	0.0
Australasian gannet	0	2.8	0	1.0	0	6.1	0	0.4
Masked booby	0	10.3	0	2.5	0	12.2	0	2.0
Pied shag	0	1.2	0	1.3	0	1.1	1	1.1
Little black shag	0	1.1	0	1.2	0	0.1	0	0.4
NZ king shag	0	0.7	0	0.0	0	0.0	0	1.4
Stewart Island shag	0	1.4	0	0.1	0	0.0	2	6.1
Chatham Island shag	0	2.1	0	1.5	0	0.0	0	0.0
Bounty Island shag	0	63.6	0	23.2	0	0.0	0	0.0
Auckland Island shag	0	27.9	0	100.0	0	0.0	0	0.0
Campbell Island shag	0	0.0	0	0.0	0	0.0	0	0.0
Spotted shag	32	1.3	0	1.3	0	2.2	3	1.5
Pitt Island shag	0	0.7	0	1.5	0	0.0	0	0.0
Subantarctic skua	0	10.0	0	1.0	0	11.9	0	3.8
Southern black-backed gull	1	1.3	2	1.4	0	2.4	0	1.6
Caspian tern	0	1.5	0	1.4	0	3.3	0	1.7
White tern	0	7.6	0	1.6	0	9.5	0	1.4

A.3 Progressive updates

Table A-5: Progressive changes to the risk ratio following data updates for seabird species included in the current risk assessment. Previous: previous assessment (Richard & Abraham 2013c); rerun: as previous assessment but with error corrections; vulnerability: updated fishing data, vulnerability estimated on seven years, annual potential fatalities (APF) on same five years of data as the previous assessment; effort: change in fishing effort, vulnerability estimated on seven years, APF on last three years; demography: updated demographic parameters; groups: updated species and fishery groups; maps: updated distribution maps. Cells were coloured according to the associated risk categories as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

Species	Previous		Rerun		Vulnerability		Effort		Demography		Groups		Maps	
	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.
Black petrel	**19.89**	11.38–32.85	**22.46**	13.23–36.44	**21.39**	12.68–35.00	**19.14**	11.31–30.93	**12.68**	7.59–21.87	**12.31**	7.52–21.67	**11.34**	6.85–19.81
Salvin's albatross	**2.88**	1.47–5.41	**6.32**	3.18–12.57	**5.16**	2.67–10.07	**5.14**	2.62–9.70	**3.73**	1.91–6.84	**3.57**	1.85–6.82	**3.44**	1.82–6.50
Southern Buller's albatross	**1.32**	0.75–2.58	**1.74**	0.91–3.75	**1.94**	1.05–4.06	**1.82**	0.98–3.67	**1.79**	0.96–3.65	**1.79**	0.96–3.64	**1.82**	0.97–3.67
Flesh-footed shearwater	**1.41**	0.59–2.94	**1.63**	0.73–3.47	**1.48**	0.65–2.96	**1.46**	0.65–2.98	**1.39**	0.52–3.03	**1.4**	0.51–3.13	**1.5**	0.56–3.36
Chatham Island albatross	**1.3**	0.68–2.59	**1.55**	0.73–2.94	**1.44**	0.73–2.81	**1.85**	0.86–3.73	**1.87**	0.86–3.82	**0.98**	0.45–2.10	**0.91**	0.42–1.90
NZ white-capped albatross	**0.78**	0.28–3.13	**1.89**	0.71–7.32	**1.85**	0.71–7.00	**1.77**	0.68–6.78	**1.1**	0.59–1.99	**1.11**	0.59–2.00	**1.1**	0.59–1.97
Northern Buller's albatross	**0.69**	0.38–1.36	**0.85**	0.45–1.65	**0.95**	0.54–1.88	**0.91**	0.51–1.81	**0.88**	0.49–1.74	**0.85**	0.48–1.67	**1.02**	0.58–2.00
Gibson's albatross	**0.48**	0.25–1.00	**0.56**	0.31–1.11	**0.59**	0.33–1.15	**0.6**	0.34–1.19	**0.68**	0.38–1.32	**1.41**	0.80–2.87	**1.26**	0.69–2.49
Antipodean albatross	**0.3**	0.18–0.49	**0.33**	0.21–0.52	**0.35**	0.23–0.55	**0.32**	0.20–0.51	**0.38**	0.24–0.60	**0.78**	0.49–1.27	**0.89**	0.56–1.47
Westland petrel	**0.25**	0.10–0.66	**0.32**	0.14–0.83	**0.4**	0.18–1.00	**0.46**	0.20–1.07	**0.53**	0.22–1.36	**0.56**	0.23–1.45	**0.53**	0.21–1.37
Northern royal albatross	**0.29**	0.12–0.70	**0.43**	0.22–0.96	**0.5**	0.26–1.10	**0.48**	0.24–1.01	**0.54**	0.28–1.19	**0.19**	0.07–0.59	**0.19**	0.07–0.59
Snares Cape petrel	**0.33**	0.12–0.93	**0.41**	0.16–1.14	**0.39**	0.15–1.05	**0.38**	0.15–1.02	**0.36**	0.14–0.99	**0.1**	0.04–0.27	**0.09**	0.03–0.25
White-chinned petrel	**0.22**	0.10–0.53	**0.3**	0.15–0.74	**0.31**	0.16–0.74	**0.28**	0.14–0.67	**0.28**	0.14–0.65	**0.28**	0.14–0.64	**0.28**	0.14–0.64
Campbell black-browed albatross	**0.19**	0.08–0.44	**0.28**	0.13–0.62	**0.3**	0.15–0.64	**0.29**	0.15–0.59	**0.29**	0.15–0.58	**0.29**	0.15–0.61	**0.31**	0.16–0.63
Southern royal albatross	**0.27**	0.16–0.43	**0.29**	0.18–0.46	**0.31**	0.20–0.48	**0.33**	0.21–0.51	**0.38**	0.24–0.58	**0.1**	0.05–0.20	**0.1**	0.05–0.20
Northern giant petrel	**0.22**	0.06–0.85	**0.31**	0.06–1.47	**0.22**	0.05–1.06	**0.22**	0.05–0.96	**0.21**	0.05–1.03	**0.21**	0.04–1.04	**0.22**	0.05–0.96
Spotted shag	**0.21**	0.09–0.48	**0.31**	0.16–0.58	**0.26**	0.13–0.45	**0.22**	0.12–0.39	**0.21**	0.11–0.38	**0.18**	0.10–0.31	**0.18**	0.10–0.32
Grey petrel	**0.12**	0.05–0.27	**0.16**	0.08–0.33	**0.14**	0.07–0.29	**0.14**	0.07–0.29	**0.1**	0.05–0.20	**0.09**	0.05–0.19	**0.08**	0.04–0.17
Stewart Island shag	**0.04**	0.01–0.11	0.04	0.01–0.10	0.03	0.01–0.09	0.03	0.01–0.08	0.01	0.00–0.04	**0.3**	0.18–0.49	**0.3**	0.19–0.49
Little black shag	**0.07**	0.03–0.15	**0.14**	0.07–0.33	**0.11**	0.06–0.21	**0.11**	0.05–0.20	**0.12**	0.05–0.23	**0.04**	0.00–0.12	**0.04**	0.01–0.13
Pied shag	**0.06**	0.01–0.20	**0.15**	0.04–0.45	**0.13**	0.04–0.39	**0.12**	0.03–0.34	0.04	0.01–0.10	0.03	0.01–0.10	0.03	0.01–0.10
Yellow-eyed penguin	**0.07**	0.03–0.12	**0.09**	0.04–0.18	**0.08**	0.04–0.17	**0.08**	0.04–0.18	**0.08**	0.04–0.17	**0.08**	0.03–0.18	**0.08**	0.03–0.21
Chatham petrel	0.02	0.00–0.10	**0.02**	0.00–0.12	**0.02**	0.00–0.10	**0.03**	0.00–0.19	**0.03**	0.00–0.19	**0.07**	0.00–0.32	**0.07**	0.00–0.32
Light-mantled sooty albatross	0.02	0.01–0.09	**0.02**	0.00–0.17	**0.04**	0.01–0.19	**0.04**	0.01–0.18	**0.04**	0.01–0.19	**0.03**	0.01–0.17	**0.03**	0.01–0.17
NZ king shag	**0.04**	0.00–0.24	**0.04**	0.00–0.31	**0.04**	0.00–0.34	**0.03**	0.00–0.25	**0.02**	0.00–0.11	**0**	0.00–0.11	**0**	0.00–0.11
Grey-headed albatross	0.01	0.00–0.07	**0.02**	0.00–0.20	**0.01**	0.00–0.13	**0.01**	0.00–0.15	**0.01**	0.00–0.13	**0.01**	0.00–0.13	**0.01**	0.00–0.12
Fiordland crested penguin	0.01	0.00–0.04	0.01	0.00–0.06	0.01	0.00–0.06	0.01	0.00–0.10	**0.01**	0.00–0.12	**0.01**	0.00–0.16	**0.02**	0.00–0.24
Australasian gannet	0.01	0.00–0.07	0.02	0.00–0.08	0.01	0.00–0.06	0.01	0.00–0.05	0.01	0.00–0.06	0.01	0.00–0.06	0.01	0.00–0.06
Soft-plumaged petrel	0.01	0.00–0.05	0.01	0.00–0.05	0.01	0.00–0.05	0.01	0.00–0.05	0.01	0.00–0.04	0.01	0.00–0.04	0.01	0.00–0.04
Kermadec storm petrel	**0.06**	0.02–0.18	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Grey-faced petrel	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Fluttering shearwater	0	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.05	0.01	0.00–0.05
Cook's petrel	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Sooty shearwater	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Pycroft's petrel	0.01	0.00–0.02	0.01	0.00–0.03	0.01	0.00–0.02	0.01	0.00–0.03	0.01	0.00–0.02	0.01	0.00–0.03	0.01	0.00–0.03
Northern little penguin	0.01	0.00–0.02	0.01	0.00–0.03	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0	0.00–0.02	0.01	0.00–0.02
White-flippered little penguin	0	0.00–0.01	0	0.00–0.02	0	0.00–0.01	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02
Mottled petrel	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Hutton's shearwater	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Southern little penguin	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
White-headed petrel	0	0.00–0.00	0	0.00–0.01	0	0.00–0.00	0	0.00–0.01	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Snares crested penguin	0	0.00–0.00	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Common diving petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Black-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Chatham Island little penguin	0	0.00–0.01	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02
Buller's shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
NZ white-faced storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Southern black-backed gull	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Little shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Pitt Island shag	0	0.00–0.06	**0**	0.00–0.12	**0**	0.00–0.13	**0**	0.00–0.12	0	0.00–0.05	0	0.00–0.04	0	0.00–0.04
Eastern rockhopper penguin	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Fairy prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Antarctic prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Kermadec petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Broad-billed prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Erect-crested penguin	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Auckland Island shag	0	0.00–0.00	0	0.00–0.01	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.01	0	0.00–0.01
Bounty Island shag	0	0.00–0.02	0	0.00–0.03	0	0.00–0.03	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Subantarctic skua	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.00	0	0.00–0.00
Caspian tern	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Chatham Island shag	0	0.00–0.08	**0**	0.00–0.12	**0**	0.00–0.12	**0**	0.00–0.14	0	0.00–0.05	0	0.00–0.04	0	0.00–0.04
Campbell Island shag	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White tern	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
South Georgian diving petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Masked booby	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
NZ storm petrel	**0**	0.00–0.12	**0**	0.00–0.12	**0**	0.00–0.11	**0**	0.00–0.16	**0**	0.00–0.13	0	0.00–0.10	**0**	0.00–0.29
Chatham Island taiko	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	**0**	0.00–0.40	**0**	0.00–0.36
Wedge-tailed shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White-naped petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00

A.4 Comparison with previous assessment

Table A-6: Comparison of the Potential Biological Removal (PBR_ρ) between the previous assessment (Richard & Abraham (2013c), after error correction) and the current, updated study for the same studied species. Species names were coloured according to the associated risk categories as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Numbers were rounded to three significant digits.

Species	Before updates		After updates	
	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	219	118–342	181	98–281
Antipodean albatross	258	185–360	136	98–187
Southern royal albatross	385	279–524	387	280–530
Northern royal albatross	259	133–419	259	134–423
Campbell black-browed albatross	675	430–939	673	437–937
NZ white-capped albatross	2 660	685–5 480	4 040	2 620–6 320
Salvin's albatross	749	440–1 230	1 020	638–1 650
Chatham Island albatross	139	86–224	139	85–228
Grey-headed albatross	219	131–324	221	130–328
Southern Buller's albatross	449	245–701	449	246–701
Northern Buller's albatross	540	295–839	540	296–845
Light-mantled sooty albatross	235	169–315	236	167–315
Northern giant petrel	166	56–358	164	57–352
Grey petrel	1 540	881–2 320	2 150	1 220–3 200
Black petrel	65	42–99	100	60–147
Westland petrel	184	124–252	157	89–234
White-chinned petrel	5 180	2 720–8 180	5 200	2 670–8 170
Flesh-footed shearwater	493	247–943	514	233–1 140
Wedge-tailed shearwater	3 890	2 590–5 380	3 900	2 580–5 460
Buller's shearwater	9 640	4 520–19 100	9 730	4 580–19 400
Sooty shearwater	230 000	92 800–412 000	230 000	93 500–410 000
Fluttering shearwater	1 800	1 030–2 810	1 800	1 040–2 850
Hutton's shearwater	4 860	3 040–6 990	4 880	3 060–7 040
Little shearwater	5 690	3 680–7 990	5 700	3 690–8 100
Snares Cape petrel	554	227–1 090	564	231–1 110
Fairy prion	85 100	53 500–132 000	85 000	53 700–133 000
Antarctic prion	14 000	7 740–24 400	13 900	7 940–24 200
Broad-billed prion	70 200	40 800–111 000	69 800	41 000–110 000
Pycroft's petrel	93	44–206	93	43–208
Cook's petrel	2 250	1 070–4 910	2 250	1 070–4 960
Chatham petrel	9	4–19	9	4–19
Mottled petrel	13 800	6 600–30 900	13 800	6 370–29 800
White-naped petrel	1 970	858–4 460	2 000	863–4 590
Kermadec petrel	299	138–703	298	140–666
Grey-faced petrel	12 000	5 790–26 700	11 900	5 540–26 300
Chatham Island taiko	1	0–2	1	0–2
White-headed petrel	12 400	5 480–25 900	12 300	5 390–25 300
Soft-plumaged petrel	60	25–135	60	25–133
Common diving petrel	26 600	17 200–38 500	26 600	17 300–38 900
South Georgian diving petrel	3	2–4	3	2–4
NZ white-faced storm petrel	55 600	33 000–91 000	55 900	32 400–92 400
White-bellied storm petrel	44	24–76	44	24–74
Black-bellied storm petrel	3 440	2 130–5 610	3 440	2 150–5 560
Kermadec storm petrel	2	1–3	2	1–3
NZ storm petrel	2	1–4	2	1–4
Yellow-eyed penguin	464	321–654	465	321–659
Northern little penguin	1 020	796–1 320	1 020	799–1 310
White-flippered little penguin	321	227–423	324	231–426
Southern little penguin	1 030	793–1 330	1 020	793–1 310
Chatham Island little penguin	1 030	799–1 320	1 020	794–1 310
Eastern rockhopper penguin	6 380	5 240–7 950	6 400	5 280–7 880
Fiordland crested penguin	324	213–433	322	210–427
Snares crested penguin	3 190	2 060–4 270	3 220	2 090–4 280
Erect-crested penguin	12 100	9 920–15 000	12 100	9 990–14 900
Australasian gannet	2 760	1 210–5 700	2 730	1 210–5 450
Masked booby	35	23–52	35	23–51
Pied shag	92	67–123	830	671–1 010
Little black shag	91	62–146	215	123–366
NZ king shag	15	12–18	15	12–18
Stewart Island shag	258	211–317	301	244–369
Chatham Island shag	45	36–56	45	35–56
Bounty Island shag	13	10–17	13	10–17
Auckland Island shag	163	122–216	163	122–216
Campbell Island shag	196	129–261	196	128–261
Spotted shag	2 390	1 590–3 870	2 400	1 580–3 890
Pitt Island shag	65	42–87	66	43–89
Subantarctic skua	30	19–44	30	19–44
Southern black-backed gull	198 000	129 000–293 000	197 000	129 000–294 000
Caspian tern	135	79–201	135	79–201
White tern	15	12–19	15	12–19

Table A-7: Comparison of the total number of annual potential fatalities in trawl and longline fisheries between the previous assessment (Richard & Abraham (2013c), after error correction) and the current, updated study for the same studied species. Values were rounded to two significant digits. Species names were coloured according to the associated risk categories as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Numbers were rounded to three significant digits.

Species	Before updates		After updates	
	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	120	86–167	223	161–303
Antipodean albatross	85	61–120	123	86–175
Southern royal albatross	112	79–156	39	20–71
Northern royal albatross	111	72–180	52	20–120
Campbell black-browed albatross	199	94–364	214	121–362
NZ white-capped albatross	4 750	2 930–7 280	4 420	2 800–6 620
Salvin's albatross	4 700	2 960–7 380	3 480	2 250–5 200
Chatham Island albatross	211	122–333	128	70–226
Grey-headed albatross	8	0–41	5	0–24
Southern Buller's albatross	778	502–1 200	812	557–1 190
Northern Buller's albatross	449	316–623	549	410–727
Light-mantled sooty albatross	9	0–39	11	1–39
Northern giant petrel	54	12–146	37	9–98
Grey petrel	244	153–389	178	109–279
Black petrel	1 430	1 060–1 890	1 130	840–1 490
Westland petrel	64	27–143	88	37–183
White-chinned petrel	1 580	985–2 780	1 450	916–2 560
Flesh-footed shearwater	768	519–1 140	696	473–991
Wedge-tailed shearwater	0	0–0	0	0–0
Buller's shearwater	8	1–26	10	1–34
Sooty shearwater	1 830	989–3 610	1 350	738–2 600
Fluttering shearwater	12	3–33	25	3–89
Hutton's shearwater	14	4–36	18	5–50
Little shearwater	3	0–10	2	0–8
Snares Cape petrel	219	123–364	50	26–89
Fairy prion	30	6–94	41	10–123
Antarctic prion	3	1–9	3	0–7
Broad-billed prion	10	2–34	14	2–66
Pycroft's petrel	1	0–2	1	0–2
Cook's petrel	17	7–33	16	6–33
Chatham petrel	0	0–1	1	0–2
Mottled petrel	45	18–85	46	18–91
White-naped petrel	0	0–0	0	0–0
Kermadec petrel	0	0–1	0	0–1
Grey-faced petrel	104	46–194	101	43–187
Chatham Island taiko	0	0–0	0	0–0
White-headed petrel	24	9–45	14	5–27
Soft-plumaged petrel	1	0–2	0	0–1
Common diving petrel	25	6–73	34	9–102
South Georgian diving petrel	0	0–0	0	0–0
NZ white-faced storm petrel	40	8–118	51	8–219
White-bellied storm petrel	0	0–0	0	0–0
Black-bellied storm petrel	4	1–10	2	0–7
Kermadec storm petrel	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0
Yellow-eyed penguin	42	20–74	44	17–91
Northern little penguin	9	1–28	7	1–21
White-flippered little penguin	2	0–5	1	0–5
Southern little penguin	3	0–11	3	0–11
Chatham Island little penguin	3	0–17	2	0–18
Eastern rockhopper penguin	3	0–10	3	0–12
Fiordland crested penguin	5	1–20	12	0–73
Snares crested penguin	7	1–24	4	0–20
Erect-crested penguin	2	0–6	1	0–3
Australasian gannet	52	4–167	41	3–129
Masked booby	0	0–0	0	0–0
Pied shag	15	4–39	31	5–78
Little black shag	14	7–28	9	1–23
NZ king shag	1	0–5	0	0–2
Stewart Island shag	11	3–24	91	58–139
Chatham Island shag	1	0–5	0	0–2
Bounty Island shag	0	0–0	0	0–0
Auckland Island shag	0	0–1	0	0–1
Campbell Island shag	0	0–0	0	0–0
Spotted shag	738	473–1 150	425	285–628
Pitt Island shag	1	0–8	0	0–3
Subantarctic skua	0	0–0	0	0–0
Southern black-backed gull	95	23–233	94	27–215
Caspian tern	0	0–0	0	0–0
White tern	0	0–0	0	0–0

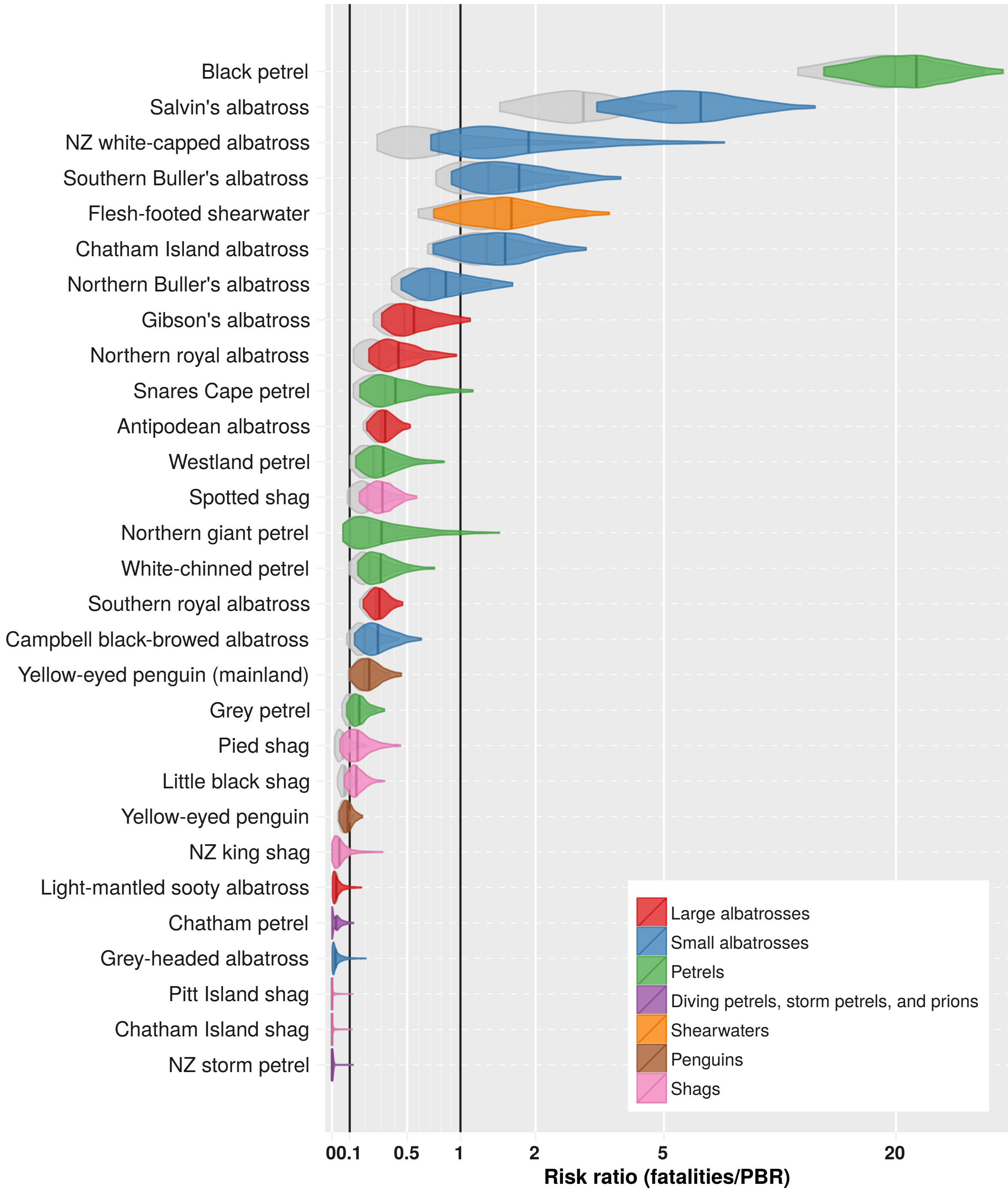
Table A-8: Comparison of the risk ratio between the previous assessment (Richard & Abraham (2013c), after error correction) and the current, updated study for the same studied species. Changes are indicated by "+" or "−" symbols for an increase or decrease in the current risk ratio, with changes only indicated if both mean values were outside the other assessment's credible intervals (although only medians are shown here). Cells were coloured according to the associated risk categories as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

Species	Before updates		After updates		Change
	Median	95% c.i.	Median	95% c.i.	
Gibson's albatross	**0.56**	0.31–1.11	**1.26**	0.69–2.48	+
Antipodean albatross	**0.33**	0.21–0.52	**0.89**	0.56–1.47	+
Southern royal albatross	**0.29**	0.18–0.46	**0.10**	0.05–0.20	−
Northern royal albatross	**0.43**	0.22–0.96	**0.19**	0.07–0.59	
Campbell black-browed albatross	**0.28**	0.13–0.62	**0.31**	0.16–0.63	
NZ white-capped albatross	**1.89**	0.70–7.32	**1.10**	0.59–1.97	
Salvin's albatross	**6.32**	3.18–12.57	**3.44**	1.82–6.50	
Chatham Island albatross	**1.55**	0.73–2.94	**0.91**	0.42–1.90	
Grey-headed albatross	**0.02**	0.00–0.20	**0.01**	0.00–0.12	
Southern Buller's albatross	**1.74**	0.91–3.75	**1.82**	0.97–3.67	
Northern Buller's albatross	**0.85**	0.45–1.65	**1.02**	0.58–2.00	
Light-mantled sooty albatross	**0.02**	0.00–0.17	**0.03**	0.00–0.17	
Northern giant petrel	**0.31**	0.06–1.47	**0.22**	0.05–0.96	
Grey petrel	**0.16**	0.08–0.33	**0.08**	0.04–0.17	
Black petrel	**22.46**	13.23–36.44	**11.34**	6.85–19.81	−
Westland petrel	**0.32**	0.14–0.83	**0.53**	0.21–1.38	
White-chinned petrel	**0.30**	0.15–0.74	**0.28**	0.14–0.64	
Flesh-footed shearwater	**1.63**	0.73–3.47	**1.50**	0.56–3.36	
Wedge-tailed shearwater	0.00	0.00–0.00	0.00	0.00–0.00	
Buller's shearwater	0.00	0.00–0.00	0.00	0.00–0.00	
Sooty shearwater	0.01	0.00–0.02	0.01	0.00–0.02	
Fluttering shearwater	0.01	0.00–0.02	0.01	0.00–0.06	
Hutton's shearwater	0.00	0.00–0.01	0.00	0.00–0.01	
Little shearwater	0.00	0.00–0.00	0.00	0.00–0.00	
Snares Cape petrel	**0.41**	0.16–1.14	**0.09**	0.04–0.25	−
Fairy prion	0.00	0.00–0.00	0.00	0.00–0.00	
Antarctic prion	0.00	0.00–0.00	0.00	0.00–0.00	
Broad-billed prion	0.00	0.00–0.00	0.00	0.00–0.00	
Pycroft's petrel	0.01	0.00–0.03	0.01	0.00–0.03	
Cook's petrel	0.01	0.00–0.02	0.01	0.00–0.02	
Chatham petrel	**0.02**	0.00–0.12	**0.07**	0.00–0.32	
Mottled petrel	0.00	0.00–0.01	0.00	0.00–0.01	
White-naped petrel	0.00	0.00–0.00	0.00	0.00–0.00	
Kermadec petrel	0.00	0.00–0.00	0.00	0.00–0.00	
Grey-faced petrel	0.01	0.00–0.02	0.01	0.00–0.02	
Chatham Island taiko	0.00	0.00–0.00	**0.00**	0.00–0.36	
White-headed petrel	0.00	0.00–0.00	0.00	0.00–0.00	
Soft-plumaged petrel	0.02	0.00–0.05	0.01	0.00–0.04	
Common diving petrel	0.00	0.00–0.00	0.00	0.00–0.00	
South Georgian diving petrel	0.00	0.00–0.00	0.00	0.00–0.00	
NZ white-faced storm petrel	0.00	0.00–0.00	0.00	0.00–0.00	
White-bellied storm petrel	0.00	0.00–0.00	0.00	0.00–0.00	
Black-bellied storm petrel	0.00	0.00–0.00	0.00	0.00–0.00	
Kermadec storm petrel	0.00	0.00–0.00	0.00	0.00–0.00	
NZ storm petrel	**0.00**	0.00–0.12	**0.00**	0.00–0.29	
Yellow-eyed penguin	**0.09**	0.04–0.18	**0.08**	0.03–0.21	
Northern little penguin	0.01	0.00–0.03	0.00	0.00–0.02	
White-flippered little penguin	0.00	0.00–0.02	0.00	0.00–0.02	
Southern little penguin	0.00	0.00–0.01	0.00	0.00–0.01	
Chatham Island little penguin	0.00	0.00–0.02	0.00	0.00–0.02	
Eastern rockhopper penguin	0.00	0.00–0.00	0.00	0.00–0.00	
Fiordland crested penguin	0.01	0.00–0.06	**0.02**	0.00–0.24	
Snares crested penguin	0.00	0.00–0.01	0.00	0.00–0.01	
Erect-crested penguin	0.00	0.00–0.00	0.00	0.00–0.00	
Australasian gannet	0.02	0.00–0.08	0.01	0.00–0.06	
Masked booby	0.00	0.00–0.01	0.00	0.00–0.01	
Pied shag	**0.15**	0.04–0.45	0.03	0.01–0.10	−
Little black shag	**0.14**	0.07–0.33	**0.04**	0.00–0.13	−
NZ king shag	**0.04**	0.00–0.31	**0.00**	0.00–0.11	
Stewart Island shag	0.04	0.01–0.10	**0.30**	0.19–0.48	+
Chatham Island shag	**0.00**	0.00–0.12	0.00	0.00–0.04	
Bounty Island shag	0.00	0.00–0.03	0.00	0.00–0.00	
Auckland Island shag	0.00	0.00–0.00	0.00	0.00–0.01	
Campbell Island shag	0.00	0.00–0.00	0.00	0.00–0.00	
Spotted shag	**0.31**	0.16–0.58	**0.18**	0.10–0.32	
Pitt Island shag	**0.00**	0.00–0.12	0.00	0.00–0.04	
Subantarctic skua	0.00	0.00–0.01	0.00	0.00–0.00	
Southern black-backed gull	0.00	0.00–0.00	0.00	0.00–0.00	
Caspian tern	0.00	0.00–0.00	0.00	0.00–0.00	
White tern	0.00	0.00–0.00	0.00	0.00–0.00	

Table A-9: Comparison of risk ratios re-calculated on data from 2006–07 to 2010–11, before and after correcting errors in Richard & Abraham (2013c). Presented are mean values as median values were not available from Richard & Abraham (2013c). Changes are indicated by "+" or "−" symbols for an increase or decrease in the current risk ratio, with changes only indicated if both mean values were outside the other assessment's credible intervals. Cells were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

Species	Before corrections		After corrections		Change
	Median	95% c.i.	Median	95% c.i.	
Black petrel	**19.89**	11.38–32.85	**22.46**	13.23–36.44	
Salvin's albatross	**2.88**	1.47–5.41	**6.32**	3.18–12.57	+
Southern Buller's albatross	**1.32**	0.75–2.58	**1.74**	0.91–3.75	
Flesh-footed shearwater	**1.41**	0.59–2.94	**1.63**	0.73–3.47	
Chatham Island albatross	**1.3**	0.68–2.59	**1.55**	0.73–2.94	
NZ white-capped albatross	**0.78**	0.28–3.13	**1.89**	0.71–7.32	
Northern Buller's albatross	**0.69**	0.38–1.36	**0.85**	0.45–1.65	
Gibson's albatross	**0.48**	0.25–1.00	**0.56**	0.31–1.11	
Antipodean albatross	**0.3**	0.18–0.49	**0.33**	0.21–0.52	
Westland petrel	**0.25**	0.10–0.66	**0.32**	0.14–0.83	
Northern royal albatross	**0.29**	0.12–0.70	**0.43**	0.22–0.96	
Snares Cape petrel	**0.33**	0.12–0.93	**0.41**	0.16–1.14	
White-chinned petrel	**0.22**	0.10–0.53	**0.3**	0.15–0.74	
Campbell black-browed albatross	**0.19**	0.08–0.44	**0.28**	0.13–0.62	
Southern royal albatross	**0.27**	0.16–0.43	**0.29**	0.18–0.46	
Northern giant petrel	**0.22**	0.06–0.85	**0.31**	0.06–1.47	
Spotted shag	**0.21**	0.09–0.48	**0.31**	0.16–0.58	
Grey petrel	**0.12**	0.05–0.27	**0.16**	0.08–0.33	
Stewart Island shag	**0.04**	0.01–0.11	0.04	0.01–0.10	
Little black shag	**0.07**	0.03–0.15	**0.14**	0.07–0.33	
Pied shag	**0.06**	0.01–0.20	**0.15**	0.04–0.45	
Yellow-eyed penguin	**0.07**	0.03–0.12	**0.09**	0.04–0.18	
Chatham petrel	0.02	0.00–0.10	**0.02**	0.00–0.12	
Light-mantled sooty albatross	0.02	0.01–0.09	**0.02**	0.00–0.17	
NZ king shag	**0.04**	0.00–0.24	**0.04**	0.00–0.31	
Grey-headed albatross	0.01	0.00–0.07	**0.02**	0.00–0.20	
Fiordland crested penguin	0.01	0.00–0.04	0.01	0.00–0.06	
Australasian gannet	0.01	0.00–0.07	0.02	0.00–0.08	
Soft-plumaged petrel	0.01	0.00–0.05	0.01	0.00–0.05	
Kermadec storm petrel	**0.06**	0.02–0.18	0	0.00–0.00	−
Grey-faced petrel	0.01	0.00–0.02	0.01	0.00–0.02	
Fluttering shearwater	0	0.00–0.02	0.01	0.00–0.02	
Cook's petrel	0.01	0.00–0.02	0.01	0.00–0.02	
Sooty shearwater	0.01	0.00–0.02	0.01	0.00–0.02	
Pycroft's petrel	0.01	0.00–0.02	0.01	0.00–0.03	
Northern little penguin	0.01	0.00–0.02	0.01	0.00–0.03	
White-flippered little penguin	0	0.00–0.01	0	0.00–0.02	
Mottled petrel	0	0.00–0.01	0	0.00–0.01	
Hutton's shearwater	0	0.00–0.01	0	0.00–0.01	
Southern little penguin	0	0.00–0.01	0	0.00–0.01	
White-headed petrel	0	0.00–0.00	0	0.00–0.01	
Snares crested penguin	0	0.00–0.00	0	0.00–0.01	
Common diving petrel	0	0.00–0.00	0	0.00–0.00	
Black-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	
Chatham Island little penguin	0	0.00–0.01	0	0.00–0.02	
Buller's shearwater	0	0.00–0.00	0	0.00–0.00	
NZ white-faced storm petrel	0	0.00–0.00	0	0.00–0.00	
Southern black-backed gull	0	0.00–0.00	0	0.00–0.00	
Little shearwater	0	0.00–0.00	0	0.00–0.00	
Pitt Island shag	0	0.00–0.06	**0**	0.00–0.12	
Eastern rockhopper penguin	0	0.00–0.00	0	0.00–0.00	
Fairy prion	0	0.00–0.00	0	0.00–0.00	
Antarctic prion	0	0.00–0.00	0	0.00–0.00	
Kermadec petrel	0	0.00–0.00	0	0.00–0.00	
Broad-billed prion	0	0.00–0.00	0	0.00–0.00	
Erect-crested penguin	0	0.00–0.00	0	0.00–0.00	
Auckland Island shag	0	0.00–0.00	0	0.00–0.01	
Bounty Island shag	0	0.00–0.02	0	0.00–0.03	
Subantarctic skua	0	0.00–0.01	0	0.00–0.01	
Caspian tern	0	0.00–0.00	0	0.00–0.00	
Chatham Island shag	0	0.00–0.08	**0**	0.00–0.12	
Campbell Island shag	0	0.00–0.00	0	0.00–0.00	
White-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	
White tern	0	0.00–0.00	0	0.00–0.00	
South Georgian diving petrel	0	0.00–0.00	0	0.00–0.00	
Masked booby	0	0.00–0.01	0	0.00–0.01	
NZ storm petrel	**0**	0.00–0.12	**0**	0.00–0.12	
Chatham Island taiko	0	0.00–0.00	0	0.00–0.00	
Wedge-tailed shearwater	0	0.00–0.00	0	0.00–0.00	
White-naped petrel	0	0.00–0.00	0	0.00–0.00	

Figure A-1: Risk ratio re-calculated with data from 2006–07 to 2010–11, after correcting errors in Richard & Abraham (2013c). The risk ratio is displayed on a logarithmic scale, with the threshold of the number of potential bird fatalities equaling PBR$_\rho$ with $f = 0.1$ and $f = 1$ indicated by the two vertical black lines, and the distribution of the corrected risk ratios within their 95% credible interval indicated by the coloured shapes, including the median risk ratio (vertical line). Grey shapes indicate the risk ratios from the previous risk assessment report (Richard & Abraham 2013c). Seabird species are listed in decreasing order of the median risk ratio. Species with a risk ratio of almost zero were not included (95% upper limit with $f = 1$ less than 0.1). The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800.



A.5 Annual potential fatalities by target fisheries

Table A-10: Estimated number of annual potential fatalities (APF) in different trawl fisheries. The definition of the target fisheries followed Richard & Abraham (2013b); SBW, southern blue whiting. Cells were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Numbers were rounded to three significant digits. Fisheries are sorted by decreasing order of the mean total APF.

Species	Inshore trawl		Squid trawl		Hoki trawl		Scampi trawl	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	5	0–31	2	0–7	7	1–17	2	0–12
Antipodean albatross	4	0–22	1	0–3	6	1–14	2	0–9
Southern royal albatross	3	0–19	9	3–20	3	0–7	2	0–9
Northern royal albatross	7	0–42	6	2–15	5	1–15	3	0–16
Campbell black-browed albatross	6	0–33	2	0–8	17	6–36	10	0–39
NZ white-capped albatross	2 110	1 180–3 440	732	478–1 070	368	231–556	149	69–270
Salvin's albatross	1 750	963–2 880	25	10–48	330	209–497	320	171–540
Chatham Island albatross	3	0–22	1	0–3	5	0–16	5	0–23
Grey-headed albatross	0	0–3	0	0–2	0	0–2	0	0–2
Southern Buller's albatross	46	4–147	179	110–271	272	171–420	17	6–36
Northern Buller's albatross	24	2–78	1	0–2	73	44–113	57	18–126
Light-mantled sooty albatross	1	0–11	2	0–7	1	0–5	1	0–6
Northern giant petrel	5	0–33	1	0–5	9	1–24	10	0–41
Grey petrel	5	0–25	1	0–4	3	0–9	2	0–8
Black petrel	36	3–128	0	0–1	1	0–5	5	0–18
Westland petrel	6	0–35	0	0–1	14	5–32	1	0–6
White-chinned petrel	12	0–57	580	320–1 110	123	62–247	341	181–675
Flesh-footed shearwater	58	6–186	0	0–2	5	0–15	103	47–213
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0	0	0–0
Buller's shearwater	0	0–2	0	0–0	0	0–1	0	0–1
Sooty shearwater	333	121–755	359	186–714	144	78–278	164	79–338
Fluttering shearwater	1	0–6	0	0–0	0	0–0	0	0–2
Hutton's shearwater	0	0–3	0	0–0	0	0–2	0	0–0
Little shearwater	0	0–1	0	0–0	0	0–0	0	0–0
Snares Cape petrel	1	0–6	0	0–2	3	0–8	0	0–2
Fairy prion	7	0–38	1	1–3	3	0–8	0	0–2
Antarctic prion	0	0–1	1	0–5	0	0–1	0	0–1
Broad-billed prion	1	0–3	0	0–2	1	0–4	1	0–3
Pycroft's petrel	0	0–0	0	0–0	0	0–0	0	0–0
Cook's petrel	0	0–1	0	0–0	0	0–0	0	0–0
Chatham petrel	0	0–0	0	0–0	0	0–0	0	0–0
Mottled petrel	0	0–2	0	0–1	0	0–1	0	0–0
White-naped petrel	0	0–0	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–0	0	0–0	0	0–0
Grey-faced petrel	0	0–3	0	0–0	0	0–1	0	0–1
Chatham Island taiko	0	0–0	0	0–0	0	0–0	0	0–0
White-headed petrel	0	0–0	0	0–0	0	0–0	0	0–0
Soft-plumaged petrel	0	0–0	0	0–0	0	0–0	0	0–0
Common diving petrel	7	0–32	0	0–2	3	0–8	2	0–8
South Georgian diving petrel	0	0–0	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	2	0–15	0	0–1	2	0–8	2	0–9
White-bellied storm petrel	0	0–0	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	0	0–2	0	0–1	0	0–1	0	0–0
Kermadec storm petrel	0	0–0	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0	0	0–0	0	0–0
Yellow-eyed penguin	0	0–3	0	0–0	0	0–0	0	0–0
Northern little penguin	0	0–1	0	0–0	0	0–0	0	0–0
White-flippered little penguin	0	0–1	0	0–0	0	0–0	0	0–0
Southern little penguin	0	0–1	0	0–0	0	0–0	0	0–0
Chatham Island little penguin	0	0–0	0	0–0	0	0–0	0	0–0
Eastern rockhopper penguin	0	0–0	0	0–0	0	0–0	0	0–0
Fiordland crested penguin	0	0–0	0	0–0	0	0–0	0	0–0
Snares crested penguin	0	0–0	0	0–0	0	0–0	0	0–0
Erect-crested penguin	0	0–0	0	0–0	0	0–0	0	0–1
Australasian gannet	1	0–7	0	0–0	0	0–1	0	0–2
Masked booby	0	0–0	0	0–0	0	0–0	0	0–0
Pied shag	1	0–8	0	0–0	0	0–1	0	0–0
Little black shag	0	0–2	0	0–0	0	0–0	0	0–0
NZ king shag	0	0–0	0	0–0	0	0–0	0	0–0
Stewart Island shag	0	0–2	0	0–0	0	0–0	0	0–0
Chatham Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Bounty Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–0	0	0–1	0	0–0	0	0–1
Campbell Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Spotted shag	6	0–26	0	0–0	2	0–7	0	0–0
Pitt Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0	0	0–0
Southern black-backed gull	9	0–50	0	0–1	1	0–8	0	0–3
Caspian tern	0	0–0	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0	0	0–0
Total	4 450	2 790–6 670	1 910	1 290–2 880	1 400	970–1 990	1 200	783–1 860

Continued on next page.

Table A-10: (*continued*)

Species	Middle depth trawl		Flatfish trawl		Ling trawl		Hake trawl	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	2	0–7	**3**	0–21	0	0–2	1	0–3
Antipodean albatross	2	0–7	**3**	0–17	0	0–1	0	0–1
Southern royal albatross	1	0–4	2	0–13	0	0–1	0	0–1
Northern royal albatross	3	0–10	**6**	0–38	0	0–1	0	0–1
Campbell black-browed albatross	5	1–14	6	0–37	1	0–3	1	0–3
NZ white-capped albatross	**405**	240–638	**240**	53–583	67	39–104	55	31–87
Salvin's albatross	**378**	227–590	**116**	16–332	46	27–71	27	15–43
Chatham Island albatross	3	0–11	2	0–12	0	0–1	0	0–0
Grey-headed albatross	0	0–1	0	0–2	0	0–0	0	0–0
Southern Buller's albatross	**69**	39–112	**41**	1–173	8	4–15	9	4–16
Northern Buller's albatross	23	12–39	3	0–11	0	0–1	0	0–1
Light-mantled sooty albatross	0	0–3	1	0–6	0	0–1	0	0–1
Northern giant petrel	3	0–9	**3**	0–20	0	0–2	1	0–2
Grey petrel	1	0–4	3	0–21	0	0–1	0	0–1
Black petrel	1	0–5	0	0–3	0	0–1	0	0–0
Westland petrel	2	0–7	**4**	0–28	0	0–1	2	0–5
White-chinned petrel	63	35–123	9	0–44	13	5–27	10	3–23
Flesh-footed shearwater	4	0–11	3	0–20	0	0–1	0	0–0
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0	0	0–0
Buller's shearwater	0	0–1	0	0–1	0	0–0	0	0–0
Sooty shearwater	144	72–291	42	4–147	23	10–47	8	2–17
Fluttering shearwater	0	0–0	0	0–0	0	0–0	0	0–0
Hutton's shearwater	0	0–1	0	0–1	0	0–0	0	0–0
Little shearwater	0	0–0	0	0–0	0	0–0	0	0–0
Snares Cape petrel	1	0–4	1	0–5	1	0–3	0	0–1
Fairy prion	2	0–9	5	0–33	0	0–1	0	0–0
Antarctic prion	0	0–0	0	0–1	0	0–0	0	0–0
Broad-billed prion	0	0–2	0	0–2	0	0–0	0	0–0
Pycroft's petrel	0	0–0	0	0–0	0	0–0	0	0–0
Cook's petrel	0	0–0	0	0–0	0	0–0	0	0–0
Chatham petrel	0	0–0	0	0–0	0	0–0	0	0–0
Mottled petrel	0	0–1	0	0–2	0	0–0	0	0–0
White-naped petrel	0	0–0	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–0	0	0–0	0	0–0
Grey-faced petrel	0	0–0	0	0–1	0	0–0	0	0–0
Chatham Island taiko	0	0–0	0	0–0	0	0–0	0	0–0
White-headed petrel	0	0–0	0	0–0	0	0–0	0	0–0
Soft-plumaged petrel	0	0–0	0	0–0	0	0–0	0	0–0
Common diving petrel	2	1–6	5	0–30	2	0–5	0	0–1
South Georgian diving petrel	0	0–0	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	2	0–9	1	0–5	0	0–0	0	0–0
White-bellied storm petrel	0	0–0	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	0	0–1	0	0–1	0	0–0	0	0–0
Kermadec storm petrel	0	0–0	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0	0	0–0	0	0–0
Yellow-eyed penguin	0	0–1	1	0–5	0	0–0	0	0–0
Northern little penguin	0	0–0	0	0–1	0	0–0	0	0–0
White-flippered little penguin	0	0–0	0	0–0	0	0–0	0	0–0
Southern little penguin	0	0–0	0	0–2	0	0–0	0	0–0
Chatham Island little penguin	0	0–0	0	0–0	0	0–0	0	0–0
Eastern rockhopper penguin	0	0–0	0	0–0	0	0–0	0	0–0
Fiordland crested penguin	0	0–0	0	0–0	0	0–0	0	0–0
Snares crested penguin	0	0–0	0	0–0	0	0–0	0	0–0
Erect-crested penguin	0	0–0	0	0–0	0	0–0	0	0–0
Australasian gannet	0	0–1	0	0–2	0	0–0	0	0–0
Masked booby	0	0–0	0	0–0	0	0–0	0	0–0
Pied shag	0	0–1	1	0–8	0	0–0	0	0–0
Little black shag	0	0–0	0	0–2	0	0–0	0	0–0
NZ king shag	0	0–0	0	0–0	0	0–0	0	0–0
Stewart Island shag	0	0–0	**88**	55–137	0	0–0	0	0–0
Chatham Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Bounty Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Campbell Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Spotted shag	1	0–4	**363**	233–552	0	0–0	0	0–0
Pitt Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0	0	0–0
Southern black-backed gull	1	0–4	21	1–91	0	0–0	0	0–0
Caspian tern	0	0–0	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0	0	0–0
Total	1 120	752–1 600	975	599–1 560	163	109–233	114	74–167

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Table A-10: (*continued*)

Species	Jack mackerel trawl		Deepwater trawl		SBW trawl	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	0	0–2	1	0–3	1	0–3
Antipodean albatross	0	0–1	1	0–4	1	0–5
Southern royal albatross	0	0–1	1	0–3	2	0–7
Northern royal albatross	0	0–3	1	0–4	0	0–1
Campbell black-browed albatross	0	0–2	0	0–2	5	1–15
NZ white-capped albatross	22	10–42	10	2–24	3	0–10
Salvin's albatross	2	0–8	34	15–62	22	9–43
Chatham Island albatross	0	0–1	**12**	3–26	0	0–1
Grey-headed albatross	0	0–0	0	0–0	0	0–1
Southern Buller's albatross	5	1–16	1	0–3	1	0–2
Northern Buller's albatross	0	0–1	3	0–9	0	0–0
Light-mantled sooty albatross	0	0–1	0	0–1	0	0–1
Northern giant petrel	0	0–2	2	0–6	1	0–4
Grey petrel	0	0–1	1	0–3	27	13–56
Black petrel	0	0–1	1	0–4	0	0–0
Westland petrel	1	0–3	0	0–2	0	0–0
White-chinned petrel	26	13–51	1	0–3	1	0–3
Flesh-footed shearwater	0	0–2	1	0–4	0	0–0
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0
Buller's shearwater	0	0–0	0	0–0	0	0–0
Sooty shearwater	14	6–29	6	2–16	1	0–3
Fluttering shearwater	0	0–0	0	0–0	0	0–0
Hutton's shearwater	0	0–0	0	0–1	0	0–0
Little shearwater	0	0–0	0	0–0	0	0–0
Snares Cape petrel	0	0–1	0	0–1	0	0–1
Fairy prion	1	0–4	0	0–0	0	0–1
Antarctic prion	0	0–0	0	0–0	0	0–0
Broad-billed prion	0	0–0	0	0–1	0	0–1
Pycroft's petrel	0	0–0	0	0–0	0	0–0
Cook's petrel	0	0–0	0	0–0	0	0–0
Chatham petrel	0	0–0	0	0–0	0	0–0
Mottled petrel	0	0–0	0	0–0	0	0–0
White-naped petrel	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–0	0	0–0
Grey-faced petrel	0	0–0	0	0–0	0	0–0
Chatham Island taiko	0	0–0	0	0–0	0	0–0
White-headed petrel	0	0–0	0	0–0	0	0–0
Soft-plumaged petrel	0	0–0	0	0–0	0	0–0
Common diving petrel	2	0–5	1	0–3	0	0–1
South Georgian diving petrel	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	1	0–2	1	0–4	0	0–0
White-bellied storm petrel	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	0	0–0	0	0–0	0	0–1
Kermadec storm petrel	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0	0	0–0
Yellow-eyed penguin	0	0–0	0	0–0	0	0–0
Northern little penguin	0	0–0	0	0–0	0	0–0
White-flippered little penguin	0	0–0	0	0–0	0	0–0
Southern little penguin	0	0–0	0	0–0	0	0–0
Chatham Island little penguin	0	0–0	0	0–0	0	0–0
Eastern rockhopper penguin	0	0–0	0	0–0	0	0–0
Fiordland crested penguin	0	0–0	0	0–0	0	0–0
Snares crested penguin	0	0–0	0	0–0	0	0–0
Erect-crested penguin	0	0–0	0	0–0	0	0–0
Australasian gannet	0	0–0	0	0–0	0	0–0
Masked booby	0	0–0	0	0–0	0	0–0
Pied shag	0	0–0	0	0–0	0	0–0
Little black shag	0	0–0	0	0–0	0	0–0
NZ king shag	0	0–0	0	0–0	0	0–0
Stewart Island shag	0	0–0	0	0–0	0	0–0
Chatham Island shag	0	0–0	0	0–0	0	0–0
Bounty Island shag	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–0	0	0–0	0	0–0
Campbell Island shag	0	0–0	0	0–0	0	0–0
Spotted shag	0	0–0	0	0–0	0	0–0
Pitt Island shag	0	0–0	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0
Southern black-backed gull	0	0–0	0	0–0	0	0–0
Caspian tern	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0
Total	77	47–123	76	44–121	65	39–106

Table A-11: Estimated number of annual potential fatalities (APF) in bottom-longline (BLL) fisheries. The definition of the target fisheries followed Richard & Abraham (2013b); Small/Large: vessels less than or over 34-m long. Cells were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Numbers were rounded to three significant digits. Fisheries are sorted by decreasing order of the mean total APF.

Species	Snapper BLL		Small ling BLL		Bluenose BLL	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	1	0–5	1	0–8	**6**	0–29
Antipodean albatross	0	0–2	1	0–7	**5**	0–25
Southern royal albatross	1	0–4	1	0–3	1	0–5
Northern royal albatross	0	0–3	2	0–11	1	0–10
Campbell black-browed albatross	2	0–16	6	0–39	**39**	4–119
NZ white-capped albatross	1	0–11	29	2–90	2	0–19
Salvin's albatross	4	0–25	**375**	226–561	6	0–41
Chatham Island albatross	1	0–8	**77**	38–130	2	0–12
Grey-headed albatross	0	0–2	1	0–5	0	0–4
Southern Buller's albatross	0	0–0	**40**	8–99	8	1–21
Northern Buller's albatross	3	0–20	**18**	3–45	**29**	6–76
Light-mantled sooty albatross	0	0–2	1	0–6	0	0–4
Northern giant petrel	0	0–1	0	0–3	0	0–2
Grey petrel	2	0–17	38	7–95	4	0–26
Black petrel	**318**	195–482	**8**	0–44	**434**	255–661
Westland petrel	1	0–10	**3**	0–20	**2**	0–17
White-chinned petrel	1	0–11	52	8–133	35	3–108
Flesh-footed shearwater	**374**	231–563	6	0–32	7	0–42
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0
Buller's shearwater	1	0–5	1	0–3	1	0–9
Sooty shearwater	3	0–19	6	0–31	3	0–19
Fluttering shearwater	1	0–5	0	0–2	1	0–8
Hutton's shearwater	0	0–3	2	0–9	0	0–4
Little shearwater	0	0–4	0	0–1	0	0–2
Snares Cape petrel	1	0–7	1	0–11	1	0–9
Fairy prion	0	0–2	1	0–5	0	0–2
Antarctic prion	0	0–0	0	0–0	0	0–0
Broad-billed prion	0	0–2	1	0–8	1	0–7
Pycroft's petrel	0	0–1	0	0–0	0	0–0
Cook's petrel	2	0–12	0	0–1	0	0–3
Chatham petrel	0	0–0	0	0–0	0	0–0
Mottled petrel	0	0–1	1	0–7	0	0–3
White-naped petrel	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–0	0	0–0
Grey-faced petrel	2	0–13	2	0–16	3	0–18
Chatham Island taiko	0	0–0	0	0–0	0	0–0
White-headed petrel	0	0–1	0	0–2	0	0–2
Soft-plumaged petrel	0	0–0	0	0–0	0	0–0
Common diving petrel	1	0–5	1	0–7	1	0–7
South Georgian diving petrel	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	0	0–3	3	0–30	1	0–11
White-bellied storm petrel	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	0	0–0	0	0–0	0	0–0
Kermadec storm petrel	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0	0	0–0
Yellow-eyed penguin	0	0–0	1	0–15	0	0–0
Northern little penguin	1	0–6	1	0–5	0	0–3
White-flippered little penguin	0	0–0	0	0–1	0	0–0
Southern little penguin	0	0–0	1	0–6	0	0–1
Chatham Island little penguin	0	0–0	0	0–2	0	0–3
Eastern rockhopper penguin	0	0–0	0	0–2	0	0–2
Fiordland crested penguin	0	0–0	**4**	0–35	0	0–4
Snares crested penguin	0	0–0	1	0–6	0	0–2
Erect-crested penguin	0	0–0	0	0–3	0	0–0
Australasian gannet	2	0–21	1	0–7	1	0–9
Masked booby	0	0–0	0	0–0	0	0–0
Pied shag	1	0–11	0	0–4	0	0–2
Little black shag	0	0–4	0	0–0	0	0–0
NZ king shag	0	0–0	0	0–0	0	0–0
Stewart Island shag	0	0–0	0	0–0	0	0–0
Chatham Island shag	0	0–0	0	0–0	0	0–0
Bounty Island shag	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–0	0	0–0	0	0–0
Campbell Island shag	0	0–0	0	0–0	0	0–0
Spotted shag	2	0–15	2	0–19	0	0–3
Pitt Island shag	0	0–0	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0
Southern black-backed gull	20	1–75	7	0–43	3	0–21
Caspian tern	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0
Total	746	523–1 010	694	477–964	602	388–872

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Table A-11: (*continued*)

Species	Hapuka BLL		Minor BLL		Large ling BLL	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	1	0–11	1	0–7	0	0–1
Antipodean albatross	**2**	0–13	1	0–5	0	0–1
Southern royal albatross	1	0–5	1	0–4	1	0–4
Northern royal albatross	3	0–23	1	0–9	4	0–11
Campbell black-browed albatross	**19**	0–72	14	1–52	1	0–5
NZ white-capped albatross	3	0–21	2	0–16	0	0–2
Salvin's albatross	6	0–36	5	0–26	5	1–14
Chatham Island albatross	**10**	0–66	**2**	0–15	3	0–11
Grey-headed albatross	1	0–5	0	0–4	0	0–1
Southern Buller's albatross	3	0–14	2	0–9	5	1–12
Northern Buller's albatross	**13**	0–66	3	0–14	3	0–8
Light-mantled sooty albatross	1	0–6	0	0–4	0	0–1
Northern giant petrel	1	0–7	0	0–2	0	0–1
Grey petrel	4	0–23	3	0–17	4	1–10
Black petrel	**156**	87–250	**84**	46–133	1	0–3
Westland petrel	**9**	0–38	**9**	0–39	0	0–3
White-chinned petrel	4	0–26	5	1–20	57	38–80
Flesh-footed shearwater	**34**	9–77	**44**	12–102	1	0–7
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0
Buller's shearwater	3	0–15	2	0–10	0	0–2
Sooty shearwater	21	1–75	18	1–66	31	16–53
Fluttering shearwater	0	0–2	19	0–81	0	0–0
Hutton's shearwater	2	0–10	6	0–27	0	0–1
Little shearwater	0	0–2	0	0–2	0	0–1
Snares Cape petrel	1	0–12	1	0–9	1	0–5
Fairy prion	3	0–22	5	0–45	0	0–1
Antarctic prion	0	0–0	0	0–0	0	0–0
Broad-billed prion	6	0–49	1	0–8	0	0–1
Pycroft's petrel	0	0–1	0	0–1	0	0–0
Cook's petrel	7	2–14	5	1–10	0	0–0
Chatham petrel	**1**	0–2	0	0–1	0	0–0
Mottled petrel	24	7–49	17	5–35	1	0–3
White-naped petrel	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–0	0	0–0
Grey-faced petrel	39	13–81	39	12–79	0	0–1
Chatham Island taiko	**0**	0–0	0	0–0	0	0–0
White-headed petrel	7	2–15	5	1–10	0	0–0
Soft-plumaged petrel	0	0–1	0	0–1	0	0–0
Common diving petrel	4	0–33	1	0–9	0	0–3
South Georgian diving petrel	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	20	0–159	3	0–25	0	0–1
White-bellied storm petrel	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	0	0–0	0	0–0	0	0–0
Kermadec storm petrel	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0	0	0–0
Yellow-eyed penguin	2	0–11	4	0–24	0	0–1
Northern little penguin	0	0–3	0	0–3	0	0–0
White-flippered little penguin	0	0–0	0	0–0	0	0–1
Southern little penguin	0	0–1	0	0–1	0	0–1
Chatham Island little penguin	2	0–14	0	0–2	0	0–0
Eastern rockhopper penguin	1	0–6	0	0–4	0	0–1
Fiordland crested penguin	**5**	0–45	1	0–7	0	0–0
Snares crested penguin	1	0–11	0	0–4	0	0–1
Erect-crested penguin	0	0–0	0	0–0	0	0–2
Australasian gannet	1	0–8	1	0–6	0	0–1
Masked booby	0	0–0	0	0–0	0	0–0
Pied shag	0	0–3	1	0–8	0	0–0
Little black shag	0	0–1	0	0–2	0	0–0
NZ king shag	0	0–1	0	0–1	0	0–0
Stewart Island shag	0	0–0	0	0–1	0	0–0
Chatham Island shag	0	0–2	0	0–0	0	0–0
Bounty Island shag	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–0	0	0–0	0	0–0
Campbell Island shag	0	0–0	0	0–0	0	0–0
Spotted shag	1	0–11	2	0–15	0	0–0
Pitt Island shag	0	0–2	0	0–1	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0
Southern black-backed gull	8	0–30	12	1–41	0	0–1
Caspian tern	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0
Total	429	264–699	322	197–499	122	89–163

Table A-12: Estimated number of annual potential fatalities (APF) in surface-longline (SLL) fisheries. The definition of the target fisheries followed Richard & Abraham (2013b); Small/Large: vessels less or greater than 45-m long; STN: southern bluefin tuna. Cells were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Fisheries are sorted by decreasing order of the mean total APF.

Species	Bigeye SLL		Small STN SLL		Swordfish SLL	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	54	34–78	50	31–73	79	50–117
Antipodean albatross	28	17–41	31	18–45	32	19–48
Southern royal albatross	4	1–11	3	0–8	1	0–3
Northern royal albatross	3	0–8	2	0–7	0	0–2
Campbell black-browed albatross	41	20–68	27	13–47	7	1–19
NZ white-capped albatross	101	66–143	87	57–123	13	3–30
Salvin's albatross	22	6–48	5	1–11	3	0–13
Chatham Island albatross	1	0–5	0	0–3	0	0–1
Grey-headed albatross	0	0–3	0	0–2	0	0–1
Southern Buller's albatross	6	3–9	53	36–73	3	0–9
Northern Buller's albatross	205	145–277	79	54–109	6	0–18
Light-mantled sooty albatross	0	0–2	0	0–2	0	0–1
Northern giant petrel	0	0–2	0	0–2	0	0–1
Grey petrel	31	15–52	30	14–51	12	2–28
Black petrel	71	32–126	2	0–5	8	1–22
Westland petrel	6	1–15	17	4–41	8	1–28
White-chinned petrel	41	19–72	26	11–48	20	6–45
Flesh-footed shearwater	47	17–94	4	1–9	4	0–18
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0
Buller's shearwater	0	0–3	0	0–1	0	0–1
Sooty shearwater	4	0–15	2	0–8	4	0–16
Fluttering shearwater	0	0–1	0	0–0	0	0–0
Hutton's shearwater	0	0–1	0	0–0	0	0–0
Little shearwater	0	0–1	0	0–1	0	0–0
Snares Cape petrel	4	0–12	3	0–10	1	0–3
Fairy prion	0	0–2	0	0–2	0	0–1
Antarctic prion	0	0–1	0	0–0	0	0–0
Broad-billed prion	0	0–2	0	0–1	0	0–1
Pycroft's petrel	0	0–1	0	0–0	0	0–0
Cook's petrel	2	0–4	0	0–0	1	0–2
Chatham petrel	0	0–0	0	0–0	0	0–0
Mottled petrel	1	0–2	0	0–1	0	0–2
White-naped petrel	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–0	0	0–0
Grey-faced petrel	6	1–15	4	0–10	4	0–12
Chatham Island taiko	0	0–0	0	0–0	0	0–0
White-headed petrel	0	0–2	0	0–1	0	0–2
Soft-plumaged petrel	0	0–0	0	0–0	0	0–0
Common diving petrel	1	0–7	0	0–1	0	0–2
South Georgian diving petrel	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	1	0–6	0	0–1	0	0–2
White-bellied storm petrel	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	0	0–1	0	0–1	0	0–0
Kermadec storm petrel	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0	0	0–0
Yellow-eyed penguin	0	0–0	0	0–0	0	0–0
Northern little penguin	1	0–5	0	0–3	0	0–2
White-flippered little penguin	0	0–0	0	0–0	0	0–0
Southern little penguin	0	0–0	0	0–2	0	0–1
Chatham Island little penguin	0	0–0	0	0–0	0	0–0
Eastern rockhopper penguin	0	0–0	0	0–2	0	0–1
Fiordland crested penguin	0	0–0	0	0–3	0	0–1
Snares crested penguin	0	0–0	0	0–1	0	0–0
Erect-crested penguin	0	0–0	0	0–0	0	0–0
Australasian gannet	1	0–7	0	0–1	0	0–3
Masked booby	0	0–0	0	0–0	0	0–0
Pied shag	1	0–11	0	0–2	0	0–5
Little black shag	0	0–1	0	0–0	0	0–0
NZ king shag	0	0–0	0	0–0	0	0–0
Stewart Island shag	0	0–0	0	0–0	0	0–0
Chatham Island shag	0	0–0	0	0–0	0	0–0
Bounty Island shag	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–0	0	0–0	0	0–0
Campbell Island shag	0	0–0	0	0–0	0	0–0
Spotted shag	1	0–5	0	0–1	0	0–0
Pitt Island shag	0	0–0	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0
Southern black-backed gull	2	0–12	0	0–3	1	0–7
Caspian tern	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0
Total	686	547–853	430	338–541	210	147–287

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Table A-12: (*continued*)

Species	Large STN SLL		Minor surface SLL		Albacore SLL	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	1	0–3	1	0–3	0	0–1
Antipodean albatross	0	0–1	1	0–3	0	0–1
Southern royal albatross	0	0–1	0	0–0	0	0–0
Northern royal albatross	0	0–0	0	0–0	0	0–0
Campbell black-browed albatross	1	0–2	1	0–2	0	0–1
NZ white-capped albatross	7	2–14	2	0–4	1	0–2
Salvin's albatross	0	0–1	0	0–1	0	0–1
Chatham Island albatross	0	0–0	0	0–0	0	0–0
Grey-headed albatross	0	0–0	0	0–0	0	0–0
Southern Buller's albatross	**24**	13–38	1	0–2	0	0–1
Northern Buller's albatross	0	0–0	4	2–7	1	0–3
Light-mantled sooty albatross	0	0–0	0	0–0	0	0–0
Northern giant petrel	0	0–0	0	0–0	0	0–0
Grey petrel	2	0–5	1	0–2	0	0–1
Black petrel	0	0–0	0	0–1	0	0–1
Westland petrel	0	0–1	0	0–1	0	0–0
White-chinned petrel	2	0–5	1	0–2	0	0–1
Flesh-footed shearwater	0	0–0	0	0–2	0	0–1
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0
Buller's shearwater	0	0–0	0	0–0	0	0–0
Sooty shearwater	0	0–1	0	0–1	0	0–0
Fluttering shearwater	0	0–0	0	0–0	0	0–0
Hutton's shearwater	0	0–0	0	0–0	0	0–0
Little shearwater	0	0–0	0	0–0	0	0–0
Snares Cape petrel	0	0–1	0	0–0	0	0–0
Fairy prion	0	0–0	0	0–0	0	0–0
Antarctic prion	0	0–0	0	0–0	0	0–0
Broad-billed prion	0	0–0	0	0–0	0	0–0
Pycroft's petrel	0	0–0	0	0–0	0	0–0
Cook's petrel	0	0–0	0	0–0	0	0–0
Chatham petrel	0	0–0	0	0–0	0	0–0
Mottled petrel	0	0–0	0	0–0	0	0–0
White-naped petrel	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–0	0	0–0
Grey-faced petrel	0	0–0	0	0–0	0	0–0
Chatham Island taiko	0	0–0	0	0–0	0	0–0
White-headed petrel	0	0–0	0	0–0	0	0–0
Soft-plumaged petrel	0	0–0	0	0–0	0	0–0
Common diving petrel	0	0–0	0	0–0	0	0–0
South Georgian diving petrel	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	0	0–0	0	0–0	0	0–0
White-bellied storm petrel	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	0	0–0	0	0–0	0	0–0
Kermadec storm petrel	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0	0	0–0
Yellow-eyed penguin	0	0–0	0	0–0	0	0–0
Northern little penguin	0	0–0	0	0–0	0	0–0
White-flippered little penguin	0	0–0	0	0–0	0	0–0
Southern little penguin	0	0–0	0	0–0	0	0–0
Chatham Island little penguin	0	0–0	0	0–0	0	0–0
Eastern rockhopper penguin	0	0–0	0	0–0	0	0–0
Fiordland crested penguin	0	0–0	0	0–0	0	0–0
Snares crested penguin	0	0–0	0	0–0	0	0–0
Erect-crested penguin	0	0–0	0	0–0	0	0–0
Australasian gannet	0	0–0	0	0–0	0	0–0
Masked booby	0	0–0	0	0–0	0	0–0
Pied shag	0	0–0	0	0–0	0	0–0
Little black shag	0	0–0	0	0–0	0	0–0
NZ king shag	0	0–0	0	0–0	0	0–0
Stewart Island shag	0	0–0	0	0–0	0	0–0
Chatham Island shag	0	0–0	0	0–0	0	0–0
Bounty Island shag	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–0	0	0–0	0	0–0
Campbell Island shag	0	0–0	0	0–0	0	0–0
Spotted shag	0	0–0	0	0–0	0	0–0
Pitt Island shag	0	0–0	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0
Southern black-backed gull	0	0–0	0	0–0	0	0–0
Caspian tern	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0
Total	39	23–57	14	9–19	4	2–7

Table A-13: Estimated number of annual potential fatalities (APF) in set-net (SN) fisheries. Cells were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Fisheries are sorted by decreasing order of the mean total APF.

Species	Shark SN		Flatfish SN		Minor SN		Grey mullet SN	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	0	0–1	0	0–1	0	0–1	0	0–0
Antipodean albatross	0	0–1	0	0–1	0	0–1	0	0–0
Southern royal albatross	0	0–2	0	0–2	0	0–1	0	0–1
Northern royal albatross	1	0–5	0	0–2	1	0–3	0	0–0
Campbell black-browed albatross	0	0–1	0	0–1	0	0–1	0	0–0
NZ white-capped albatross	1	0–4	1	0–3	1	0–2	0	0–1
Salvin's albatross	0	0–1	0	0–1	0	0–1	0	0–0
Chatham Island albatross	0	0–0	0	0–0	0	0–0	0	0–0
Grey-headed albatross	0	0–1	0	0–0	0	0–0	0	0–0
Southern Buller's albatross	1	0–3	0	0–1	0	0–2	0	0–0
Northern Buller's albatross	0	0–1	0	0–1	0	0–1	0	0–0
Light-mantled sooty albatross	0	0–2	0	0–2	0	0–1	0	0–0
Northern giant petrel	0	0–0	0	0–0	0	0–0	0	0–0
Grey petrel	2	0–5	1	0–4	1	0–3	0	0–1
Black petrel	0	0–1	0	0–1	0	0–1	0	0–0
Westland petrel	1	0–3	1	0–2	1	0–2	0	0–1
White-chinned petrel	10	3–21	5	1–12	5	1–10	1	0–2
Flesh-footed shearwater	0	0–0	0	0–0	0	0–1	0	0–0
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0	0	0–0
Buller's shearwater	0	0–1	0	0–1	0	0–0	0	0–0
Sooty shearwater	14	6–25	2	0–5	7	3–14	0	0–1
Fluttering shearwater	0	0–1	2	0–4	0	0–1	0	0–0
Hutton's shearwater	3	1–6	0	0–1	2	1–5	0	0–0
Little shearwater	0	0–0	0	0–0	0	0–0	0	0–0
Snares Cape petrel	16	7–28	6	2–10	6	2–11	1	0–2
Fairy prion	7	0–28	1	0–2	3	0–10	0	0–0
Antarctic prion	0	0–1	0	0–0	0	0–0	0	0–0
Broad-billed prion	0	0–2	0	0–1	0	0–1	0	0–0
Pycroft's petrel	0	0–0	0	0–0	0	0–0	0	0–0
Cook's petrel	0	0–1	0	0–1	0	0–1	0	0–0
Chatham petrel	0	0–0	0	0–0	0	0–0	0	0–0
Mottled petrel	1	0–5	0	0–0	0	0–1	0	0–0
White-naped petrel	0	0–0	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–0	0	0–0	0	0–0
Grey-faced petrel	0	0–2	1	0–3	0	0–2	0	0–1
Chatham Island taiko	0	0–0	0	0–0	0	0–0	0	0–0
White-headed petrel	0	0–0	0	0–0	0	0–0	0	0–0
Soft-plumaged petrel	0	0–0	0	0–0	0	0–0	0	0–0
Common diving petrel	2	0–6	0	0–1	0	0–1	0	0–0
South Georgian diving petrel	0	0–0	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	3	0–11	5	0–19	2	0–7	0	0–2
White-bellied storm petrel	0	0–0	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	0	0–2	0	0–1	0	0–1	0	0–0
Kermadec storm petrel	0	0–0	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	**0**	0–0	0	0–0	0	0–0
Yellow-eyed penguin	**24**	10–42	5	2–10	6	2–11	0	0–0
Northern little penguin	1	0–4	1	0–5	1	0–3	0	0–1
White-flippered little penguin	0	0–1	0	0–1	1	0–2	0	0–0
Southern little penguin	1	0–4	0	0–1	0	0–1	0	0–0
Chatham Island little penguin	0	0–0	0	0–0	0	0–0	0	0–0
Eastern rockhopper penguin	0	0–2	0	0–0	0	0–1	0	0–0
Fiordland crested penguin	1	0–4	0	0–1	0	0–2	0	0–0
Snares crested penguin	1	0–5	0	0–1	0	0–1	0	0–0
Erect-crested penguin	0	0–0	0	0–0	0	0–0	0	0–0
Australasian gannet	11	0–39	15	0–55	5	0–19	1	0–5
Masked booby	0	0–0	0	0–0	0	0–0	0	0–0
Pied shag	7	1–19	10	1–29	5	0–15	2	0–5
Little black shag	2	0–6	4	0–11	1	0–4	1	0–2
NZ king shag	0	0–0	0	0–0	0	0–1	0	0–0
Stewart Island shag	2	0–4	0	0–0	0	0–1	0	0–0
Chatham Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Bounty Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Campbell Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Spotted shag	13	4–25	21	7–41	11	3–22	2	0–4
Pitt Island shag	0	0–0	0	0–0	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0	0	0–0
Southern black-backed gull	3	0–10	3	0–12	2	0–8	1	0–2
Caspian tern	0	0–0	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0	0	0–0
Total	131	92–178	88	53–138	65	44–92	10	5–17

Table A-14: Estimated number of annual potential fatalities (APF) in trawl, surface-longline (SLL), bottom-longline (BLL), and set-net (SN) fisheries. Cells were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Numbers were rounded to three significant digits.

Species	Trawl		BLL		SLL		SN		Total	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	**25**	6–72	**10**	0–43	**186**	134–250	1	0–3	**222**	161–301
Antipodean albatross	**20**	5–56	**9**	0–36	**93**	65–126	1	0–2	**122**	85–175
Southern royal albatross	**24**	10–53	4	0–17	8	1–20	1	0–5	**37**	18–70
Northern royal albatross	**33**	9–94	**11**	1–44	6	1–15	2	0–8	**52**	20–119
Campbell black-browed albatross	**53**	19–120	**82**	16–212	**77**	41–124	0	0–2	**213**	121–359
NZ white-capped albatross	**4 160**	2 540–6 380	38	4–111	211	143–293	2	0–9	**4 410**	2 800–6 620
Salvin's albatross	**3 050**	1 840–4 770	**401**	247–602	31	10–65	1	0–3	**3 480**	2 250–5 200
Chatham Island albatross	**31**	10–78	**95**	47–179	1	0–9	0	0–0	**127**	70–226
Grey-headed albatross	2	0–11	2	0–19	1	0–6	0	0–1	**5**	0–24
Southern Buller's albatross	**647**	403–1 020	**57**	20–119	**86**	61–116	1	0–4	**791**	541–1 160
Northern Buller's albatross	**184**	105–307	**68**	24–152	**296**	210–398	0	0–2	**549**	409–723
Light-mantled sooty albatross	**7**	0–28	2	0–19	1	0–5	1	0–4	**11**	1–40
Northern giant petrel	**35**	8–95	**2**	0–14	1	0–4	0	0–0	**37**	9–99
Grey petrel	43	18–99	55	15–126	75	41–121	5	1–10	**177**	110–274
Black petrel	**45**	6–148	**1 000**	724–1 330	**81**	39–142	1	0–2	**1 130**	836–1 490
Westland petrel	**30**	9–92	**24**	1–91	**31**	8–70	3	0–6	**88**	37–181
White-chinned petrel	**1 180**	652–2 270	154	81–267	91	48–150	20	6–43	**1 440**	906–2 540
Flesh-footed shearwater	**174**	72–388	**466**	296–679	**56**	21–110	0	0–1	**696**	478–995
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
Buller's shearwater	1	0–5	8	0–30	1	0–5	0	0–1	10	1–33
Sooty shearwater	1 240	637–2 490	82	30–192	10	1–31	24	11–42	1 350	745–2 600
Fluttering shearwater	1	0–7	21	0–85	0	0–1	2	1–5	25	3–90
Hutton's shearwater	1	0–7	11	0–41	0	0–1	5	2–10	18	5–49
Little shearwater	0	0–1	2	0–7	0	0–2	0	0–1	2	0–8
Snares Cape petrel	8	1–23	7	0–36	8	1–23	**28**	13–50	**50**	26–89
Fairy prion	20	4–77	9	0–69	1	0–4	11	0–39	41	10–122
Antarctic prion	2	0–6	0	0–1	0	0–1	0	0–1	3	0–7
Broad-billed prion	4	0–11	9	0–61	1	0–4	1	0–4	14	2–66
Pycroft's petrel	0	0–0	1	0–2	0	0–1	0	0–0	1	0–2
Cook's petrel	0	0–1	14	4–29	2	0–6	0	0–2	16	6–32
Chatham petrel	0	0–0	**1**	0–2	0	0–0	0	0–0	**1**	0–2
Mottled petrel	1	0–5	42	14–85	1	0–4	1	0–6	46	17–89
White-naped petrel	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–1	0	0–0	0	0–0	0	0–1
Grey-faced petrel	1	0–4	85	30–168	13	3–31	1	0–6	101	43–187
Chatham Island taiko	0	0–0	**0**	0–0	0	0–0	0	0–0	**0**	0–0
White-headed petrel	0	0–1	12	4–25	1	0–4	0	0–1	14	5–27
Soft-plumaged petrel	0	0–0	0	0–1	0	0–0	0	0–0	0	0–2
Common diving petrel	23	6–71	7	0–52	1	0–9	2	0–8	34	9–103
South Georgian diving petrel	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
NZ white-faced storm petrel	11	2–36	28	0–192	1	0–8	10	0–38	51	8–223
White-bellied storm petrel	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
Black-bellied storm petrel	1	0–5	0	0–1	0	0–2	1	0–4	2	0–7
Kermadec storm petrel	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
NZ storm petrel	**0**	0–0	0	0–0	0	0–0	**0**	0–0	**0**	0–0
Yellow-eyed penguin	1	0–8	**8**	0–51	0	0–0	**35**	16–60	**44**	17–90
Northern little penguin	0	0–2	2	0–14	1	0–8	3	0–12	7	1–22
White-flippered little penguin	0	0–1	0	0–2	0	0–0	1	0–4	1	0–5
Southern little penguin	0	0–3	1	0–7	0	0–3	1	0–6	3	0–11
Chatham Island little penguin	0	0–1	2	0–18	0	0–0	0	0–0	2	0–18
Eastern rockhopper penguin	0	0–1	2	0–11	0	0–3	1	0–2	3	0–12
Fiordland crested penguin	0	0–0	**10**	0–70	0	0–4	2	0–6	**12**	0–72
Snares crested penguin	0	0–1	3	0–17	0	0–1	2	0–6	5	0–20
Erect-crested penguin	0	0–1	1	0–3	0	0–0	0	0–0	1	0–3
Australasian gannet	1	0–10	6	0–39	2	0–10	32	1–117	41	3–129
Masked booby	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
Pied shag	2	0–16	3	0–22	2	0–17	24	3–66	31	5–79
Little black shag	1	0–4	1	0–5	0	0–1	**7**	1–21	**9**	1–23
NZ king shag	0	0–1	0	0–1	0	0–0	0	0–1	**0**	0–2
Stewart Island shag	**89**	56–138	0	0–1	0	0–0	2	0–5	**91**	58–139
Chatham Island shag	0	0–0	0	0–2	0	0–0	0	0–0	0	0–2
Bounty Island shag	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
Auckland Island shag	0	0–1	0	0–0	0	0–0	0	0–0	0	0–1
Campbell Island shag	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
Spotted shag	**372**	240–564	7	0–50	1	0–6	46	17–90	**426**	285–628
Pitt Island shag	0	0–0	0	0–3	0	0–0	0	0–0	0	0–3
Subantarctic skua	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
Southern black-backed gull	33	2–122	49	7–132	3	0–19	8	0–32	94	27–214
Caspian tern	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
All birds	11 600	8 000–16 300	2 910	2 290–3 680	1 380	1 120–1 710	293	202–416	16 100	12 500–20 900

A.6 Vulnerabilities

Table A-15: Vulnerability to capture of each seabird species group in trawl, bottom-longline (BLL), and surface-longline (SLL) fisheries. Vulnerabilities were estimated relative to that of white-chinned petrel (set to 1 as the base case).

Species groups	Trawl Mean	Trawl 95% c.i.	BLL Mean	BLL 95% c.i.	SLL Mean	SLL 95% c.i.
Wandering albatrosses (spp.)	1.81	0.25–6.98	10.31	0.06–66.42	88.95	13.79–327.24
Royal albatrosses (spp.)	0.65	0.09–2.37	4.85	0.03–33.01	1.43	0.09–6.74
White-capped albatross	7.34	1.42–23.60	2.02	0.02–12.76	6.69	0.95–27.68
Salvin's albatross	20.72	3.96–69.41	33.15	0.80–187.14	5.73	0.65–23.11
Campbell black-browed albatross	0.56	0.07–2.26	41.18	0.89–271.89	19.77	2.46–84.56
Chatham albatross	1.47	0.14–5.76	23.32	0.49–139.76	0.90	0.00–7.49
Grey-headed albatross	0.06	0.00–0.42	1.36	0.00–12.74	0.31	0.00–2.20
Buller's albatrosses (spp.)	4.58	0.78–16.14	22.51	0.56–135.00	27.01	3.94–107.91
Light-mantled sooty albatross	0.17	0.00–0.89	1.56	0.00–12.06	0.22	0.00–1.62
Giant petrel	5.11	0.54–21.35	3.33	0.00–24.24	1.26	0.00–6.91
Grey petrel	0.84	0.11–3.25	24.93	0.27–144.32	11.50	1.70–49.71
Black petrel	10.53	0.72–47.34	887.54	33.61–4 783.45	7.44	0.65–33.63
Westland petrel	1.68	0.18–7.24	9.56	0.04–63.39	6.71	0.63–31.33
White-chinned petrel	1.00	1.00–1.00	1.00	1.00–1.00	1.00	1.00–1.00
Flesh-footed shearwater	3.47	0.38–12.66	105.41	1.15–665.52	3.96	0.26–19.04
Shearwaters (spp.)	0.00	0.00–0.02	0.22	0.00–1.39	0.01	0.00–0.07
Sooty shearwater	0.16	0.03–0.54	0.16	0.00–1.09	0.02	0.00–0.09
Cape petrel	0.66	0.05–2.74	11.71	0.04–86.84	3.08	0.14–14.39
Prions (spp.)	0.00	0.00–0.02	0.01	0.00–0.10	0.00	0.00–0.02
Pterodroma petrels (spp.)	0.00	0.00–0.01	0.28	0.00–1.57	0.06	0.00–0.24
Diving petrels (spp.)	0.04	0.01–0.16	0.04	0.00–0.28	0.02	0.00–0.10
Storm petrels (spp.)	0.04	0.00–0.15	0.03	0.00–0.26	0.02	0.00–0.14
Crested penguins (spp.)	0.00	0.00–0.03	1.47	0.00–11.24	0.29	0.00–2.17
Yellow-eyed penguin	0.17	0.00–1.27	8.94	0.00–70.38	66.34	0.00–927.65
Blue penguins (spp.)	0.01	0.00–0.08	0.18	0.00–1.42	0.09	0.00–0.59
Boobies and gannets (spp.)	0.02	0.00–0.12	0.21	0.00–1.76	0.07	0.00–0.47
Group foraging shags (spp.)	0.76	0.06–3.29	0.45	0.00–3.54	5.92	0.00–53.14
Solitary shags (spp.)	0.11	0.00–0.78	0.45	0.00–3.72	4.89	0.00–41.41
Gulls, terns and skua (spp.)	0.00	0.00–0.01	0.06	0.00–0.39	0.04	0.00–0.29

Table A-16: Vulnerability to capture of each seabird species group in set-net fisheries. Vulnerabilities were estimated relative to that of white-chinned petrel (set to 1 as the base case).

Species groups	Mean	95% c.i.
Shearwaters (spp.)	0.01	0.00–0.01
Cape petrel	32.33	15.27–55.72
Prions (spp.)	0.01	0.00–0.03
Pterodroma petrels (spp.)	0.01	0.00–0.04
Diving petrels (spp.)	0.01	0.00–0.04
Storm petrels (spp.)	0.18	0.00–0.65
Crested penguins (spp.)	0.74	0.10–2.08
Yellow-eyed penguin	11.71	5.49–19.94
Blue penguins (spp.)	0.13	0.00–0.47
Boobies and gannets (spp.)	0.54	0.01–1.95
Group foraging shags (spp.)	0.29	0.11–0.55
Solitary shags (spp.)	0.43	0.05–1.21
Gulls, terns and skua (spp.)	0.00	0.00–0.00
Small albatrosses and giant petrel	0.13	0.00–0.51
Procellaria petrels (spp.)	1.23	0.41–2.49
Great albatrosses (spp.)	0.76	0.02–2.80

Table A-17: Vulnerability to capture of seabirds in each fishery group, for trawl and longline methods (bottom longline, BLL; surface longline, SLL). Vulnerabilities for each fishing method were estimated independently and relative to the vulnerability in deepwater trawling, large-vessel bottom longlining, and small-vessel bottom longlining, respectively (set to 1 as the base case).

Method	Fishery group	Mean	95% c.i.
Trawl	Small inshore trawl	1.55	0.29–4.58
	Large processor trawl	7.39	1.84–20.01
	Large meal trawl	6.43	1.66–17.16
	Large fresher trawl	0.23	0.01–0.97
	SBW trawl	7.82	1.54–23.25
	Scampi trawl	7.26	1.67–19.45
	Mackerel trawl	2.00	0.41–5.68
	Squid trawl	5.93	1.30–17.07
	Deepwater trawl	1.00	1.00–1.00
	Flatfish trawl	1.42	0.22–4.76
Bottom longline	Bluenose BLL	1.41	0.11–5.85
	Small BLL	2.64	0.23–10.47
	Snapper BLL	0.23	0.01–1.08
	Small ling BLL	2.14	0.20–8.14
	Large BLL	1.00	1.00–1.00
Surface longline	Small tuna SLL	2.17	0.76–4.99
	Small swordfish SLL	3.16	0.94–7.35
	Large SLL	1.00	1.00–1.00

A.7 Sensitivities

Table A-18: Sensitivity of the uncertainty in the risk ratio to uncertainty in the underlying parameters. For each seabird type, the following parameters were considered: annual potential fatalities in trawl, bottom-longline, surface-longline and set-net fisheries (TWL, BLL, SLL, SN, respectively); the cryptic multipliers (CM); age at first reproduction (A); adult survival (S_A); the number of annual breeding pairs (N_{BP}); and the proportion of adults breeding (P_{B}). The sensitivity was defined as the percentage of reduction in the 95% credible interval of the risk ratio that occurs when the parameter is set to its arithmetic mean. For each species, the highest value is indicated in bold. Species without sensitivity values had a risk ratio that is too small for the sensitivity to be defined. Species names were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

Species	Fishing methods					Demographic parameters			
	TWL	BLL	SLL	SN	CM	A	S_A	N_{BP}	P_{B}
Gibson's albatross	2	0	10	0	2	0	**47**	1	0
Antipodean albatross	13	7	16	0	7	0	**17**	3	7
Southern royal albatross	**38**	8	8	1	10	0	9	3	3
Northern royal albatross	**35**	9	3	1	4	0	18	10	0
Campbell black-browed albatross	5	**28**	4	0	3	0	4	13	0
New Zealand white-capped albatross	**30**	0	0	0	22	0	24	2	1
Salvin's albatross	28	1	0	0	19	1	**32**	0	2
Chatham Island albatross	8	**29**	1	0	3	0	18	2	1
Grey-headed albatross	12	**41**	6	1	2	0	1	4	0
Southern Buller's albatross	19	0	0	0	15	1	**43**	3	2
Northern Buller's albatross	4	1	6	0	4	0	**51**	0	1
Light-mantled sooty albatross	**40**	23	2	1	2	1	3	0	0
Northern giant petrel	**37**	1	0	0	2	0	34	0	0
Grey petrel	5	14	7	0	4	0	**33**	2	0
Black petrel	2	14	1	0	3	1	15	**25**	2
Westland petrel	13	**17**	7	0	2	0	17	0	0
White-chinned petrel	**26**	0	1	0	26	1	24	7	1
Flesh-footed shearwater	2	6	0	0	3	1	**52**	1	0
Wedge-tailed shearwater	.	.	.	.	.	.	.	.	.
Buller's shearwater	3	**55**	4	0	1	0	11	1	0
Sooty shearwater	26	0	0	0	24	1	**36**	6	0
Fluttering shearwater	1	**69**	1	1	4	2	5	5	1
Hutton's shearwater	4	**57**	0	3	0	1	7	3	0
Little shearwater	2	**61**	3	0	0	0	3	0	0
Snares Cape petrel	2	7	3	7	1	0	**36**	7	0
Fairy prion	**22**	22	1	7	0	0	1	2	0
Antarctic prion	**50**	2	1	0	13	0	9	5	0
Broad-billed prion	4	**73**	0	0	0	0	5	5	0
Pycroft's petrel	0	**40**	9	1	2	0	15	0	0
Cook's petrel	0	**32**	1	1	2	0	28	0	0
Chatham petrel	0	**57**	0	0	0	0	15	0	0
Mottled petrel	0	**30**	1	1	0	0	27	0	0
White-naped petrel	0	4	**88**	0	4	1	13	2	0
Kermadec petrel	0	**43**	7	0	7	1	16	2	0
Grey-faced petrel	1	28	0	1	2	0	**32**	0	0
Chatham Island taiko	0	**93**	0	0	0	0	0	0	0
White-headed petrel	0	**30**	0	0	1	1	24	7	1
Soft-plumaged petrel	0	**48**	3	0	5	0	16	3	0
Common diving petrel	**35**	26	0	0	8	2	5	3	0
South Georgian diving petrel	.	.	.	.	.	.	.	.	.
New Zealand white-faced storm petrel	4	**64**	0	0	0	0	0	0	0
White-bellied storm petrel	.	.	.	.	.	.	.	.	.
Black-bellied storm petrel	**32**	4	4	23	7	0	11	3	1
Kermadec storm petrel	.	.	.	.	.	.	.	.	.
New Zealand storm petrel	6	3	6	**31**	6	1	10	18	0
Yellow-eyed penguin	0	**28**	0	16	0	0	7	0	2
Northern little penguin	1	**26**	10	19	0	1	1	1	0
White-flippered little penguin	7	11	0	**48**	2	0	2	3	0
Southern little penguin	8	**31**	5	20	0	0	1	1	0
Chatham Island little penguin	0	**92**	0	0	3	0	2	2	0
Eastern rockhopper penguin	0	**63**	5	5	0	0	0	0	0
Fiordland crested penguin	0	**84**	0	1	0	0	0	0	0
Snares crested penguin	0	**65**	1	9	0	0	2	4	0
Erect-crested penguin	3	**71**	0	0	0	0	2	0	0
Australasian gannet	1	5	0	**48**	0	1	12	8	1
Masked booby	1	7	3	**96**	0	0	0	0	1
Pied shag	2	4	5	**47**	0	0	0	1	0
Little black shag	2	5	1	**50**	0	5	1	4	0
New Zealand king shag	13	**38**	0	10	2	0	4	0	2
Stewart Island shag	**57**	0	0	1	13	1	5	0	2
Chatham Island shag	0	**95**	0	0	0	1	2	4	2
Bounty Island shag	.	.	.	.	.	.	.	.	.
Auckland Island shag	**90**	0	0	0	6	0	0	3	0
Campbell Island shag	.	.	.	.	.	.	.	.	.
Spotted shag	**26**	1	0	1	8	20	3	5	2
Pitt Island shag	0	**92**	0	0	5	0	3	4	0
Subantarctic skua	.	.	.	.	.	.	.	.	.
Southern black-backed gull	24	**25**	1	4	3	0	6	1	0
Caspian tern	9	15	3	3	2	3	**17**	3	0
White tern	.	.	.	.	.	.	.	.	.

Table A-19: Sensitivity of the estimated risk ratio to large capture events. For black petrel, a fishing trip with 27 observed captures was considered unobserved and the captures were not included. Similarly, for Chatham Island albatross, a fishing trip with 12 observed captures was considered unobserved. For Gibson's albatross, the observed captures of 33 unidentified albatross during a single fishing trip were assumed to be of Gibson's albatross. Median risk ratio values were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

Species	Base case		Black petrel		Chatham albatross		Spotted shag		Gibson's albatross	
	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.
Black petrel	11.34	6.85–19.81	6.45	3.76–11.61	11.32	6.95–19.67	11.26	6.96–19.69	11.24	6.85–19.79
Salvin's albatross	3.44	1.82–6.50	3.46	1.83–6.38	3.06	1.53–5.86	3.45	1.81–6.30	3.46	1.85–6.37
Southern Buller's albatross	1.82	0.97–3.67	1.83	0.98–3.77	1.81	0.99–3.71	1.82	0.98–3.74	1.82	0.99–3.66
Flesh-footed shearwater	1.5	0.56–3.36	1.48	0.56–3.38	1.48	0.59–3.38	1.49	0.55–3.33	1.48	0.58–3.41
Gibson's albatross	1.26	0.69–2.49	1.25	0.71–2.57	1.24	0.70–2.51	1.25	0.69–2.49	1.76	1.01–3.50
NZ white-capped albatross	1.1	0.59–1.97	1.1	0.59–2.03	1.1	0.59–2.02	1.09	0.60–2.01	1.1	0.59–2.02
Northern Buller's albatross	1.02	0.58–2.00	1.04	0.59–2.01	1.04	0.58–2.05	1.04	0.58–2.01	1.03	0.57–2.01
Antipodean albatross	0.89	0.56–1.47	0.9	0.56–1.49	0.9	0.56–1.46	0.89	0.55–1.44	1.17	0.76–1.82
Chatham Island albatross	0.91	0.42–1.90	0.91	0.43–1.95	0.27	0.09–0.89	0.92	0.42–1.91	0.92	0.41–2.04
Westland petrel	0.53	0.21–1.37	0.52	0.21–1.35	0.52	0.21–1.34	0.52	0.21–1.37	0.52	0.21–1.36
Campbell black-browed albatross	0.31	0.16–0.63	0.31	0.16–0.62	0.3	0.16–0.62	0.31	0.16–0.62	0.31	0.16–0.63
White-chinned petrel	0.28	0.14–0.64	0.28	0.13–0.64	0.27	0.14–0.66	0.27	0.14–0.68	0.28	0.14–0.66
Stewart Island shag	0.3	0.19–0.49	0.3	0.18–0.48	0.3	0.19–0.49	0.01	0.00–0.04	0.3	0.18–0.48
Northern giant petrel	0.22	0.05–0.96	0.21	0.05–0.97	0.21	0.05–0.99	0.21	0.05–1.02	0.21	0.04–0.97
Northern royal albatross	0.19	0.07–0.59	0.19	0.07–0.58	0.19	0.07–0.59	0.19	0.07–0.54	0.19	0.07–0.57
Spotted shag	0.18	0.10–0.32	0.18	0.10–0.32	0.18	0.10–0.32	0.03	0.01–0.06	0.18	0.10–0.32
Southern royal albatross	0.1	0.05–0.20	0.1	0.05–0.20	0.1	0.05–0.20	0.09	0.05–0.19	0.1	0.05–0.19
Snares Cape petrel	0.09	0.03–0.25	0.09	0.04–0.27	0.09	0.03–0.26	0.09	0.03–0.27	0.09	0.04–0.27
Grey petrel	0.08	0.04–0.17	0.08	0.04–0.17	0.08	0.04–0.16	0.08	0.04–0.17	0.08	0.04–0.17
Yellow-eyed penguin	0.08	0.03–0.21	0.08	0.03–0.22	0.08	0.03–0.19	0.08	0.03–0.21	0.08	0.04–0.20
Chatham petrel	0.07	0.00–0.32	0.07	0.00–0.32	0.07	0.00–0.33	0.07	0.00–0.33	0.07	0.00–0.32
Little black shag	0.04	0.01–0.13	0.04	0.01–0.13	0.04	0.01–0.13	0.04	0.01–0.13	0.04	0.01–0.13
Light-mantled sooty albatross	0.03	0.01–0.17	0.03	0.01–0.18	0.03	0.01–0.17	0.03	0.01–0.16	0.03	0.01–0.17
Pied shag	0.03	0.01–0.10	0.03	0.01–0.10	0.03	0.01–0.10	0.03	0.01–0.10	0.03	0.01–0.10
Fiordland crested penguin	0.02	0.00–0.24	0.01	0.00–0.20	0.01	0.00–0.19	0.01	0.00–0.23	0.02	0.00–0.22
Grey-headed albatross	0.01	0.00–0.12	0.01	0.00–0.13	0.01	0.00–0.19	0.01	0.00–0.12	0.01	0.00–0.12
Australasian gannet	0.01	0.00–0.06	0.01	0.00–0.06	0.01	0.00–0.06	0.01	0.00–0.06	0.01	0.00–0.06
Fluttering shearwater	0.01	0.00–0.05	0.01	0.00–0.05	0.01	0.00–0.06	0.01	0.00–0.06	0.01	0.00–0.06
Grey-faced petrel	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Cook's petrel	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Soft-plumaged petrel	0.01	0.00–0.04	0.01	0.00–0.04	0.01	0.00–0.04	0.01	0.00–0.04	0.01	0.00–0.04
Pycroft's petrel	0.01	0.00–0.03	0.01	0.00–0.03	0.01	0.00–0.03	0.01	0.00–0.03	0.01	0.00–0.03
Sooty shearwater	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Northern little penguin	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Mottled petrel	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
White-flippered little penguin	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02
Hutton's shearwater	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Southern little penguin	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
White-headed petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Common diving petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Snares crested penguin	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Buller's shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Black-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
NZ white-faced storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Chatham Island little penguin	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02
Southern black-backed gull	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Fairy prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Little shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Eastern rockhopper penguin	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Antarctic prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Broad-billed prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Erect-crested penguin	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Auckland Island shag	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.00	0	0.00–0.01
Bounty Island shag	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Subantarctic skua	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Caspian tern	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Chatham Island shag	0	0.00–0.04	0	0.00–0.04	0	0.00–0.04	0	0.00–0.04	0	0.00–0.04
Campbell Island shag	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White tern	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
South Georgian diving petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
NZ king shag	0	0.00–0.11	0	0.00–0.12	0	0.00–0.13	0	0.00–0.11	0	0.00–0.12
Kermadec storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Masked booby	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
NZ storm petrel	0	0.00–0.29	0	0.00–0.29	0	0.00–0.26	0	0.00–0.27	0	0.00–0.30
Pitt Island shag	0	0.00–0.04	0	0.00–0.05	0	0.00–0.06	0	0.00–0.05	0	0.00–0.05
Chatham Island taiko	0	0.00–0.36	0	0.00–0.39	0	0.00–0.35	0	0.00–0.35	0	0.00–0.37
Wedge-tailed shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Kermadec petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White-naped petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00

Table A-20: Sensitivity of the estimated risk ratio to the live status of captured birds. All captures: captures of live, injured, and dead birds; no unharmed captures: captures of injured or dead birds only; only dead captures: captures of dead birds only. Median risk ratio values were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. The species are sorted by decreasing order of the average median risk ratio across the three scenarios.

Species	All captures		No unharmed captures		Only dead captures	
	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.
Black petrel	11.34	6.85–19.81	8.41	5.06–14.90	4.64	2.64–8.28
Salvin's albatross	3.44	1.82–6.50	3.04	1.59–5.69	3.01	1.56–5.60
Southern Buller's albatross	1.82	0.97–3.67	1.42	0.77–2.86	1.27	0.69–2.68
Flesh-footed shearwater	1.5	0.56–3.36	0.87	0.33–2.02	0.69	0.25–1.71
NZ white-capped albatross	1.1	0.59–1.97	0.96	0.51–1.76	0.93	0.50–1.71
Gibson's albatross	1.26	0.69–2.49	0.86	0.47–1.74	0.76	0.41–1.56
Northern Buller's albatross	1.02	0.58–2.00	0.93	0.52–1.84	0.84	0.46–1.62
Chatham Island albatross	0.91	0.42–1.90	0.91	0.43–1.99	0.89	0.41–1.87
Antipodean albatross	0.89	0.56–1.47	0.64	0.38–1.06	0.55	0.32–0.90
Westland petrel	0.53	0.21–1.37	0.45	0.17–1.25	0.45	0.17–1.30
Stewart Island shag	0.3	0.19–0.49	0.3	0.19–0.49	0.3	0.18–0.48
Campbell black-browed albatross	0.31	0.16–0.63	0.28	0.14–0.59	0.28	0.14–0.58
White-chinned petrel	0.28	0.14–0.64	0.2	0.10–0.49	0.2	0.10–0.49
Northern giant petrel	0.22	0.05–0.96	0.18	0.03–0.90	0.18	0.03–0.89
Spotted shag	0.18	0.10–0.32	0.18	0.09–0.32	0.18	0.10–0.32
Northern royal albatross	0.19	0.07–0.59	0.12	0.04–0.44	0.12	0.04–0.42
Yellow-eyed penguin	0.08	0.03–0.21	0.08	0.04–0.27	0.08	0.03–0.21
Grey petrel	0.08	0.04–0.17	0.08	0.04–0.16	0.08	0.04–0.16
Southern royal albatross	0.1	0.05–0.20	0.06	0.03–0.15	0.06	0.03–0.15
Chatham petrel	0.07	0.00–0.32	0.07	0.00–0.32	0.07	0.00–0.33
Snares Cape petrel	0.09	0.03–0.25	0.04	0.01–0.14	0.03	0.01–0.10
Little black shag	0.04	0.01–0.13	0.04	0.00–0.12	0.04	0.00–0.12
Pied shag	0.03	0.01–0.10	0.03	0.01–0.10	0.03	0.01–0.09
Light-mantled sooty albatross	0.03	0.01–0.17	0.02	0.00–0.13	0.02	0.00–0.14
Fiordland crested penguin	0.02	0.00–0.24	0.02	0.00–0.25	0.01	0.00–0.13
Australasian gannet	0.01	0.00–0.06	0.01	0.00–0.06	0.01	0.00–0.06
Grey-headed albatross	0.01	0.00–0.12	0.01	0.00–0.13	0.01	0.00–0.13
Fluttering shearwater	0.01	0.00–0.05	0.01	0.00–0.05	0.01	0.00–0.07
Grey-faced petrel	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Cook's petrel	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Soft-plumaged petrel	0.01	0.00–0.04	0.01	0.00–0.04	0.01	0.00–0.04
Pycroft's petrel	0.01	0.00–0.03	0.01	0.00–0.03	0.01	0.00–0.03
Sooty shearwater	0.01	0.00–0.02	0	0.00–0.01	0	0.00–0.01
Northern little penguin	0.01	0.00–0.02	0	0.00–0.02	0	0.00–0.02
Mottled petrel	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
White-flippered little penguin	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02
Hutton's shearwater	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Southern little penguin	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
White-headed petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Buller's shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Snares crested penguin	0	0.00–0.01	0	0.00–0.01	0	0.00–0.00
Common diving petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
NZ white-faced storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Black-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Southern black-backed gull	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Chatham Island little penguin	0	0.00–0.02	0	0.00–0.02	0	0.00–0.01
Fairy prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Little shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Eastern rockhopper penguin	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Antarctic prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Broad-billed prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Erect-crested penguin	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Auckland Island shag	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Bounty Island shag	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Subantarctic skua	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Caspian tern	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Chatham Island shag	0	0.00–0.04	0	0.00–0.04	0	0.00–0.04
Campbell Island shag	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White tern	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
South Georgian diving petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
NZ king shag	0	0.00–0.11	0	0.00–0.12	0	0.00–0.10
Kermadec storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Masked booby	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
NZ storm petrel	0	0.00–0.29	0	0.00–0.27	0	0.00–0.27
Pitt Island shag	0	0.00–0.04	0	0.00–0.05	0	0.00–0.04
Chatham Island taiko	0	0.00–0.36	0	0.00–0.34	0	0.00–0.36
Wedge-tailed shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Kermadec petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White-naped petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00

Table A-21: Sensitivity of the estimated risk ratio to the treatment of southern and northern Buller's albatrosses. Single vulnerability: single vulnerability for both species (base case); split vulnerability (1): split vulnerability with re-assignment of southern Buller's captures north of 40°S and in October and November to northern Buller's; split vulnerability (2): split vulnerability with further re-assignment of captures east of 180°E to be of northern Buller's albatross. Median risk ratio values were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. The species are sorted by decreasing order of the average median risk ratio across the three scenarios.

Species	Single vulnerability		Split vulnerability (1)		Split vulnerability (2)	
	Median	95% c.i.	Median	95% c.i.	Median	95% c.i.
Black petrel	**11.34**	6.85–19.81	**11.17**	6.86–19.56	**11.28**	6.80–19.93
Salvin's albatross	**3.44**	1.82–6.50	**3.44**	1.80–6.45	**3.42**	1.79–6.35
Southern Buller's albatross	**1.82**	0.97–3.67	**2.81**	1.56–5.60	**2.5**	1.38–5.00
Flesh-footed shearwater	**1.5**	0.56–3.36	**1.47**	0.56–3.26	**1.47**	0.58–3.24
Gibson's albatross	**1.26**	0.69–2.49	**1.24**	0.69–2.53	**1.25**	0.69–2.54
NZ white-capped albatross	**1.1**	0.59–1.97	**1.1**	0.57–2.02	**1.09**	0.58–1.98
Chatham Island albatross	**0.91**	0.42–1.90	**0.93**	0.43–1.95	**0.91**	0.44–1.93
Antipodean albatross	**0.89**	0.56–1.47	**0.89**	0.55–1.45	**0.9**	0.56–1.49
Northern Buller's albatross	**1.02**	0.58–2.00	**0.33**	0.17–0.71	**0.58**	0.29–1.24
Westland petrel	**0.53**	0.21–1.37	**0.53**	0.22–1.40	**0.53**	0.22–1.42
Campbell black-browed albatross	**0.31**	0.16–0.63	**0.31**	0.16–0.62	**0.31**	0.16–0.63
Stewart Island shag	**0.3**	0.19–0.49	**0.3**	0.18–0.47	**0.3**	0.19–0.47
White-chinned petrel	**0.28**	0.14–0.64	**0.27**	0.14–0.65	**0.27**	0.13–0.65
Northern giant petrel	**0.22**	0.05–0.96	**0.21**	0.05–0.92	**0.21**	0.04–1.00
Northern royal albatross	**0.19**	0.07–0.59	**0.19**	0.07–0.58	**0.18**	0.07–0.59
Spotted shag	**0.18**	0.10–0.32	**0.18**	0.09–0.32	**0.18**	0.09–0.32
Southern royal albatross	**0.1**	0.05–0.20	**0.09**	0.05–0.20	**0.1**	0.05–0.20
Snares Cape petrel	**0.09**	0.03–0.25	**0.09**	0.04–0.27	**0.09**	0.04–0.26
Grey petrel	**0.08**	0.04–0.17	**0.08**	0.04–0.17	**0.08**	0.04–0.17
Yellow-eyed penguin	**0.08**	0.03–0.21	**0.08**	0.03–0.25	**0.08**	0.04–0.20
Chatham petrel	**0.07**	0.00–0.32	**0.07**	0.00–0.31	**0.07**	0.00–0.33
Little black shag	**0.04**	0.01–0.13	**0.04**	0.01–0.13	**0.04**	0.01–0.13
Light-mantled sooty albatross	**0.03**	0.01–0.17	**0.03**	0.01–0.16	**0.03**	0.01–0.18
Pied shag	0.03	0.01–0.10	0.03	0.01–0.10	**0.03**	0.01–0.11
Fiordland crested penguin	**0.02**	0.00–0.24	**0.01**	0.00–0.21	**0.02**	0.00–0.23
Grey-headed albatross	**0.01**	0.00–0.12	**0.01**	0.00–0.13	**0.01**	0.00–0.13
Australasian gannet	0.01	0.00–0.06	0.01	0.00–0.06	0.01	0.00–0.06
Fluttering shearwater	0.01	0.00–0.05	0.01	0.00–0.05	0.01	0.00–0.05
Grey-faced petrel	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Cook's petrel	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Soft-plumaged petrel	0.01	0.00–0.04	0.01	0.00–0.04	0.01	0.00–0.03
Pycroft's petrel	0.01	0.00–0.03	0.01	0.00–0.03	0.01	0.00–0.03
Sooty shearwater	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Northern little penguin	0.01	0.00–0.02	0.01	0.00–0.02	0.01	0.00–0.02
Mottled petrel	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
White-flippered little penguin	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02
Hutton's shearwater	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Southern little penguin	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
White-headed petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Common diving petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Snares crested penguin	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Buller's shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Black-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
NZ white-faced storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Chatham Island little penguin	0	0.00–0.02	0	0.00–0.02	0	0.00–0.02
Southern black-backed gull	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Fairy prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Little shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Eastern rockhopper penguin	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Antarctic prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Broad-billed prion	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Erect-crested penguin	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Auckland Island shag	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
Bounty Island shag	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Subantarctic skua	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Caspian tern	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Chatham Island shag	0	0.00–0.04	0	0.00–0.05	0	0.00–0.05
Campbell Island shag	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White tern	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
South Georgian diving petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
NZ king shag	**0**	0.00–0.11	**0**	0.00–0.13	**0**	0.00–0.12
Kermadec storm petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Masked booby	0	0.00–0.01	0	0.00–0.01	0	0.00–0.01
NZ storm petrel	**0**	0.00–0.29	**0**	0.00–0.29	**0**	0.00–0.29
Pitt Island shag	0	0.00–0.04	0	0.00–0.06	0	0.00–0.06
Chatham Island taiko	**0**	0.00–0.36	**0**	0.00–0.38	**0**	0.00–0.32
Wedge-tailed shearwater	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
Kermadec petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00
White-naped petrel	0	0.00–0.00	0	0.00–0.00	0	0.00–0.00

Table A-22: Sensitivity of the estimation of annual potential fatalities to the population size of black petrel. Population sizes included the base case, and the population size divided by 10 or multiplied by 10. Species names were coloured according to the associated risk category in the base case as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. The species are sorted by decreasing order of the median risk ratio of the base case.

Species	Base case		Population size / 10		Population size × 10	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Black petrel	1 128	840–1 488	1 127	836–1 478	1 134	846–1 487
Salvin's albatross	3 481	2 247–5 205	3 463	2 265–5 138	3 481	2 294–5 078
Southern Buller's albatross	812	557–1 188	808	551–1 166	811	567–1 173
Flesh-footed shearwater	696	473–991	695	481–997	693	470–994
Gibson's albatross	223	161–303	223	160–304	223	161–302
NZ white-capped albatross	4 417	2 800–6 615	4 400	2 814–6 670	4 442	2 851–6 659
Northern Buller's albatross	549	410–727	546	403–716	548	409–717
Chatham Island albatross	128	70–226	129	70–232	128	69–226
Antipodean albatross	123	86–175	122	85–175	123	86–176
Westland petrel	88	37–183	86	37–177	87	37–177
Campbell black-browed albatross	214	121–362	214	118–361	215	120–362
Stewart Island shag	91	58–139	91	58–134	90	58–137
White-chinned petrel	1 453	916–2 556	1 459	905–2 601	1 449	899–2 570
Northern giant petrel	37	9–98	36	9–96	36	9–97
Northern royal albatross	52	20–120	52	21–121	51	20–116
Spotted shag	425	285–628	426	286–614	430	287–632
Southern royal albatross	39	20–71	38	19–71	39	20–70
Snares Cape petrel	50	26–89	51	26–91	50	26–93
Grey petrel	178	109–279	179	110–277	177	109–280
Yellow-eyed penguin	44	17–91	46	18–103	42	18–82
Chatham petrel	1	0–2	1	0–2	1	0–2
Little black shag	9	1–23	9	1–23	9	1–23
Light-mantled sooty albatross	11	1–39	11	1–37	11	1–39
Pied shag	31	5–78	31	5–79	31	5–81
Fiordland crested penguin	12	0–73	12	0–71	11	0–64
Australasian gannet	41	3–129	40	3–126	39	3–128
Grey-headed albatross	5	0–24	5	0–27	5	0–25
Fluttering shearwater	25	3–89	25	3–86	25	3–91
Grey-faced petrel	101	43–187	101	44–189	100	42–189
Cook's petrel	16	6–33	17	6–33	16	6–32
Soft-plumaged petrel	0	0–1	0	0–2	0	0–1
Pycroft's petrel	1	0–2	1	0–2	1	0–2
Sooty shearwater	1 353	738–2 603	1 362	747–2 614	1 352	733–2 650
Northern little penguin	7	1–21	7	0–22	7	0–22
Mottled petrel	46	18–91	46	18–90	46	18–90
White-flippered little penguin	1	0–5	1	0–5	1	0–5
Hutton's shearwater	18	5–50	18	5–49	18	5–50
Southern little penguin	3	0–11	3	0–12	3	0–12
White-headed petrel	14	5–27	14	5–27	14	5–27
Common diving petrel	34	9–102	34	9–97	34	9–99
Snares crested penguin	4	0–20	5	0–20	4	0–17
Buller's shearwater	10	1–34	10	1–34	10	1–35
Black-bellied storm petrel	2	0–7	2	0–7	2	0–7
NZ white-faced storm petrel	51	8–219	48	9–203	46	8–186
Chatham Island little penguin	2	0–18	3	0–19	2	0–18
Southern black-backed gull	94	27–215	94	26–218	94	29–214
Fairy prion	41	10–123	41	9–126	41	9–133
Little shearwater	2	0–8	2	0–8	2	0–8
Eastern rockhopper penguin	3	0–12	3	0–12	2	0–10
Antarctic prion	3	0–7	3	0–6	3	0–7
Broad-billed prion	14	2–66	15	2–70	15	2–77
Erect-crested penguin	1	0–3	1	0–4	1	0–4
Auckland Island shag	0	0–1	0	0–1	0	0–1
Bounty Island shag	0	0–0	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0	0	0–0
Caspian tern	0	0–0	0	0–0	0	0–0
Chatham Island shag	0	0–2	0	0–2	0	0–2
Campbell Island shag	0	0–0	0	0–0	0	0–0
White-bellied storm petrel	0	0–0	0	0–0	0	0–0
White tern	0	0–0	0	0–0	0	0–0
South Georgian diving petrel	0	0–0	0	0–0	0	0–0
NZ king shag	0	0–2	0	0–2	0	0–2
Kermadec storm petrel	0	0–0	0	0–0	0	0–0
Masked booby	0	0–0	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0	0	0–0
Pitt Island shag	0	0–3	0	0–3	0	0–3
Chatham Island taiko	0	0–0	0	0–0	0	0–0
Wedge-tailed shearwater	0	0–0	0	0–0	0	0–0
Kermadec petrel	0	0–1	0	0–1	0	0–1
White-naped petrel	0	0–0	0	0–0	0	0–0

Table A-23: Sensitivity of the estimation of annual potential fatalities to the method of creating a single at-sea distribution of black petrel. Base case: spatially-varying proportions of fisheries; constant proportion: single proportion of fisheries, not varying in space. Species names were coloured according to the associated risk category in the base case as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. The species are sorted by decreasing order of the median risk ratio of the base case.

Species	Base case		Constant proportion	
	Mean	95% c.i.	Mean	95% c.i.
Black petrel	1 128	840–1 488	1 219	901–1 615
Salvin's albatross	3 481	2 247–5 205	3 623	2 313–5 469
Southern Buller's albatross	812	557–1 188	796	538–1 146
Flesh-footed shearwater	696	473–991	694	472–989
Gibson's albatross	223	161–303	224	163–304
New Zealand white-capped albatross	4 417	2 800–6 615	4 508	2 874–6 692
Northern Buller's albatross	549	410–727	452	335–601
Chatham Island albatross	128	70–226	140	74–252
Antipodean albatross	123	86–175	123	86–178
Westland petrel	88	37–183	87	38–176
Campbell black-browed albatross	214	121–362	205	112–357
Stewart Island shag	91	58–139	92	57–137
White-chinned petrel	1 453	916–2 556	1 459	917–2 578
Northern giant petrel	37	9–98	37	9–99
Northern royal albatross	52	20–120	52	21–124
Spotted shag	425	285–628	428	285–617
Southern royal albatross	39	20–71	39	19–73
Snares Cape petrel	50	26–89	52	27–91
Grey petrel	178	109–279	194	120–300
Yellow-eyed penguin	44	17–91	46	17–102
Chatham petrel	1	0–2	1	0–2
Little black shag	9	1–23	9	1–23
Light-mantled sooty albatross	11	1–39	11	1–43
Pied shag	31	5–78	31	5–79
Fiordland crested penguin	12	0–73	8	0–43
Australasian gannet	41	3–129	37	3–119
Grey-headed albatross	5	0–24	5	0–25
Fluttering shearwater	25	3–89	24	3–85
Grey-faced petrel	101	43–187	98	41–184
Cook's petrel	16	6–33	15	6–30
Soft-plumaged petrel	0	0–1	1	0–2
Pycroft's petrel	1	0–2	1	0–2
Sooty shearwater	1 353	738–2 603	1 344	738–2 617
Northern little penguin	7	1–21	7	0–21
Mottled petrel	46	18–91	43	16–83
White-flippered little penguin	1	0–5	1	0–5
Hutton's shearwater	18	5–50	18	5–46
Southern little penguin	3	0–11	3	0–11
White-headed petrel	14	5–27	19	7–37
Common diving petrel	34	9–102	33	9–95
Snares crested penguin	4	0–20	7	1–26
Buller's shearwater	10	1–34	10	1–32
Black-bellied storm petrel	2	0–7	3	0–8
New Zealand white-faced storm petrel	51	8–219	46	8–195
Chatham Island little penguin	2	0–18	2	0–19
Southern black-backed gull	94	27–215	94	27–216
Fairy prion	41	10–123	41	9–124
Little shearwater	2	0–8	3	0–11
Eastern rockhopper penguin	3	0–12	3	0–11
Antarctic prion	3	0–7	4	1–9
Broad-billed prion	14	2–66	14	2–68
Erect-crested penguin	1	0–3	1	0–2
Auckland Island shag	0	0–1	0	0–1
Bounty Island shag	0	0–0	0	0–0
Subantarctic skua	0	0–0	0	0–0
Caspian tern	0	0–0	0	0–0
Chatham Island shag	0	0–2	0	0–2
Campbell Island shag	0	0–0	0	0–0
White-bellied storm petrel	0	0–0	0	0–0
White tern	0	0–0	0	0–0
South Georgian diving petrel	0	0–0	0	0–0
New Zealand king shag	0	0–2	0	0–2
Kermadec storm petrel	0	0–0	0	0–0
Masked booby	0	0–0	0	0–0
New Zealand storm petrel	0	0–0	0	0–0
Pitt Island shag	0	0–3	0	0–3
Chatham Island taiko	0	0–0	0	0–0
Wedge-tailed shearwater	0	0–0	0	0–0
Kermadec petrel	0	0–1	0	0–1
White-naped petrel	0	0–0	0	0–0

A.8 Annual potential fatalities and breeding season

Table A-24: Total observed captures and annual potential fatalities, relative to the breeding season of each seabird species. Species with unspecified breeding periods breed all year long (e.g., albatrosses), their distribution does not change between seasons (e.g., coastal species), or their distribution is unknown (e.g., New Zealand storm petrel); only one distribution map was used for these species. Species names were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Numbers were rounded to three significant digits.

			During breeding season			Outside breeding season		
Species	Breeding period	Percentage staying in the NZEEZ	Observed captures	Estimated fatalities Mean	Estimated fatalities 95% c.i.	Observed captures	Estimated fatalities Mean	Estimated fatalities 95% c.i.
Gibson's albatross	–		27	223	161–303	0	0	0–0
Antipodean albatross	–		28	123	86–175	0	0	0–0
Southern royal albatross	–		15	39	20–71	0	0	0–0
Northern royal albatross	–		1	52	20–120	0	0	0–0
Campbell black-browed albatross	Aug–May (10)	50.0	20	189	105–322	11	26	14–41
New Zealand white-capped albatross	Nov–Aug (10)	50.0	552	4 080	2 600–6 080	10	339	202–530
Salvin's albatross	Sep–Mar (7)	10.0	204	3 260	2 110–4 880	18	219	141–331
Chatham Island albatross	Aug–May (10)	2.5	21	127	70–225	0	0	0–1
Grey-headed albatross	Sep–May (9)	20.0	0	5	0–23	0	0	0–2
Southern Buller's albatross	Jan–Sep (9)	2.5	387	807	554–1 180	0	5	2–9
Northern Buller's albatross	Oct–Jun (9)	2.5	19	545	406–721	5	5	2–7
Light-mantled sooty albatross	Sep–Jun (10)	20.0	1	10	1–38	0	0	0–2
Northern giant petrel	Aug–Feb (7)	75.0	4	25	6–65	1	12	2–35
Grey petrel	Feb–Nov (10)	2.5	70	177	109–277	0	1	0–2
Black petrel	Oct–Jul (10)	0.5	74	1 130	840–1 490	0	0	0–0
Westland petrel	Mar–Dec (10)	2.5	19	87	37–182	1	1	0–2
White-chinned petrel	Oct–May (8)	20.0	804	1 370	859–2 400	3	86	52–149
Flesh-footed shearwater	Oct–May (8)	0.5	64	695	473–990	0	1	0–2
Wedge-tailed shearwater	Oct–May (8)	0.5	0	0	0–0	0	0	0–0
Buller's shearwater	Sep–May (9)	0.5	0	10	1–34	0	0	0–0
Sooty shearwater	Oct–May (8)	0.5	631	1 350	736–2 600	1	3	1–6
Fluttering shearwater	Jul–Feb (8)	80.0	1	24	3–88	1	0	0–2
Hutton's shearwater	Sep–Apr (8)	2.5	0	18	5–50	0	0	0–1
Little shearwater	Apr–Nov (8)	5.0	0	2	0–8	0	0	0–0
Snares Cape petrel	Nov–Feb (4)	90.0	2	24	12–41	13	27	12–50
Fairy prion	Mar–Jan (11)	15.0	6	40	9–122	1	0	0–1
Antarctic prion	Nov–Mar (5)	15.0	1	2	0–6	0	0	0–1
Broad-billed prion	Feb–Jan (12)	5.0	0	14	2–66	0	0	0–0
Pycroft's petrel	Oct–Apr (7)	0.0	0	1	0–2	0	0	0–0
Cook's petrel	Sep–Apr (8)	0.5	0	16	6–33	0	0	0–0
Chatham petrel	Nov–Jun (8)	0.0	0	1	0–2	0	0	0–0
Mottled petrel	Oct–May (8)	0.0	0	46	18–91	0	0	0–0
White-naped petrel	Oct–May (8)	0.0	0	0	0–0	0	0	0–0
Kermadec petrel	–		0	0	0–1	0	0	0–0
Grey-faced petrel	Mar–Jan (11)	10.0	9	100	43–187	0	0	0–1
Chatham Island taiko	Sep–May (9)	20.0	0	0	0–0	0	0	0–0
White-headed petrel	Nov–Jun (8)	10.0	0	13	5–25	0	1	0–2
Soft-plumaged petrel	Aug–May (10)	0.5	0	0	0–1	0	0	0–0
Common diving petrel	Sep–Mar (7)	20.0	4	32	8–98	3	2	0–5
South Georgian diving petrel	Sep–Feb (6)	0.0	0	0	0–0	0	0	0–0
New Zealand white-faced storm petrel	Sep–Apr (8)	0.5	2	51	8–219	0	0	0–0
White-bellied storm petrel	Apr–Aug (5)	100.0	0	0	0–0	0	0	0–0
Black-bellied storm petrel	Oct–May (8)	50.0	1	2	0–6	0	1	0–2
Kermadec storm petrel	Jun–Dec (7)	50.0	0	0	0–0	0	0	0–0
New Zealand storm petrel	–		0	0	0–0	0	0	0–0
Yellow-eyed penguin	Aug–Apr (9)	100.0	9	32	12–66	0	12	4–26
Northern little penguin	Jul–Feb (8)	100.0	0	5	0–16	0	2	0–8
White-flippered little penguin	Jul–Feb (8)	100.0	0	1	0–3	0	1	0–2
Southern little penguin	Jul–Feb (8)	100.0	0	2	0–9	0	1	0–4
Chatham Island little penguin	Jul–Feb (8)	100.0	0	1	0–11	0	1	0–7
Eastern rockhopper penguin	Oct–May (8)	5.0	0	3	0–11	0	0	0–1
Fiordland crested penguin	Jul–Mar (9)	50.0	1	11	0–71	0	1	0–3
Snares crested penguin	Sep–Feb (6)	5.0	0	4	0–18	0	0	0–2
Erect-crested penguin	Sep–Mar (7)	50.0	0	1	0–3	0	0	0–1
Australasian gannet	Aug–Mar (8)	20.0	0	40	3–127	0	1	0–2
Masked booby	–		0	0	0–0	0	0	0–0
Pied shag	–	100.0	1	31	5–78	0	0	0–0
Little black shag	Oct–Dec (3)	100.0	0	3	0–7	0	6	1–16
New Zealand king shag	Mar–Oct (8)	100.0	0	0	0–1	0	0	0–1
Stewart Island shag	Aug–Mar (8)	100.0	2	63	40–96	0	28	17–44
Chatham Island shag	Sep–Feb (6)	100.0	0	0	0–1	0	0	0–1
Bounty Island shag	Oct–Dec (3)	100.0	0	0	0–0	0	0	0–0
Auckland Island shag	Nov–Mar (5)	100.0	0	0	0–0	0	0	0–1
Campbell Island shag	Nov–Feb (4)	100.0	0	0	0–0	0	0	0–0
Spotted shag	–		35	425	285–628	0	0	0–0
Pitt Island shag	Sep–Feb (6)	100.0	0	0	0–1	0	0	0–2
Subantarctic skua	Sep–Feb (6)	50.0	0	0	0–0	0	0	0–0
Southern black-backed gull	Sep–Mar (7)	100.0	2	58	17–131	1	36	10–83
Caspian tern	Sep–Jan (5)	100.0	0	0	0–0	0	0	0–0
White tern	Sep–Apr (8)	100.0	0	0	0–0	0	0	0–0

A.9 Effect of cryptic mortality

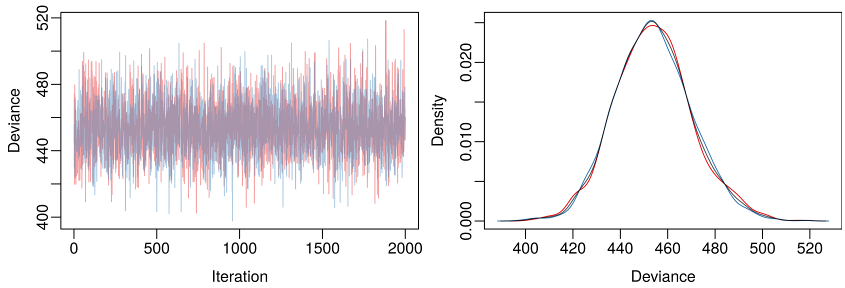
Table A-25: Estimated number of annual observable captures of seabirds (not including cryptic mortality), and estimated number of annual potential fatalities (including cryptic mortality) in trawl, bottom-longline, surface-longline, and set-net fisheries in New Zealand's Exclusive Economic Zone. Species names were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk. Numbers were rounded to three significant digits.

Species	No cryptic mortality		With cryptic mortality	
	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	95	71–125	223	161–303
Antipodean albatross	51	37–70	123	86–175
Southern royal albatross	12	7–21	39	20–71
Northern royal albatross	13	5–32	52	20–120
Campbell black-browed albatross	84	46–145	214	121–362
NZ white-capped albatross	633	525–759	4 420	2 800–6 620
Salvin's albatross	580	460–711	3 480	2 250–5 200
Chatham Island albatross	50	26–91	128	70–226
Grey-headed albatross	2	0–10	5	0–24
Southern Buller's albatross	167	139–204	812	557–1 190
Northern Buller's albatross	194	146–253	549	410–727
Light-mantled sooty albatross	3	0–12	11	1–39
Northern giant petrel	5	1–14	37	9–98
Grey petrel	78	50–119	178	109–279
Black petrel	532	411–668	1 130	840–1 490
Westland petrel	38	17–76	88	37–183
White-chinned petrel	514	461–580	1 450	916–2 560
Flesh-footed shearwater	302	218–400	696	473–991
Wedge-tailed shearwater	0	0–0	0	0–0
Buller's shearwater	5	0–16	10	1–34
Sooty shearwater	418	342–511	1 350	738–2 600
Fluttering shearwater	13	2–43	25	3–89
Hutton's shearwater	11	4–26	18	5–50
Little shearwater	1	0–4	2	0–8
Snares Cape petrel	37	19–63	50	26–89
Fairy prion	23	5–64	41	10–123
Antarctic prion	1	0–2	3	0–7
Broad-billed prion	6	1–31	14	2–66
Pycroft's petrel	0	0–1	1	0–2
Cook's petrel	8	3–16	16	6–33
Chatham petrel	0	0–1	1	0–2
Mottled petrel	23	8–43	46	18–91
White-naped petrel	0	0–0	0	0–0
Kermadec petrel	0	0–1	0	0–1
Grey-faced petrel	48	21–88	101	43–187
Chatham Island taiko	0	0–0	0	0–0
White-headed petrel	7	2–13	14	5–27
Soft-plumaged petrel	0	0–1	0	0–1
Common diving petrel	14	5–39	34	9–102
South Georgian diving petrel	0	0–0	0	0–0
NZ white-faced storm petrel	28	4–109	51	8–219
White-bellied storm petrel	0	0–0	0	0–0
Black-bellied storm petrel	1	0–5	2	0–7
Kermadec storm petrel	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0
Yellow-eyed penguin	39	17–72	44	17–91
Northern little penguin	5	0–15	7	1–21
White-flippered little penguin	1	0–4	1	0–5
Southern little penguin	2	0–8	3	0–11
Chatham Island little penguin	1	0–8	2	0–18
Eastern rockhopper penguin	2	0–6	3	0–12
Fiordland crested penguin	7	0–35	12	0–73
Snares crested penguin	3	0–11	4	0–20
Erect-crested penguin	0	0–2	1	0–3
Australasian gannet	36	3–122	41	3–129
Masked booby	0	0–0	0	0–0
Pied shag	28	4–71	31	5–78
Little black shag	8	1–22	9	1–23
NZ king shag	0	0–1	0	0–2
Stewart Island shag	71	47–100	91	58–139
Chatham Island shag	0	0–1	0	0–2
Bounty Island shag	0	0–0	0	0–0
Auckland Island shag	0	0–1	0	0–1
Campbell Island shag	0	0–0	0	0–0
Spotted shag	335	233–456	425	285–628
Pitt Island shag	0	0–1	0	0–3
Subantarctic skua	0	0–0	0	0–0
Southern black-backed gull	45	14–95	94	27–215
Caspian tern	0	0–0	0	0–0
White tern	0	0–0	0	0–0

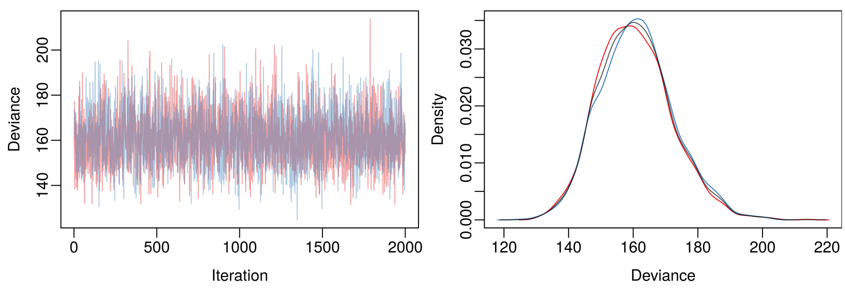
A.10 Model diagnostics

Figure A-2: Trace of model deviance for the four Bayesian models that were fitted to estimate the vulnerabilities to capture in trawl, bottom-longline, surface-longline, and set-net fisheries, obtained from two chains (in red and blue). The density distribution of the deviance value for both chains are shown in the right panel, including the distribution from both chains combined (in black).

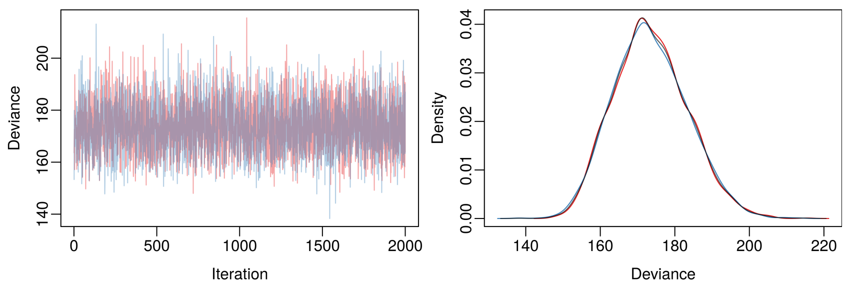
(a) Trawl



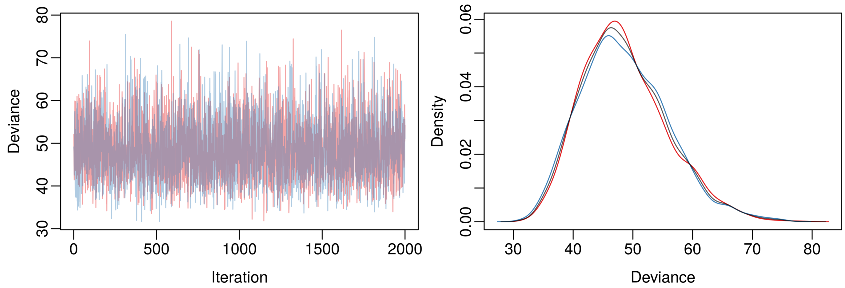
(b) Bottom longline



(c) Surface longline



(d) Set net



APPENDIX B ESTIMATION OF CRYPTIC FATALITIES

B.1 Introduction

Not all seabirds that are killed by fishing activity are recorded by observers, even when observers are on-board the vessels. Birds may be killed, but not brought on-board the fishing vessel. These cryptic fatalities must be included in an assessment of the risk to seabirds from fishing. The total number of potential fatalities, F, is calculated as the sum of observable captures, C, and unobservable or cryptic fatalities, U:

$$F = C + U \tag{B-1}$$

Some of the captures, C, involve birds that were released alive. As the fate of these birds following release is unknown, it was assumed in the risk assessment that all observed captures were fatalities.

The methods in this section follow the framework originally developed by Sharp et al. (2011), applied and presented in an previous risk assessment (Richard et al. 2011), following review by the Aquatic Environment Working Group of the Ministry for Primary Industries. We derived multipliers for cryptic mortalities ("cryptic multipliers"), $M = F/C$, that allowed the total fatalities to be expressed as the product of the cryptic multiplier and the observable captures. Cryptic multipliers were estimated separately for longline and trawl fisheries. For longline fisheries, a single cryptic multiplier was estimated for all species, whereas for trawl fisheries, different multipliers were estimated for four different species groups.

In the present risk assessment, the estimates of cryptic fatality have been updated to include more recent data, and uncertainties around the cryptic multipliers have been estimated.

B.2 Longline fisheries

A multi-year study conducted in Australia that compared the number of individual birds hooked during the set and haul processes with observed captures that were subsequently recorded, revealed that of 176 seabirds observed caught on hooks, only 85 carcasses were retrieved (Brothers et al. 2010). Using these values, we deduced the probability distribution of capturing a bird, given it was caught on the line, from the likelihood of the binomial distribution (Equation B-2):

$$\mathcal{L} = \frac{n!}{k!(n-k)!} p^k (1-p)^{n-k}, \tag{B-2}$$

where n is the number of birds observed hooked, k is the number of retrieved carcasses, and p is the probability of a bird being retrieved on board, given that it was hooked. The cryptic multiplier for longline fisheries is then $M = 1/p$. Using $n = 176$ and $k = 85$ in Equation B-2 led to a mean of M of 2.09, with a 95% credible interval of 1.8 to 2.46.

This distribution was used for all seabird species and all surface-longline fisheries. Each sample of estimated observable captures was multiplied by a sample from this distribution to estimate the total annual potential fatalities. In the absence of other information, the same distribution for the cryptic multiplier was used for bottom-longline fisheries. The uncertainly was the statistical uncertainty associated with the study by Brothers et al. (2010). Structural uncertainty associated with applying these values to different fisheries, impacting a different assemblage of seabird species, was not considered.

B.3 Trawl fisheries

To estimate total fatalities in trawl fisheries, it is useful to first distinguish between three types of seabird-trawler interactions:

- Net entanglement. Birds that become entrapped or entangled in the net during shooting or hauling gear.

- Surface warp strike. Birds resting or hovering on the surface of the water that are overtaken and potentially entangled or drowned by a moving warp line, or that are struck by warp movement arising from the lateral movement of the vessel.

- Aerial warp strike. Flying birds that collide with the warp.

The number of fatalities per observed fishing event can then be defined as:

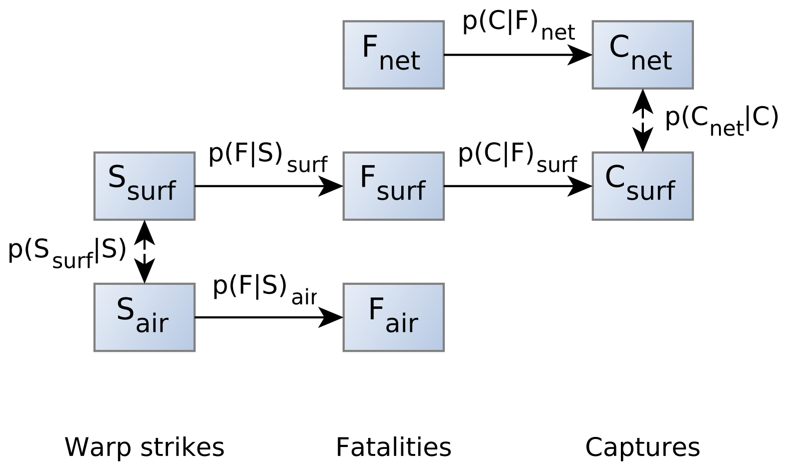
$$F_{tot} = F_{net} + F_{surf} + F_{air} \tag{B-3}$$
$$= C_{net}M_{net} + C_{surf}M_{surf} + C_{air}M_{air} \tag{B-4}$$

where F_{net}, F_{surf}, and F_{air} are the total fatalities in the net, due to surface warp strikes and aerial warp strikes respectively, C_{net}, C_{surf}, and C_{air} the corresponding observed captures, and M_{net}, M_{surf}, and M_{air}, the corresponding cryptic multipliers.

To determine the relationship between captures and fatalities, different probabilities were estimated (illustrated in Figure B-3). Uncertainties were estimated by drawing 5000 samples from a probability distribution for the underlying data. When the data were given as a number of incidents in a number of trials, a binomial distribution was assumed (Equation B-2). When estimated proportions were reported as a mean and 95% confidence interval (e.g., the number of strikes per capture), a log-normal distribution was assumed and defined to match the 95% confidence interval. From a mean μ and a standard deviation σ, mortality rates were assumed to follow a beta distribution, with its two shape parameters α and β defined using the equations (Samaranayaka & Fletcher 2010):

$$\alpha = \mu \left(\frac{\mu(1-\mu)}{\sigma^2} - 1 \right), \qquad \beta = \frac{(1-\mu)\alpha}{\mu}.$$

Figure B-3: Diagram of the parameters and processes involving seabird fatalities in trawl fisheries. Seabirds can be struck by warps either on the surface of the water, S_{surf}, or when flying, S_{air}. These warp strikes can lead to fatalities (F_{surf}, F_{air}). Fatalities of seabirds can also occur from their entanglement or capture in nets, F_{net}. Captures of seabirds recovered on board the fishing vessel were assumed to be only from interactions with the net, C_{net}, or from surface warp strikes, C_{surf}.



B.3.1 Net entanglement

Net entanglements can occur either when shooting or hauling the net, with the majority of net captures occurring during hauling. Birds can become enmeshed in the trawl wings during setting, trapped inside the net as it closes (i.e., primarily diving species) or trapped on the outside of the net as the mesh tightens and closes during hauling. In the latter instance, birds may be released alive. In this analysis, these live captures were treated as fatalities as long-term impacts resulting from the capture are unknown. Cryptic net fatalities U_{net} arise when birds become entangled in the trawl wings during setting or on the outside of the net during hauling, but subsequently fall off and are not recorded. Cryptic net fatalities also include birds caught inside the net that are subsequently lost through the slack mesh during the haul.

In preparation of a previous risk assessment (Richard et al. 2011), it was agreed that the number of cryptic net fatalities, U_{net}, is likely to be lower than the number of observable captures, C_{net}. A ratio of cryptic to observable captures of $U_{net}/C_{net} = 0.3$ was used in the earlier assessment by Richard et al. (2011). To consider uncertainty around this ratio, we assumed that U_{net}/C_{net} followed a log-normal distribution with a 95% confidence interval of 0.1 to 0.7, and mean of 0.3. This range was not based on data.

The total number of fatalities due to net entanglements is the sum of observed and unobserved fatalities, therefore

$$M_{net} = F_{net}/C_{net} = 1 + U_{net}/C_{net}. \tag{B-5}$$

B.3.2 Warp strikes

Limited data for estimating cryptic mortality from warp strikes are provided by two studies. Watkins et al. (2008) provide data on the number of warp strikes and subsequent fatalities, based on 190 hours of dedicated observations in the South African deepwater hake fishery in 2004 and 2005. Abraham (2010) provide estimates of the number of warp strikes per observed capture, using 7266 observations of warp strikes collected in New Zealand trawl fisheries in the fishing years between 2004–2005 and 2008–2009.

To relate observed warp captures to estimated warp fatalities, it is first necessary to distinguish between types of warp interactions and species- or guild-specific differences likely to affect the outcome of warp-bird interactions.

Due to behavioural and anatomical differences affecting warp-bird interactions, estimates of warp strike parameters were calculated independently for large versus small seabirds (see the grouping of seabird species in Table B-26). Small birds were further differentiated into “fast-flying”, “slow-flying”, or “diving” species, with distinct assumptions about their relative susceptibilities to different kinds of capture. In general, fast-flying birds are larger than slow-flying birds; they are slower to accelerate from the surface of the water, turn less quickly, and may fly with considerable forward momentum. Diving birds (shags and penguins) do not forage while flying and were assumed to be killed only in the net.

B.3.3 Surface warp strikes

The total cryptic fatalities from surface warp strikes are:

$$F_{surf} = C_{surf} + U_{surf}. \tag{B-6}$$

Surface warp strikes occur when birds resting or hovering on the surface of the water are overtaken by the moving warp, or struck by warp movement arising from lateral movement of the vessel. Watkins et al. (2008) report that surface warp strike rates are strongly correlated with large swell conditions due to the resulting erratic movement of the warps relative to resting seabirds. Surface strikes leading to capture or fatality occur primarily when bird wings become entangled, and they are dragged underwater by the force of the water passing over the warp. Birds dragged underwater may resurface, or they may drown. Drowned birds may subsequently fall off the warp during the setting and hauling processes (U_{surf}); alternatively, they may be impaled on a sprag (loose warp splice) or pulled all the way to the trawl door, and subsequently retrieved (i.e., C_{surf}). Non-lethal warp captures are not observed.

Large birds such as albatrosses are particularly susceptible to being dragged underwater by surface warp strikes, because they habitually sit or hover on the surface with their wings spread; when struck from

Table B-26: Classification of species into behavioural groups, used for estimating cryptic fatalities in trawl fisheries.

Species	Group
Gibson's albatross	Large
Antipodean albatross	Large
Southern royal albatross	Large
Northern royal albatross	Large
Campbell black-browed albatross	Large
New Zealand white-capped albatross	Large
Salvin's albatross	Large
Chatham Island albatross	Large
Grey-headed albatross	Large
Southern Buller's albatross	Large
Northern Buller's albatross	Large
Light-mantled sooty albatross	Large
Northern giant petrel	Large
Grey petrel	Small fast-flying
Black petrel	Small fast-flying
Westland petrel	Small fast-flying
White-chinned petrel	Small fast-flying
Flesh-footed shearwater	Small fast-flying
Wedge-tailed shearwater	Small fast-flying
Buller's shearwater	Small fast-flying
Sooty shearwater	Small fast-flying
Fluttering shearwater	Small fast-flying
Hutton's shearwater	Small fast-flying
Little shearwater	Small slow-flying
Snares Cape petrel	Small slow-flying
Fairy prion	Small slow-flying
Antarctic prion	Small slow-flying
Broad-billed prion	Small slow-flying
Pycroft's petrel	Small slow-flying
Cook's petrel	Small slow-flying
Chatham petrel	Small slow-flying
Mottled petrel	Small slow-flying
White-naped petrel	Small slow-flying
Kermadec petrel	Small slow-flying
Grey-faced petrel	Small slow-flying
Chatham Island taiko	Small slow-flying
White-headed petrel	Small slow-flying
Soft-plumaged petrel	Small slow-flying
Common diving petrel	Small slow-flying
South Georgian diving petrel	Small slow-flying
New Zealand white-faced storm petrel	Small slow-flying
White-bellied storm petrel	Small slow-flying
Black-bellied storm petrel	Small slow-flying
Kermadec storm petrel	Small slow-flying
New Zealand storm petrel	Small slow-flying
Yellow-eyed penguin	Small diving
Northern little penguin	Small diving
White-flippered little penguin	Small diving
Southern little penguin	Small diving
Chatham Island little penguin	Small diving
Eastern rockhopper penguin	Small diving
Fiordland crested penguin	Small diving
Snares crested penguin	Small diving
Erect-crested penguin	Small diving
Australasian gannet	Small diving
Masked booby	Small diving
Pied shag	Small diving
Little black shag	Small diving
New Zealand king shag	Small diving
Stewart Island shag	Small diving
Chatham Island shag	Small diving
Bounty Island shag	Small diving
Auckland Island shag	Small diving
Campbell Island shag	Small diving
Spotted shag	Small diving
Pitt Island shag	Small diving
Subantarctic skua	Large
Southern black-backed gull	Small slow-flying
Caspian tern	Small slow-flying
White tern	Small slow-flying

behind by a moving warp, the wing tends to wrap around the warp leading to entanglement. In contrast, because small birds habitually sit on the water with their wings closed, they are seldom entangled in the warps, and only very rarely observed as warp captures. Both fast-flying and slow-flying small birds were assumed to be susceptible to surface warp capture; the lower susceptibility of the slow-flying birds was expected to be reflected in lower observed capture rates. In contrast, diving birds (penguins and shags) were assumed not to be captured or killed in warp interactions; all diving bird fatalities were assumed to occur in the net, with no cryptic surface or aerial warp fatalities ($U^{fast}_{surf} = U^{fast}_{air} = 0$).

The probability that a bird hit by the warp (aerial or surface strike) is recovered on board the vessel is the product of the probability of entanglement (or impalement; F) given the strike (S) and the probability that the bird is recovered (C) given it gets entangled (or impaled). In mathematical terms,

$$p(C|S) \quad = \quad p(C|F)p(F|S). \tag{B-7}$$

Assuming that fatal aerial warp strikes do not result in captures ($C_{air} = 0$), the number of fatalities from surface warp strikes per warp capture (F_{surf}/C_{warp}) is the probability that a surface warp strike is fatal, $p(F_{surf}|S_{surf})$, times the number of surface warp strikes per warp capture (S_{surf}/C_{warp}). In the earlier studies, Abraham (2010) found that for large birds, there were an estimated 244 (95% c.i.: 190–330) warp strikes for each capture (S_{warp}/C_{warp}); Watkins et al. (2008) reports that of a total 376 observed strikes, 139 were surface warp strikes for large birds, leading to the mean probability that a strike is on the surface, $p(S_{surf}|S_{warp})$, of 0.37 (95% c.i.: 0.32 – 0.42). The ratio S_{surf}/C_{warp} was then estimated to be 93.88 (95% c.i.: 67.61 – 127.29). Watkins et al. (2008) also reports that 24 fatalities were observed following 139 surface warp strikes, resulting in a probability of observing a fatality from a surface warp strike of 0.18 (95% c.i.: 0.12 – 0.24). The same authors reported that 16 albatrosses were seen dragged under the water without resurfacing, so that their fate was unknown. The fatalities following the observed surface warp strikes were then estimated to be 26.85 (95% c.i.: 24 – 30), and the probability of a surface warp strike being fatal was estimated as 0.2 (95% c.i.: 0.13 – 0.27). From the product of $p(F_{surf}|S_{surf})$ and S_{surf}/C_{warp}, the number of large-birds fatalities per surface warp capture, F_{surf}/C_{warp}, was estimated to be 18.5 (95% c.i.: 11.01 – 28.8).

For small birds, there were an estimated 6440 (95% c.i.: 3400–20 000) strikes per warp capture (Abraham 2010). There were 124 surface warp strikes out of 615 observed strikes, and they resulted in 6 fatalities (and 10 that were unsure) (Watkins et al. 2008). Repeating the calculations, the mean number of small-bird fatalities per surface warp capture, F_{surf}/C_{warp}, was estimated to be 112.16 (95% c.i.: 29.02 – 296.33).

B.3.4 Aerial warp strikes

Aerial warp strikes occur when flying birds collide with the moving warps. Aerial strikes are defined as any heavy contact between the bird and the warp, sufficient to deflect the bird's flight trajectory; wing contacts are only included if they occur above the wrist (Abraham 2010), coinciding with the definition of "heavy" collisions used by Watkins et al. (2008).

Because impacts occur primarily on the front surface of the wings, aerial strikes do not result in entanglement in the warp, and captures on warps due to aerial strikes can be assumed to be non-existent. Fatalities from aerial strikes are only cryptic, and thus a multiplier cannot be defined relative to aerial captures. However, as in the previous analysis of surface warp strikes, the number of aerial strikes can be estimated relative to the number of surface strikes; the latter is estimated relative to the number of warp captures.

The number of fatalities due to aerial strikes per warp capture, F_{air}/C_{warp}, is the probability that an aerial warp strike is fatal, $p(F_{air}|S_{air})$, times the number of aerial strikes per warp capture, S_{air}/C_{warp}.

Aerial strike fatality is expected to arise primarily from damage to wing bones or tendons, but empirical data to estimate the subsequent fatality rate among affected birds are not currently available. Watkins et al. (2008) report that aerial strikes "usually had little apparent impact on birds" and recorded only one confirmed broken wing for a small fast-flying bird (white-chinned petrel) in 728 observed heavy collisions. Fatality rates for aerial warp strikes are thought to be low (e.g., 0 to 5%), and expected to be highest for large birds, and moderate for small, fast-flying birds, which may collide under their own forward momentum; they are expected to be low for small, slow-flying birds which have a minimal forward momentum and for which strikes are more likely to arise from the lateral movement of the warp itself. For small diving birds, it was assumed that there are no cryptic warp fatalities, i.e., $F_{air} = 0$. It is important to note, however, that without dedicated efforts to assess the post-collision status of affected birds, any conclusion about associated fatality rates is highly speculative. We assumed that the fatality rate due to aerial warp strikes, $p(F_{air}|S_{air})$, followed a beta distribution, with a coefficient of variation of 0.2, and we applied the following mean fatality rate estimates previously proposed by Sharp et al. (2011) (see Richard et al. 2011): 2% for large birds, 1% for small, fast-flying birds, and 0.5% for small, slow-flying birds.

The ratio S_{air}/C_{warp} is the number of warp strikes per warp capture, S_{warp}/C_{warp}, times the proportion of aerial strikes among warp strikes, $p(S_{air}|S_{warp}) = 1 - p(S_{surf}|S_{warp})$, as calculated in the analysis of surface warp strikes above. Using this ratio led to the number of fatalities due to aerial strike per observed capture of 3.19 (95% c.i.: 1.89 – 4.99) for large birds, 73.35 (95% c.i.: 24.71 – 168.37) for small, fast-flying birds, and 36.23 (95% c.i.: 12.14 – 83.82) for small, slow-flying birds. These estimates are speculative.

B.4 Total fatality estimation in trawl fisheries

The total number of fatalities in trawl fisheries, F_{trawl}, is the number of fatalities due to entanglements in the net, F_{net}, due to surface warp strikes, F_{surf}, and due to aerial warp strikes, F_{air}. Following the previous calculations,

$$\begin{aligned} F_{trawl} &= F_{net} + F_{surf} + F_{air} && \text{(B-8)} \\ &= M_{net}C_{net} + (M_{surf} + M_{air})C_{warp} && \text{(B-9)} \\ &= M_{net}p(C_{net}|C_{trawl}) + (M_{surf} + M_{air})(1 - p(C_{net}|C_{trawl}))C_{trawl}, && \text{(B-10)} \end{aligned}$$

where $p(C_{net}|C_{trawl})$ is the proportion of trawl captures that are retrieved in the net. This proportion can be estimated as observers in New Zealand trawl fisheries record whether captured birds were retrieved in the net or on the warps. In the fishing years between 2006–2007 and 2010–2011, the number of observed captures of large seabirds retrieved in nets was 251 out of the 379 captures in trawl fisheries. For small birds, this ratio was 1383 out of 1398. From these values, we estimated that the mean proportion of trawl captures retrieved in the net, $p(C_{net}|C_{trawl})$, was 0.66 (95% c.i.: 0.61 – 0.71) for large birds, and 0.99 (95% c.i.: 0.98 – 0.99) for small birds.

Values for the parameters involving seabird fatalities in trawl fisheries (illustrated in Figure B-3) are summarised in Table B-27. From these parameters, and from Equation B-10, the number of fatalities in trawl fisheries relative to the number of observable captures was estimated for each seabird group (Table B-28).

To allow cryptic mortalities to be estimated in trawl fisheries, the following simplifying assumptions were made:

- All bird captures on warps result in mortality, and only captures in the net include live captures;
- All bird captures on warps are only due to surface warp strikes;
- Small diving birds are killed only in the net;
- The mortality rate for surface warp strikes in New Zealand trawl fisheries can be approximated by applying that observed in South African deepwater hake fisheries;
- The same cryptic multiplier can be applied to all trawl fisheries.

Table B-27: Transition probabilities (%; mean and 95% credible interval) for the calculation of cryptic mortality of seabirds in trawl fisheries (illustrated in Figure B-3), for different types of birds. "All" includes large, small slow-flying, small fast-flying, and small diving seabirds. (Fatalities of small diving seabirds were assumed to only occur due to interactions with nets.)

Transition probability	Seabird type	Mean	95% c.i.
$p(C\|F)_{surf}$	Large	5.74	3.47–9.08
	Small fast-flying	1.28	0.34–3.45
	Small slow-flying	1.29	0.35–3.50
$p(F\|S)_{surf}$	Large	19.70	13.27–27.22
	Small fast-flying	5.99	2.42–11.08
	Small slow-flying	6.01	2.43–11.13
$p(F\|S)_{air}$	Large	2.00	1.29–2.88
	Small fast-flying	1.00	0.65–1.43
	Small slow-flying	0.50	0.32–0.71
$p(S_{surf}\|S)$	Large	37.05	32.21–41.97
	Small	20.29	17.21–23.57
$p(C_{net}\|C)$	Large	66.15	61.22–70.93
	Small	98.84	98.21–99.33
$p(C\|F)_{net}$	All	77.98	58.40–90.95

Table B-28: Number of seabird fatalities (mean and 95% credible interval) in trawl fisheries relative to the number of observed captures, for each species type.

Species type	Mean	95% c.i.
Large	8.20	5.41–11.96
Small fast-flying	3.42	1.85–6.69
Small slow-flying	2.98	1.68–5.73
Small diving	1.30	1.10–1.71