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Summary of the capture of seabirds in New Zealand commercial fisheries, 2002–03 to 2013–14

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EXECUTIVE SUMMARY

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Fisheries worldwide interact with non-target and protected species, including interactions that result in mortality. In commercial fisheries in New Zealand's Exclusive Economic Zone, government fisheries observers document the incidental captures of protected species on-board fishing vessels. These independently recorded data, together with records of fishing effort, provide the basis for the development of statistical models that are used to estimate the total number of incidental captures in commercial fisheries. The present study provides an update of previous assessments by including data from the 2013–14 fishing year to estimate the total number of seabird captures in commercial trawl, surface-longline and bottom-longline fisheries in New Zealand waters. In addition to the data update, the present study updated the statistical models by applying a unified framework that allowed direct comparisons across species groups and fisheries.

Based on the unified modelling framework, the present study estimated that a total of 5075 (95% c.i.: 4547–5726) seabirds were incidentally captured in commercial fisheries during the 2013–14 fishing year. This total estimate included 2277 (95% c.i.: 2041–2542) seabirds in trawl fisheries, 2137 (95% c.i.: 1722–2745) seabirds in bottom-longline fisheries, and 659 (95% c.i.: 523–835) seabirds in surface-longline fisheries.

There were ten species or species groups distinguished in the modelling framework. For individual species, the highest number of total estimated captures was of white-chinned petrel (*Procellaria aequinoctialis*) with 653 (95% c.i.: 414–1131) captures, followed closely by flesh-footed shearwater (*Puffinus carneipes*) and Salvin's albatross (*Thalassarche salvini*), with 637 (95% c.i.: 495–822) and 623 (95% c.i.: 462–884) captures, respectively. Other estimates included 490 (95% c.i.: 380–627) estimated captures of New Zealand white-capped albatross (*Thalassarche steadi*), 392 (95% c.i.: 276–552) captures of black petrel (*Procellaria parkinsoni*), 385 (95% c.i.: 306–488) captures of sooty shearwater (*Puffinus griseus*), 298 (95% c.i.: 224–398) captures of Buller's albatrosses (*Thalassarche bulleri*, combining both southern *T. b. bulleri* and northern *T. b. platei* subspecies), and 207 (95% c.i.: 114–354) captures of grey petrel (*Procellaria cinerea*). For the two seabird groupings, there were 1022 (95% c.i.: 820–1269) and 659 (95% c.i.: 523–835) estimated captures for other birds and other albatrosses, respectively.

This study used a unified modelling approach, with the same model structure for each of the ten modelled species groups. We recommend that this same structure is used for future modelling, as it can be applied relatively straightforwardly to new data. There were some convergence issues with some of the models, however, and we recommend increasing the length of the chains in the statistical modelling to improve the accuracy of the estimates.

A comparison between the results from this study and the estimates of observable captures from the seabird risk estimation highlights some differences. Most notably, estimates of captures of flesh-footed shearwater and grey petrel were higher when estimated using this method than when estimated in the risk assessment. We recommend that, for the seven species that are the same between both models, the capture estimates made using this approach are used as the observable captures in the risk assessment. We also recommend that the uncertainty in the observable captures in the risk assessment is inflated to account for the differences in the estimates between the two approaches. These differences indicate that there is a structural uncertainty in the risk-assessment modelling that is not currently being accounted for.

Total estimated captures of seabirds in all trawl and longline fisheries fell from from 9185 (95% c.i: 8390–10096) in 2002–03 to 5075 (95% c.i.: 4547–5726) in 2013–14. Over this period the direct impact of New Zealand fisheries on seabirds, as measured by the mean number of estimated annual seabird captures, has decreased by 45%. This decrease is associated with both decreases in fishing effort and in changes in seabird capture rates. While there was a decrease in total seabird captures over the twelve

years, however, there has been no change in the total estimated seabird captures since 2008–09.

Estimated captures were highest in small-vessel fisheries, which were typically poorly observed. The fishing-method—vessel-size group with the highest total number of seabird captures was small-vessel bottom longline, with estimated captures of 1612 (95% c.i.: 1331–1953) seabirds. Because of low observer coverage in small-vessel trawl and bottom-longline fisheries (in many years, less than 2%), the estimates were uncertain, and the model was unable to estimate trends in estimated captures in these fisheries (other than from changes in fishing effort). In order to better understand and manage seabird bycatch in New Zealand fisheries, it is important to increase observer coverage in small-vessel trawl and bottom-longline fisheries.

1. INTRODUCTION

Interactions with fisheries have been recognised as significant at-sea threats that affect the conservation status of protected species such as seabirds (Favero & Seco Pon 2014). These incidental captures can have a significant impact on the viability of seabird populations, especially for species with low productivity and low reproductive rates (e.g., albatrosses and petrels), for which small decreases in adult survival can lead to marked population decreases (Croxall & Gales 1998). The threat posed by fisheries has been assessed in a number of incidental capture studies across different spatial scales and fisheries, including global assessments (Anderson et al. 2011, Croxall et al. 2012, Zydelis et al. 2013).

In New Zealand waters, government fisheries observers on-board commercial fishing vessels monitor the interactions between fishing operations and protected species. Although observer coverage can vary greatly across fisheries, observer data provide a systematic and independent record of the number and identity of incidental captures. This record forms the basis of regular assessments that use statistical models to estimate total captures of seabirds and other protected species in New Zealand waters based on all fishing effort in different fisheries (e.g., Abraham et al. 2013, Thompson et al. 2013). The estimates reflect the number of captures that would have been reported by observers, if there had been an observer on board every vessel. These captures are referred to as “observable captures”, and do not include mortalities that would not be recorded by observers (e.g., birds that are hooked during longlining, but become unhooked before the line is hauled).

The most recent previous assessment estimated the incidental capture of marine mammals, seabirds and turtles in commercial trawl and longline fisheries for the period including the 2012–13 fishing year (Abraham et al. 2016), with the fishing year being from 1 October to 30 September the following year. The present study presents an update of the assessment for seabirds by including data from the 2013–14 fishing year (updates for marine mammals and turtles will be reported elsewhere). It is part of project PRO2013-01, with the aim “to estimate protected species captures in commercial fisheries within the New Zealand Exclusive Economic Zone”.

In addition to including recent data, the present study also applied an updated modelling approach to the estimation of the total number of seabird captures. Statistical models in previous assessments have become increasingly complex, from estimating seabird captures for individual fisheries to a New Zealand-wide approach (Baird & Smith 2007, 2008, Waugh et al. 2008, Abraham & Thompson 2010). The most recent estimation included a total of 35 different models (Abraham et al. 2016), with varying structures. In this study, we have taken a more unified modelling approach allowing more direct comparisons across species. This approach should also allow a more prompt update as new data become available. Specifically, a single model was used for each species group, including all trawl and longline fisheries; all covariates were based on a set of strata (fishing year, area, fishery, season), so that the data could be aggregated before the modelling; and covariates that reflected the distribution of seabirds (e.g., area and season) were shared across different fisheries. An identical model structure was used for each species group.

As data were updated and all statistical models were re-developed, previous assessments are superseded, and any comparison across fishing years should be made using the present report. The impact of incidental captures on the respective seabird populations was not considered.

2. METHODS

This analysis used at-sea mortality data recorded by government observers on board commercial fishing vessels to estimate the captures of seabirds in trawl and longline fisheries. The estimates were made for the period between 1998–99 and 2013–14 for surface- and bottom-longline fisheries, and from 2002–03 to 2013–14 for trawl fisheries. Earlier observer records of seabird captures in trawl fisheries were not considered complete, and so were not used for the estimation.

Estimates of the total number of observable captures were obtained for the seabird species with the largest

Table 1: Annual average number of observed seabird captures in trawl and longline fisheries for the period between 2002–03 and 2013–14. Data are restricted to species or species groups with an annual average number of one or more observed captures.

Common name	Scientific name	Observed captures
White-chinned petrel	*Procellaria aequinoctialis*	106.0
Sooty shearwater	*Puffinus griseus*	101.5
New Zealand white-capped albatross	*Thalassarche cauta steadi*	101.2
Southern Buller’s albatross	*Thalassarche bulleri bulleri*	53.2
Salvin’s albatross	*Thalassarche salvini*	32.2
Grey petrel	*Procellaria cinerea*	14.5
Flesh-footed shearwater	*Puffinus carneipes*	11.7
Fulmars, petrels, prions and shearwaters	Procellariidae	8.4
Black petrel	*Procellaria parkinsoni*	8.0
Albatrosses	Diomedeidae	6.9
Cape petrel	*Daption capense*	5.3
Campbell black-browed albatross	*Thalassarche impavida*	5.2
Gibson’s albatross	*Diomedea antipodensis gibsoni*	3.2
Westland petrel	*Procellaria westlandica*	3.1
Antipodean albatross	*Diomedea antipodensis antipodensis*	2.7
Spotted shag	*Stictocarbo punctatus*	2.7
Cape petrels	*Daption* spp.	2.6
Petrels, prions, and shearwaters	Hydrobatidae, Procellariidae, and Pelecanoididae	2.6
Chatham Island albatross	*Thalassarche eremita*	2.4
Grey-faced petrel	*Pterodroma macroptera gouldi*	2.4
Common diving petrel	*Pelecanoides urinatrix*	2.2
Southern royal albatross	*Diomedea epomophora*	1.9
Fairy prion	*Pachyptila turtur*	1.6
Antarctic prion	*Pachyptila desolata*	1.4
Wandering albatrosses	*Diomedea exulans* and *D. antipodensis* sspp.	1.2
Prions	*Pachyptila* spp.	1.2
Smaller albatrosses	*Thalassarche* spp.	1.0
Northern giant petrel	*Macronectes halli*	1.0
Other species		11.7
Total		499.0

number of observed captures between the 2002–03 and 2013–14 fishing years (Table 1). These species included New Zealand white-capped albatross (*Thalassarche steadi*), Salvin's albatross (*Thalassarche salvini*), Buller's albatross (*Thalassarche bulleri*, combining both southern *T. b. bulleri* and northern *T. b. platei* subspecies), white-chinned petrel (*Procellaria aequinoctialis*), black petrel (*Procellaria parkinsoni*), grey petrel (*Procellaria cinerea*), sooty shearwater (*Puffinus griseus*), and flesh-footed shearwater (*Puffinus carneipes*). Estimates were also derived for other species with fewer observed captures, and these seabirds were grouped as either "other albatrosses" or "other birds". These categories also included all seabird captures that were not identified to species or subspecies. For black petrel, grey petrel, and flesh-footed shearwater, individual estimates were derived for the first time. Captures of these three species were previously included in the "other birds" group (e.g., Abraham et al. 2016).

2.1 Data preparation

Ministry for Primary Industries (MPI) observers on commercial fishing vessels record captures of protected species, including seabirds and marine mammals. The capture events are recorded on paper forms by the observers, and subsequently entered into a database maintained by the National Institute of Water and Atmospheric Research (NIWA) on behalf of MPI. Currently, data are housed in the Centralised Observer Database (COD; Sanders & Fisher 2010), and this protected species bycatch information from COD was used in the current analysis (Table 2). Observers also record characteristics of the fishing events that they observe, such as the target species, fishing gear, and mitigation methods used.

Table 2: Protected species bycatch information from the Centralised Observer Database used in the current bycatch estimation.

Data	Description
Species	Species identification as recorded by the observer. This identification may either be at the species level or be a more general classification, depending on how accurately the observer was able to identify the animal.
Capture method	Code indicating how the animal was captured. For example, the capture may have been in the net, on the warps, or entanglement in the line. Additional information from the observer's comments were also used to identify the capture method.
Life status	Observers record whether the animal was alive, dead, killed by the crew, or decomposed (i.e., dead before capture).
Station details	Trip number, station number, date at beginning of the tow or set, and target species. This information is required for all observed stations, including stations where there were no incidental captures of protected species.

In addition to the observer data, fishing effort data were required to allow for the observed captures to be appropriately scaled. Commercial fishing vessels return a record of all fishing effort on each trip to MPI. Skippers complete either a Trawl Catch Effort Processing Return (TCEPR), Trawl Catch Effort Return (TCER), Tuna Longline Catch Effort Return (TLCER), Catch Effort Landing Return (CELR), Lining Catch Effort Return (LCER), Lining Trip Catch Effort Return (LTCER) form, or Netting Catch Effort Landing Return (NCELR) form. During the 2007–08 fishing year, inshore trawl fisheries moved from reporting fishing effort on CELR forms to TCER forms. The TCER form requires the recording of the latitude and longitude of fishing effort, instead of only the statistical area. This recording of greater spatial detail has allowed a more accurate understanding of where inshore fishing is occurring. Data from these forms are stored in databases administered by MPI (Ministry for Primary Industries 2012). In this report, information on station date, position, and effort (either number of trawls, number of hooks, or total net length) was used.

Preparation of the data was first necessary to link captures to fishing events and to minimise the number of species misidentifications. The data preparation methods followed those used previously (Abraham

& Thompson 2011). One important step in the data preparation was allocating a fishery to each fishing event. The fishery was allocated on the basis of the fishing method, and the fisher-declared target species. There were some unusual codes that were targeted in fewer than 100 fishing events (these codes included misspelled codes for common species). The fishery of these events was set to the fishery of the closest fishing event in time, by the same vessel, that had a defined fishery. For the few events that remained without a defined fishery, the fishery was imputed by randomly sampling from fishing events by vessels of the same class in the same statistical area.

Before carrying out the estimation, the observer data were linked to the effort data reported by the fishers. The linking was carried out by searching for fishing events recorded by the fisher from the same vessel at a similar place and time as recorded by the observer, using the same fishing method and targeting the same species. The criteria for matching the records were progressively relaxed to allow most of the observed fishing events to be associated with fisher-reported effort. In each of the years used in the estimation, over 99% of observed bottom-longline fishing events, 97.5% of observed surface-longline sets, and over 98.5% of observed trawl tows were able to be linked to effort reported by the fisher. A small number of captures were during observations that could not be linked to fishing effort, and were not included in the modelling. From 2002–03 and onwards, these unlinked captures were of Salvin's albatross (6 captures), sooty shearwater (3), flesh-footed shearwater (2), white-chinned petrel (2), Campbell black-browed albatross (1), Chatham Island albatross (1), Gibson's albatross (1), and New Zealand white-capped albatross (1).

Non-fishing related captures (such as birds that had hit the superstructure of the vessel) were excluded from the estimation. Before 2006–07, these captures were identified from observer comments. During the 2006–07 fishing year, the Non-Fish Bycatch form was changed to provide more information on the captures than had previously been noted, including information on where on the vessel the animals were caught. These additional data were recorded from February 2007, and were used to exclude non-fishing related captures from the reporting. Of the total 7089 reported seabird captures in trawl and longline fisheries between 2002–03 and 2013–14, 569 captures were identified as being due to collisions with the vessel, or of birds landing on the deck, and were removed from the study dataset. These observed deck captures occurred predominantly in trawl fisheries (541 captures), while the remainder were in bottom-longline (24) and surface-longline (4) fisheries. They involved a range of species, including common diving petrel (86 captures), sooty shearwater (53), New Zealand white-capped albatross (42), Snares Cape petrel (29), grey petrel (29), fairy prion (37), and storm petrel species (24).

Any animals that were reported by the observer as decomposed were excluded from the estimation. In addition, captures on research fishing trips that experimentally tested the efficacy of mitigation measures were also excluded. These fishing trips required a special permit, and included bottom-longline fishing trips in 2002–03 and early 2003–04 that assessed line weighting as a mitigation measure (Robertson et al. 2006). For this assessment, special longlines were used that had weighted and unweighted sections, and many birds were caught on the unweighted line. Similarly, during 2007–08, a trial was carried out on a surface-longline trip to test the efficacy of dyeing bait blue to reduce the number of birds that were hooked. All observed captures from these trips were excluded from the analysis and treated as unobserved. In 2004–05, an experiment was conducted in the Auckland Islands squid trawl fishery, comparing the performance of different mitigation measures (Middleton & Abraham 2007). As part of this experiment, some observed tows were made without any warp mitigation. The observed captures that occurred on the unmitigated tows were not included, and the tows were treated as unobserved. In 2013–14, there were eight bottom-longline trips that were carried out in north-eastern New Zealand where the observer carried out experimental work with line-weighting, time-depth recording, or other mitigation-related activities. Data from these trips were not included in COD, and so were excluded from this report.

The high seabird diversity in the New Zealand region represents a challenge for the identification of captured seabirds by observers. Around 60% of the seabirds observed captured between 2002–03 and 2013–14 were sent to experts for formal identification via necropsy. In recent years, observers have taken photographs of captured birds, which have then been subsequently identified by experts. This approach has allowed the additional identification of seabirds that were captured and released alive.

When a seabird was not identified via necropsy or from photographs, an imputation process was used to derive an identification. The imputation worked as follows. First, a key was generated for each capture event, based on observer data. On the first pass, the key was a composite of all these identifiers: trip number, fishing year, observers' names, target fishery, fishing method, area, and observed species code. For each bird that had not been necropsied, all capture events with the same key were selected. If there were matching observed captures where a necropsy had been made, then a necropsy identification was chosen at random, and this identification was the imputed identification. If no matching capture events were found, or if none of the matching captures had been necropsied, then no imputation was made at that level, and the species identification by the observer was retained. The imputation process was repeated, in a total of four passes. At each pass, the key was made more general, dropping the requirement that the trip number matched, then that the fishing year matched, then that the observers' names matched, and then that the target fishery matched. On the final pass, the observed captures used for imputation were required to match on the fishing method, area, and the species code recorded by the observer. In addition to the imputation, some manual grooming of the species codes was carried out. In a small number of cases, comments made by the observer were used to groom the species code recorded by the observer.

As part of its data reconciliation processes, MPI has found records of observed protected species captures that were not included in COD, and so were not included here. There may be up to 2% more captures than were included here, and this omission would affect the estimates. Improving the data quality is an ongoing process. Discrepancies were also found with the matching of photo-identified records with the records in COD, resulting in some observer identifications being treated as expert identifications. This discrepancy may have affected the number of reported captures of some species (as records treated as identified by experts are not subject to imputation). These issues will be addressed in future updates of this work.

2.2 Statistical modelling

Generalised Linear Models (GLMs) were fitted to the observer data, and then used to estimate the observable captures on unobserved fishing effort. Bayesian methods were used to fit the models. The Bayesian models have the advantage of allowing for hierarchical model structures, and they also allow for samples of the estimated quantities to be generated. By using the samples, uncertainty in any derived quantities may be derived, allowing for estimates to be combined or to be reported for different fisheries or for the area breakdowns that were used for the modelling.

To standardise the models across species, a single model structure was used for all species groupings, combining all trawl, surface-longline, and bottom-longline fisheries. This approach differed from the previous assessment (Abraham et al. 2016), where a model was fitted for each combination of species and fishing method. Each of these models was able to have different covariates and to vary in complexity.

Observed captures were assumed to be drawn from a negative binomial distribution, following previous work (Baird & Smith 2008, Abraham & Thompson 2011), as this distribution provides an adequate representation of capture data, which is characterised by many zeros and occasional large values. The negative binomial distribution is parametrised by a mean, μ, and an overdispersion, θ, with the variance given by $\mu + \mu^2/\theta$. As the overdispersion increases to infinity, the variance nears the mean, and the negative binomial distribution converges to a Poisson distribution. As θ gets small relative to the mean, the negative binomial distribution becomes increasingly peaked at zero and becomes skewed-right (i.e., it develops a long right-hand tail). The negative binomial distribution has the convenient attribute that the sum of n samples drawn from a negative binomial distribution is also negative-binomially distributed, with mean $n\mu$ and overdispersion $n\theta$. This characteristic of the negative binomial distribution allowed the model to be applied to grouped event level data (multiple fishing events reported as a single record).

The negative binomial distribution may be generated by a Poisson mixture distribution, with a gamma-distributed mean. The seabird captures, y_i, during a group of n_i fishing events, were generated as

$$y_i \sim \text{Poisson}(n_i \mu_i \delta_i), \tag{1}$$
$$\delta_i \sim \text{Gamma}(n_i \theta, n_i \theta), \tag{2}$$

where μ_i is the mean capture rate for a single event in the group of fishing events i, δ_i the overdispersion representing the effect of unknown processes on the variation of the mean capture rate, $n_i\theta$ is both the shape and the rate of the Gamma distribution, which has in this case a mean of 1.

The mean catch rate for a single fishing event was assumed to vary with:

- $M_{m,v}$: combination of fishing method (m; either trawl, surface-longline, or bottom-longline), and vessel class (v; "large" for vessels with a length over 45 m, 34 m, or 28 m, for surface-longline, bottom-longline, and trawl fishing, respectively, "small" otherwise),
- F: target fishery,
- A: area (see areas in Figure 1),
- R: region ("north" or "south", with "north" being the region including the Kermadec Islands, West Coast North Island, East of North Island, and North East areas; "south" otherwise),
- S: season (period of three months, with January–March called summer, April–June autumn, July–September winter, and October–December spring),
- $Y_{m,v,y}$: year.

The mean catch rate for a single fishing event in the group i of events was assumed to be the product of the effects:

$$\mu_i = \alpha M_{m,v,i} F_i A_i R_i S_i Y_{m,v,y,i}, \tag{3}$$

where α is the intercept, with a log-normal prior, defined with a mean of -3 and a standard deviation of 5 on the log scale.

The area, region, and season effects were assumed to apply to all fisheries, irrespective of the fishing method, fishery, or vessel class. Under this assumption, spatial and temporal effects are primarily determined by the ecology of the species, not by the fishing practice. In contrast, the year effect was estimated independently for each combination of method and vessel class, recognising that inter-annual variations may occur not only due to the ecology of species, but also due to changes in fishing practice.

The main effect of the combination of fishing method and vessel class, and the season and region effects, were modelled as fixed effects, relative to the base case, taken as the combination of method, vessel class, region, and season with the highest number of observed captures. These base-levels were different for each species (see Table 3 for the base levels of these factors for each species). The prior for the fixed effects was a log-normal distribution, having a mean of 0 and a standard deviation of 5 on the log scale.

The effects of area, fishery, and year were modelled as random effects, assumed to be drawn from a gamma distribution. The year effect was only applied to large vessels, because the number of observations in the small-vessel fleets was insufficient to fit these random variable. For each random effect, the shape and rate of the gamma distribution were set to be the same, so that the mean was one for each random effect, and the coefficient of variation (CV) of the random effect was drawn from an exponential distribution (the coefficient of variation of a gamma-distributed random variable with a mean of 1 is the inverse of the square-root of the shape). The rate of the exponential distribution was the same for all random effects, and had a uniform prior between 0.2 and 10.0. The exponential distribution was truncated at 5 to prevent extreme values and facilitate model stability.

A proportion of large-vessel bottom-longline vessels have used integrated weight lines as a mitigation measure to reduce the capture rate of seabirds. The integrated weight lines have an added lead core so

Table 3: Base levels for fishing method—vessel class, region, and season, for which the number of observed captures was highest, for the ten models used to estimate the number of incidental captures of ten species groups in commercial trawl, bottom-longline, and surface-longline fisheries. For each model, the effects were estimated relative to these base levels.

Model	Method—vessel class	Region	Season
White-capped albatross	Trawl—Large vessels	South	Summer
Salvin's albatross	Trawl—Large vessels	South	Summer
Buller's albatrosses	SLL—Large vessels	South	Summer
Other albatrosses	SLL—Large vessels	North	Summer
White-chinned petrel	Trawl—Large vessels	South	Summer
Black petrel	BLL—Small vessels	North	Summer
Grey petrel	BLL—Large vessels	South	Summer
Sooty shearwater	Trawl—Large vessels	South	Summer
Flesh-footed shearwater	SLL—Small vessels	North	Summer
Other birds	Trawl—Large vessels	South	Summer

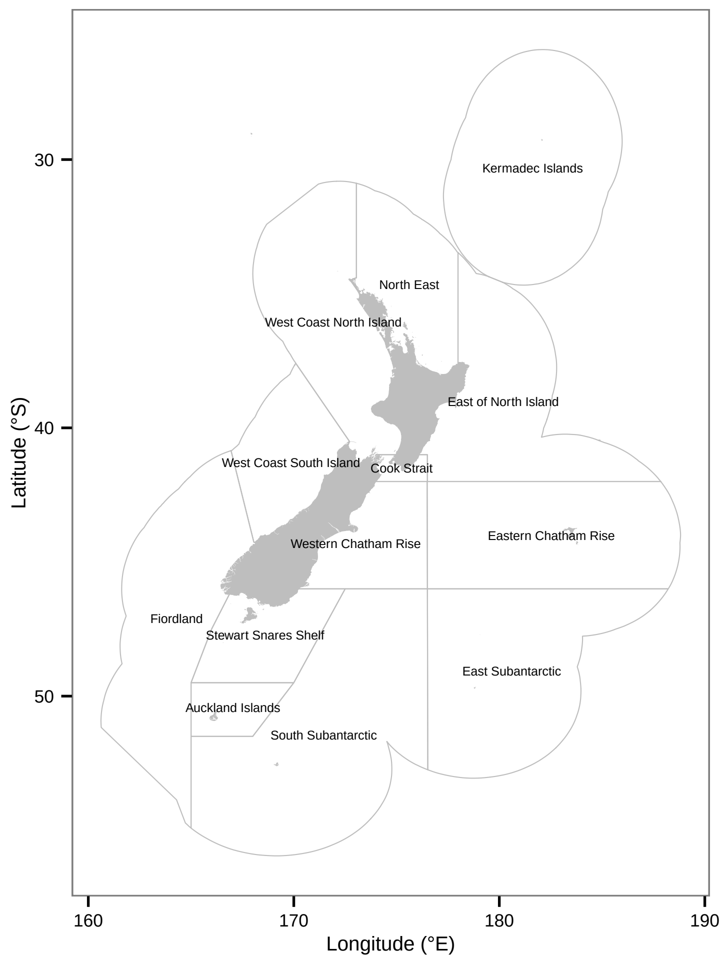

Figure 1: Areas used for the estimation of the number of incidental captures of seabirds in New Zealand commercial fisheries. All else being equal, the capture rate of each species was assumed to be constant within each area.

that they sink faster, which minimises the time baited hooks are available to seabirds. The efficacy of line-weighting has been demonstrated during experimental trials (Robertson et al. 2006), and was found to significantly reduce capture rates in models used for estimating seabird bycatch (Abraham et al. 2016). To account for the use of integrated weight lines, the fisheries targeting ling were split into three different target fisheries, including small vessels, large vessels using integrated weight lines, and large vessels not using integrated weight lines. The other target fisheries were the same as those used by Abraham et al. (2016) in the previous assessment (see Table 4).

The models were coded in the BUGS (Bayesian inference Using Gibbs Sampling) language (Spiegelhalter et al. 2003), a domain-specific language for describing Bayesian models. Each model was fitted with the software package JAGS (Just Another Gibbs Sampler) (Plummer 2005), using Monte Carlo Markov chains (MCMCs). Two chains were fitted to each model, with the output including samples of the posterior distribution from each chain. Model convergence was assessed with diagnostics provided by the CODA package for the R statistical system (Plummer et al. 2006), including the criteria of Heidelberger & Welch (1983) and Geweke (1992). The models were run for 150 000 updates during burn-in, and then run for up to a further 400 000 updates, with every 200$^{\text{th}}$ sample being retained for analysis.

To shorten the computing time for fitting the Bayesian models, the data were aggregated before fitting the model, by summing the number of fishing events and the number of observed captures by fishing method, target fishery, vessel class, region, area, fishing year, and season.

The use of a single model structure, applied to each species grouping, simplified the computation of these models. It also provided a consistent framework across species and fisheries for the interpretation of results. The model structure that was chosen in the present study was a compromise between simplicity, allowing model fitting even for data-poor strata, and complexity, allowing the main sources of variability in capture rates to be considered, and spatial or temporal trends to be explored. This model structure resulted from preliminary analyses during which over 1000 models were fitted, testing different model structures, with varying degrees of complexity. The structures explored included:

- random effect of year for both vessel classes,
- random effect of the combination of year and target fishery,
- step change at a given year, with the year varying with fishing method, fishery, and vessel class, and the step selected by the model,
- random effect of the combination of area and season, with and without a random effect of the combination of year and target fishery.

Increasing model complexity from the selected model structure led to either the model fitting to fail due to a lack of convergence, or to the estimated number of captures having considerable uncertainty. In some cases, the parameters' posterior distributions reflected the priors with no information gained from the model fitting.

3. RESULTS

3.1 The model dataset

The dataset consisted of 7602 observed captures of seabirds, including 4387 captures in trawl fisheries in the period between the 2002–03 and 2013–14 fishing years; in longline fisheries, there were 1974 captures in bottom longlining and 1241 captures in surface longlining between 1998–99 and 2013–14 (see Appendix A.1 to A.11 for information on each species group, by fishing method and vessel size).

The large-vessel trawl fishery targeting squid had the highest number of observed captures (32.83% of all observed seabird captures), mostly of New Zealand white-capped albatross, white-chinned petrel, and sooty shearwater. Other fisheries with large numbers of observed captures included the large-vessel bottom-longline fishery targeting ling, which recorded 21.42% of observed seabird captures. The

Table 4: Summary of total effort, observed effort, and proportion of effort observed by modelled fishery, which consisted of a combination of fishing method, vessel class, and target fishery. Also shown are the fishing years when the fisheries were active, between 2002–03 and 2013–14 for trawl, and between 1998–99 and 2013–14 for bottom- and surface-longline fisheries. Cut-off lengths for large-vessel size classes were >45 m, >34 m, and >28 m, for surface-longline, bottom-longline, and trawl fishing, respectively. IWL: integrated weight line.

Method	Vessel class	Target fishery	Fishing years		Fishing events		
			First	Last	Total	Observed	Proportion (%)
Trawl	Large vessels	Deepwater	2003	2014	68 724	17 819	25.9
		Flatfish	2003	2012	136	0	0.0
		Hake	2003	2014	13 857	3 632	26.2
		Hoki	2003	2014	145 549	28 247	19.4
		Inshore	2003	2014	29 505	351	1.2
		Ling	2003	2014	9 368	1 543	16.5
		Mackerel	2003	2014	29 199	11 216	38.4
		Middle depths	2003	2014	37 940	7 113	18.7
		S. blue whiting	2003	2014	10 342	5 007	48.4
		Scampi	2003	2014	8 451	968	11.5
		Squid	2003	2014	61 802	18 699	30.3
	Small vessels	Deepwater	2003	2014	5 629	148	2.6
		Flatfish	2003	2014	249 780	1 499	0.6
		Hake	2003	2014	417	0	0.0
		Hoki	2003	2014	14 782	684	4.6
		Inshore	2003	2014	395 568	4 135	1.0
		Ling	2003	2014	5 026	74	1.5
		Mackerel	2003	2014	83	0	0.0
		Middle depths	2003	2014	56 661	622	1.1
		Scampi	2003	2014	46 052	3 580	7.8
		Squid	2003	2014	4 218	8	0.2
SLL	Large vessels	Albacore	2003	2003	231	224	97.0
		Bigeye	1999	2013	138	113	81.9
		Bluefin	1999	2014	4 176	3 647	87.3
	Small vessels	Albacore	1999	2014	4 015	32	0.8
		Bigeye	1999	2014	42 348	862	2.0
		Bluefin	1999	2014	15 892	823	5.2
		Minor species	1999	2014	1 546	41	2.7
		Swordfish	1999	2014	1 853	161	8.7
BLL	Large vessels	Minor species	1999	2013	284	135	47.5
		Bluenose	1999	2006	384	40	10.4
		Hāpuku	1999	2004	14	0	0.0
		Ling, large vessel, with IWL	2003	2014	8 951	2 582	28.8
		Ling, large vessel, no IWL	1999	2014	31 427	4 595	14.6
	Small vessels	Minor species	1999	2014	26 190	221	0.8
		Bluenose	1999	2014	47 708	231	0.5
		Hāpuku	1999	2014	32 202	129	0.4
		Snapper	1999	2014	138 887	1 202	0.9
		Ling, small vessel	1999	2014	44 436	726	1.6

Table 5: Number of estimated captures (mean and 95% credible interval, c.i.) for each seabird species group in trawl, bottom-longline (BLL), and surface-longline (SLL) fisheries for the 2013–14 fishing year.

Species grouping	Trawl		BLL		SLL		Total	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
White-capped albatross	344	264–439	31	6–83	113	59–207	490	380–627
Salvin's albatross	406	308–530	209	97–450	7	2–16	623	462–884
Buller's albatrosses	111	75–167	58	26–112	128	82–201	298	224–398
Other albatrosses	98	61–155	154	90–242	109	67–171	362	272–477
White-chinned petrel	184	158–217	443	210–919	25	10–49	653	414–1 131
Black petrel	46	23–81	293	183–449	52	28–88	392	276–552
Grey petrel	16	11–35	168	77–313	23	12–40	207	114–354
Sooty shearwater	364	292–463	20	1–57	0	0–4	385	306–488
Flesh-footed shearwater	116	76–169	340	239–482	181	99–306	637	495–822
Other birds	586	442–763	417	293–588	17	8–31	1 022	820–1 269
All birds	2 277	2 041–2 542	2 137	1 722–2 745	659	523–835	5 075	4 547–5 726

large-vessel trawl fishery targeting hoki had 9.58% of all observed seabird captures, and the large-vessel surface-longline fishery targeting southern bluefin tuna had 8.79% of observed captures.

The number of observed captures reflected seabird capture rates, fishing effort and observer coverage. Observer coverage varied widely between fisheries (Table 4). In general, observer coverage was high in large-vessel fisheries, with the highest observer coverage in surface-longline fisheries targeting tuna species (over 80% of the fishing events observed). In contrast, observer coverage in small-vessel fisheries was generally low, even though fishing effort was considerable in some of these fisheries. For example, observer coverage was less than 1% in bottom-longline fisheries targeting snapper, bluenose, or hāpuku, which had between 32 202 and 138 887 fishing events over the reporting period from 1998–99 to 2013–14.

3.2 Estimated captures

An estimated total of 5075 (95% c.i.: 4547–5726) seabirds were captured during the 2013–14 fishing year, including 2277 (95% c.i.: 2041–2542) seabirds in trawl fisheries, 2137 (95% c.i.: 1722–2745) seabirds in bottom-longline fisheries, and 659 (95% c.i.: 523–835) seabirds in surface-longline fisheries (Table 5) (see Appendix B for model details for each species group). The species group other birds had the highest number of total estimated captures, with an estimated 1022 (95% c.i.: 820–1269) captures. Many of the estimated captures of other birds were in small-vessel trawl fisheries (461 captures, 95% c.i.: 315–638, subsubsection A.10.2). Observer coverage in these fisheries was low, and the observed captures of other birds were dominated by a single capture event: of the 53 observed captures of other birds in these fisheries, 32 captures were of spotted shag (*Stictocarbo punctatus*) caught on a trawl targeting flatfish in 2008–09. There were also high numbers of other bird species estimated caught in small-vessel bottom-longline fisheries, with 365 (95% c.i.: 256–510) estimated captures in this species grouping (see Appendix A, A.10.3 for more information). Since 2002–03, observer coverage in these fisheries has been less than 1%, and so this estimate is based on relatively little information.

Of the individual species, white-chinned petrel had the highest number of total estimated captures during the 2013–14 fishing year, 653 (95% c.i.: 414–1131) estimated captures, followed closely by flesh-footed shearwater, 637 (95% c.i.: 495–822) estimated captures, and Salvin's albatross, 623 (95% c.i.: 462–884) estimated captures.

Total captures of seabirds in all trawl and longline fisheries decreased from 9185 (95% c.i: 8390–10096) in 2002–03 to 5075 (95% c.i.: 4547–5726) in 2013–14 (Figure 2). Although this decrease was a 45% reduction in estimated captures over the 12-year period, total capture estimates in 2013–14 were similar to the total estimate in 2008–09 (a mean of 5032 estimated captures, 95% c.i: 4488–5796). For most species, the total estimated number of captures across all fishing methods decreased over the period. The only modelled species that did not show a clear decrease were Salvin's albatross, white-chinned petrel and sooty shearwater. Changes in the number of captures were related to both changes in capture rates and changes in the annual fishing effort in different fisheries. There have been some marked changes in fishing effort; for example in large-vessel trawl fisheries, effort fell from 54 200 tows in 2002–03 to 25 660 tows in 2013–14. At the same time, for small-vessel surface-longline fisheries, the effort fell from 8 572 966 hooks in 2002–03 to 1 893 434 hooks in 2013–14 (for information on the change in fishing effort see Appendix A, subsection A.11). For fishing by small vessels, there was no year effect in the model, and so changes in estimated captures were primarily determined by changes in fishing effort.

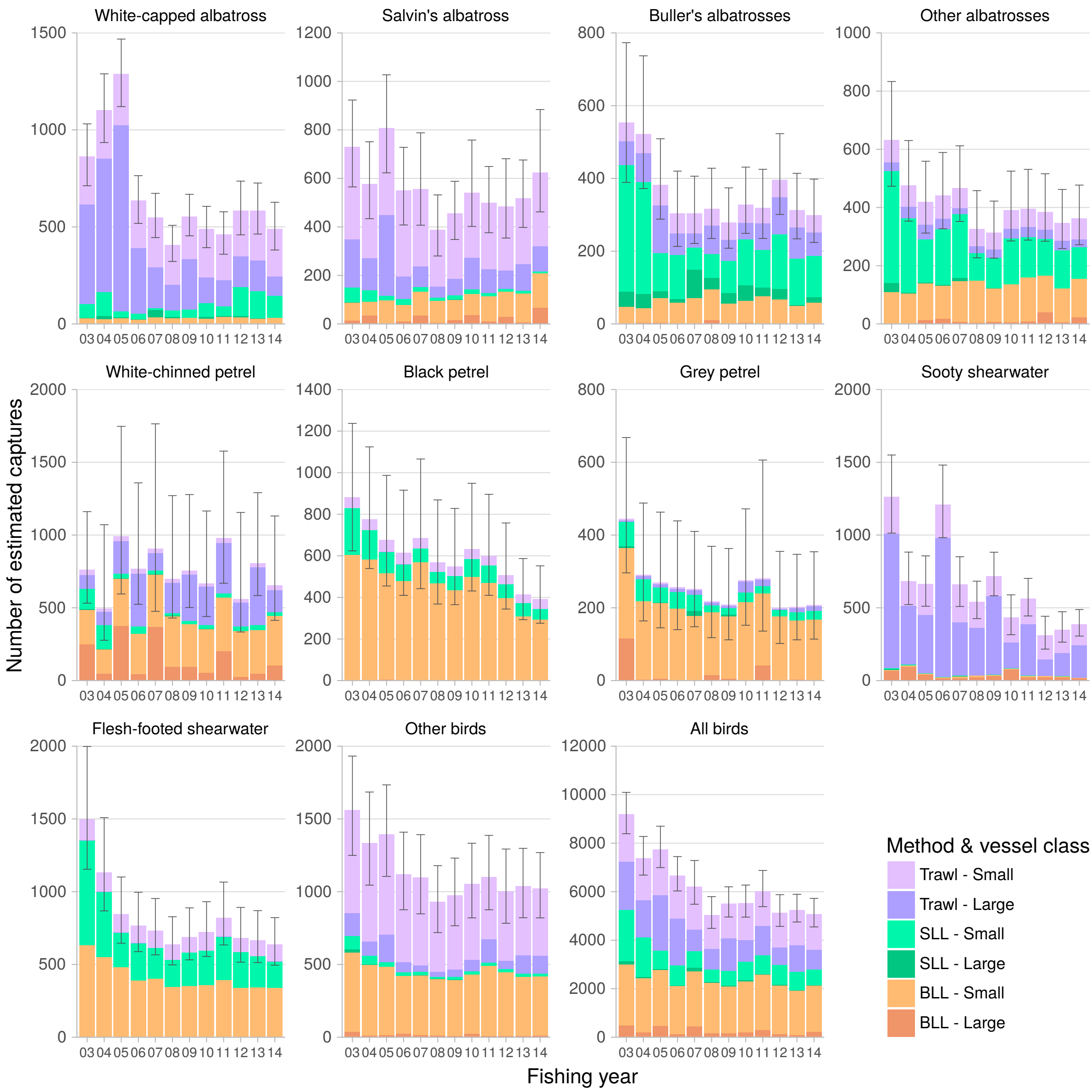

Figure 2: Time series of the number of estimated captures for the seabird species groups and for all birds for the 2002–03 to 2013–14 fishing years. Estimates are shown by fishing method and vessel size class. Cut-off lengths for large-vessel size classes were 45 m, 34 m, and 28 m, for surface-longline (SLL), bottom-longline (BLL), and trawl fishing, respectively. Coloured bars indicate mean captures, error bars are the 95% credible interval in the total estimated captures within each fishing year. (Note different y-axis scales.)

Changes in seabird captures rates (captures per 100 fishing events) in the six large-vessel fisheries with the highest number of seabird captures showed different patterns across fisheries and seabird groupings (Figure 3). In large-vessel trawl fisheries, the highest capture rates were in squid trawl fisheries. Capture rates of albatrosses in squid and hoki fisheries decreased from the 2005–06 fishing year, when warp mitigation was made mandatory on trawl vessels over 28 m long (Department of Internal Affairs 2006). In hoki trawl fisheries, however, there appeared to have been a subsequent increase in the capture rates of albatrosses, with the mean capture rates from 2011–12 to 2013–14 higher than the mean capture rates in any year between 2005–06 and 2010–11. While the capture rates of albatrosses decreased following 2005–06, the capture rates of petrels and other birds did not show a consistent decrease. In large-vessel hoki and squid trawl fisheries, there was considerable interannual variability in the capture rates of petrels and other birds. The interannual variation was correlated between hoki and squid target fisheries, as the year effect was the same across all large-vessel target fisheries in each model.

A decrease in capture rates was evident in large-vessel ling fisheries, from the early 2000s, for both albatrosses and petrels and other seabirds. The decrease coincided with the introduction of integrated weight lines, and with an increasing emphasis on measures aimed at reducing seabird bycatch. There has been some fishing by large vessels targeting scampi, with only one or two large scampi vessels fishing in any year since 2004–05. While there has been an increase in the capture rate of petrels and other birds by the large-vessel scampi fishery, most scampi fishing was by vessels that were less than 28 m long. For this reason, these data are not representative of the scampi fleet as a whole. In the large-vessel bluefin surface-longline fishery most captures were of albatrosses, and their capture rate varied widely over the period. The peak capture rate was in 2009–10, and it subsequently decreased, with the lowest capture rate in any year in 2012–13.

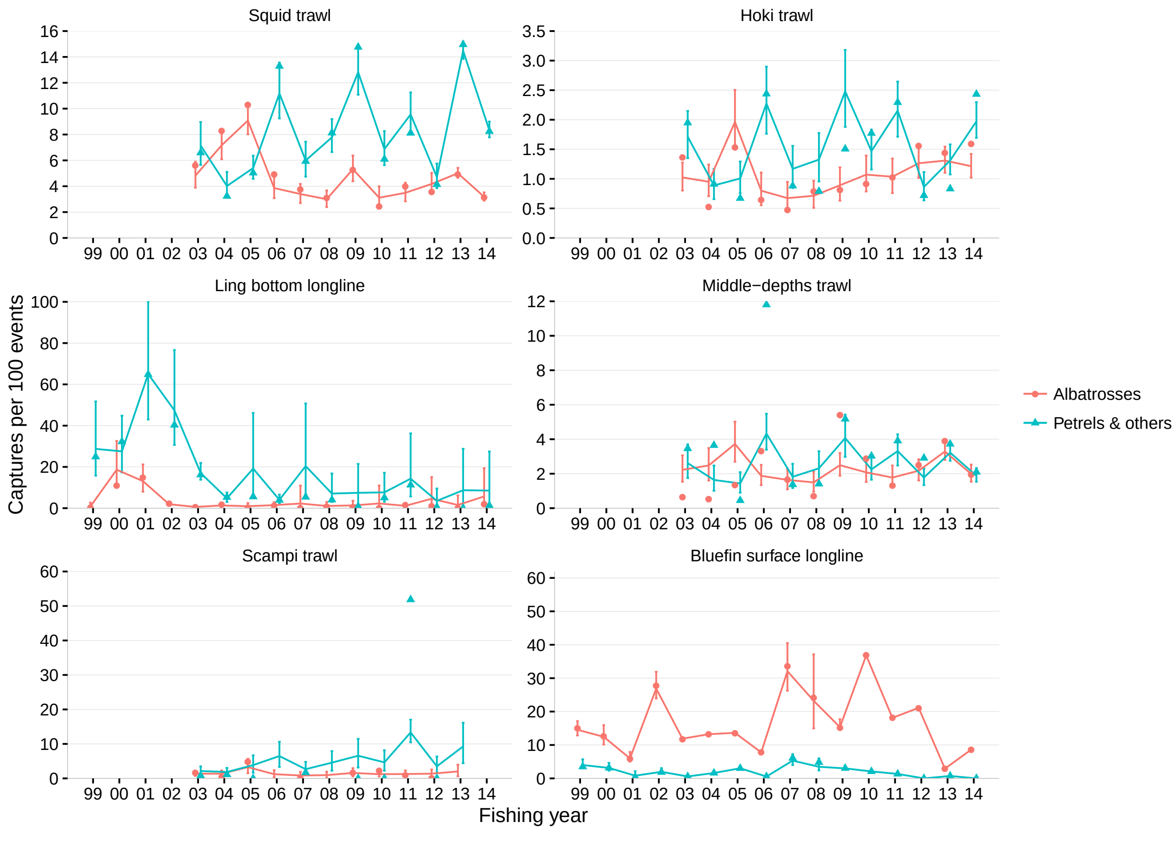

Figure 3: Capture rates (captures per 100 fishing events) of two seabird groupings in selected large-vessel fisheries, for fishing years between 2002–03 and 2013–14 for trawling, and between 1998–99 and 2013–14 for bottom and surface longlining. Cut-off lengths for large-vessel size classes were 45 m, 34 m, and 28 m, for surface-longline, bottom-longline, and trawl fishing, respectively. Lines show the mean estimated capture rate per fishing year, error bars indicate the 95% credible interval of the estimates, and symbols mark observed capture rates. (Note different y-axis scales.)

Considering the number of estimated captures in 2013–14 by target fishery showed that trawl fisheries

Table 6: Total number of estimated seabird captures for the 2013–14 fishing year in trawl, bottom-longline (BLL), and surface-longline (SLL) fisheries. Presented for each fishing method and target fishery are the mean and 95% credible interval (c.i.) of the posterior distribution of the total seabird captures, summed over all the modelled species groups.

Method	Target fishery	Mean	95% c.i.
Trawl	Inshore	556	425–701
	Flatfish	443	297–627
	Hoki	410	365–463
	Middle depths	317	244–414
	Squid	236	223–252
	Scampi	194	158–236
	Ling	56	39–81
	Deepwater	23	13–36
	S. blue whiting	19	19–20
	Hake	10	7–15
	Mackerel	9	8–13
BLL	Ling	798	539–1 233
	Snapper	716	568–899
	Hāpuku	251	121–522
	Minor species	193	107–354
	Bluenose	177	91–319
SLL	Bigeye	289	200–420
	Bluefin	289	209–400
	Swordfish	74	38–134
	Minor species	4	0–14
	Albacore	2	0–9

with high numbers of estimated captures included inshore, flatfish, and hoki trawl fisheries, which each had a mean of over 400 estimated seabird captures in that fishing year (Table 6). Among bottom-longline fisheries, ling and snapper target fisheries had the highest numbers of estimated captures, each with a mean of over 700 seabird captures in 2013–14. Among surface-longline fisheries, the highest estimated captures were in bigeye and bluefin tuna target fisheries, with a mean of 289 estimated captures each.

Comparison of estimated captures between target fisheries (for fisheries with a mean number of 50 or more estimated captures) showed how different species were caught in different fisheries (Figure 4). For white-chinned petrel, estimated captures were high in bottom-longline fisheries targeting ling, with fewer estimated captures in bottom-longline fisheries targeting minor species, and the trawl fishery targeting squid. In the ling bottom-longline fishery, estimated captures were also relatively high for Salvin's albatross, and capture estimates of this species were also high in the inshore trawl fishery. For white-capped albatross, the highest capture estimate was also in the inshore trawl fishery, with few estimated captures in other target fisheries except for bluefin surface longlining. Buller's albatross had a similar number of estimated captures as white-capped albatross in bluefin surface longlining. The grouping other birds had the highest estimated captures in flatfish trawling, while few other captures in this fishery were assigned to a particular species group. For black petrel, the highest number of estimated captures was in the bottom-longline bluenose fishery, and this target fishery had only a few other associated estimated captures. Estimated captures of black petrel were also high in the snapper bottom-longline fishery, as were captures of grey petrel, flesh-footed shearwater, and other birds. Estimates for flesh-footed shearwater also dominated the bigeye surface-longline fishery, with fewer estimated captures of black petrel and of other albatrosses in this target fishery.

The spatial distribution of estimated captures in 2013–14 showed distinct patterns for each seabird species group across the New Zealand region (Figure 5). For most species groups, capture estimates were high in one or two specific areas, with fewer estimated captures in other areas. Estimated captures of black petrel and flesh-footed shearwater were mainly in northern areas, reflecting the distribution of these species. The generic group other birds had relatively high capture estimates (i.e., more than 50 captures) in many areas.

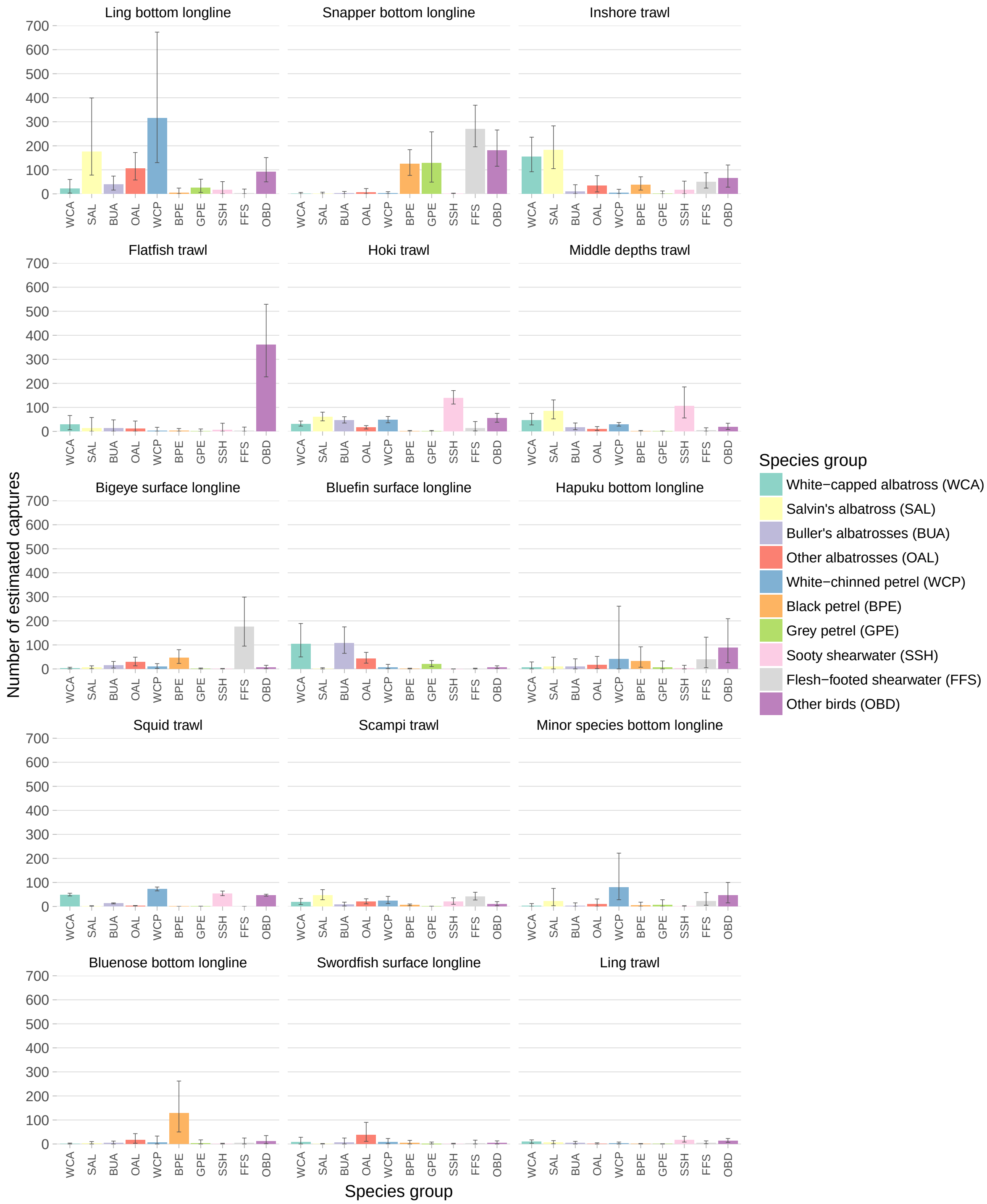

Figure 4: Number of estimated captures for the modelled seabird species groups for the 2013–14 fishing year. For each species group and fishery, the bars show mean captures and the 95% credible interval. Shown are only fisheries that were estimated to have caught a mean of more than 50 birds.

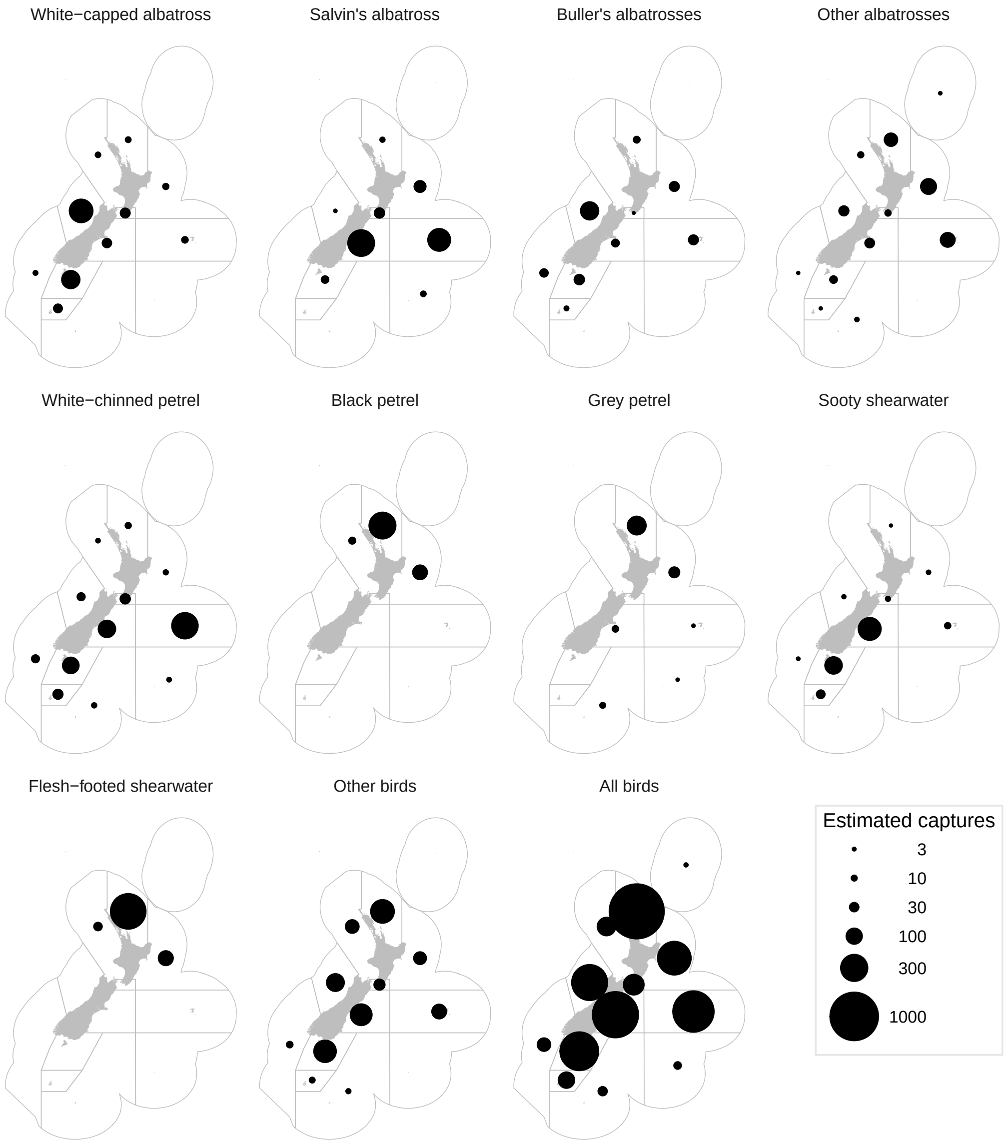

Figure 5: Estimated captures of seabird species groups by model area in the 2013–14 fishing year. For each of the modelled species groups, the size of the circles is proportional to the mean number of estimated captures in each of the model areas (mean estimated captures of less than one bird are not shown).

Table 7: Number of estimated seabird captures by model-area and fishing method in the 2013–14 fishing year. Presented are the mean and 95% credible interval of the posterior distribution of the total estimated seabird captures, summed across all the modelled species groups. The areas are sorted in decreasing order of the mean number of estimated captures.

Area	Trawl		SLL		BLL		Total	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
North East	134	102–174	261	177–387	897	718–1 102	1 294	1 078–1 537
Western Chatham Rise	673	554–809	0	0–0	228	133–399	901	738–1 119
Eastern Chatham Rise	178	146–215	0	0–4	537	349–888	716	524–1 068
Stewart Snares Shelf	600	522–692	0	0–0	27	11–69	628	546–726
West Coast South Island	242	191–300	222	145–331	75	42–122	539	428–672
East of North Island	152	103–216	138	98–190	179	115–273	470	364–600
Cook Strait	98	63–147	0	0–0	70	32–148	169	108–262
West Coast North Island	58	34–89	17	6–34	58	30–102	134	85–196
Auckland Islands	102	83–124	0	0–0	0	0–6	103	84–125
Fiordland	14	8–23	16	16–16	36	14–83	67	42–112
South Subantarctic	14	13–17	0	0–0	14	5–41	28	18–55
East Subantarctic	7	7–8	0	0–0	10	1–37	17	8–44
Kermadec Islands	0	0–0	3	0–14	0	0–0	3	0–14

The highest number of estimated captures were in the north-east area, followed by western and eastern Chatham Rise, and the Stewart-Snares shelf (Table 7). The high number of captures in the north-east area was determined by estimated captures in bottom-longline fisheries, while the high number of captures in the Chatham Rise areas was primarily due to high capture estimates in trawl fishing and bottom longlining, respectively. Most estimated captures at the Stewart-Snares shelf were in trawl fisheries, with only few captures in this area in bottom-longline fisheries.

For each species, fishing method, and vessel class that had annual mean estimated captures of over 50 birds, a summary of the estimated captures is given in Appendix A. The summary gives the number of observed captures, the fishing effort, and the estimated captures for each fishing year from 2002–03 to 2013–14. A more detailed presentation of the data is currently available online (at https://data.dragonfly.co.nz/psc/). This website allows exploration of the model results by fishery, vessel size, area, and year.

3.3 Model fit

For each species group, diagnostics of the model fitting, and summaries of the posterior distributions of the model parameters are given in Appendix B.

A comparison between the estimated and observed captures in fishery, vessel-size, area, and season strata indicates how the model performs, relative to a simple ratio estimate calculated by dividing the observed captures in each stratum by the observer coverage (as an example, Table B-57 shows the strata with the highest estimated captures). In the small-vessel snapper bottom-longline fishery, in the north-east area during winter, there was an estimated total of 2338 (95% c.i.: 902–4834) captures over the 15-year period from 1998–99 to 2013–14. Despite the high estimates, there have been no observations of this fishery during winter, and so there were no observed captures in this stratum. In other cases, the model-estimated captures were close to the ratio estimate. For example, the stratum with the highest number of estimated captures of white-capped albatross had 1191 captures (95% c.i.: 1038–1359) from 2002–03 to 2013–14, compared with a ratio estimate of 1061 captures Table B-33.

Convergence and model-fit was summarised through the Heidelberger & Welch (1983) test. There was a total of 108 parameters in each model, and in most of the models some chains failed either the convergence or the half-width test (this tests indicates whether the posterior mean may be estimated with an accuracy of two significant digits). A poorly-performing model was the model for white-chinned petrel (Table B-50). In this model, 10.2% of parameters had one chain that failed the convergence test (although there were no parameters in any of the models that failed for both chains).

For each model, Appendix B provides a summary of the posterior distributions of each model parameter. For example, the model of white-capped albatross captures is summarised in Table B-35. In this model, the highest vessel-size-method effect was for small-vessel surface longline with an effect of 11.41 (95% c.i.: 3.00–46.86) relative to large-vessel trawl fishing. Interpretation of these parameters needs to consider that for any fishing event multiple parameters apply. While the small-vessel surface-longline effect was high, much of this fishing was in the northern half of New Zealand, which had a small effect of 0.07 (95% c.i.: 0.02–0.35). There were also effects associated with the particular target fisheries (such as southern bluefin, bigeye tuna). The random effects and the overdispersion are summarised through their coefficient of variation (CV, the ratio of the standard deviation to the mean). The highest CVs were associated with the negative-binomial distribution, which describes the event-level distribution of the number of captures. Across all the models, the highest overdispersion was for the model of white-chinned petrel in bottom-longline fisheries. In this model, the distribution had a CV of 6.51 (95% c.i.: 5.66–7.42) (Table B-51). The high overdispersion may explain the non-convergence of some chains in the white-chinned petrel model.

A key indicator of model performance is the comparison between the observed captures and the number of captures estimated on the observed fishing effort. Elsewhere in the report, no estimation was carried out on the observed fishing effort (the number of observed captures was used directly); however, this measure indicates the skill of the model. As an example, for the model of white-capped albatross, there was a close relationship between the number of observed captures in fisheries, area, season strata and the number of captures that were estimated on the observed fishing effort in these strata (Figure B-33). Out of 561 strata, there were only six strata where the observed captures were outside the 95% credible interval of the number of captures estimated on the observed effort in those strata. Across all the species groups, the two models that had the highest number of strata whose observed captures lay outside the estimated range were of white-chinned petrel (Figure B-37) and of other birds (Figure B-42). For white-chinned petrel, the biggest discrepancy was in large-vessel ling bottom-longline fishing (without integrated weight line) on the Stewart-Snares shelf during spring. There was a total of 144 observed captures in this stratum, while the model estimated 338.95 (95% c.i.: 53–637) captures. This deviation was probably caused by the extremely variable nature of captures of white-chinned petrel by bottom-longliners without integrated weight line. On one observed trip, in 2001, 292 white-chinned petrel were reported caught. The variability in other-bird captures was expected, due to the heterogeneous nature of this species group. The model of the other albatross group did not estimate the observed number of captures in the Kermadec Islands swordfish surface-longline stratum (Figure B-36). The observed captures were from two trips in 2006, one of which caught 51 albatrosses. These captures were more than would have been expected from other observations of other albatross captures.

4. DISCUSSION

4.1 Model structure

The use of a single model structure applied to each species grouping provided a consistent framework for the estimation of incidental seabird captures. This approach differs from previous seabird bycatch estimation (Abraham et al. 2013, 2016), where the models varied in complexity between species and fishing methods. The previous models included covariates, selected using step selection methods, and different models had different assumptions on statistical distributions (e.g., captures could either follow a negative-binomial or a Poisson distribution).

One of the challenges for the unified modelling approach was the ability to share information between well-observed and poorly-observed fisheries. The resulting model structure chosen in this study was a compromise between simplicity, allowing model fitting for data-poor strata, and complexity, allowing the main sources of variability in capture rates to be considered. The inclusion of the three fishing methods within the same model for each species, and the sharing of both areas and seasons across all fishing methods meant that information on well observed fisheries could be used to inform estimation of capture rates in poorly-observed fisheries. The single model structure will allow the estimation process to be more easily repeated as new data become available.

The models used in this study did not have covariates that could vary from fishing event to fishing event (such as time of day, or the use of mitigation). These covariates will vary between species and fisheries. When they are not included, the model is able to have the same structure across all species. It also simplifies the model fitting, as the data can be aggregated to the strata level before fitting the model (from the point of view of the model, all fishing effort in the same method, fishery, vessel-length, area, season stratum is equally likely to catch a seabird of a given species). Including covariates would be essential, however, for a more detailed understanding of the factors that are associated with bycatch events.

We recommend that this same model structure is applied to updated data. There were indications of convergence limitations with the parameters of some models, however, and we recommend increasing the length of the chains in the statistical modelling to improve the accuracy of the estimates.

4.2 Comparison with other estimates

As the modelling method has been updated, it is important to compare the results with previous estimations (Figure 6). The latter include the previous assessment of incidental seabird captures (Abraham et al. 2016) and the recent seabird risk assessment (Richard & Abraham 2015). For most of the fishing-method vessel-size groups, estimates of total seabird bycatch between this study and the preceding assessment (i.e., Abraham et al. 2016) were similar, relative to the uncertainty. The marked exception was the estimated number of seabird captures in small-vessel bottom-longline fisheries, which had about twice as many estimated seabird captures than were estimated previously by Abraham et al. (2016), with no overlap in the credible intervals. This increase in the number of seabird captures in these poorly-observed fisheries was related to separating the other birds category into flesh-footed shearwater, grey petrel, black petrel, and other birds. All these species groups had mean estimates of between 100 and 400 captures in the 2012–13 fishing year in small-vessel bottom-longline fisheries, and the sum of the mean number of captures of these species groups was 1192. This value was over twice the mean estimate of 498 other bird captures in these fisheries in 2012–13 by Abraham et al. (2016).

For grey petrel and other birds, most captures were in the stratum of small-vessel bottom-longline snapper fisheries in north-eastern New Zealand during winter (July to September; see Table B-57, Table B-69). There have not been any observations in these fisheries at this time of year. The differences in the estimates caused by changing the model structure emphasised the need for more observations in poorly-observed small-vessel fisheries. When observer coverage is low, estimates are more strongly influenced by the modelling assumptions.

The recent risk assessment (Richard & Abraham 2015) estimated observable captures for each seabird species as an annual average over the three years from 2010–11 to 2012–13. The estimates of total seabird bycatch from the risk assessment are similar to those presented here, with the exception of estimates of seabird captures in small-vessel bottom-longline fisheries (Figure 6). It is likely that the risk assessment estimates are affected by the lack of observations in the snapper bottom-longline fishery during winter.

A comparison of estimated observable captures of individual species between the risk assessment and this study showed some significant discrepancies (Figure 7). There were 637 (95% c.i.: 495–822) estimated captures of flesh-footed shearwater during 2013–14 in this study, compared with the number of estimated observable captures of 302 (95% c.i.: 218–400) in the risk assessment (an annual average over the 2010–11 to 2013–14 years). In the current study, captures of flesh-footed shearwater were estimated to be primarily in small-vessel bottom-longline, surface-longline and trawl fisheries (see Appendix A, subsubsection A.9.3), with no clear trend in the number of estimated captures in recent years. In the risk assessment, flesh-footed shearwater was found to be at very-high risk, with a risk ratio of 1.50 (95% c.i.: 0.56–3.36). Doubling the number of estimated observable captures would double the risk score, leading

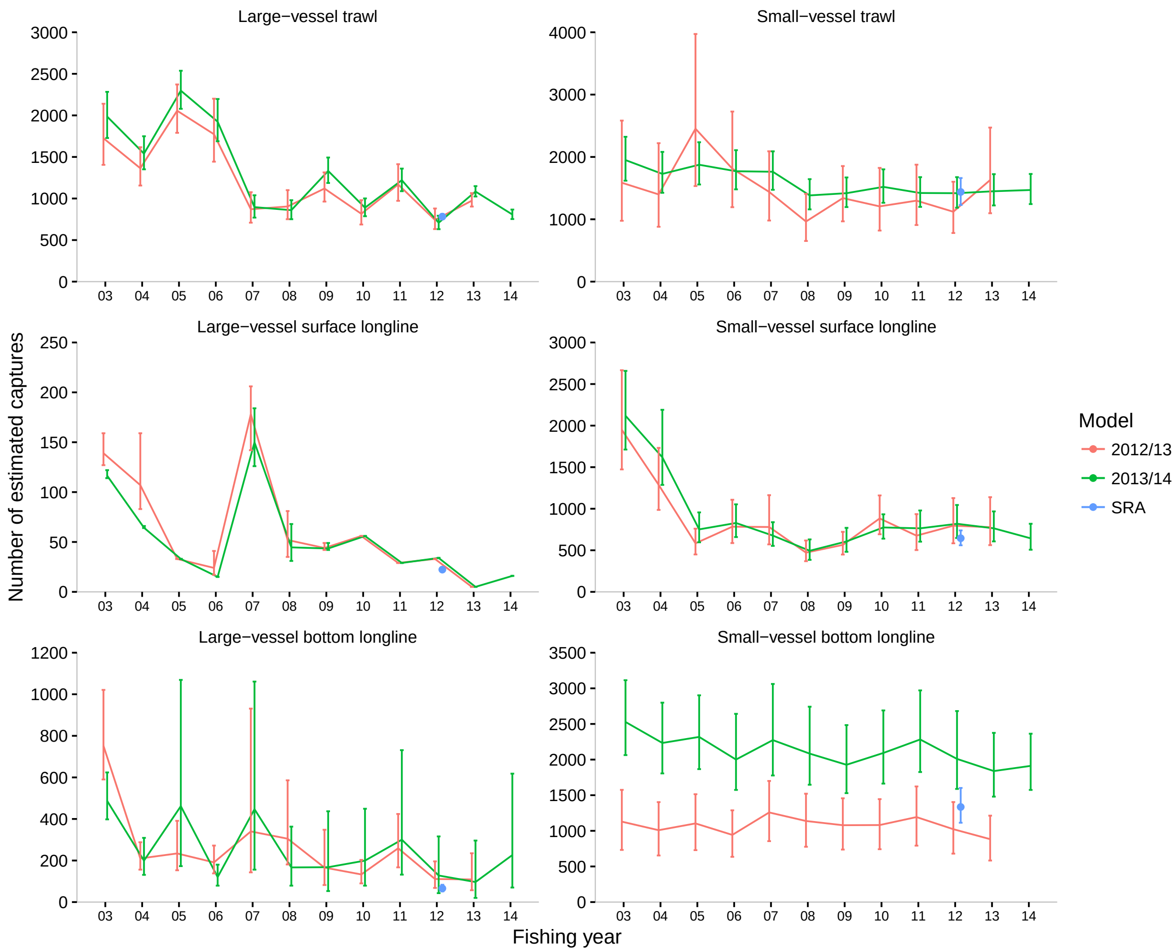

Figure 6: Comparison of the number of seabird captures estimated with three different statistical models. For each fishing method (trawl, surface longline, bottom longline) and vessel class, estimated captures are from the previous assessment (2012–13, see Abraham et al. 2016), this study (2013–14), and the seabird risk assessment (SRA; see Richard & Abraham 2015). Estimates for the risk assessment were an average over the three fishing years 2010–11 to 2012–13. Cut-off lengths for small and large vessel size classes were 45 m, 34 m, and 28 m, for surface-longline (SLL), bottom-longline (BLL), and trawl fishing, respectively. Lines and symbols indicate mean captures, error bars are the 95% credible interval for the total number of estimated captures within each fishing year. (Note different y-axis scales.)

to a risk that was entirely above one. Similarly the captures of grey petrel were higher in the current study, with estimated captures of 207 (95% c.i. 114–354), compared with estimated observable captures of 78 (95% c.i. 50–119) in the recent risk assessment by Richard & Abraham (2015). Nevertheless, the risk score of grey petrel is currently low at 0.08 (95% c.i.: 0.04–0.17).

For the remaining species, the two estimates from the current study and the risk assessment were either within the respective credible intervals, or the estimated captures from the risk assessment were higher than were estimated here. It is also worth noting that the estimated uncertainty for white-chinned petrel captures was considerably higher in this study than in the risk assessment by Richard & Abraham (2015). The high uncertainty in this study is likely to be caused by the longer time period, which includes large capture events of white-chinned petrel in the early 2000s, before the introduction of integrated weight line. These data affect the overdispersion in the model, causing high uncertainty, even in recent years. In comparison, the risk assessment used a shorter time period that did not include the large capture events, and had no overdispersion. This difference in time periods means that the risk assessment may underestimate the uncertainty in the estimates.

The use of the different method in the risk assessment allows estimates of observable captures for species where there have been few (or no) observed captures. By necessity, the model used in the risk assessment for the estimation is simple, and it relies on assumptions about the distribution of the birds, which may be poorly known. The ratio of the mean estimates in the risk assessment relative to this study varied from 0.47 to 1.35, with a standard deviation of 0.40. When the risk assessment and the seabird capture estimation are updated, we recommend first that the risk assessment uses the estimates of seabird bycatch for species where they are available, and second that, for other species, the uncertainty in the bycatch estimates from the risk assessment is inflated to account for the variation between the estimates made by the two approaches. The difference in the estimates from the two approaches indicates the potential errors due to structural assumptions in the risk-assessment modelling.

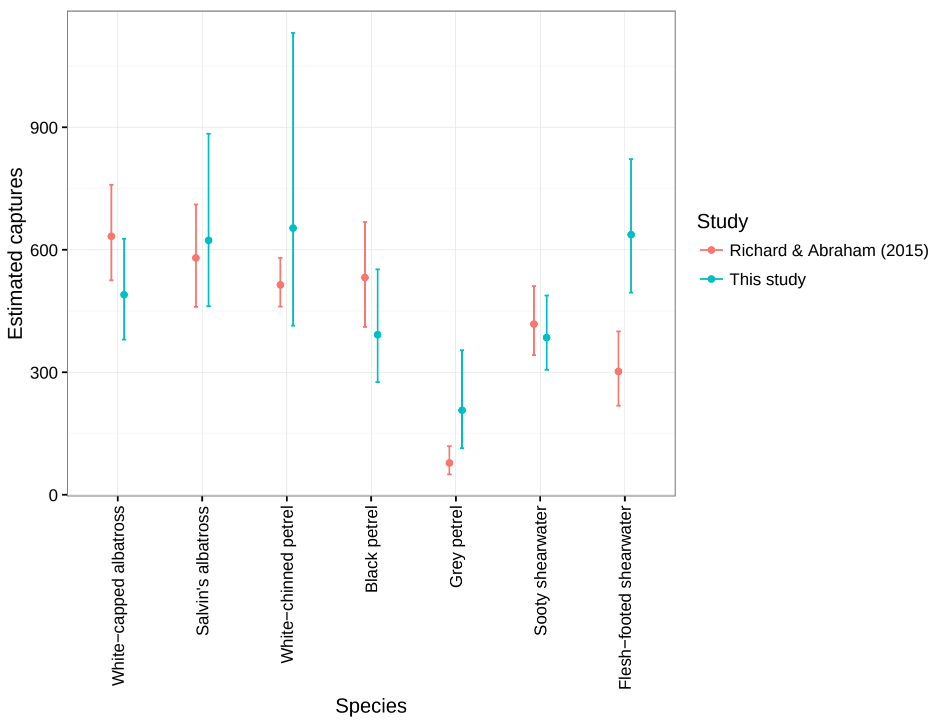

Figure 7: Comparison of the number of seabird captures estimated in this study (for the 2013–14 fishing year), and in the seabird risk assessment (Richard & Abraham 2015). For each species with estimates in both studies, values are the mean and 95% credible intervals of the estimated observable captures.

4.3 Seabird bycatch

This study estimated seabird captures in all trawl and longline fisheries within the New Zealand Exclusive Economic Zone. The estimation used a consistent framework, and provides bycatch estimates for eight seabird species and two species groups. Total estimated captures of seabirds in all trawl and longline fisheries fell from from 9185 (95% c.i: 8390–10096) in 2002–03 to 5075 (95% c.i.: 4547–5726) in 2013–14. Over this period the direct impact of New Zealand fisheries on seabirds, as measured by the mean number of estimated annual seabird captures, has decreased by 45%. This decrease is associated with both decreases in fishing effort and in changes in seabird capture rates. While there was a decrease in total seabird captures over the twelve years, however, there has been no change in the total estimated seabird captures since 2008–09.

Estimated captures were highest in small-vessel fisheries, which were typically poorly observed (summaries of the captures of all birds are given in Appendix A, subsection A.11). The fishing-method—vessel-size group with the highest total number of seabird captures was small-vessel bottom longline, with estimated captures of 1612 (95% c.i.: 1331–1953) seabirds. Because of low observer coverage in small-vessel trawl and bottom-longline fisheries (in many years, less than 2%), the estimates were uncertain, and the model was unable to estimate trends in estimated captures in these fisheries (other than from changes in fishing effort). The low observer coverage makes the estimates of bycatch in these fisheries sensitive to the model assumptions. For example, the current model estimated captures of grey petrel in the snapper bottom longline fishery during the three month period July to September. There are no observations in this fishery in this season, and so no way to validate these estimated captures. In order to better understand and manage seabird bycatch in New Zealand fisheries, it is important to increase observer coverage in small-vessel trawl and bottom-longline fisheries.

Of the large vessel fisheries where changes in capture rates could be estimated, a decrease in capture rate was most evident for albatross captures in squid trawl, and for albatross and petrel captures in ling bottom longline. These decreases were associated with the introduction of new mitigation. In large-vessel trawl fisheries, warp mitigation was introduced in January 2006, and many large bottom-longline vessels began using integrated weight line in the early 2000s. There was a marked decrease in the capture of albatross in bluefin tuna surface longline fisheries between 2009—10 and 2013–14, however there was considerable variability in the capture rates of albatross before that, so it is unclear whether this decrease was due to variability or a change in practice by the fishery. There was a decrease in the capture rates of albatross in large-vessel hoki trawl fisheries following the introduction of warp mitigation, but in more recent years the capture rates appear to have risen. There was no evidence for a reduction in the capture rates of petrels and other birds in large-vessel trawl fisheries. Although there has been a sustained focus by the Ministry for Primary Industries and the fishing industry on reducing seabird bycatch, it remains a challenging issue.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Abraham, E.R., ; Richard, Y., ; Berkenbusch, K., ; Thompson, F., (2016). Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 2002–03 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 169*. 205 p. Retrieved 11 July 2016, from http://mpi.govt.nz/document-vault/12180

Abraham, E.R., ; Thompson, F.N., (2010). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2006–07. Final Research Report for research project PRO2007-01 (Unpublished report held by Ministry for Primary Industries, Wellington). Retrieved 4 August

2015, from http://fs.fish.govt.nz/Doc/22909/PRO2007-01%20%28Obj%201%20RR%207%29.pdf.ashx

Abraham, E.R., ; Thompson, F.N., (2011). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 79*. 74 p.

Abraham, E.R., ; Thompson, F.N., ; Berkenbusch, K., (2013). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2010–11. Final Research Report for project PRO2010/01 (Unpublished report held by Ministry for Primary Industries, Wellington).

Anderson, O.R.J., ; Small, C.J., ; Croxall, J.P., ; Dunn, E.K., ; Sullivan, B.J., ; Yates, O., ; Black, A., (2011). Global seabird bycatch in longline fisheries. *Endangered Species Research 14*: 91–106.

Baird, S.J., ; Smith, M.H., (2007). Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2003–04 and 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 9*. 108 p.

Baird, S.J., ; Smith, M.H., (2008). Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 18*. 124 p.

Croxall, J.P., ; Gales, R., (1998). An assessment of the conservation status of albatrosses. In: Robertson, G., ; Gales, R., (Eds.), The albatross: biology and conservation, Surrey Beatty & Sons, Chipping Norton, Australia, pp. 46–65.

Croxall, J.P., ; Butchart, S.H., ; Lascelles, B., ; Stattersfield, A.J., ; Sullivan, B., ; Symes, A., ; Taylor, P., (2012). Seabird conservation status, threats and priority actions: a global assessment. *Bird Conservation International 22*: 1–34.

Department of Internal Affairs, (2006). Fisheries (Incidental bycatch of seabirds by trawl vessels 28m+) notice 2006. *New Zealand Gazette* 12 January 2006: 31–34.

Favero, M., ; Seco Pon, J.P., (2014). Challenges in seabird by-catch mitigation. *Animal Conservation 17(6)*: 532–533.

Geweke, J., (1992). Evaluating the accuracy of sampling-based approaches to the calculation of posterior moments. *Bayesian Statistics 4*: 169–194.

Heidelberger, P., ; Welch, P.D., (1983). Simulation run length control in the presence of an initial transient. *Operations Research 31*: 1109–1144.

Middleton, D.A.J., ; Abraham, E.R., (2007). The efficacy of warp strike mitigation devices: trials in the 2006 squid fishery. Final Research Report for research project IPA2006/02. (Unpublished report held by Ministry for Primary Industries, Wellington). Retrieved from http://fs.fish.govt.nz/Page.aspx?pk=113&dk=22910

Ministry for Primary Industries, (2012). Research database documentation. Retrieved 17 March 2015, from http://tinyurl.com/fdbdoc

Plummer, M., (2005). JAGS: Just another Gibbs sampler. Version 1.0.3. Retrieved 15 January 2009, from http://www-fis.iarc.fr/~martyn/software/jags

Plummer, M., ; Best, N., ; Cowles, K., ; Vines, K., (2006). CODA: Convergence diagnosis and output analysis for MCMC. *R News 6*: 7–11.

Richard, Y., ; Abraham, E.R., (2015). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 162*. 85 p. Retrieved 1 July 2016, from https://mpi.govt.nz/document-vault/10523

Robertson, G., ; McNeill, M., ; Smith, N., ; Wienecke, B., ; Candy, S., ; Olivier, F., (2006). Fast sinking (integrated weight) longlines reduce mortality of white-chinned petrels (*Procellaria aequinoctialis*) and sooty shearwaters (*Puffinus griseus*) in demersal longline fisheries. *Biological Conservation 132*: 458–471.

Sanders, B.M., ; Fisher, D.O., (2010). Database documentation for the Ministry of Fisheries Centralised Observer Database. *NIWA Fisheries Data Management Database Documentation Series*.

Spiegelhalter, D.J., ; Thomas, A., ; Best, N., ; Lunn, D., (2003). WinBUGS version 1.4 user manual. MRC Biostatistics Unit, Cambridge. 60 p.

Thompson, F.N., ; Berkenbusch, K., ; Abraham, E.R., (2013). Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. Retrieved 27 July 2015, from https://www.mpi.govt.nz/document-vault/4241

Waugh, S., ; MacKenzie, D., ; Fletcher, D., (2008). Seabird bycatch in New Zealand trawl and longline fisheries. *Papers and Proceedings of the Royal Society of Tasmania 142(1)*: 45.

Zydelis, R., ; Small, C., ; French, G., (2013). The incidental catch of seabirds in gillnet fisheries: a global review. *Biological Conservation 162*: 76–88.

A APPENDIX A: SUMMARIES OF CAPTURES BY SPECIES AND FISHERY

A.1 White-capped albatross captures

A.1.1 White-capped albatross captures in large-vessel trawl fisheries

Table A-1: Annual fishing effort and number of tows observed in large-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of white-capped albatross, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	54 200	11.9	85	1.32	513	408–632	0.95	0.75–1.17
2003–04	47 339	13.4	148	2.33	687	575–811	1.45	1.21–1.71
2004–05	44 156	17.2	243	3.20	961	834–1 098	2.18	1.89–2.49
2005–06	39 122	15.8	68	1.10	337	265–419	0.86	0.68–1.07
2006–07	35 188	20.6	51	0.70	211	161–267	0.60	0.46–0.76
2007–08	32 766	25.3	41	0.49	133	101–171	0.41	0.31–0.52
2008–09	29 978	24.7	83	1.12	262	214–318	0.87	0.71–1.06
2009–10	29 506	26.0	38	0.49	133	100–174	0.45	0.34–0.59
2010–11	27 393	22.7	38	0.61	135	101–175	0.49	0.37–0.64
2011–12	25 593	32.3	58	0.70	158	126–195	0.62	0.49–0.76
2012–13	23 972	49.3	121	1.02	159	144–175	0.66	0.60–0.73
2013–14	25 660	43.7	67	0.60	100	86–116	0.39	0.34–0.45

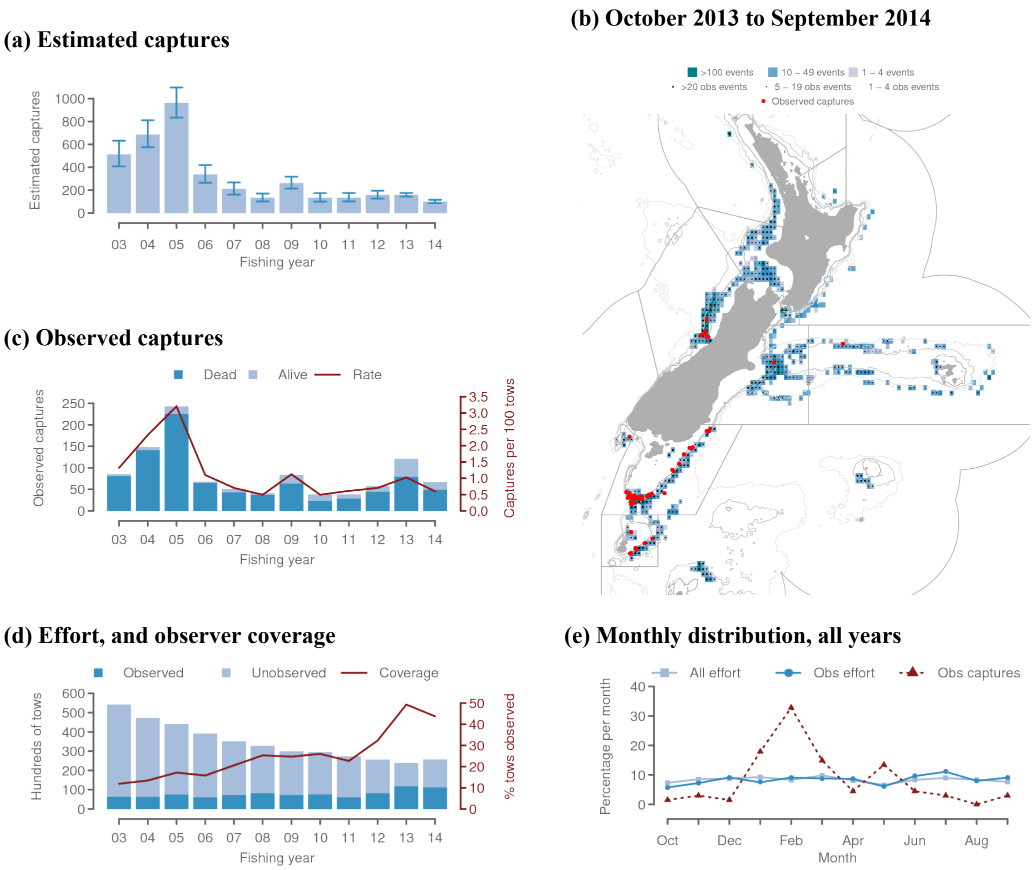


Figure A-1: White-capped albatross captures in large-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.1.2 White-capped albatross captures in small-vessel trawl fisheries

Table A-2: Annual fishing effort and number of tows observed in small-vessel trawl fisheries, number of observed captures of white-capped albatross and observed capture rate (captures per hundred tows), and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	75 973	0.5	0	0.00	248	166–349	0.33	0.22–0.46
2003–04	73 491	0.3	0	0.00	249	166–349	0.34	0.23–0.47
2004–05	76 292	0.2	0	0.00	263	178–368	0.34	0.23–0.48
2005–06	70 817	0.6	1	0.23	244	164–342	0.34	0.23–0.48
2006–07	68 130	1.0	6	0.87	256	176–356	0.38	0.26–0.52
2007–08	56 758	1.3	1	0.13	205	137–290	0.36	0.24–0.51
2008–09	57 575	4.2	13	0.54	218	151–296	0.38	0.26–0.51
2009–10	63 382	2.1	10	0.75	249	170–343	0.39	0.27–0.54
2010–11	58 696	2.1	2	0.16	236	161–327	0.40	0.27–0.56
2011–12	58 828	1.4	9	1.09	234	161–324	0.40	0.27–0.55
2012–13	59 867	1.0	5	0.86	256	174–355	0.43	0.29–0.59
2013–14	59 431	3.2	4	0.21	245	166–338	0.41	0.28–0.57

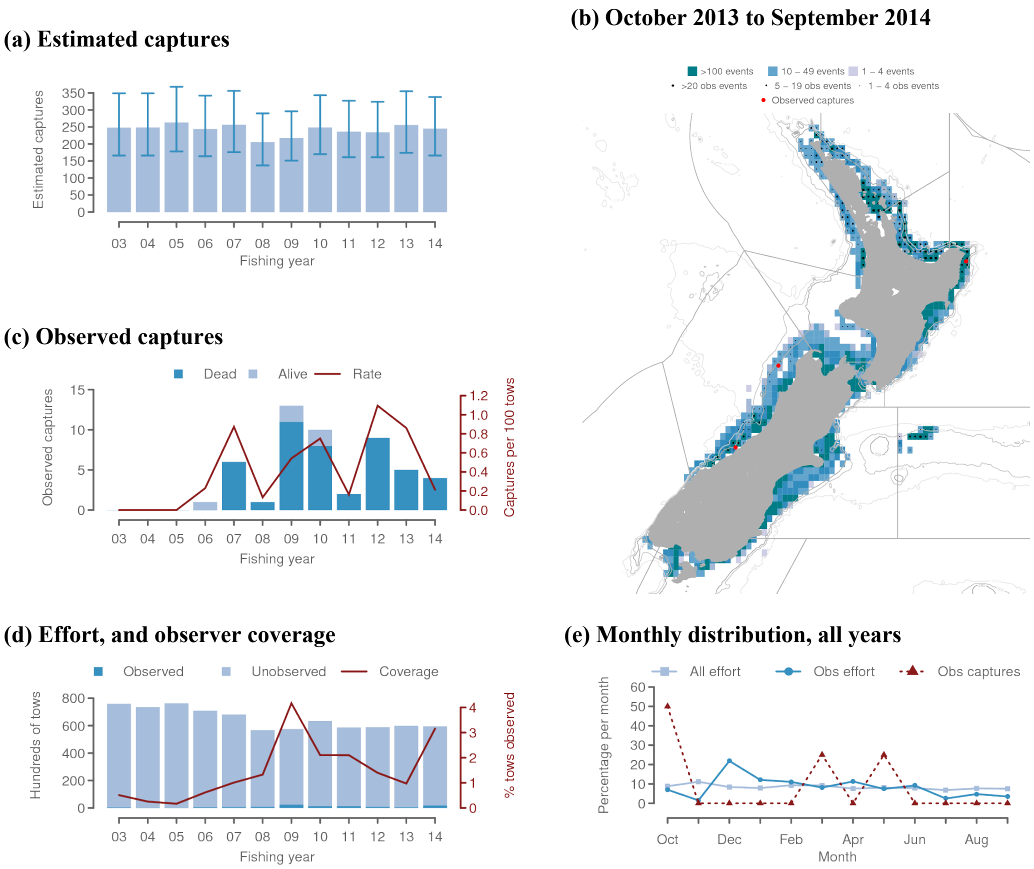


Figure A-2: White-capped albatross captures in small-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 , (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.1.3 White-capped albatross captures in small-vessel surface-longline fisheries

Table A-3: Annual fishing effort and number of hooks observed in small-vessel surface-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of white-capped albatross, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 572 966	0.0	0	.	65	30–117	0.08	0.03–0.14
2003–04	5 730 964	2.4	1	0.07	118	59–208	0.21	0.10–0.36
2004–05	3 041 381	4.7	0	0.00	30	12–59	0.10	0.04–0.19
2005–06	3 026 689	3.2	1	0.10	30	12–58	0.10	0.04–0.19
2006–07	2 332 733	8.1	1	0.05	8	2–18	0.03	0.01–0.08
2007–08	1 678 054	8.1	1	0.07	33	13–66	0.20	0.08–0.39
2008–09	2 306 403	6.5	1	0.07	41	17–80	0.18	0.07–0.35
2009–10	2 516 706	7.4	21	1.12	71	44–112	0.28	0.17–0.45
2010–11	2 684 809	6.4	0	0.00	50	21–92	0.19	0.08–0.34
2011–12	2 548 537	6.8	2	0.12	151	76–265	0.59	0.30–1.04
2012–13	2 389 412	3.0	10	1.37	139	75–241	0.58	0.31–1.01
2013–14	1 893 434	6.3	6	0.50	114	59–207	0.60	0.31–1.09

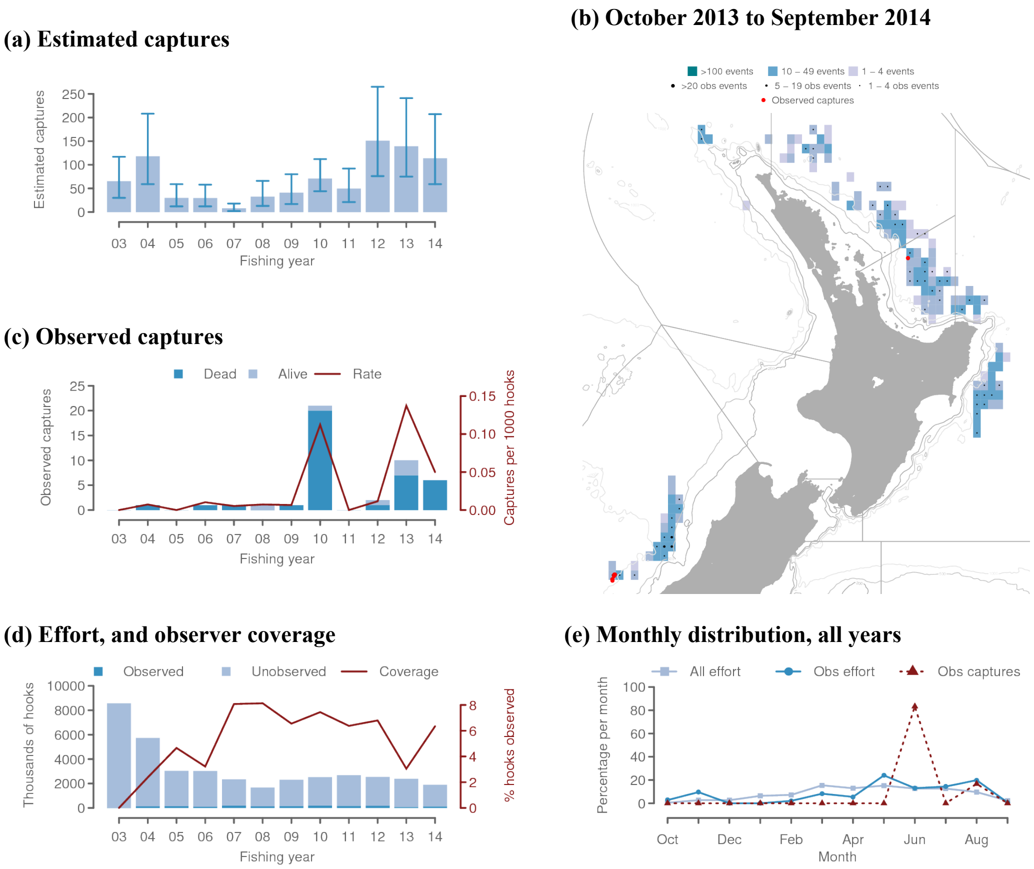


Figure A-3: White-capped albatross captures in small-vessel surface-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (95.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2 Salvin's albatross captures

A.2.1 Salvin's albatross captures in large-vessel trawl fisheries

Table A-4: Annual fishing effort and number of tows observed in large-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of Salvin's albatross, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	54 200	11.9	22	0.341	199	133–285	0.367	0.245–0.526
2003–04	47 339	13.4	8	0.126	131	67–217	0.277	0.142–0.458
2004–05	44 156	17.2	35	0.461	334	223–476	0.756	0.505–1.078
2005–06	39 122	15.8	8	0.129	94	49–156	0.240	0.125–0.399
2006–07	35 188	20.6	10	0.138	84	46–134	0.239	0.131–0.381
2007–08	32 766	25.3	5	0.060	46	20–83	0.140	0.061–0.253
2008–09	29 978	24.7	9	0.122	67	35–108	0.223	0.117–0.360
2009–10	29 506	26.0	30	0.391	129	92–176	0.437	0.312–0.596
2010–11	27 393	22.7	16	0.258	98	61–145	0.358	0.223–0.529
2011–12	25 593	32.3	20	0.242	76	51–106	0.297	0.199–0.414
2012–13	23 972	49.3	47	0.398	111	89–141	0.463	0.371–0.588
2013–14	25 660	43.7	42	0.374	104	80–133	0.405	0.312–0.518

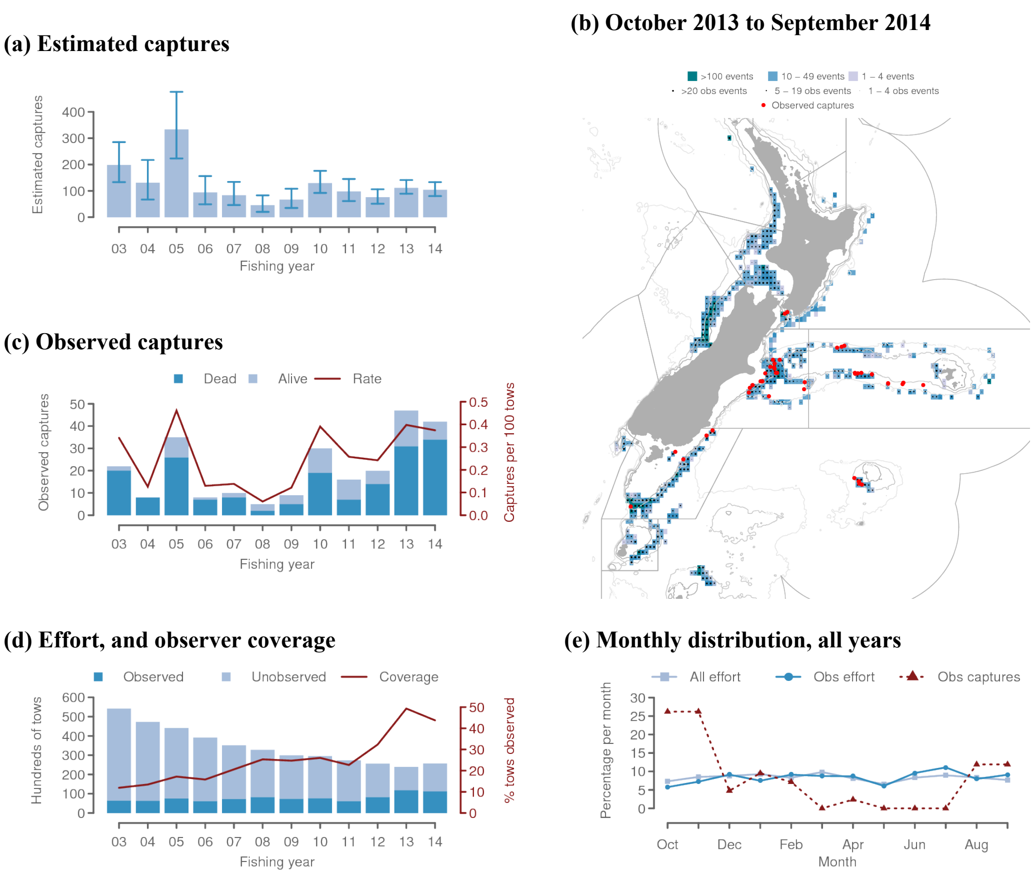


Figure A-4: Salvin's albatross captures in large-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.2 Salvin's albatross captures in small-vessel trawl fisheries

Table A-5: Annual fishing effort and number of tows observed in small-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of Salvin's albatross, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	75 973	0.5	2	0.52	380	254–537	0.50	0.33–0.71
2003–04	73 491	0.3	3	1.62	305	199–441	0.42	0.27–0.60
2004–05	76 292	0.2	2	1.57	358	241–504	0.47	0.32–0.66
2005–06	70 817	0.6	1	0.23	355	242–498	0.50	0.34–0.70
2006–07	68 130	1.0	4	0.58	319	217–442	0.47	0.32–0.65
2007–08	56 758	1.3	6	0.80	234	158–334	0.41	0.28–0.59
2008–09	57 575	4.2	28	1.17	269	189–372	0.47	0.33–0.65
2009–10	63 382	2.1	10	0.75	268	180–376	0.42	0.28–0.59
2010–11	58 696	2.1	4	0.32	272	183–381	0.46	0.31–0.65
2011–12	58 828	1.4	4	0.49	264	180–368	0.45	0.31–0.63
2012–13	59 867	1.0	1	0.17	272	184–386	0.45	0.31–0.64
2013–14	59 431	3.2	3	0.16	303	208–422	0.51	0.35–0.71

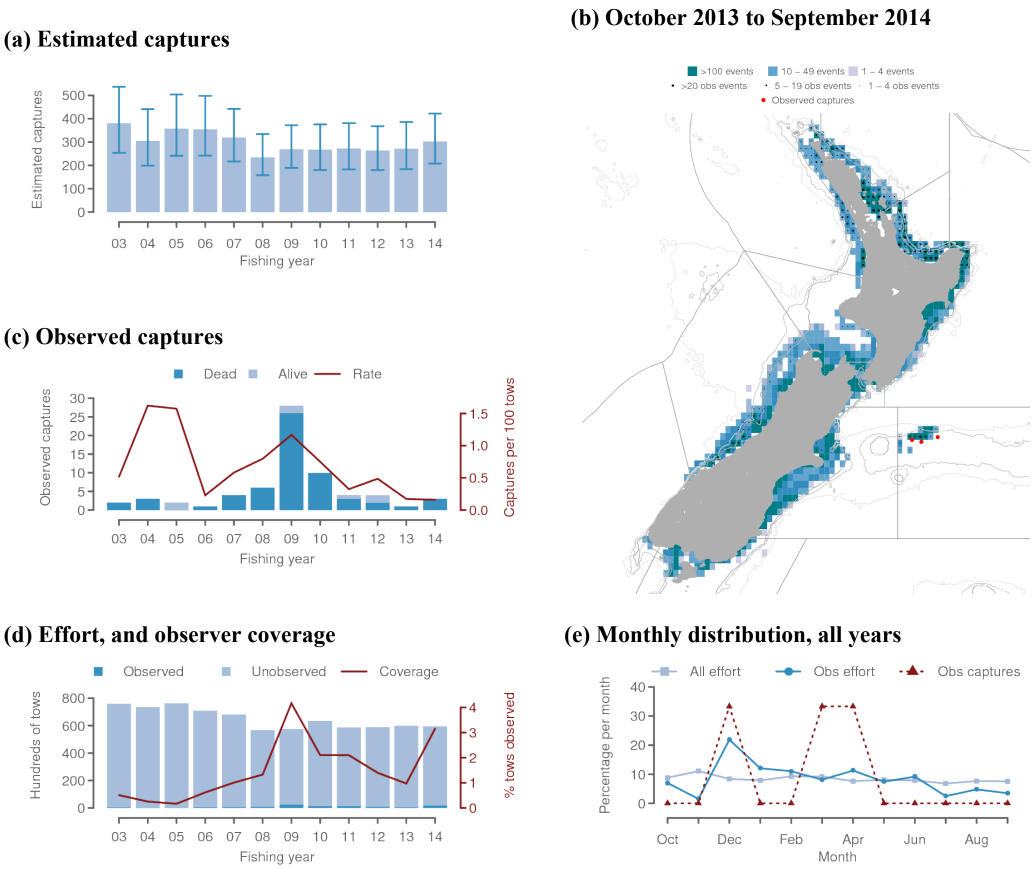


Figure A-5: Salvin's albatross captures in small-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 , (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.3 Salvin's albatross captures in small-vessel bottom-longline fisheries

Table A-6: Annual fishing effort and number of hooks observed in small-vessel bottom-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of Salvin's albatross, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	0	0.000	53	22–103	0.027	0.011–0.052
2003–04	19 872 683	1.2	0	0.000	43	16–96	0.022	0.008–0.048
2004–05	22 907 282	1.3	0	0.000	71	28–152	0.031	0.012–0.066
2005–06	22 256 860	0.7	0	0.000	57	19–137	0.026	0.009–0.062
2006–07	25 367 652	1.9	22	0.446	91	51–161	0.036	0.020–0.063
2007–08	27 376 403	1.8	0	0.000	79	34–160	0.029	0.012–0.058
2008–09	24 574 649	3.4	0	0.000	83	38–149	0.034	0.015–0.061
2009–10	26 831 061	2.1	0	0.000	84	39–155	0.031	0.015–0.058
2010–11	27 984 389	0.8	0	0.000	100	45–194	0.036	0.016–0.069
2011–12	26 316 056	0.3	0	0.000	101	46–200	0.038	0.017–0.076
2012–13	24 270 014	0.5	0	0.000	90	39–183	0.037	0.016–0.075
2013–14	24 249 354	3.4	0	0.000	87	40–158	0.036	0.016–0.065

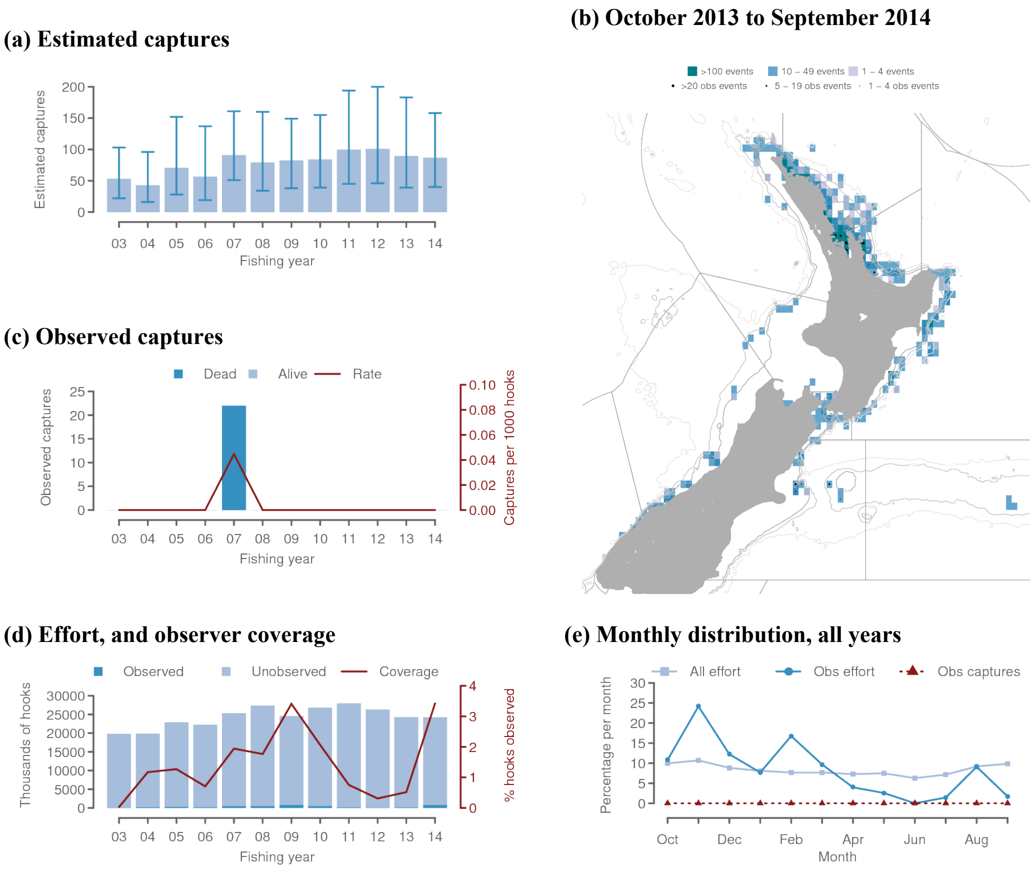


Figure A-6: Salvin's albatross captures in small-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.3 Buller's albatrosses captures

A.3.1 Buller's albatrosses captures in large-vessel trawl fisheries

Table A-7: Annual fishing effort and number of tows observed in large-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of Buller's albatrosses, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	54 200	11.9	6	0.093	65	30–112	0.120	0.055–0.207
2003–04	47 339	13.4	9	0.141	79	43–125	0.167	0.091–0.264
2004–05	44 156	17.2	22	0.290	132	89–187	0.299	0.202–0.423
2005–06	39 122	15.8	8	0.129	60	33–99	0.153	0.084–0.253
2006–07	35 188	20.6	5	0.069	39	17–69	0.111	0.048–0.196
2007–08	32 766	25.3	18	0.217	79	53–113	0.241	0.162–0.345
2008–09	29 978	24.7	16	0.216	58	38–84	0.193	0.127–0.280
2009–10	29 506	26.0	11	0.143	46	27–69	0.156	0.092–0.234
2010–11	27 393	22.7	20	0.322	73	50–101	0.266	0.183–0.369
2011–12	25 593	32.3	33	0.399	102	76–133	0.399	0.297–0.520
2012–13	23 972	49.3	58	0.491	85	73–100	0.355	0.305–0.417
2013–14	25 660	43.7	36	0.321	64	51–80	0.249	0.199–0.312

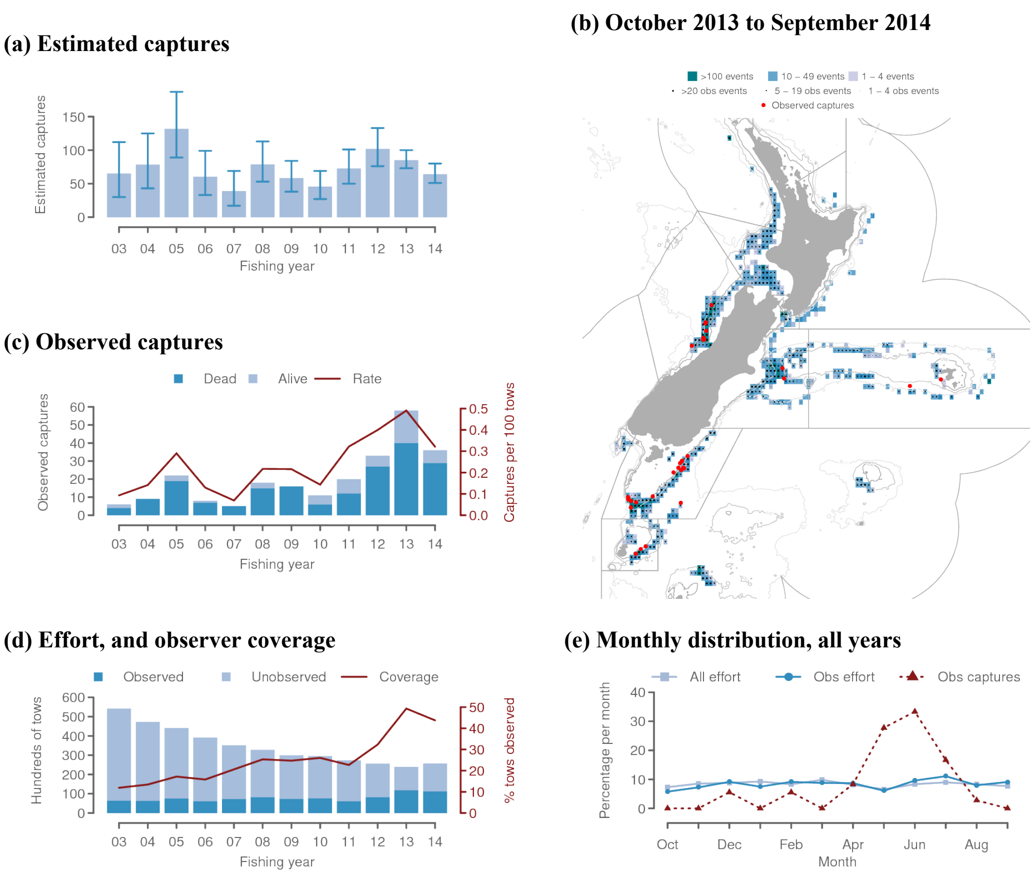


Figure A-7: Buller's albatrosses captures in large-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.3.2 Buller’s albatrosses captures in small-vessel surface-longline fisheries

Table A-8: Annual fishing effort and number of hooks observed in small-vessel surface-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of Buller’s albatrosses, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 572 966	0.0	0	.	335	197–541	0.39	0.23–0.63
2003–04	5 730 964	2.4	0	0.00	297	171–492	0.52	0.30–0.86
2004–05	3 041 381	4.7	2	0.14	104	58–171	0.34	0.19–0.56
2005–06	3 026 689	3.2	5	0.51	118	66–197	0.39	0.22–0.65
2006–07	2 332 733	8.1	1	0.05	60	29–108	0.26	0.12–0.46
2007–08	1 678 054	8.1	4	0.29	64	35–108	0.38	0.21–0.64
2008–09	2 306 403	6.5	2	0.13	88	48–147	0.38	0.21–0.64
2009–10	2 516 706	7.4	27	1.44	126	86–184	0.50	0.34–0.73
2010–11	2 684 809	6.4	4	0.23	104	59–164	0.39	0.22–0.61
2011–12	2 548 537	6.8	4	0.23	151	85–250	0.59	0.33–0.98
2012–13	2 389 412	3.0	8	1.10	128	75–207	0.54	0.31–0.87
2013–14	1 893 434	6.3	8	0.67	113	67–186	0.60	0.35–0.98

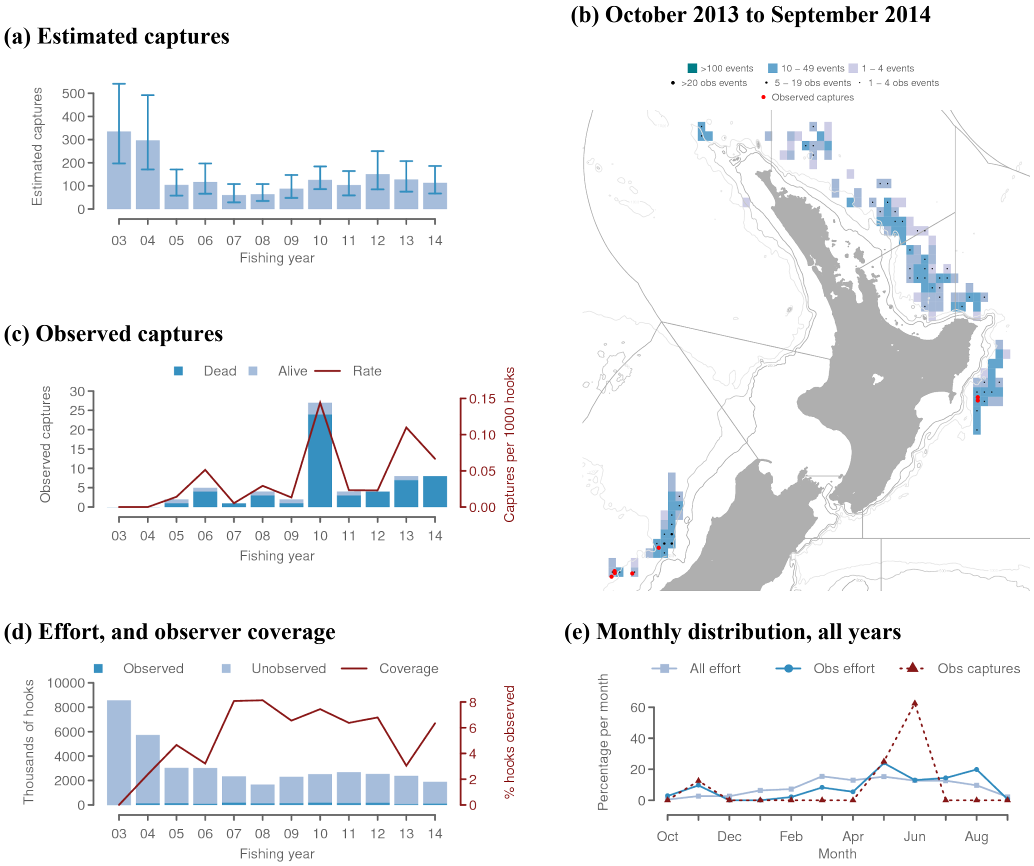


Figure A-8: Buller’s albatrosses captures in small-vessel surface-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (95.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.3.3 Buller's albatrosses captures in small-vessel bottom-longline fisheries

Table A-9: Annual fishing effort and number of hooks observed in small-vessel bottom-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of Buller's albatrosses, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	1	1.82	40	15–80	0.02	0.01–0.04
2003–04	19 872 683	1.2	0	0.00	32	11–64	0.02	0.01–0.03
2004–05	22 907 282	1.3	0	0.00	58	22–113	0.03	0.01–0.05
2005–06	22 256 860	0.7	0	0.00	46	17–91	0.02	0.01–0.04
2006–07	25 367 652	1.9	0	0.00	66	24–128	0.03	0.01–0.05
2007–08	27 376 403	1.8	2	0.04	78	31–151	0.03	0.01–0.06
2008–09	24 574 649	3.4	0	0.00	52	21–100	0.02	0.01–0.04
2009–10	26 831 061	2.1	0	0.00	55	22–108	0.02	0.01–0.04
2010–11	27 984 389	0.8	0	0.00	67	26–133	0.02	0.01–0.05
2011–12	26 316 056	0.3	3	0.37	63	26–125	0.02	0.01–0.05
2012–13	24 270 014	0.5	0	0.00	41	15–84	0.02	0.01–0.03
2013–14	24 249 354	3.4	2	0.02	46	19–88	0.02	0.01–0.04

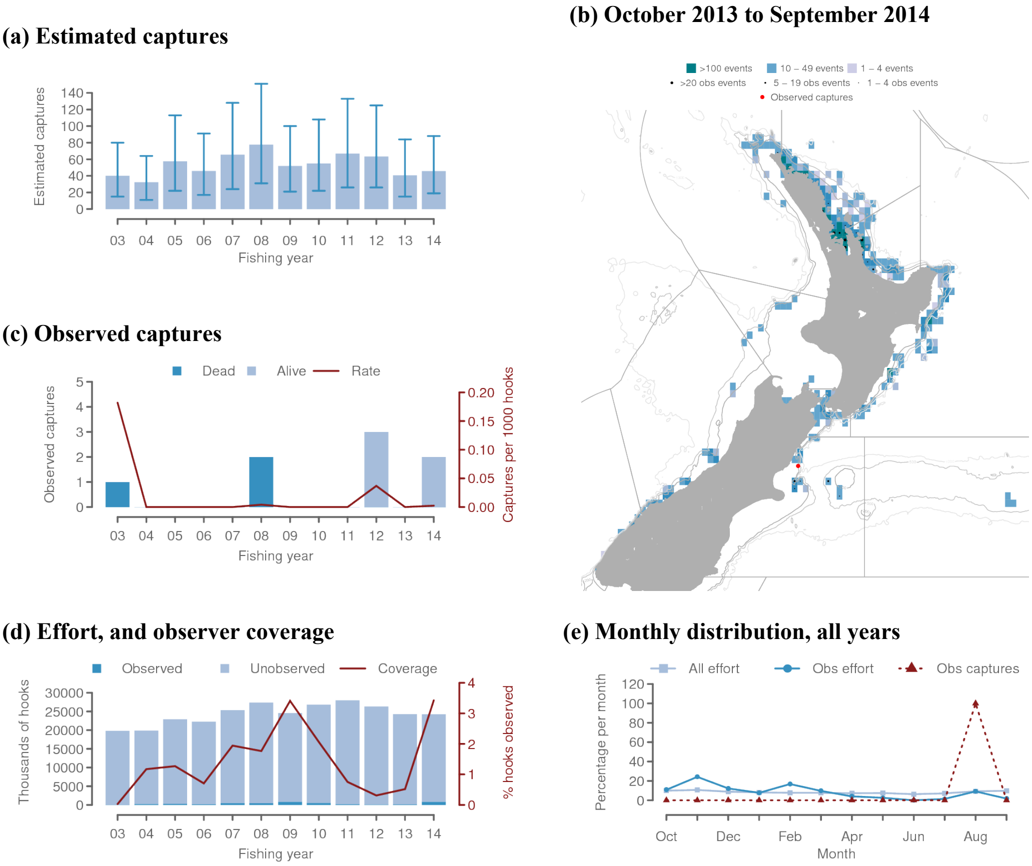


Figure A-9: Buller's albatrosses captures in small-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.4 Other albatrosses captures

A.4.1 Other albatrosses captures in small-vessel trawl fisheries

Table A-10: Annual fishing effort and number of tows observed in small-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of other albatrosses, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	75 973	0.5	0	0.000	77	32–143	0.101	0.042–0.188
2003–04	73 491	0.3	1	0.541	73	30–139	0.099	0.041–0.189
2004–05	76 292	0.2	1	0.787	77	34–142	0.101	0.045–0.186
2005–06	70 817	0.6	4	0.917	79	36–148	0.112	0.051–0.209
2006–07	68 130	1.0	1	0.146	69	29–129	0.101	0.043–0.189
2007–08	56 758	1.3	0	0.000	59	24–112	0.104	0.042–0.197
2008–09	57 575	4.2	1	0.042	58	24–109	0.101	0.042–0.189
2009–10	63 382	2.1	2	0.150	64	28–120	0.101	0.044–0.189
2010–11	58 696	2.1	0	0.000	62	26–115	0.106	0.044–0.196
2011–12	58 828	1.4	1	0.122	61	26–117	0.104	0.044–0.199
2012–13	59 867	1.0	0	0.000	61	26–115	0.102	0.043–0.192
2013–14	59 431	3.2	6	0.320	71	35–125	0.119	0.059–0.210

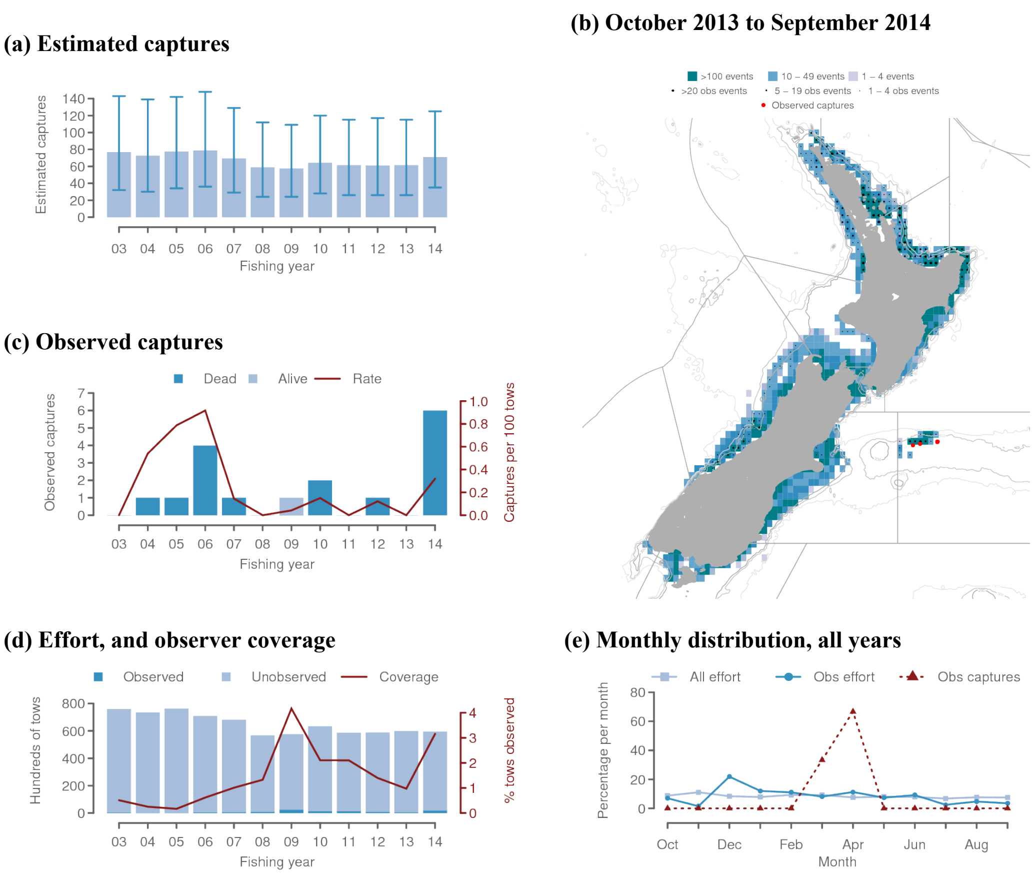


Figure A-10: Other albatrosses captures in small-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 , (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.4.2 Other albatrosses captures in small-vessel surface longline fisheries

Table A-11: Annual fishing effort and number of hooks observed in small-vessel surface longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of other albatrosses, estimated captures and capture rate of other albatross (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 572 966	0.0	0	.	384	254–556	0.45	0.30–0.65
2003–04	5 730 964	2.4	1	0.07	250	165–366	0.44	0.29–0.64
2004–05	3 041 381	4.7	3	0.21	148	95–218	0.49	0.31–0.72
2005–06	3 026 689	3.2	5	0.51	187	122–279	0.62	0.40–0.92
2006–07	2 332 733	8.1	56	2.97	204	146–290	0.87	0.63–1.24
2007–08	1 678 054	8.1	3	0.22	94	58–148	0.56	0.35–0.88
2008–09	2 306 403	6.5	5	0.33	103	66–151	0.45	0.29–0.65
2009–10	2 516 706	7.4	19	1.01	156	108–223	0.62	0.43–0.89
2010–11	2 684 809	6.4	4	0.23	140	91–205	0.52	0.34–0.76
2011–12	2 548 537	6.8	16	0.92	126	87–178	0.49	0.34–0.70
2012–13	2 389 412	3.0	4	0.55	129	83–193	0.54	0.35–0.81
2013–14	1 893 434	6.3	4	0.33	108	67–170	0.57	0.35–0.90

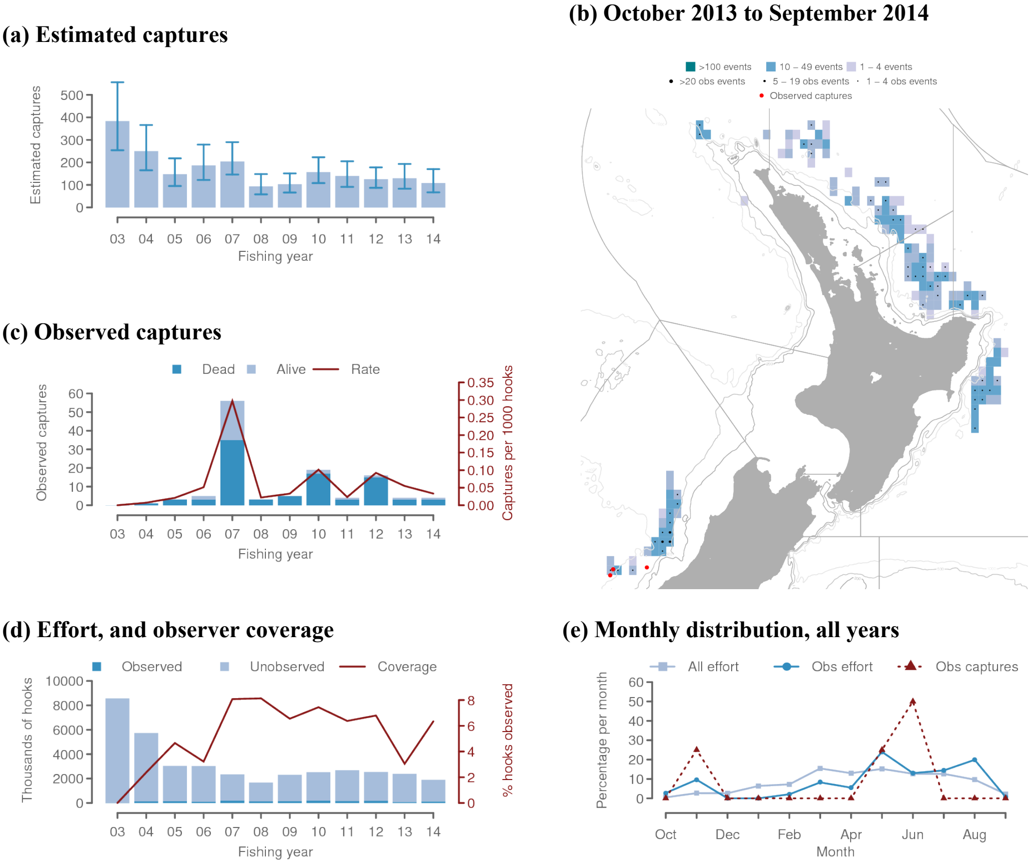


Figure A-11: Other albatrosses captures in small-vessel surface longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (95.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.4.3 Other albatrosses captures in small-vessel bottom longline fisheries

Table A-12: Annual fishing effort and number of hooks observed in small-vessel bottom longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of other albatrosses, estimated captures and capture rate of other albatross (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	0	0.000	96	46–167	0.048	0.023–0.084
2003–04	19 872 683	1.2	0	0.000	91	42–166	0.046	0.021–0.084
2004–05	22 907 282	1.3	0	0.000	111	54–196	0.048	0.024–0.086
2005–06	22 256 860	0.7	0	0.000	102	47–184	0.046	0.021–0.083
2006–07	25 367 652	1.9	14	0.284	136	72–231	0.054	0.028–0.091
2007–08	27 376 403	1.8	4	0.083	135	67–241	0.049	0.024–0.088
2008–09	24 574 649	3.4	0	0.000	108	53–188	0.044	0.022–0.077
2009–10	26 831 061	2.1	0	0.000	120	59–208	0.045	0.022–0.078
2010–11	27 984 389	0.8	0	0.000	140	71–241	0.050	0.025–0.086
2011–12	26 316 056	0.3	0	0.000	120	62–207	0.046	0.024–0.079
2012–13	24 270 014	0.5	0	0.000	100	49–175	0.041	0.020–0.072
2013–14	24 249 354	3.4	1	0.012	104	55–169	0.043	0.023–0.070

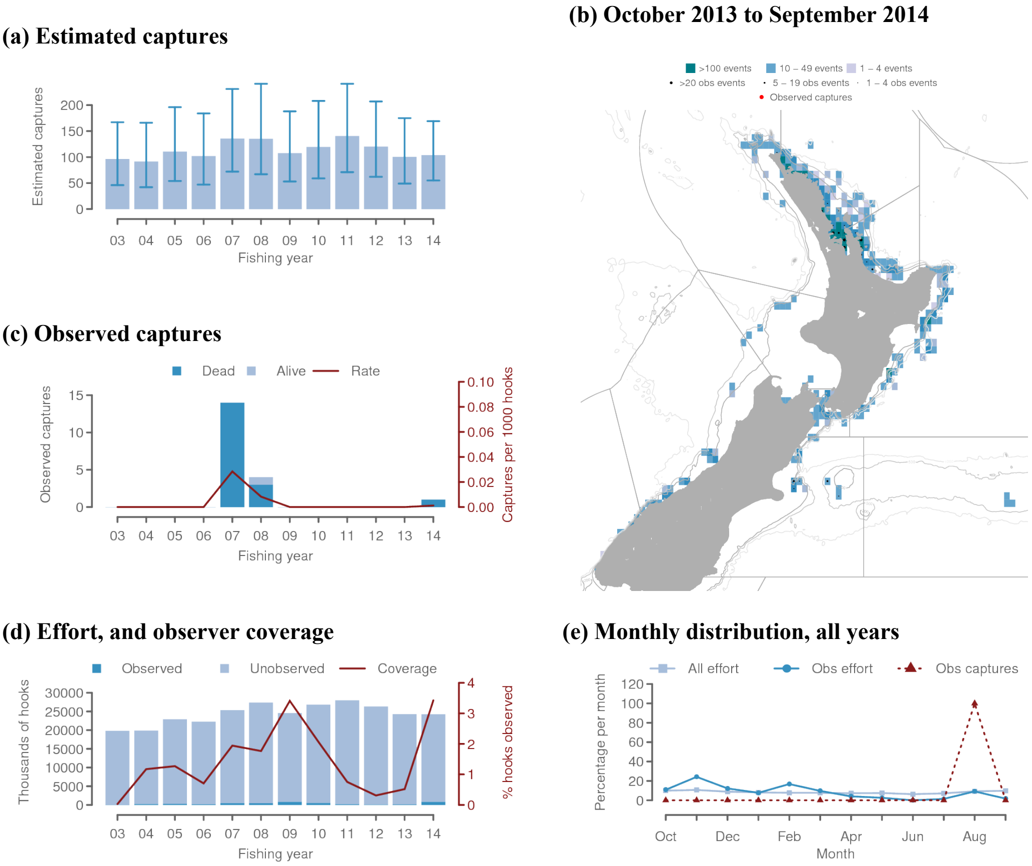


Figure A-12: Other albatrosses captures in small-vessel bottom longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.5 White-chinned petrel captures

A.5.1 White-chinned petrel captures in large-vessel trawl fisheries

Table A-13: Annual fishing effort and number of tows observed in large-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of white-chinned petrel, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	54 200	11.9	13	0.20	95	54–150	0.18	0.10–0.28
2003–04	47 339	13.4	18	0.28	90	58–133	0.19	0.12–0.28
2004–05	44 156	17.2	54	0.71	221	170–284	0.50	0.38–0.64
2005–06	39 122	15.8	70	1.13	364	282–462	0.93	0.72–1.18
2006–07	35 188	20.6	29	0.40	119	83–163	0.34	0.24–0.46
2007–08	32 766	25.3	60	0.72	207	161–265	0.63	0.49–0.81
2008–09	29 978	24.7	104	1.40	319	261–387	1.06	0.87–1.29
2009–10	29 506	26.0	74	0.96	264	207–333	0.89	0.70–1.13
2010–11	27 393	22.7	108	1.74	346	282–424	1.26	1.03–1.55
2011–12	25 593	32.3	54	0.65	164	126–212	0.64	0.49–0.83
2012–13	23 972	49.3	276	2.34	400	363–446	1.67	1.51–1.86
2013–14	25 660	43.7	103	0.92	151	133–172	0.59	0.52–0.67

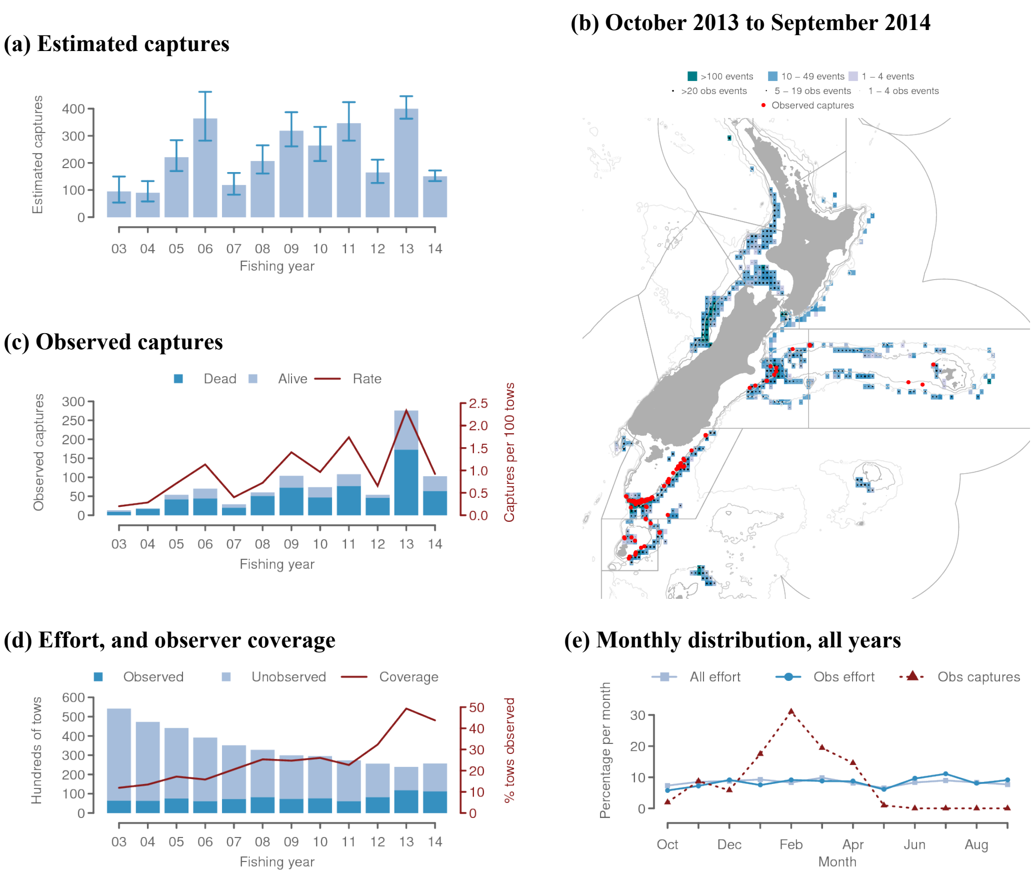


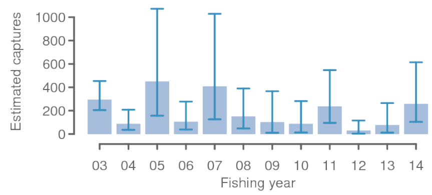
Figure A-13: White-chinned petrel captures in large-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.5.2 White-chinned petrel captures in large-vessel bottom-longline fisheries

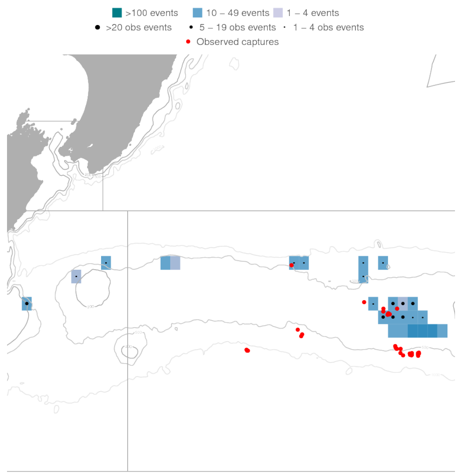
Table A-14: Annual fishing effort and number of hooks observed in large-vessel bottom-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of white-chinned petrel, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	17 928 519	60.1	132	0.123	295	205–454	0.165	0.114–0.253
2003–04	23 341 383	20.7	15	0.031	87	36–208	0.037	0.015–0.089
2004–05	18 932 296	13.7	11	0.042	451	157–1 072	0.238	0.083–0.566
2005–06	14 888 723	24.5	13	0.036	105	39–278	0.071	0.026–0.187
2006–07	12 759 288	14.3	11	0.060	410	126–1 029	0.321	0.099–0.806
2007–08	14 123 096	22.0	7	0.023	153	48–390	0.108	0.034–0.276
2008–09	12 870 071	24.8	1	0.003	103	11–366	0.080	0.009–0.284
2009–10	13 607 740	12.6	1	0.006	87	13–282	0.064	0.010–0.207
2010–11	12 914 717	11.8	24	0.158	238	95–547	0.184	0.074–0.424
2011–12	11 560 277	17.5	1	0.005	31	3–116	0.027	0.003–0.100
2012–13	8 240 515	3.3	0	0.000	77	12–265	0.093	0.015–0.322
2013–14	16 448 081	11.7	34	0.177	258	104–614	0.157	0.063–0.373

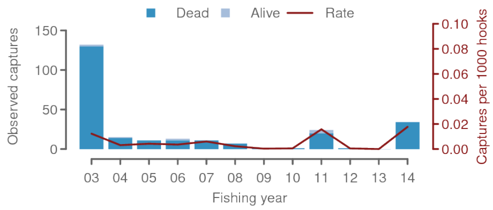
(a) Estimated captures



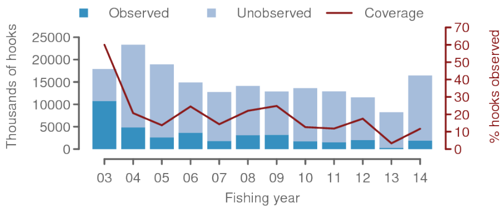
(b) October 2013 to September 2014



(c) Observed captures



(d) Effort, and observer coverage



(e) Monthly distribution, all years

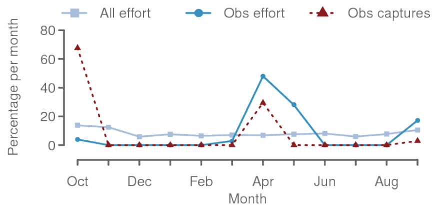


Figure A-14: White-chinned petrel captures in large-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (65.8% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.5.3 White-chinned petrel captures in small-vessel bottom-longline fisheries

Table A-15: Annual fishing effort and number of hooks observed in small-vessel bottom-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of white-chinned petrel, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	0	0.000	192	76–426	0.097	0.038–0.215
2003–04	19 872 683	1.2	0	0.000	127	42–330	0.064	0.021–0.166
2004–05	22 907 282	1.3	0	0.000	250	97–566	0.109	0.042–0.247
2005–06	22 256 860	0.7	0	0.000	217	69–596	0.097	0.031–0.268
2006–07	25 367 652	1.9	1	0.020	318	105–878	0.125	0.041–0.346
2007–08	27 376 403	1.8	3	0.062	289	103–723	0.106	0.038–0.264
2008–09	24 574 649	3.4	0	0.000	285	105–709	0.116	0.043–0.289
2009–10	26 831 061	2.1	0	0.000	267	101–636	0.100	0.038–0.237
2010–11	27 984 389	0.8	0	0.000	332	126–812	0.119	0.045–0.290
2011–12	26 316 056	0.3	0	0.000	311	105–889	0.118	0.040–0.338
2012–13	24 270 014	0.5	0	0.000	270	99–683	0.111	0.041–0.281
2013–14	24 249 354	3.4	0	0.000	186	74–416	0.077	0.031–0.172

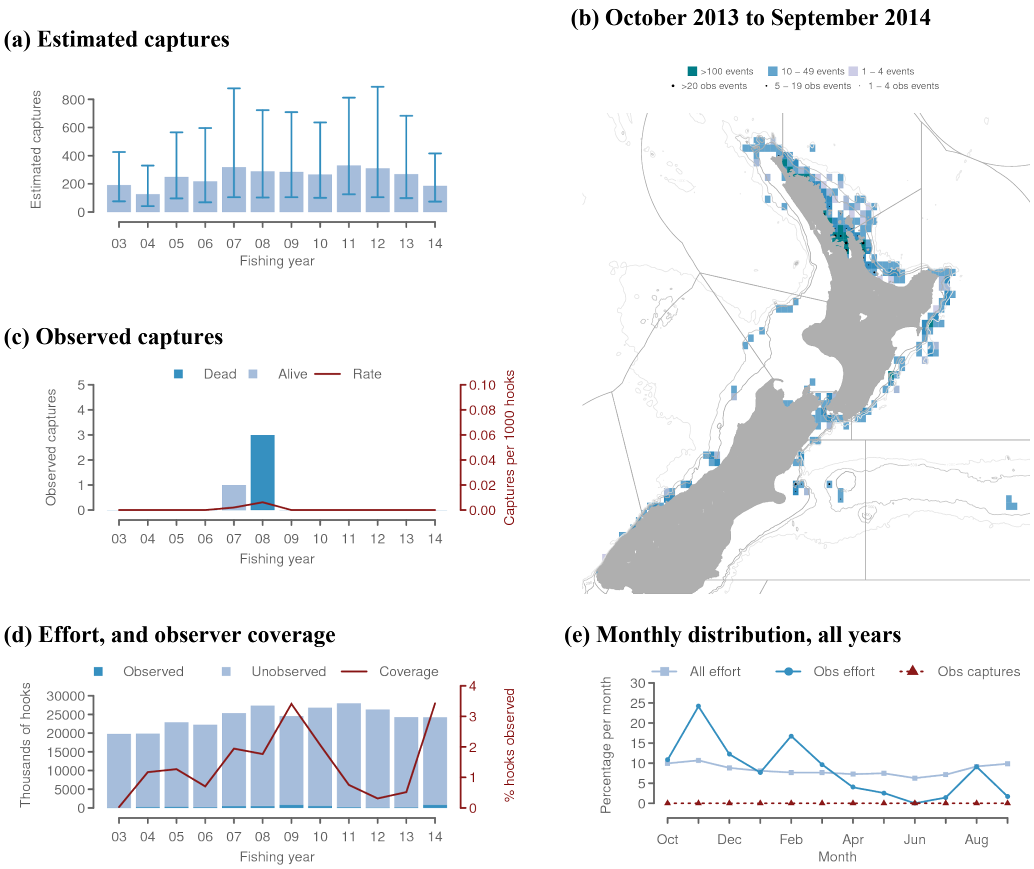


Figure A-15: White-chinned petrel captures in small-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.6 Black petrel captures

A.6.1 Black petrel captures in small-vessel surface-longline fisheries

Table A-16: Annual fishing effort and number of hooks observed in small-vessel surface-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of black petrel, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 572 966	0.0	0	.	226	133–375	0.264	0.155–0.437
2003–04	5 730 964	2.4	1	0.074	140	82–228	0.244	0.143–0.398
2004–05	3 041 381	4.7	0	0.000	104	53–194	0.342	0.174–0.638
2005–06	3 026 689	3.2	0	0.000	80	44–126	0.264	0.145–0.416
2006–07	2 332 733	8.1	0	0.000	66	36–107	0.283	0.154–0.459
2007–08	1 678 054	8.1	1	0.073	56	30–90	0.334	0.179–0.536
2008–09	2 306 403	6.5	2	0.132	68	38–110	0.295	0.165–0.477
2009–10	2 516 706	7.4	18	0.961	86	57–126	0.342	0.226–0.501
2010–11	2 684 809	6.4	1	0.058	85	48–136	0.317	0.179–0.507
2011–12	2 548 537	6.8	1	0.058	67	37–110	0.263	0.145–0.432
2012–13	2 389 412	3.0	0	0.000	65	35–106	0.272	0.146–0.444
2013–14	1 893 434	6.3	0	0.000	52	28–88	0.275	0.148–0.465

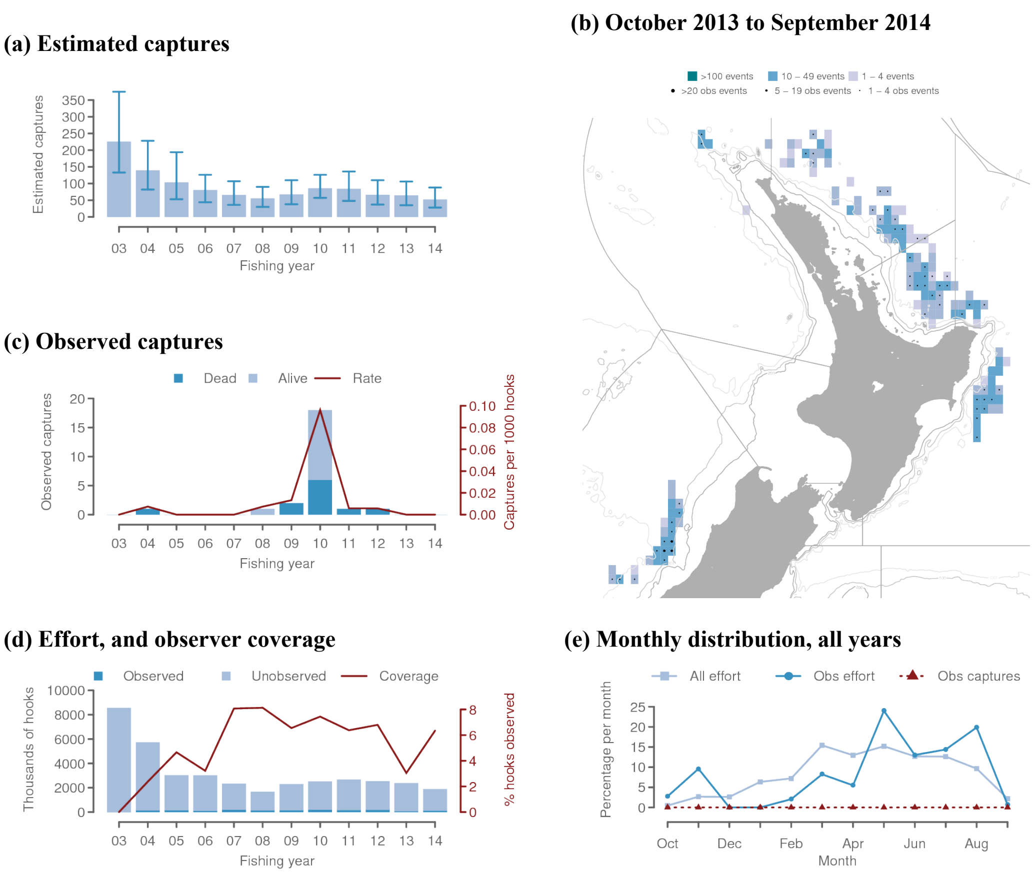


Figure A-16: Black petrel captures in small-vessel surface-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (95.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.6.2 Black petrel captures in small-vessel bottom-longline fisheries

Table A-17: Annual fishing effort and number of hooks observed in small-vessel bottom-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of black petrel, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	0	0.000	602	379–938	0.304	0.191–0.473
2003–04	19 872 683	1.2	2	0.086	581	356–915	0.292	0.179–0.460
2004–05	22 907 282	1.3	1	0.034	510	317–808	0.223	0.138–0.353
2005–06	22 256 860	0.7	2	0.127	478	283–774	0.215	0.127–0.348
2006–07	25 367 652	1.9	4	0.081	569	335–948	0.224	0.132–0.374
2007–08	27 376 403	1.8	3	0.062	463	274–756	0.169	0.100–0.276
2008–09	24 574 649	3.4	8	0.096	424	255–687	0.173	0.104–0.280
2009–10	26 831 061	2.1	31	0.560	485	296–778	0.181	0.110–0.290
2010–11	27 984 389	0.8	2	0.095	456	282–733	0.163	0.101–0.262
2011–12	26 316 056	0.3	0	0.000	373	231–590	0.142	0.088–0.224
2012–13	24 270 014	0.5	0	0.000	308	193–472	0.127	0.080–0.194
2013–14	24 249 354	3.4	7	0.084	292	182–447	0.120	0.075–0.184

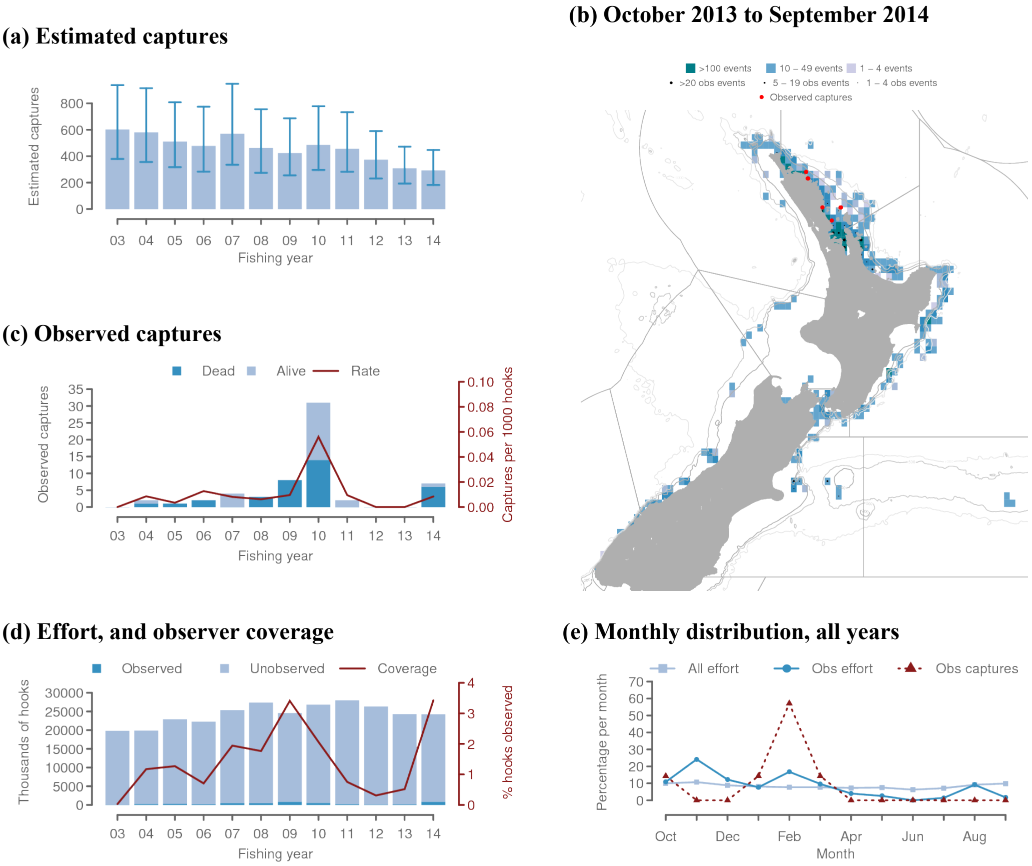


Figure A-17: Black petrel captures in small-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.7 Grey petrel captures

A.7.1 Grey petrel captures in small-vessel bottom-longline fisheries

Table A-18: Annual fishing effort and number of hooks observed in small-vessel bottom longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of grey petrel, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	0	0.000	247	110–475	0.125	0.055–0.239
2003–04	19 872 683	1.2	0	0.000	215	95–409	0.108	0.048–0.206
2004–05	22 907 282	1.3	0	0.000	207	89–394	0.090	0.039–0.172
2005–06	22 256 860	0.7	0	0.000	195	87–376	0.088	0.039–0.169
2006–07	25 367 652	1.9	1	0.020	175	81–330	0.069	0.032–0.130
2007–08	27 376 403	1.8	0	0.000	171	76–318	0.062	0.028–0.116
2008–09	24 574 649	3.4	2	0.024	167	75–314	0.068	0.031–0.128
2009–10	26 831 061	2.1	0	0.000	210	94–396	0.078	0.035–0.148
2010–11	27 984 389	0.8	0	0.000	196	89–371	0.070	0.032–0.133
2011–12	26 316 056	0.3	0	0.000	175	80–329	0.066	0.030–0.125
2012–13	24 270 014	0.5	0	0.000	161	73–301	0.066	0.030–0.124
2013–14	24 249 354	3.4	1	0.012	163	75–307	0.067	0.031–0.127

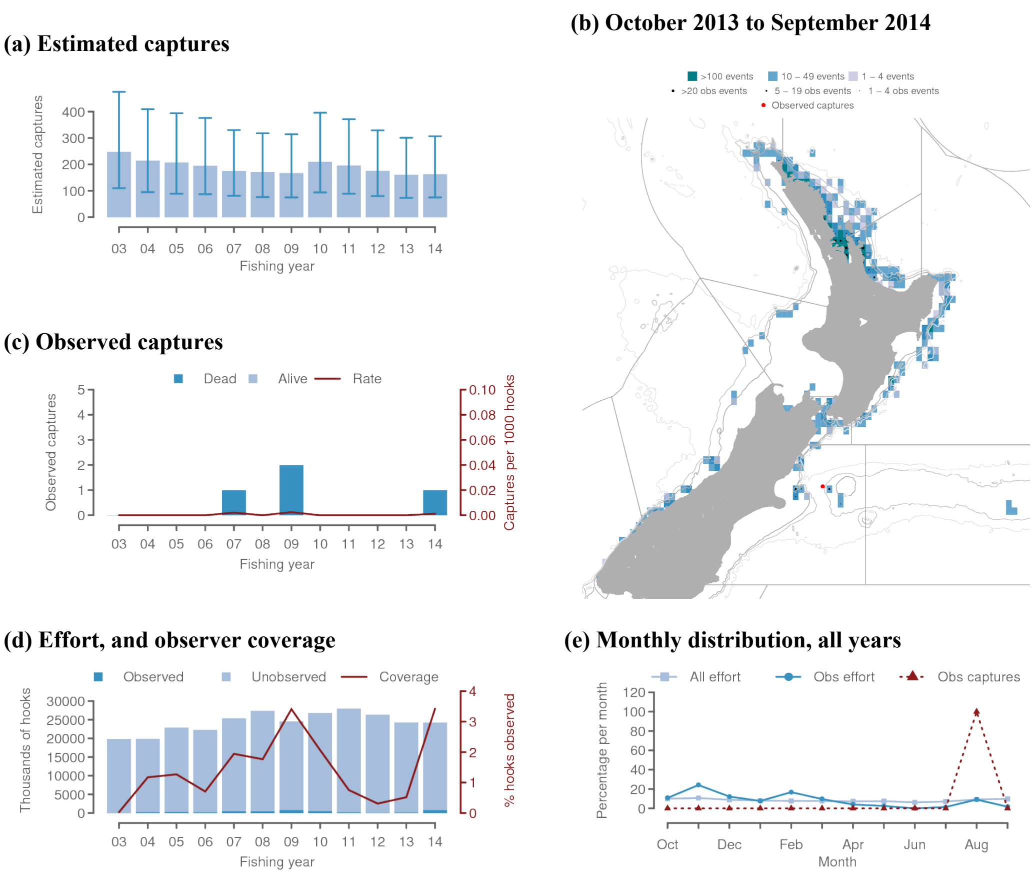


Figure A-18: Grey petrel captures in small-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.8 Sooty shearwater captures

A.8.1 Sooty shearwater captures in large-vessel trawl fisheries

Table A-19: Annual fishing effort and number of tows observed in large-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of sooty shearwater, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	54 200	11.9	120	1.86	921	720–1 169	1.70	1.33–2.16
2003–04	47 339	13.4	54	0.85	405	297–541	0.86	0.63–1.14
2004–05	44 156	17.2	74	0.98	399	307–515	0.90	0.70–1.17
2005–06	39 122	15.8	169	2.73	955	764–1 182	2.44	1.95–3.02
2006–07	35 188	20.6	70	0.97	367	275–476	1.04	0.78–1.35
2007–08	32 766	25.3	80	0.96	326	252–414	0.99	0.77–1.26
2008–09	29 978	24.7	141	1.90	541	435–662	1.80	1.45–2.21
2009–10	29 506	26.0	43	0.56	177	130–236	0.60	0.44–0.80
2010–11	27 393	22.7	87	1.40	354	277–444	1.29	1.01–1.62
2011–12	25 593	32.3	32	0.39	115	82–155	0.45	0.32–0.61
2012–13	23 972	49.3	104	0.88	159	140–183	0.66	0.58–0.76
2013–14	25 660	43.7	125	1.11	222	190–258	0.87	0.74–1.01

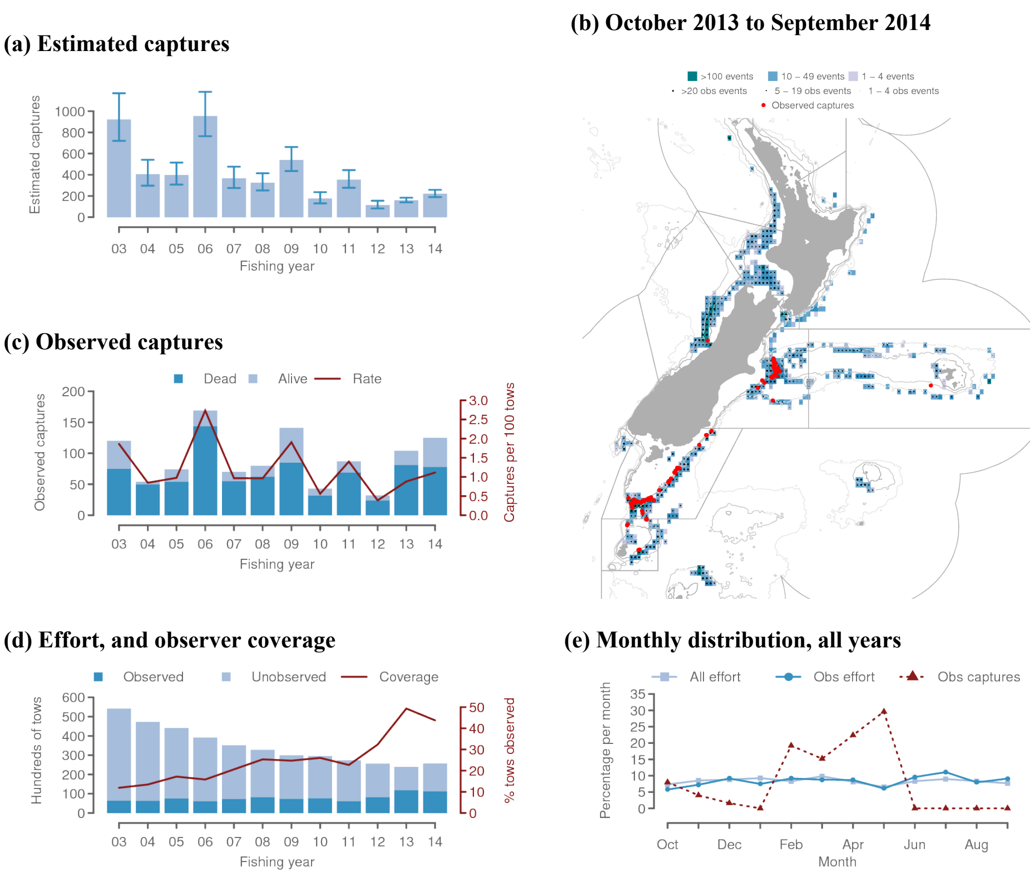


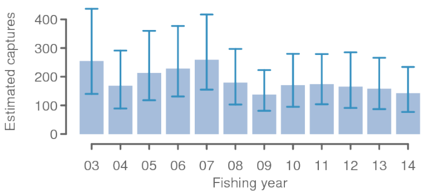
Figure A-19: Sooty shearwater captures in large-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.8.2 Sooty shearwater captures in small-vessel trawl fisheries

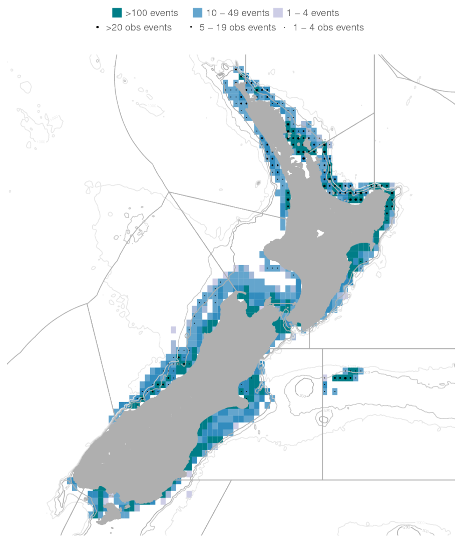
Table A-20: Annual fishing effort and number of tows observed in small-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of sooty shearwater, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	75 973	0.5	0	0.00	255	140–437	0.34	0.18–0.58
2003–04	73 491	0.3	0	0.00	169	89–291	0.23	0.12–0.40
2004–05	76 292	0.2	0	0.00	213	118–360	0.28	0.15–0.47
2005–06	70 817	0.6	0	0.00	228	131–377	0.32	0.18–0.53
2006–07	68 130	1.0	14	2.04	259	155–417	0.38	0.23–0.61
2007–08	56 758	1.3	2	0.27	180	103–297	0.32	0.18–0.52
2008–09	57 575	4.2	11	0.46	138	81–223	0.24	0.14–0.39
2009–10	63 382	2.1	0	0.00	171	95–280	0.27	0.15–0.44
2010–11	58 696	2.1	19	1.54	174	104–279	0.30	0.18–0.48
2011–12	58 828	1.4	0	0.00	165	91–285	0.28	0.15–0.48
2012–13	59 867	1.0	0	0.00	158	87–266	0.26	0.15–0.44
2013–14	59 431	3.2	0	0.00	143	77–234	0.24	0.13–0.39

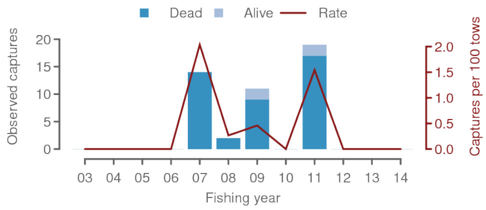
(a) Estimated captures



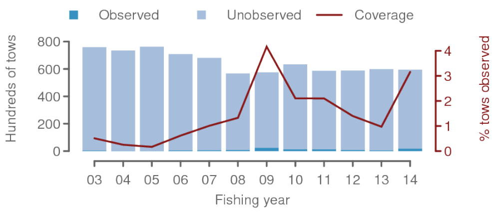
(b) October 2013 to September 2014



(c) Observed captures



(d) Effort, and observer coverage



(e) Monthly distribution, all years

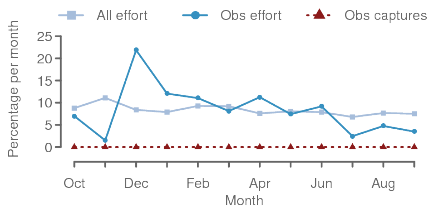


Figure A-20: Sooty shearwater captures in small-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 , (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.9 Flesh-footed shearwater captures

A.9.1 Flesh-footed shearwater captures in small-vessel trawl fisheries

Table A-21: Annual fishing effort and number of tows observed in small-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of flesh-footed shearwater, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	75 973	0.5	0	0.00	142	87–214	0.19	0.11–0.28
2003–04	73 491	0.3	0	0.00	129	78–197	0.18	0.11–0.27
2004–05	76 292	0.2	0	0.00	124	73–188	0.16	0.10–0.25
2005–06	70 817	0.6	8	1.83	117	71–179	0.17	0.10–0.25
2006–07	68 130	1.0	6	0.87	118	73–175	0.17	0.11–0.26
2007–08	56 758	1.3	4	0.53	105	65–157	0.18	0.11–0.28
2008–09	57 575	4.2	3	0.13	105	64–158	0.18	0.11–0.27
2009–10	63 382	2.1	1	0.08	126	79–186	0.20	0.12–0.29
2010–11	58 696	2.1	15	1.22	128	84–185	0.22	0.14–0.32
2011–12	58 828	1.4	0	0.00	96	57–147	0.16	0.10–0.25
2012–13	59 867	1.0	0	0.00	109	68–163	0.18	0.11–0.27
2013–14	59 431	3.2	19	1.01	116	76–168	0.20	0.13–0.28

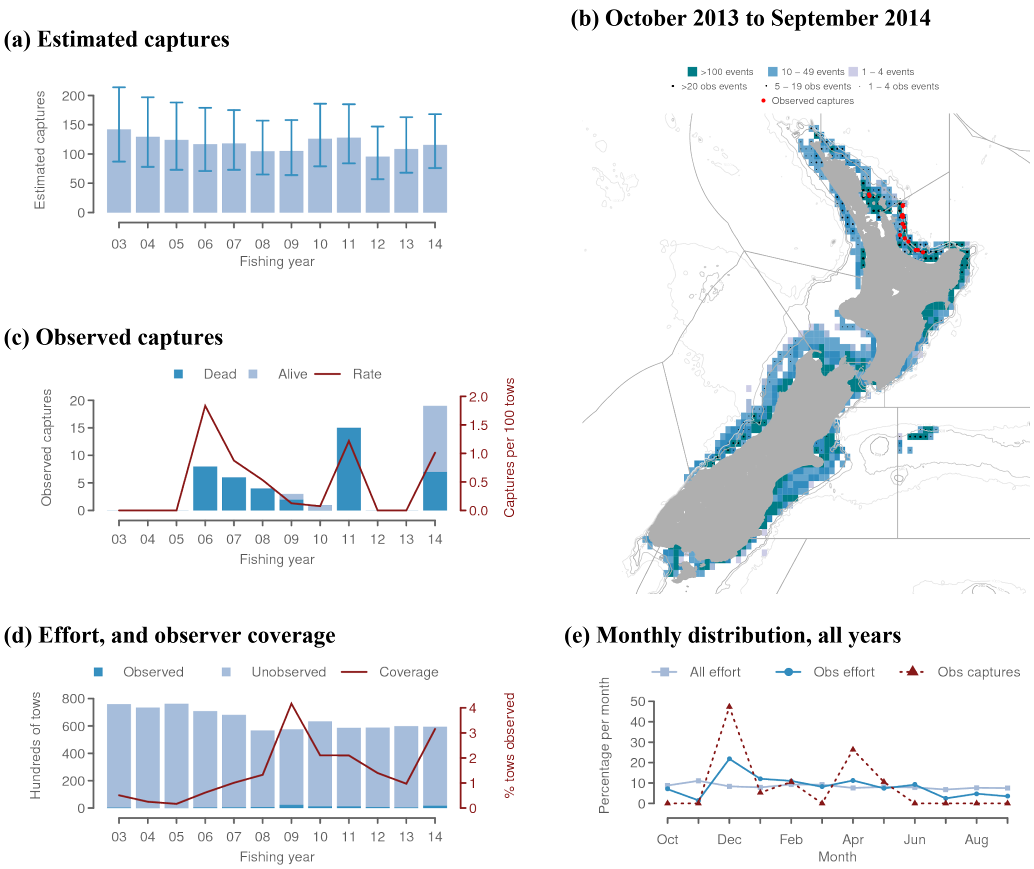


Figure A-21: Flesh-footed shearwater captures in small-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 , (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.9.2 Flesh-footed shearwater captures in small-vessel surface-longline fisheries

Table A-22: Annual fishing effort and number of hooks observed in small-vessel surface-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of flesh-footed shearwater, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 572 966	0.0	0	.	720	469–1 122	0.840	0.547–1.309
2003–04	5 730 964	2.4	0	0.000	442	284–681	0.771	0.496–1.188
2004–05	3 041 381	4.7	1	0.071	239	141–387	0.786	0.464–1.272
2005–06	3 026 689	3.2	4	0.411	256	158–399	0.846	0.522–1.318
2006–07	2 332 733	8.1	3	0.159	209	126–332	0.896	0.540–1.423
2007–08	1 678 054	8.1	2	0.147	185	107–306	1.102	0.638–1.824
2008–09	2 306 403	6.5	0	0.000	231	140–367	1.002	0.607–1.591
2009–10	2 516 706	7.4	0	0.000	238	144–372	0.946	0.572–1.478
2010–11	2 684 809	6.4	2	0.117	299	174–488	1.114	0.648–1.818
2011–12	2 548 537	6.8	0	0.000	245	137–413	0.961	0.538–1.621
2012–13	2 389 412	3.0	0	0.000	214	122–357	0.896	0.511–1.494
2013–14	1 893 434	6.3	0	0.000	181	99–306	0.956	0.523–1.616

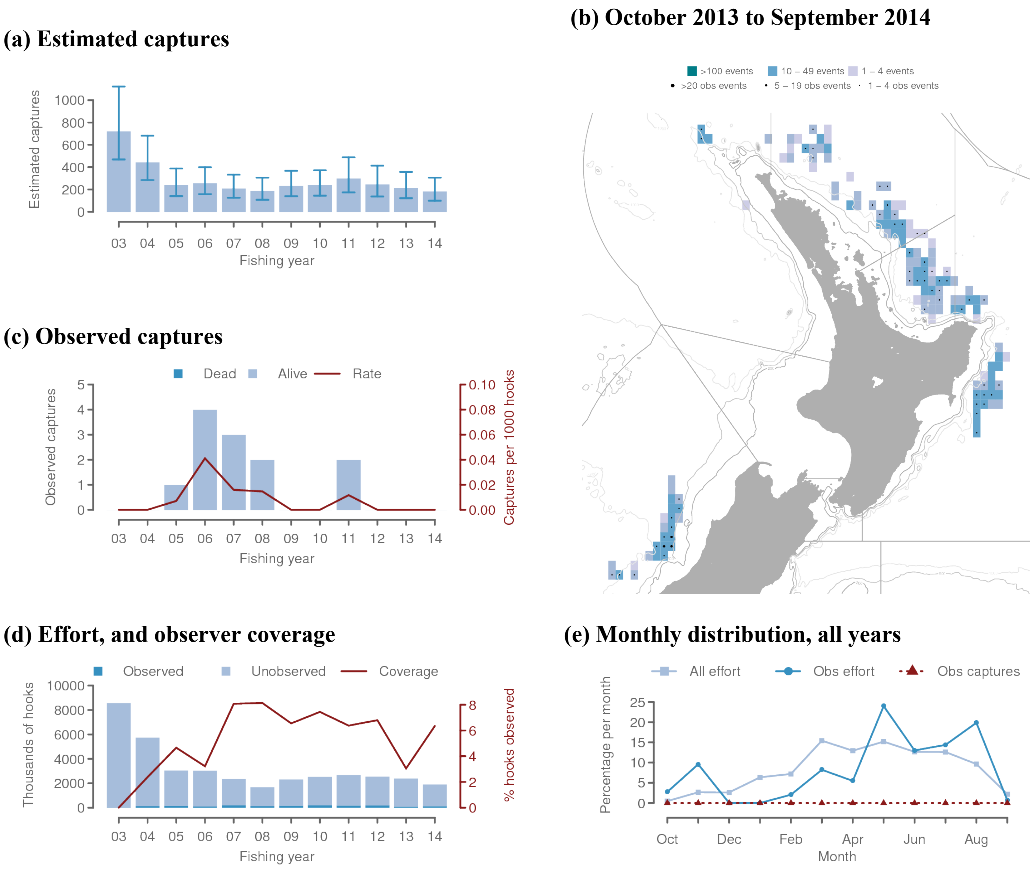


Figure A-22: Flesh-footed shearwater captures in small-vessel surface-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (95.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.9.3 Flesh-footed shearwater captures in small-vessel bottom-longline fisheries

Table A-23: Annual fishing effort and number of hooks observed in small-vessel bottom-longline fisheries, number of observed captures of flesh-footed shearwater and observed capture rate (captures per thousand hooks), and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	0	0.000	631	431–945	0.318	0.217–0.476
2003–04	19 872 683	1.2	3	0.129	551	373–842	0.277	0.188–0.424
2004–05	22 907 282	1.3	9	0.310	481	331–703	0.210	0.144–0.307
2005–06	22 256 860	0.7	1	0.064	389	266–573	0.175	0.120–0.257
2006–07	25 367 652	1.9	0	0.000	404	277–593	0.159	0.109–0.234
2007–08	27 376 403	1.8	0	0.000	346	242–495	0.126	0.088–0.181
2008–09	24 574 649	3.4	13	0.155	348	242–495	0.142	0.098–0.201
2009–10	26 831 061	2.1	14	0.253	356	248–509	0.133	0.092–0.190
2010–11	27 984 389	0.8	0	0.000	392	269–565	0.140	0.096–0.202
2011–12	26 316 056	0.3	0	0.000	339	236–474	0.129	0.090–0.180
2012–13	24 270 014	0.5	1	0.080	341	235–487	0.141	0.097–0.201
2013–14	24 249 354	3.4	30	0.361	338	238–477	0.139	0.098–0.197

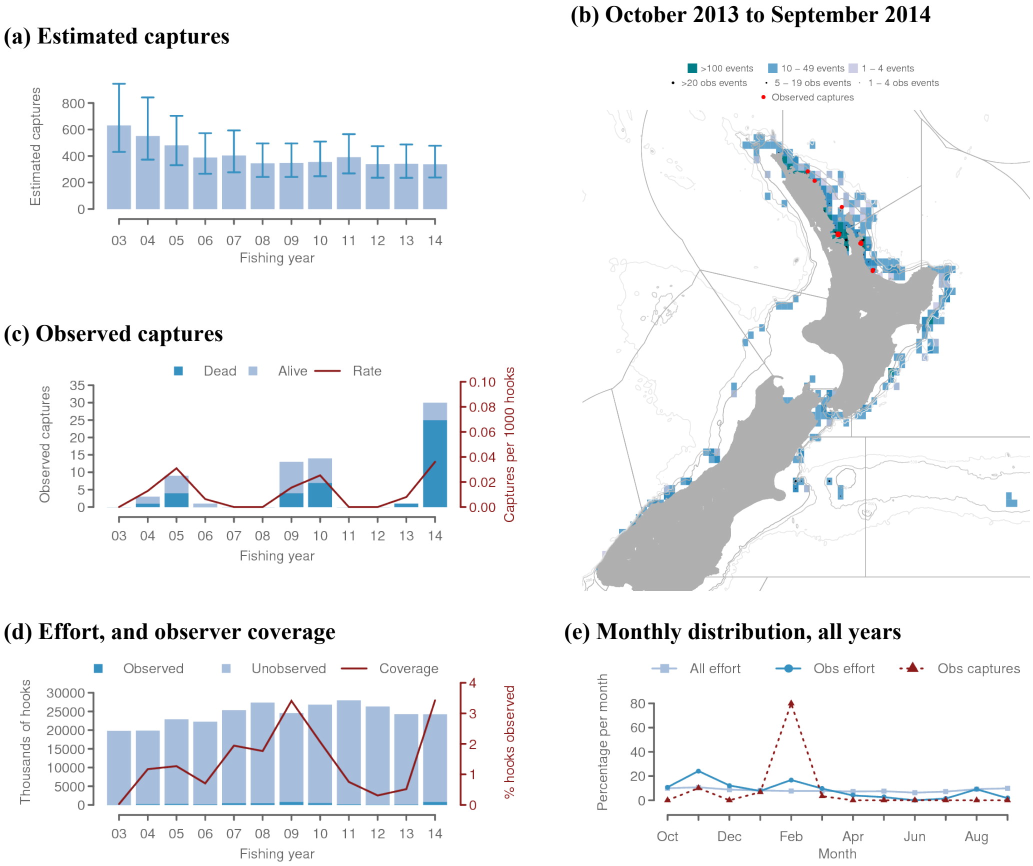


Figure A-23: Flesh-footed shearwater captures in small-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.10 Other birds captures

A.10.1 Other birds captures in large-vessel trawl fisheries

Table A-24: Annual fishing effort and number of tows observed in large-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of other birds, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	54 200	11.9	20	0.310	158	103–228	0.292	0.190–0.421
2003–04	47 339	13.4	15	0.236	98	60–147	0.207	0.127–0.311
2004–05	44 156	17.2	38	0.501	190	140–247	0.430	0.317–0.559
2005–06	39 122	15.8	10	0.162	67	37–106	0.171	0.095–0.271
2006–07	35 188	20.6	8	0.110	44	23–72	0.125	0.065–0.205
2007–08	32 766	25.3	8	0.096	33	18–55	0.101	0.055–0.168
2008–09	29 978	24.7	13	0.176	51	31–76	0.170	0.103–0.254
2009–10	29 506	26.0	21	0.274	77	53–108	0.261	0.180–0.366
2010–11	27 393	22.7	42	0.676	161	120–208	0.588	0.438–0.759
2011–12	25 593	32.3	19	0.230	58	40–81	0.227	0.156–0.316
2012–13	23 972	49.3	72	0.609	125	105–147	0.521	0.438–0.613
2013–14	25 660	43.7	64	0.570	126	104–151	0.491	0.405–0.588

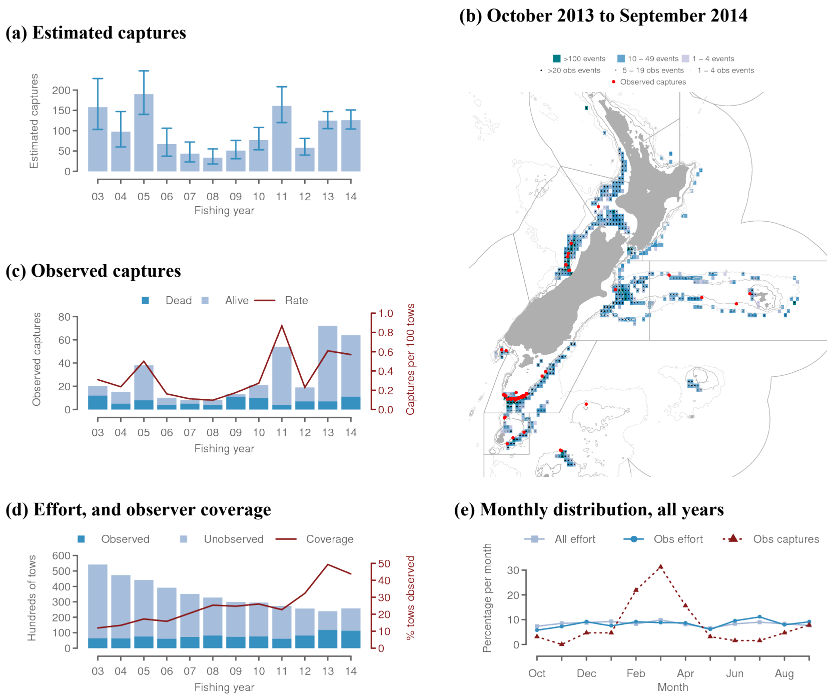


Figure A-24: Other birds captures in large-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.10.2 Other birds captures in small-vessel trawl fisheries

Table A-25: Annual fishing effort and number of tows observed in small-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of other birds, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	75 973	0.5	0	0.00	707	479–987	0.93	0.63–1.30
2003–04	73 491	0.3	0	0.00	675	456–949	0.92	0.62–1.29
2004–05	76 292	0.2	0	0.00	689	463–970	0.90	0.61–1.27
2005–06	70 817	0.6	2	0.46	603	410–841	0.85	0.58–1.19
2006–07	68 130	1.0	2	0.29	603	409–846	0.89	0.60–1.24
2007–08	56 758	1.3	1	0.13	481	326–669	0.85	0.57–1.18
2008–09	57 575	4.2	38	1.58	510	355–699	0.89	0.62–1.21
2009–10	63 382	2.1	0	0.00	520	352–730	0.82	0.56–1.15
2010–11	58 696	2.1	1	0.08	426	290–597	0.73	0.49–1.02
2011–12	58 828	1.4	0	0.00	479	323–670	0.81	0.55–1.14
2012–13	59 867	1.0	0	0.00	476	323–665	0.80	0.54–1.11
2013–14	59 431	3.2	9	0.48	461	315–638	0.78	0.53–1.07

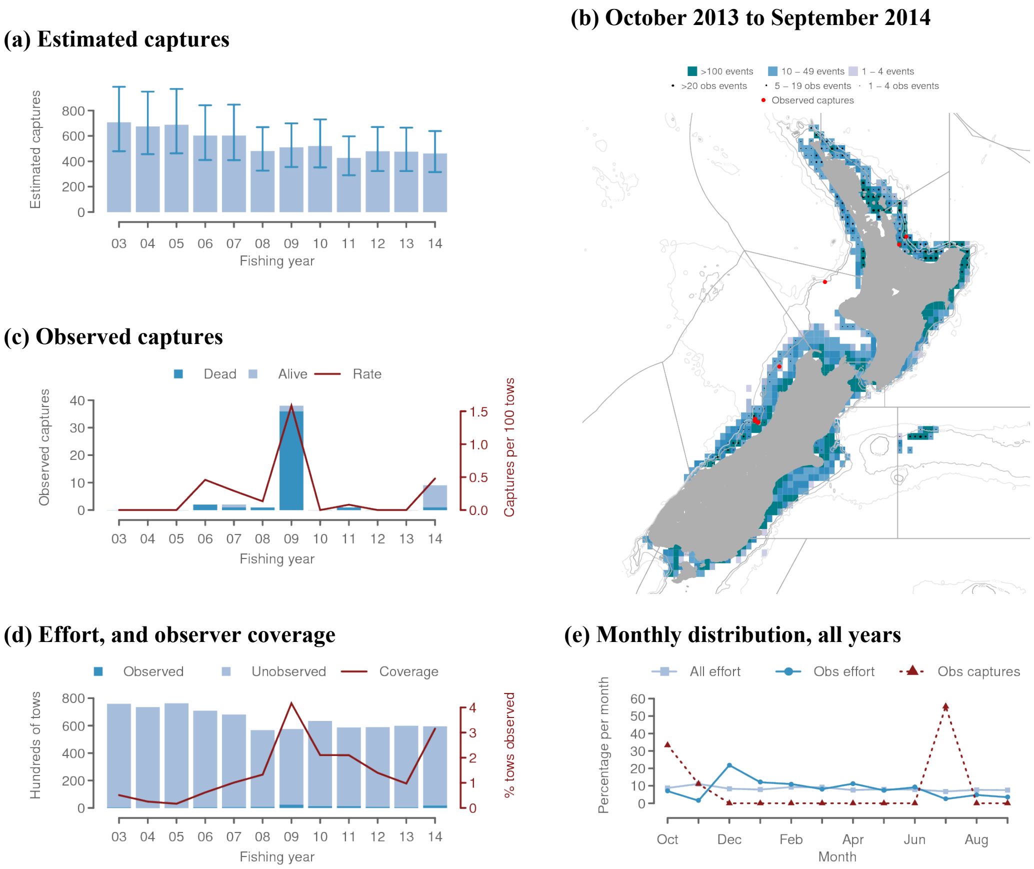


Figure A-25: Other birds captures in small-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 , (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.10.3 Other birds captures in small-vessel bottom-longline fisheries

Table A-26: Annual fishing effort and number of hooks observed in small-vessel bottom-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of other birds, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	2	3.64	523	358–741	0.26	0.18–0.37
2003–04	19 872 683	1.2	5	0.21	471	325–669	0.24	0.16–0.34
2004–05	22 907 282	1.3	3	0.10	456	315–635	0.20	0.14–0.28
2005–06	22 256 860	0.7	9	0.57	385	266–537	0.17	0.12–0.24
2006–07	25 367 652	1.9	3	0.06	402	273–571	0.16	0.11–0.23
2007–08	27 376 403	1.8	6	0.12	379	259–536	0.14	0.09–0.20
2008–09	24 574 649	3.4	5	0.06	378	259–541	0.15	0.11–0.22
2009–10	26 831 061	2.1	1	0.02	397	269–565	0.15	0.10–0.21
2010–11	27 984 389	0.8	0	0.00	472	316–683	0.17	0.11–0.24
2011–12	26 316 056	0.3	1	0.12	435	292–647	0.17	0.11–0.25
2012–13	24 270 014	0.5	2	0.16	382	258–554	0.16	0.11–0.23
2013–14	24 249 354	3.4	19	0.23	365	256–510	0.15	0.11–0.21

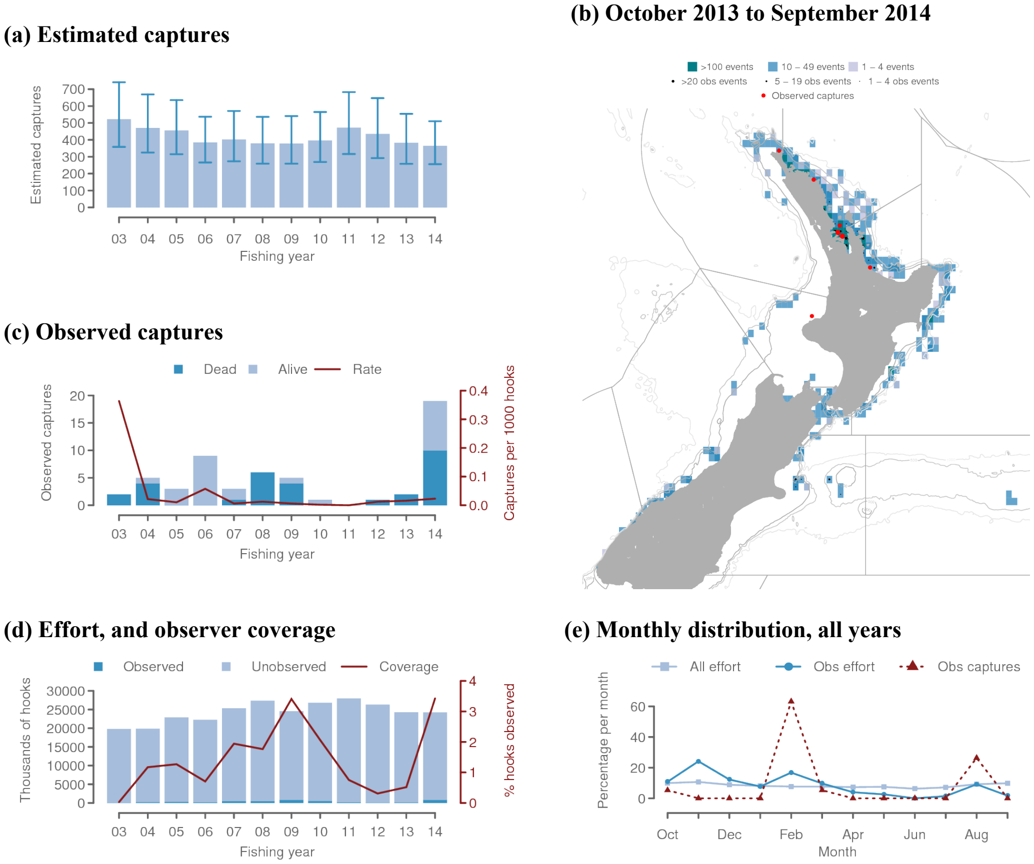


Figure A-26: Other birds captures in small-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.11 All birds captures

A.11.1 All bird captures in large-vessel trawl fisheries

Table A-27: Annual fishing effort and number of tows observed in large-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of all birds, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	54 200	11.9	267	4.14	1 985	1 728–2 283	3.66	3.19–4.21
2003–04	47 339	13.4	258	4.05	1 540	1 351–1 749	3.25	2.85–3.69
2004–05	44 156	17.2	477	6.29	2 298	2 079–2 537	5.20	4.71–5.75
2005–06	39 122	15.8	339	5.48	1 924	1 689–2 197	4.92	4.32–5.62
2006–07	35 188	20.6	177	2.44	896	770–1 039	2.55	2.19–2.95
2007–08	32 766	25.3	220	2.65	860	751–980	2.62	2.29–2.99
2008–09	29 978	24.7	373	5.04	1 332	1 187–1 493	4.44	3.96–4.98
2009–10	29 506	26.0	235	3.06	890	787–1 001	3.02	2.67–3.39
2010–11	27 393	22.7	326	5.25	1 220	1 088–1 360	4.45	3.97–4.96
2011–12	25 593	32.3	228	2.76	708	631–793	2.77	2.47–3.10
2012–13	23 972	49.3	705	5.97	1 084	1 024–1 149	4.52	4.27–4.79
2013–14	25 660	43.7	461	4.11	808	753–867	3.15	2.93–3.38

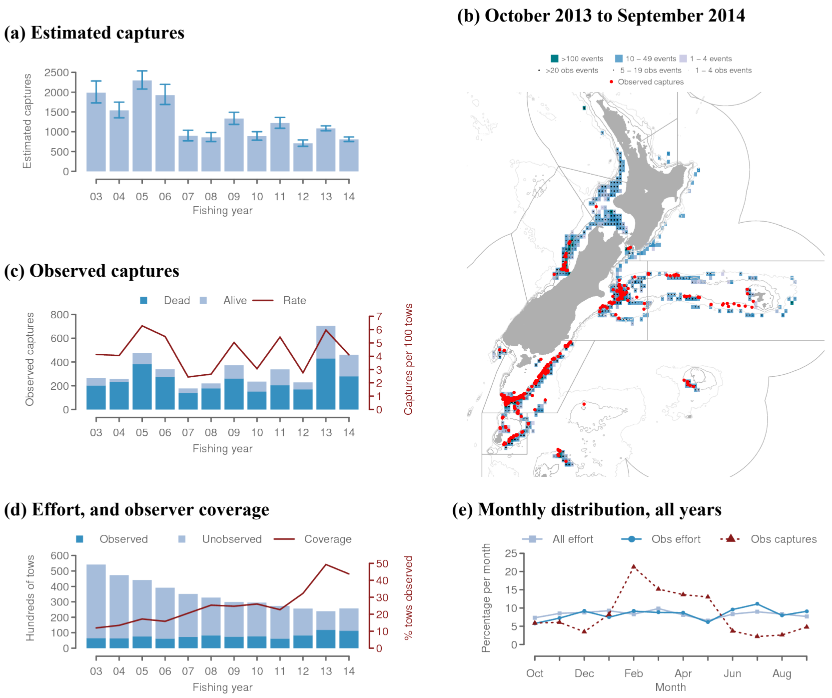


Figure A-27: All bird captures in large-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.11.2 All birds captures in small-vessel trawl fisheries

Table A-28: Annual fishing effort and number of tows observed in small-vessel trawl fisheries, number of observed captures and observed capture rate (captures per hundred tows) of all birds, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	75 973	0.5	2	0.52	1 950	1 619–2 323	2.57	2.13–3.06
2003–04	73 491	0.3	4	2.16	1 728	1 425–2 081	2.35	1.94–2.83
2004–05	76 292	0.2	6	4.72	1 875	1 558–2 236	2.46	2.04–2.93
2005–06	70 817	0.6	17	3.90	1 771	1 480–2 109	2.50	2.09–2.98
2006–07	68 130	1.0	34	4.95	1 762	1 473–2 090	2.59	2.16–3.07
2007–08	56 758	1.3	15	1.99	1 383	1 159–1 644	2.44	2.04–2.90
2008–09	57 575	4.2	96	4.00	1 419	1 196–1 671	2.46	2.08–2.90
2009–10	63 382	2.1	23	1.73	1 520	1 265–1 801	2.40	2.00–2.84
2010–11	58 696	2.1	54	4.38	1 422	1 199–1 676	2.42	2.04–2.86
2011–12	58 828	1.4	20	2.43	1 419	1 186–1 676	2.41	2.02–2.85
2012–13	59 867	1.0	7	1.20	1 450	1 222–1 724	2.42	2.04–2.88
2013–14	59 431	3.2	51	2.72	1 470	1 244–1 727	2.47	2.09–2.91

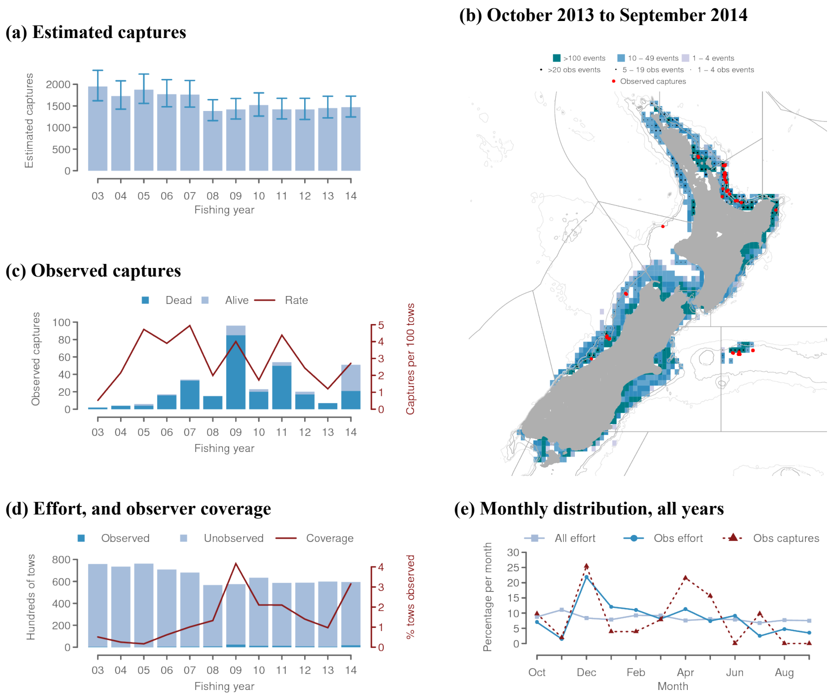


Figure A-28: All bird captures in small-vessel trawl fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 , (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.11.3 All birds captures in large-vessel surface-longline fisheries

Table A-29: Annual fishing effort and number of hooks observed in large-vessel surface-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of all birds, and estimated captures and capture rate (mean and 95% credible interval). Effort data are not shown where there were not enough vessels fishing to meet MPI data anonymisation requirements.

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	2 197 522	99.9	115	0.52	141	123–176	0.64	0.56–0.80
2003–04	1 655 920	88.9	64	0.43	167	96–449	1.01	0.58–2.71
2004–05	.	.	33	0.51	33	33–33	.	.–.
2005–06	.	.	15	0.25	27	19–41	.	.–.
2006–07	1 407 149	60.6	111	1.30	167	142–204	1.19	1.01–1.45
2007–08	.	.	24	0.84	45	31–68	.	.–.
2008–09	.	.	42	0.53	43	42–49	.	.–.
2009–10	.	.	56	1.17	56	56–56	.	.–.
2010–11	.	.	29	0.58	29	29–29	.	.–.
2011–12	.	.	34	0.61	34	34–34	.	.–.
2012–13	.	.	5	0.10	5	5–5	.	.–.
2013–14	.	.	16	0.24	16	16–16	.	.–.

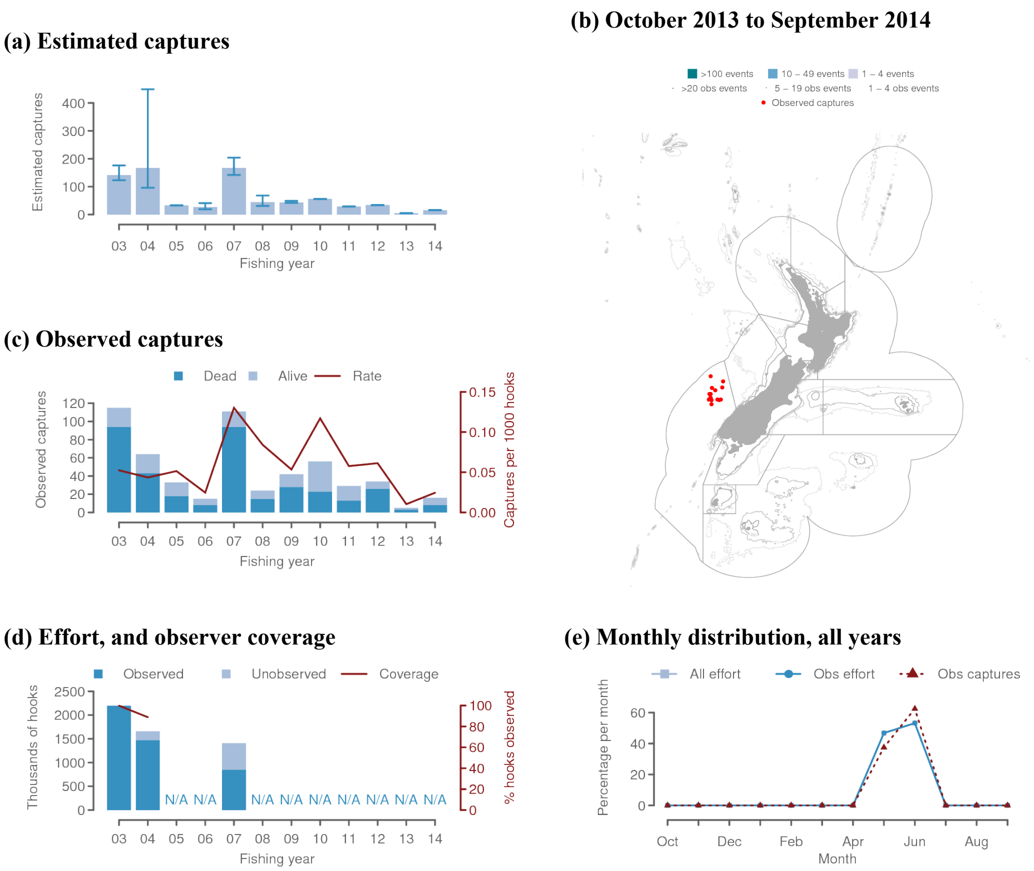


Figure A-29: All bird captures in large-vessel surface-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (0.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.11.4 All birds captures in small-vessel surface-longline fisheries

Table A-30: Annual fishing effort and number of hooks observed in small-vessel surface-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of all birds, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 572 966	0.0	0	.	2 094	1 689–2 632	2.44	1.97–3.07
2003–04	5 730 964	2.4	7	0.52	1 516	1 230–1 929	2.65	2.15–3.37
2004–05	3 041 381	4.7	8	0.56	752	596–956	2.47	1.96–3.14
2005–06	3 026 689	3.2	22	2.26	816	647–1 037	2.70	2.14–3.43
2006–07	2 332 733	8.1	76	4.04	660	537–819	2.83	2.30–3.51
2007–08	1 678 054	8.1	13	0.95	494	385–631	2.94	2.29–3.76
2008–09	2 306 403	6.5	15	0.99	607	482–770	2.63	2.09–3.34
2009–10	2 516 706	7.4	91	4.86	775	640–933	3.08	2.54–3.71
2010–11	2 684 809	6.4	18	1.05	764	604–979	2.85	2.25–3.65
2011–12	2 548 537	6.8	31	1.79	819	648–1 045	3.21	2.54–4.10
2012–13	2 389 412	3.0	22	3.02	764	607–968	3.20	2.54–4.05
2013–14	1 893 434	6.3	21	1.75	644	507–819	3.40	2.68–4.33

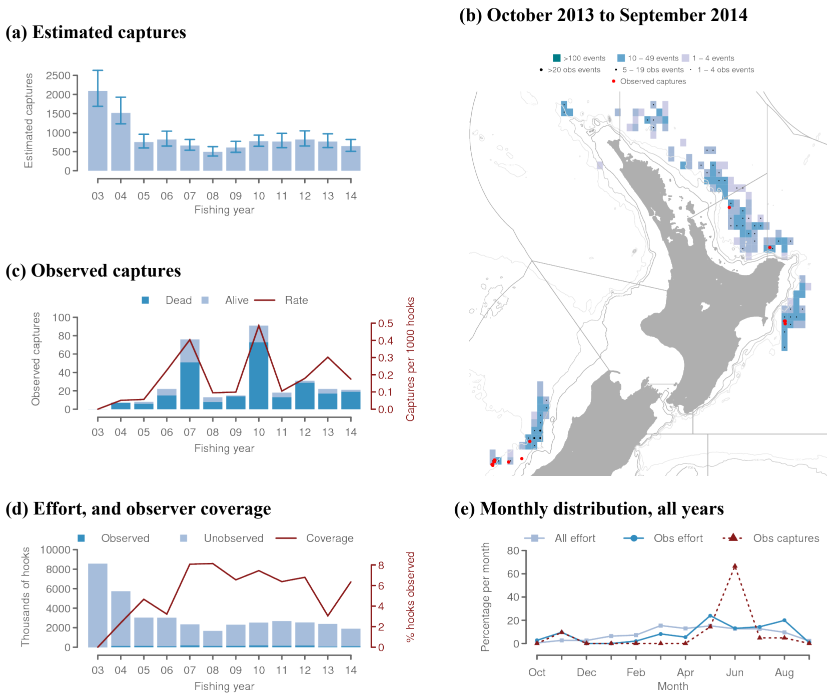


Figure A-30: All bird captures in small-vessel surface-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (95.3% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.11.5 All birds captures in large-vessel bottom-longline fisheries

Table A-31: Annual fishing effort and number of hooks observed in large-vessel bottom-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of all birds, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	17 928 519	60.1	262	0.243	599	488–764	0.334	0.272–0.426
2003–04	23 341 383	20.7	43	0.089	296	203–458	0.127	0.087–0.196
2004–05	18 932 296	13.7	17	0.066	602	298–1 240	0.318	0.157–0.655
2005–06	14 888 723	24.5	29	0.080	227	144–406	0.152	0.097–0.273
2006–07	12 759 288	14.3	13	0.071	518	212–1 145	0.406	0.166–0.897
2007–08	14 123 096	22.0	22	0.071	274	155–516	0.194	0.110–0.365
2008–09	12 870 071	24.8	5	0.016	213	91–482	0.166	0.071–0.375
2009–10	13 607 740	12.6	10	0.058	286	144–569	0.210	0.106–0.418
2010–11	12 914 717	11.8	27	0.177	382	192–824	0.296	0.149–0.638
2011–12	11 560 277	17.5	4	0.020	177	84–368	0.153	0.073–0.318
2012–13	8 240 515	3.3	0	0.000	210	115–415	0.255	0.140–0.504
2013–14	16 448 081	11.7	46	0.240	526	319–949	0.320	0.194–0.577

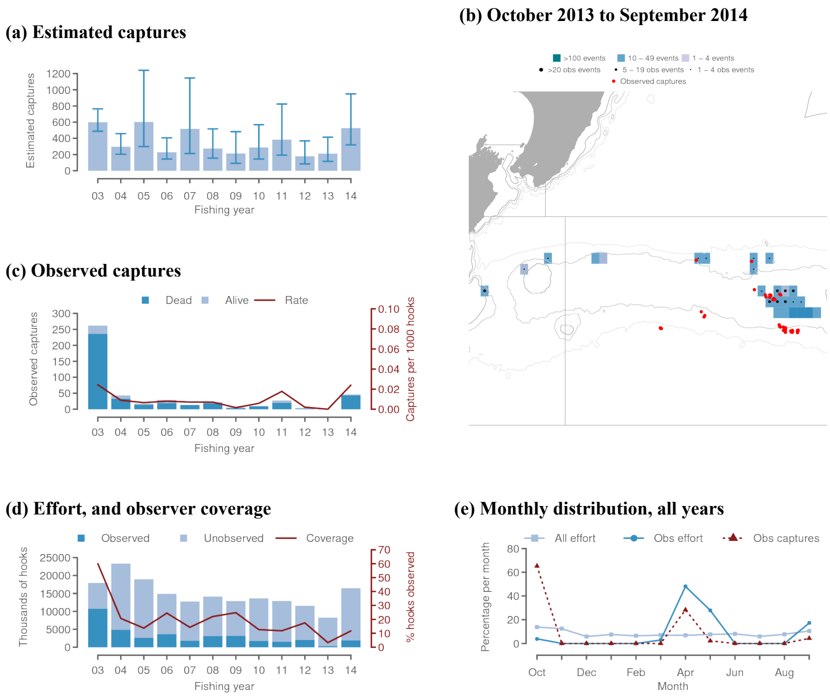


Figure A-31: All bird captures in large-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (65.8% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.11.6 All birds captures in small-vessel bottom-longline fisheries

Table A-32: Annual fishing effort and number of hooks observed in small-vessel bottom-longline fisheries, number of observed captures and observed capture rate (captures per thousand hooks) of all birds, and estimated captures and capture rate (mean and 95% credible interval).

		Observed			Est. captures		Est. capture rate	
Year	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	19 833 434	0.0	3	5.46	2 416	1 955–2 968	1.22	0.99–1.50
2003–04	19 872 683	1.2	11	0.47	2 137	1 733–2 676	1.08	0.87–1.35
2004–05	22 907 282	1.3	13	0.45	2 177	1 756–2 704	0.95	0.77–1.18
2005–06	22 256 860	0.7	12	0.76	1 894	1 506–2 451	0.85	0.68–1.10
2006–07	25 367 652	1.9	45	0.91	2 203	1 735–2 898	0.87	0.68–1.14
2007–08	27 376 403	1.8	18	0.37	1 977	1 572–2 546	0.72	0.57–0.93
2008–09	24 574 649	3.4	28	0.33	1 882	1 504–2 415	0.77	0.61–0.98
2009–10	26 831 061	2.1	46	0.83	2 007	1 605–2 552	0.75	0.60–0.95
2010–11	27 984 389	0.8	2	0.09	2 200	1 765–2 833	0.79	0.63–1.01
2011–12	26 316 056	0.3	6	0.74	1 960	1 554–2 626	0.74	0.59–1.00
2012–13	24 270 014	0.5	3	0.24	1 725	1 381–2 239	0.71	0.57–0.92
2013–14	24 249 354	3.4	60	0.72	1 612	1 331–1 953	0.66	0.55–0.81

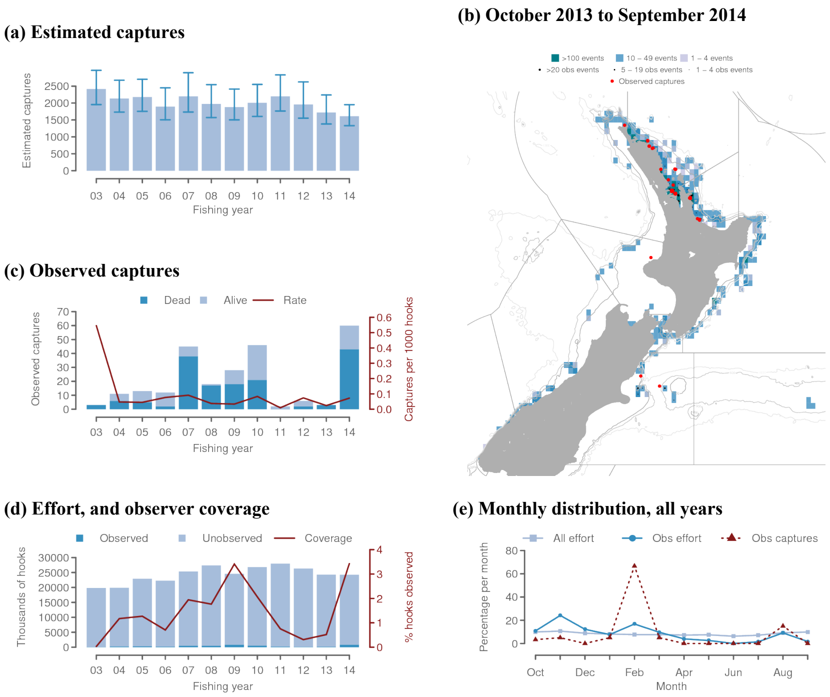


Figure A-32: All bird captures in small-vessel bottom-longline fisheries. (a) Estimated captures, with 95% bootstrap credible intervals, (b) Mapped effort and captures in 2013–14 (97.6% of total effort, following confidentiality agreements), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

B APPENDIX B: SUMMARIES OF MODELS USED FOR ESTIMATION

B.1 White-capped albatross

Table B-33: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
Trawl	Squid	Large	Stewart Snares Shelf	Summer	346	8014	0.326	1061	1191	1038–1359
Trawl	Squid	Large	Auckland Islands	Summer	316	5407	0.429	736	677	580–785
SLL	Southern bluefin	Small	West Coast South Island	Autumn	36	91	0.047	758	572	303–1000
Trawl	Squid	Large	Stewart Snares Shelf	Autumn	91	2236	0.272	334	369	297–450
Trawl	Squid	Large	Auckland Islands	Autumn	70	2099	0.308	227	322	255–395
Trawl	Inshore	Small	Stewart Snares Shelf	Summer	2	132	0.020	99	245	137–392
Trawl	Inshore	Small	West Coast South Island	Summer	15	452	0.051	293	232	135–355
Trawl	Inshore	Small	West Coast South Island	Autumn	2	13	0.002	1207	194	111–300
Trawl	Inshore	Small	Stewart Snares Shelf	Autumn	0	0	0.000		160	87–264
Trawl	Flatfish	Small	Stewart Snares Shelf	Summer	0	463	0.021	0	127	32–288
Trawl	Inshore	Small	West Coast South Island	Spring	2	99	0.011	185	107	56–179
SLL	Southern bluefin	Large	Fiordland	Autumn	75	2930	0.896	83	97	66–134
Trawl	Inshore	Small	Stewart Snares Shelf	Spring	0	22	0.004	0	91	45–163
Trawl	Inshore	Small	Western Chatham Rise	Summer	0	435	0.022	0	89	42–156
SLL	Southern bluefin	Small	West Coast South Island	Summer	0	0	0.000		87	38–171

Table B-34: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	108	108	0	0	0.00	0.00
Half-width	108	105	105	3	3	2.78	2.78

Table B-35: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Large trawl for method, South for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.01	0.01	0.00–0.03	
Method - Large-vessel SLL	1.77	1.78	0.46–7.48	
Method - Large-vessel BLL	0.28	0.29	0.05–1.91	
Method - Small-vessel trawl	1.12	1.12	0.62–2.03	
Method - Small-vessel SLL	11.32	11.41	3.00–46.86	+
Method - Small-vessel BLL	1.07	1.04	0.17–5.71	
Region - North	0.07	0.07	0.02–0.35	-
Season - Autumn (Apr-Jun)	0.94	0.94	0.79–1.12	
Season - Winter (Jul-Sep)	0.24	0.23	0.15–0.35	-
Season - Spring (Oct-Dec)	0.44	0.44	0.31–0.61	-
CV(Year) - Trawl	0.46	0.48	0.31–0.74	
CV(Year) - SLL	0.82	0.84	0.49–1.29	
CV(Year) - BLL	0.62	0.74	0.02–2.10	
Area - Stewart Snares Shelf	2.08	2.18	0.95–3.93	
Area - Auckland Islands	2.35	2.45	1.07–4.42	+
Area - West Coast South Island	1.47	1.55	0.65–2.90	
Area - Fiordland	0.96	1.02	0.41–1.97	
Area - Western Chatham Rise	0.25	0.26	0.10–0.52	-
Area - Eastern Chatham Rise	0.31	0.33	0.12–0.67	-
Area - East of North Island	0.79	0.92	0.16–2.54	
Area - Cook Strait	0.71	0.78	0.22–1.76	
Area - West Coast North Island	1.11	1.30	0.24–3.47	
Area - North East	0.71	0.85	0.13–2.34	
Area - South Subantarctic	0.16	0.20	0.02–0.63	-
Area - East Subantarctic	0.15	0.23	0.00–0.89	-
Area - Kermadec Islands	0.60	0.81	0.01–2.81	
CV(Area)	0.92	0.95	0.57–1.49	
Fishery - Squid	2.11	2.18	1.05–3.71	+
Fishery - Southern bluefin	1.91	2.17	0.58–5.43	
Fishery - Middle depths	1.96	2.04	1.01–3.55	+
Fishery - Hoki	0.61	0.64	0.29–1.13	
Fishery - Inshore	1.63	1.74	0.70–3.43	
Fishery - Scampi	0.79	0.84	0.34–1.61	
Fishery - Ling	1.31	1.40	0.57–2.74	
Fishery - Hake	0.55	0.59	0.22–1.16	
Fishery - Mackerel	0.58	0.62	0.23–1.30	
Fishery - Large-vessel ling (no IWL)	1.41	1.65	0.27–4.74	
Fishery - Deepwater	0.12	0.14	0.03–0.34	-
Fishery - Small-vessel ling	1.56	1.85	0.33–5.12	
Fishery - Swordfish	0.66	0.80	0.12–2.35	
Fishery - Flatfish	0.24	0.28	0.06–0.70	-
Fishery - Bigeye	0.37	0.48	0.04–1.52	
Fishery - Large-vessel ling (IWL)	0.28	0.41	0.00–1.56	
Fishery - Bluenose	0.53	0.73	0.01–2.70	
Fishery - Minor targets	0.55	0.74	0.01–2.59	
Fishery - Snapper	0.48	0.68	0.01–2.53	
Fishery - Hāpuku	0.64	0.87	0.02–3.08	
Fishery - Albacore	0.63	0.86	0.02–3.14	
Fishery - Minor surface longline	0.63	0.84	0.02–3.03	
Fishery - Southern blue whiting	0.29	0.42	0.01–1.57	
CV(Fishery)	0.91	0.93	0.59–1.41	
CV(Overdispersion) - Trawl	2.60	2.60	2.12–3.02	
CV(Overdispersion) - SLL	3.17	3.16	2.49–3.85	
CV(Overdispersion) - BLL	0.94	1.08	0.18–2.61	

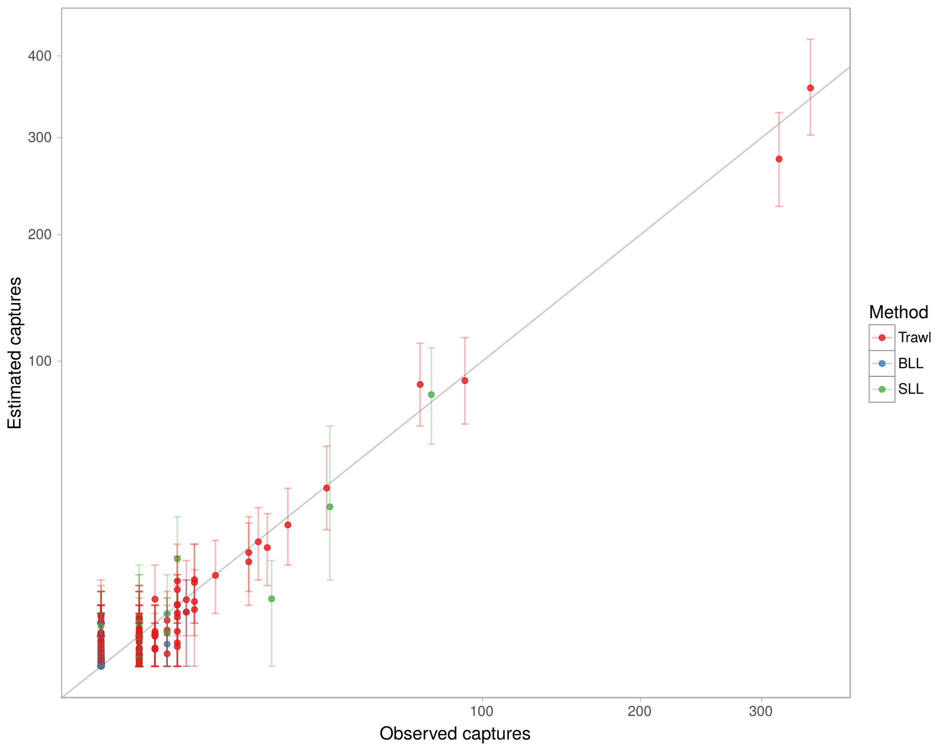


Figure B-33: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-36: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were six such strata, representing 1.1% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
SLL	Southern bluefin	Large	South	Stewart Snares Shelf	Autumn (Apr-Jun)	98	20	4.88	0–12
Trawl	Hoki	Large	South	Fiordland	Autumn (Apr-Jun)	127	4	0.59	0–3
Trawl	Ling	Small	South	West Coast South Island	Autumn (Apr-Jun)	20	4	0.41	0–2
Trawl	Flatfish	Small	South	Stewart Snares Shelf	Autumn (Apr-Jun)	32	3	0.17	0–1
Trawl	Inshore	Small	North	West Coast North Island	Winter (Jul-Sep)	26	1	0.01	0–0
Trawl	Inshore	Small	North	East of North Island	Spring (Oct-Dec)	14	1	0.01	0–0

B.2 Salvin's albatross

Table B-37: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries. IWL: Integrated weight line.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
Trawl	Inshore	Small	Western Chatham Rise	Spring	4	167	0.011	374	792	457–1244
Trawl	Middle depths	Small	Western Chatham Rise	Spring	1	35	0.007	140	341	178–586
Trawl	Inshore	Small	Western Chatham Rise	Winter	2	131	0.012	162	332	181–541
Trawl	Inshore	Small	Western Chatham Rise	Summer	15	435	0.022	686	308	175–483
BLL	Large-vessel ling (no IWL)	Large	Eastern Chatham Rise	Winter	1	964	0.153	6	296	143–551
BLL	Large-vessel ling (no IWL)	Large	East Subantarctic	Spring	101	548	0.417	241	259	134–464
BLL	Large-vessel ling (no IWL)	Large	Eastern Chatham Rise	Spring	12	290	0.100	120	234	106–485
BLL	Small-vessel ling	Small	Western Chatham Rise	Spring	1	56	0.021	47	219	106–395
Trawl	Inshore	Small	East of North Island	Spring	0	14	0.001	0	208	66–465
Trawl	Hoki	Large	Western Chatham Rise	Spring	31	2025	0.186	166	197	143–259
Trawl	Hoki	Large	Eastern Chatham Rise	Spring	48	1838	0.224	214	190	137–254
BLL	Small-vessel ling	Small	Eastern Chatham Rise	Spring	6	101	0.059	101	168	85–293
SLL	Bigeye	Small	East of North Island	Summer	7	151	0.025	275	165	63–314
BLL	Small-vessel ling	Small	Eastern Chatham Rise	Winter	22	126	0.046	476	163	83–278
BLL	Large-vessel ling (no IWL)	Large	Western Chatham Rise	Spring	0	44	0.019	0	156	65–336

Table B-38: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	101	108	0	7	0.00	6.48
Half-width	101	99	100	1	2	0.99	1.98

Table B-39: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Large trawl for method, South for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.00	0.00	0.00–0.02	
Method - Large-vessel BLL	1.64	1.74	0.25–16.53	
Method - Large-vessel SLL	27.05	27.65	3.60–264.38	+
Method - Small-vessel trawl	2.08	2.08	1.12–3.94	+
Method - Small-vessel BLL	2.47	2.53	0.54–13.46	
Method - Small-vessel SLL	14.44	14.58	2.61–88.16	+
Region - North	0.09	0.10	0.01–1.77	
Season - Autumn (Apr-Jun)	0.27	0.27	0.14–0.47	-
Season - Winter (Jul-Sep)	2.01	2.00	1.35–2.90	+
Season - Spring (Oct-Dec)	3.27	3.28	2.44–4.49	+
CV(Year) - Trawl	0.50	0.52	0.29–0.86	
CV(Year) - BLL	1.53	1.59	0.97–2.55	
CV(Year) - SLL	0.55	0.73	0.02–2.41	
Area - Eastern Chatham Rise	1.68	1.91	0.39–4.61	
Area - Western Chatham Rise	1.42	1.61	0.31–3.87	
Area - East Subantarctic	3.98	4.46	0.91–10.84	
Area - Stewart Snares Shelf	0.19	0.22	0.04–0.55	-
Area - East of North Island	2.46	3.20	0.13–10.39	
Area - Cook Strait	0.39	0.47	0.08–1.30	
Area - South Subantarctic	0.15	0.18	0.03–0.55	-
Area - North East	0.23	0.34	0.01–1.32	
Area - Auckland Islands	0.02	0.03	0.00–0.12	-
Area - Fiordland	0.03	0.05	0.00–0.18	-
Area - West Coast South Island	0.01	0.02	0.00–0.07	-
Area - West Coast North Island	0.01	0.06	0.00–0.44	-
Area - Kermadec Islands	0.02	0.13	0.00–0.97	-
CV(Area)	1.66	1.70	1.16–2.46	
Fishery - Large-vessel ling (no IWL)	1.70	2.07	0.24–6.14	
Fishery - Hoki	0.87	0.92	0.36–1.77	
Fishery - Middle depths	1.54	1.62	0.63–3.07	
Fishery - Scampi	0.58	0.63	0.21–1.33	
Fishery - Small-vessel ling	1.54	1.85	0.33–5.19	
Fishery - Squid	1.93	2.07	0.76–4.19	
Fishery - Inshore	1.13	1.24	0.41–2.65	
Fishery - Deepwater	0.16	0.17	0.06–0.36	-
Fishery - Southern blue whiting	0.35	0.40	0.11–0.98	-
Fishery - Bigeye	1.95	2.28	0.45–6.24	
Fishery - Ling	1.44	1.56	0.51–3.32	
Fishery - Hake	1.55	1.68	0.57–3.61	
Fishery - Southern bluefin	0.26	0.34	0.03–1.10	
Fishery - Minor targets	1.11	1.42	0.18–4.22	
Fishery - Large-vessel ling (IWL)	0.13	0.21	0.01–0.88	-
Fishery - Albacore	0.86	1.09	0.09–3.36	
Fishery - Bluenose	0.27	0.46	0.00–1.93	
Fishery - Snapper	0.39	0.63	0.00–2.62	
Fishery - Hāpuku	0.27	0.47	0.00–2.10	
Fishery - Swordfish	0.49	0.78	0.00–3.06	
Fishery - Minor surface longline	0.52	0.81	0.00–3.28	
Fishery - Flatfish	0.06	0.11	0.00–0.51	-
Fishery - Mackerel	0.07	0.13	0.00–0.55	-
CV(Fishery)	1.08	1.11	0.71–1.66	
CV(Overdispersion) - Trawl	2.42	2.41	1.90–2.87	
CV(Overdispersion) - BLL	4.23	4.24	3.36–5.18	
CV(Overdispersion) - SLL	1.09	1.18	0.22–2.60	

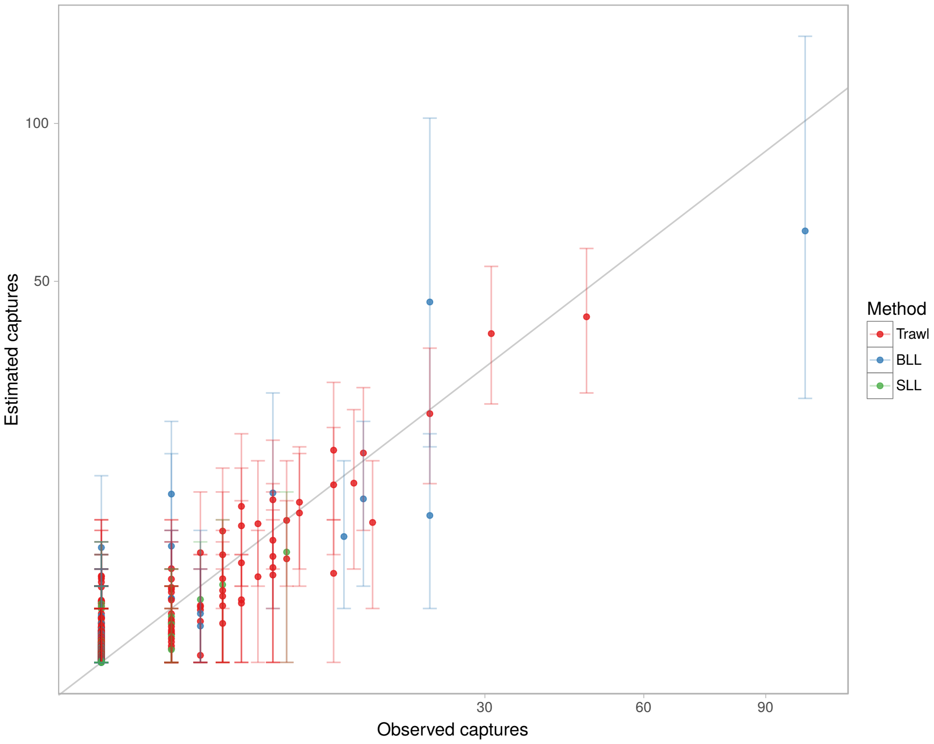


Figure B-34: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-40: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were five such strata, representing 0.9% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
BLL	Large-vessel ling (no IWL)	Large	South	Eastern Chatham Rise	Winter (Jul-Sep)	964	1	9.76	3–20
BLL	Small-vessel ling	Small	South	Eastern Chatham Rise	Winter (Jul-Sep)	126	22	7.43	1–18
Trawl	Inshore	Small	South	Western Chatham Rise	Summer (Jan-Mar)	435	15	6.74	1–14
Trawl	Middle depths	Large	South	Western Chatham Rise	Winter (Jul-Sep)	190	11	2.73	0–7
Trawl	Middle depths	Small	South	West Coast South Island	Summer (Jan-Mar)	80	2	0.02	0–0

B.3 Buller's albatrosses

Table B-41: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
SLL	Bigeye	Small	East of North Island	Autumn	0	96	0.022	0	535	210–1087
SLL	Southern bluefin	Small	West Coast South Island	Autumn	33	91	0.047	695	512	270–887
SLL	Southern bluefin	Large	Fiordland	Autumn	406	2930	0.896	453	473	374–593
SLL	Southern bluefin	Small	East of North Island	Autumn	14	263	0.035	399	436	243–724
SLL	Albacore	Small	East of North Island	Autumn	1	23	0.015	67	300	94–702
SLL	Southern bluefin	Small	Fiordland	Autumn	0	0	0.000		195	83–373
Trawl	Squid	Large	Stewart Snares Shelf	Autumn	59	2236	0.272	216	167	120–222
SLL	Bigeye	Small	North East	Autumn	2	43	0.010	203	150	49–320
BLL	Small-vessel ling	Small	West Coast South Island	Autumn	4	20	0.010	400	97	34–203
Trawl	Hoki	Large	West Coast South Island	Winter	34	10038	0.298	114	95	63–132
SLL	Bigeye	Small	North East	Winter	2	94	0.013	157	85	27–182
SLL	Bigeye	Small	East of North Island	Summer	6	151	0.025	235	82	30–168
BLL	Bluenose	Small	Eastern Chatham Rise	Autumn	2	25	0.015	130	81	16–206
Trawl	Hoki	Large	Stewart Snares Shelf	Autumn	18	1632	0.287	62	69	44–100
Trawl	Flatfish	Small	Stewart Snares Shelf	Autumn	0	32	0.002	0	65	0–239

Table B-42: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	104	108	0	4	0.00	3.70
Half-width	104	103	103	1	1	0.96	0.96

Table B-43: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Large SLL for method, South for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.01	0.01	0.00–0.05	
Method - Large-vessel trawl	0.08	0.08	0.02–0.32	-
Method - Large-vessel BLL	0.06	0.06	0.01–0.67	-
Method - Small-vessel SLL	3.70	3.70	1.81–7.41	+
Method - Small-vessel trawl	0.07	0.07	0.02–0.32	-
Method - Small-vessel BLL	0.35	0.36	0.07–2.02	
Region - North	0.13	0.14	0.02–1.26	
Season - Autumn (Apr-Jun)	8.90	8.92	6.35–12.93	+
Season - Winter (Jul-Sep)	2.97	2.97	1.85–4.75	+
Season - Spring (Oct-Dec)	0.56	0.55	0.25–1.11	
CV(Year) - SLL	0.51	0.52	0.27–0.84	
CV(Year) - Trawl	0.45	0.47	0.25–0.79	
CV(Year) - BLL	1.04	1.22	0.04–3.58	
Area - Fiordland	2.74	2.98	0.83–6.67	
Area - Stewart Snares Shelf	1.80	1.96	0.53–4.25	
Area - West Coast South Island	1.33	1.45	0.40–3.16	
Area - East of North Island	2.23	2.66	0.28–7.65	
Area - Eastern Chatham Rise	1.05	1.15	0.30–2.62	
Area - Western Chatham Rise	0.49	0.54	0.13–1.22	
Area - Auckland Islands	0.40	0.45	0.11–1.06	
Area - North East	0.61	0.77	0.07–2.47	
Area - South Subantarctic	0.08	0.12	0.00–0.45	-
Area - East Subantarctic	0.08	0.19	0.00–1.06	
Area - Cook Strait	0.03	0.07	0.00–0.37	-
Area - West Coast North Island	0.05	0.14	0.00–0.78	-
Area - Kermadec Islands	0.12	0.30	0.00–1.69	
CV(Area)	1.32	1.38	0.84–2.26	
Fishery - Southern bluefin	0.60	0.69	0.19–1.69	
Fishery - Squid	1.74	1.84	0.77–3.52	
Fishery - Hoki	0.99	1.05	0.43–1.96	
Fishery - Middle depths	1.78	1.89	0.79–3.64	
Fishery - Bigeye	1.24	1.40	0.36–3.40	
Fishery - Albacore	1.84	2.10	0.58–5.27	
Fishery - Scampi	1.56	1.76	0.50–4.07	
Fishery - Small-vessel ling	1.10	1.31	0.25–3.60	
Fishery - Hake	0.51	0.55	0.15–1.22	
Fishery - Large-vessel ling (no IWL)	1.44	1.71	0.24–4.76	
Fishery - Ling	1.42	1.57	0.47–3.52	
Fishery - Bluenose	1.32	1.57	0.28–4.38	
Fishery - Deepwater	0.11	0.13	0.02–0.33	-
Fishery - Mackerel	0.25	0.30	0.05–0.82	-
Fishery - Swordfish	0.26	0.37	0.02–1.30	
Fishery - Southern blue whiting	0.72	0.95	0.08–3.22	
Fishery - Large-vessel ling (IWL)	0.20	0.33	0.00–1.35	
Fishery - Minor targets	0.49	0.69	0.01–2.54	
Fishery - Snapper	0.34	0.50	0.01–1.94	
Fishery - Hāpuku	0.51	0.71	0.01–2.55	
Fishery - Minor surface longline	0.58	0.82	0.01–2.99	
Fishery - Flatfish	0.28	0.41	0.00–1.54	
Fishery - Inshore	0.23	0.35	0.00–1.32	
CV(Fishery)	0.96	0.99	0.61–1.52	
CV(Overdispersion) - SLL	3.38	3.38	2.67–4.09	
CV(Overdispersion) - Trawl	1.80	1.70	0.41–2.48	
CV(Overdispersion) - BLL	1.03	1.14	0.20–2.63	

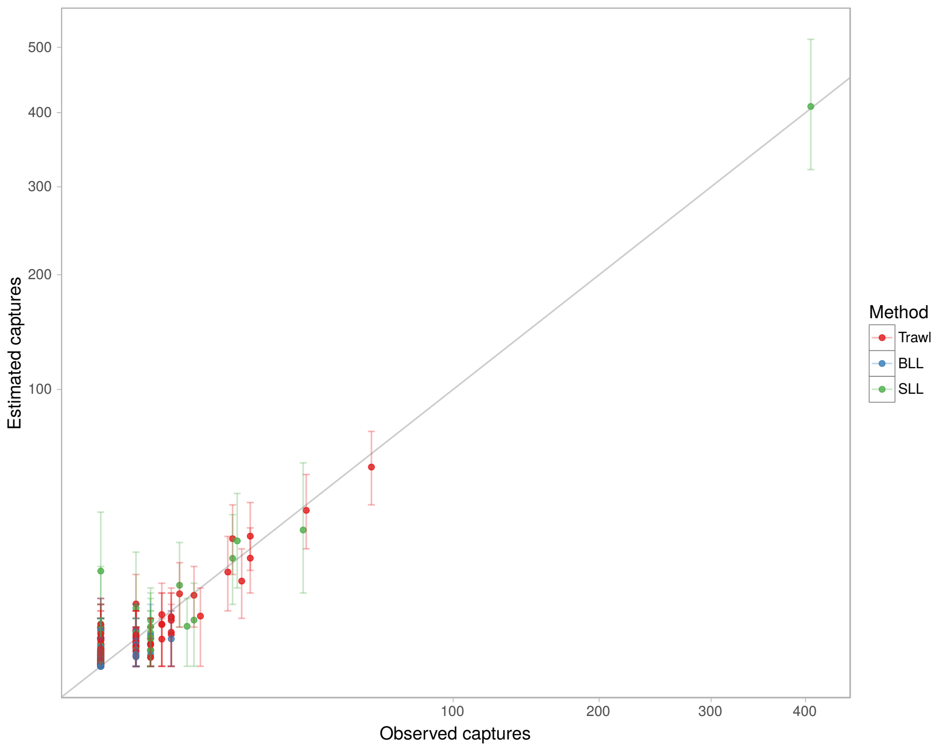


Figure B-35: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-44: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were four such strata, representing 0.7% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
SLL	Bigeye	Small	North	East of North Island	Autumn (Apr-Jun)	96	0	11.83	2–31
BLL	Large-vessel ling (no IWL)	Large	South	Western Chatham Rise	Winter (Jul-Sep)	47	2	0.17	0–1
SLL	Southern bluefin	Large	North	East of North Island	Autumn (Apr-Jun)	9	2	0.11	0–1
Trawl	Scampi	Small	South	Eastern Chatham Rise	Summer (Jan-Mar)	87	2	0.10	0–1

B.4 Other albatrosses

Table B-45: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
SLL	Southern bluefin	Small	East of North Island	Autumn	12	263	0.035	342	499	294–787
SLL	Bigeye	Small	North East	Spring	21	148	0.022	938	423	237–680
SLL	Bigeye	Small	East of North Island	Autumn	0	96	0.022	0	319	153–581
SLL	Bigeye	Small	North East	Winter	2	94	0.013	157	285	152–479
SLL	Bigeye	Small	East of North Island	Summer	3	151	0.025	117	203	96–362
SLL	Albacore	Small	East of North Island	Autumn	0	23	0.015	0	197	66–445
SLL	Bigeye	Small	North East	Autumn	1	43	0.010	101	177	93–302
BLL	Bluenose	Small	East of North Island	Spring	0	0	0.000		127	27–329
BLL	Small-vessel ling	Small	East of North Island	Winter	1	46	0.010	101	109	45–212
SLL	Bigeye	Small	East of North Island	Spring	0	11	0.013	0	101	46–188
SLL	Southern bluefin	Small	East of North Island	Winter	10	143	0.093	107	97	52–161
SLL	Bigeye	Small	North East	Summer	3	133	0.027	112	95	47–164
BLL	Small-vessel ling	Small	East of North Island	Spring	0	0	0.000		93	35–189
SLL	Southern bluefin	Small	North East	Winter	6	247	0.097	62	91	46–156
SLL	Swordfish	Small	East of North Island	Autumn	0	10	0.062	0	82	23–203

Table B-46: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	106	108	0	2	0.00	1.85
Half-width	106	104	105	1	2	0.94	1.89

Table B-47: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Large SLL for method, North for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.05	0.05	0.01–0.20	
Method - Large-vessel trawl	0.01	0.01	0.00–0.04	-
Method - Large-vessel BLL	0.08	0.08	0.01–0.57	-
Method - Small-vessel SLL	1.00	1.00	0.54–1.92	
Method - Small-vessel trawl	0.02	0.02	0.00–0.06	-
Method - Small-vessel BLL	0.09	0.09	0.02–0.38	-
Region - South	0.89	0.89	0.29–2.72	
Season - Autumn (Apr-Jun)	2.15	2.15	1.34–3.41	+
Season - Winter (Jul-Sep)	2.04	2.04	1.24–3.38	+
Season - Spring (Oct-Dec)	3.42	3.42	2.11–5.51	+
CV(Year) - SLL	0.19	0.24	0.01–0.70	
CV(Year) - Trawl	0.36	0.37	0.03–0.82	
CV(Year) - BLL	1.30	1.34	0.78–2.12	
Area - East of North Island	1.62	1.73	0.63–3.43	
Area - Kermadec Islands	0.97	1.06	0.32–2.39	
Area - North East	0.91	0.97	0.34–1.98	
Area - Eastern Chatham Rise	2.16	2.25	1.12–3.89	+
Area - Stewart Snares Shelf	1.29	1.34	0.64–2.30	
Area - West Coast South Island	0.71	0.75	0.32–1.41	
Area - Auckland Islands	0.99	1.05	0.44–1.96	
Area - Fiordland	0.17	0.18	0.06–0.38	-
Area - South Subantarctic	1.02	1.08	0.45–2.09	
Area - Western Chatham Rise	1.00	1.05	0.45–1.99	
Area - West Coast North Island	0.24	0.27	0.05–0.69	-
Area - Cook Strait	0.87	0.96	0.27–2.15	
Area - East Subantarctic	0.36	0.41	0.06–1.09	
CV(Area)	0.73	0.75	0.47–1.16	
Fishery - Southern bluefin	0.42	0.46	0.14–1.02	
Fishery - Swordfish	2.94	3.22	1.20–6.78	+
Fishery - Bigeye	0.45	0.50	0.15–1.14	
Fishery - Squid	2.27	2.39	1.05–4.56	+
Fishery - Large-vessel ling (no IWL)	0.84	0.97	0.17–2.62	
Fishery - Hoki	0.82	0.86	0.37–1.63	
Fishery - Albacore	0.75	0.84	0.22–2.08	
Fishery - Small-vessel ling	1.72	1.91	0.58–4.30	
Fishery - Scampi	1.28	1.41	0.48–3.01	
Fishery - Deepwater	0.53	0.56	0.21–1.14	
Fishery - Middle depths	0.89	0.96	0.36–1.94	
Fishery - Large-vessel ling (IWL)	0.64	0.76	0.11–2.13	
Fishery - Southern blue whiting	1.34	1.48	0.47–3.37	
Fishery - Bluenose	1.09	1.25	0.28–3.13	
Fishery - Inshore	0.63	0.73	0.14–1.85	
Fishery - Ling	0.76	0.85	0.17–2.11	
Fishery - Hake	0.63	0.71	0.14–1.73	
Fishery - Minor targets	0.69	0.83	0.10–2.35	
Fishery - Hāpuku	0.79	0.94	0.12–2.63	
Fishery - Snapper	0.11	0.17	0.00–0.66	-
Fishery - Minor surface longline	0.34	0.48	0.01–1.76	
Fishery - Flatfish	0.37	0.49	0.01–1.64	
Fishery - Mackerel	0.17	0.24	0.00–0.89	-
CV(Fishery)	0.86	0.88	0.54–1.34	
CV(Overdispersion) - SLL	3.76	3.76	3.12–4.43	
CV(Overdispersion) - Trawl	1.26	1.26	0.24–2.29	
CV(Overdispersion) - BLL	3.31	3.31	2.26–4.32	

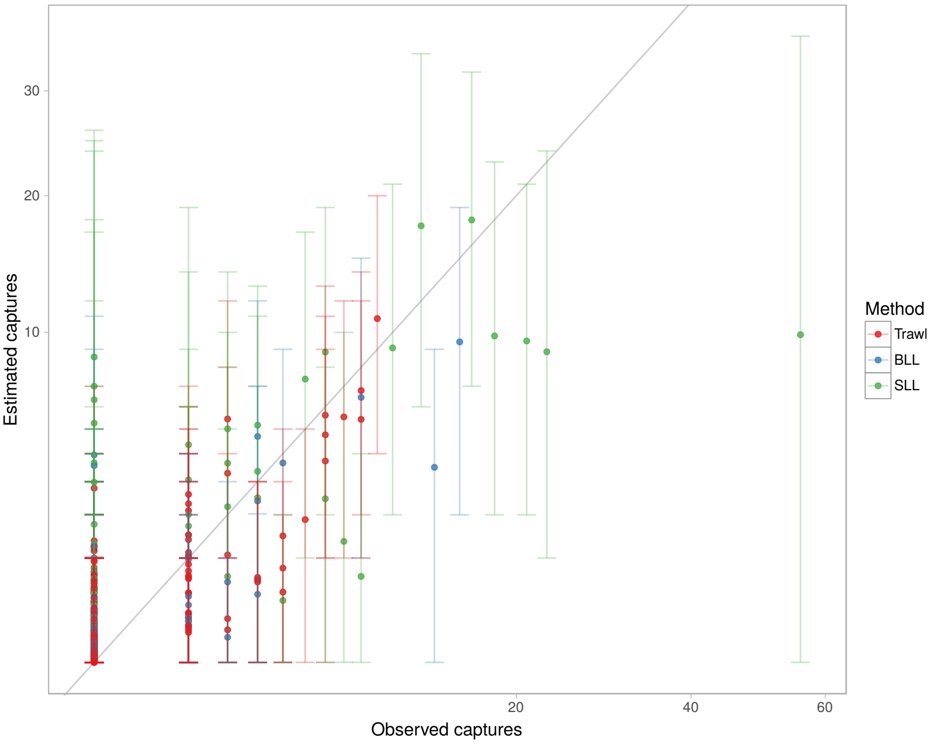


Figure B-36: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-48: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were twelve such strata, representing 2.1% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
SLL	Swordfish	Small	North	Kermadec Islands	Spring (Oct-Dec)	21	56	9.86	0–36
SLL	Albacore	Large	North	Kermadec Islands	Winter (Jul-Sep)	106	0	8.56	1–24
SLL	Bigeye	Small	North	East of North Island	Autumn (Apr-Jun)	96	0	7.00	1–18
BLL	Small-vessel ling	Small	South	Eastern Chatham Rise	Winter (Jul-Sep)	126	13	3.49	0–9
Trawl	Deepwater	Large	South	Eastern Chatham Rise	Winter (Jul-Sep)	782	4	0.82	0–3
SLL	Southern bluefin	Large	North	East of North Island	Autumn (Apr-Jun)	9	8	0.68	0–4
Trawl	Scampi	Small	South	Eastern Chatham Rise	Autumn (Apr-Jun)	107	4	0.45	0–2
BLL	Bluenose	Small	North	North East	Autumn (Apr-Jun)	44	3	0.43	0–2
SLL	Bigeye	Small	North	West Coast North Island	Spring (Oct-Dec)	19	4	0.35	0–2
Trawl	Scampi	Small	South	Eastern Chatham Rise	Summer (Jan-Mar)	87	2	0.18	0–1
Trawl	Inshore	Small	North	East of North Island	Winter (Jul-Sep)	57	2	0.10	0–1
BLL	Large-vessel ling (no IWL)	Large	South	Auckland Islands	Autumn (Apr-Jun)	20	2	0.06	0–1

B.5 White-chinned petrel

Table B-49: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries. IWL: Integrated weight line.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
Trawl	Squid	Large	Stewart Snares Shelf	Summer	289	8014	0.326	886	762	645–888
BLL	Large-vessel ling (no IWL)	Large	Stewart Snares Shelf	Spring	144	909	0.464	310	737	401–1267
BLL	Large-vessel ling (no IWL)	Large	East Subantarctic	Summer	82	526	0.368	222	723	295–1557
Trawl	Squid	Large	Auckland Islands	Summer	291	5407	0.429	678	610	512–722
BLL	Large-vessel ling (no IWL)	Large	Eastern Chatham Rise	Summer	40	285	0.171	233	490	200–1014
BLL	Large-vessel ling (no IWL)	Large	Eastern Chatham Rise	Spring	313	290	0.100	3142	485	250–867
BLL	Bluenose	Small	Eastern Chatham Rise	Summer	0	32	0.018	0	358	25–1557
BLL	Large-vessel ling (no IWL)	Large	East Subantarctic	Spring	69	548	0.417	165	320	136–668
BLL	Large-vessel ling (no IWL)	Large	South Subantarctic	Summer	13	12	0.008	1568	311	104–722
BLL	Large-vessel ling (no IWL)	Large	Eastern Chatham Rise	Autumn	0	9	0.005	0	307	147–576
BLL	Small-vessel ling	Small	Western Chatham Rise	Spring	3	56	0.021	141	306	117–683
BLL	Small-vessel ling	Small	Eastern Chatham Rise	Summer	0	8	0.007	0	302	113–659
BLL	Large-vessel ling (no IWL)	Large	Western Chatham Rise	Summer	6	65	0.053	114	285	113–615
BLL	Large-vessel ling (no IWL)	Large	Western Chatham Rise	Spring	6	44	0.019	313	283	137–528
BLL	Small-vessel ling	Small	Eastern Chatham Rise	Spring	24	101	0.059	406	252	103–540

Table B-50: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	97	108	0	11	0.00	10.19
Half-width	97	97	97	0	0	0.00	0.00

Table B-51: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Large trawl for method, South for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.01	0.02	0.01–0.05	
Method - Large-vessel BLL	7.99	8.00	1.42–42.37	+
Method - Large-vessel SLL	11.98	12.13	1.65–104.96	+
Method - Small-vessel trawl	0.19	0.19	0.09–0.38	-
Method - Small-vessel BLL	23.38	24.92	4.38–224.31	+
Method - Small-vessel SLL	117.57	119.95	16.20–1013.57	+
Region - North	0.02	0.02	0.00–0.08	-
Season - Autumn (Apr-Jun)	0.41	0.41	0.34–0.50	-
Season - Winter (Jul-Sep)	0.01	0.01	0.00–0.02	-
Season - Spring (Oct-Dec)	0.54	0.55	0.42–0.71	-
CV(Year) - Trawl	0.68	0.70	0.46–1.06	
CV(Year) - BLL	1.08	1.10	0.74–1.59	
CV(Year) - SLL	0.40	0.43	0.02–0.98	
Area - Stewart Snares Shelf	1.64	1.69	0.85–2.83	
Area - Auckland Islands	2.40	2.48	1.27–4.20	+
Area - Eastern Chatham Rise	0.97	1.01	0.48–1.76	
Area - East Subantarctic	1.02	1.11	0.44–2.26	
Area - Fiordland	0.66	0.69	0.30–1.29	
Area - Western Chatham Rise	0.76	0.79	0.37–1.36	
Area - South Subantarctic	0.77	0.82	0.33–1.58	
Area - East of North Island	0.81	0.93	0.20–2.34	
Area - North East	0.68	0.78	0.14–1.98	
Area - West Coast South Island	0.06	0.08	0.01–0.22	-
Area - Cook Strait	0.36	0.42	0.08–1.05	
Area - West Coast North Island	0.67	0.76	0.13–2.01	
Area - Kermadec Islands	1.27	1.45	0.28–3.80	
CV(Area)	0.80	0.82	0.51–1.26	
Fishery - Large-vessel ling (no IWL)	2.75	3.23	0.68–8.63	
Fishery - Squid	1.68	1.76	0.63–3.35	
Fishery - Middle depths	1.07	1.14	0.40–2.25	
Fishery - Scampi	3.86	4.10	1.45–8.11	+
Fishery - Hoki	0.48	0.52	0.18–1.06	
Fishery - Large-vessel ling (IWL)	0.70	0.86	0.14–2.52	
Fishery - Small-vessel ling	0.78	0.97	0.09–3.06	
Fishery - Southern bluefin	0.23	0.33	0.03–1.19	
Fishery - Mackerel	1.13	1.21	0.39–2.49	
Fishery - Minor targets	0.92	1.14	0.13–3.38	
Fishery - Bigeye	0.80	1.01	0.13–3.07	
Fishery - Ling	0.46	0.51	0.14–1.19	
Fishery - Swordfish	0.97	1.24	0.14–3.92	
Fishery - Hake	0.19	0.22	0.04–0.58	-
Fishery - Bluenose	0.38	0.60	0.02–2.50	
Fishery - Albacore	1.93	2.39	0.30–7.13	
Fishery - Deepwater	0.01	0.02	0.00–0.07	-
Fishery - Snapper	0.08	0.22	0.00–1.25	
Fishery - Hāpuku	0.11	0.31	0.00–1.78	
Fishery - Minor surface longline	0.24	0.50	0.00–2.55	
Fishery - Flatfish	0.10	0.20	0.00–0.94	-
Fishery - Inshore	0.13	0.25	0.00–1.20	
Fishery - Southern blue whiting	0.16	0.31	0.00–1.51	
CV(Fishery)	1.24	1.27	0.85–1.87	
CV(Overdispersion) - Trawl	3.08	3.08	2.67–3.48	
CV(Overdispersion) - BLL	6.50	6.51	5.66–7.42	
CV(Overdispersion) - SLL	2.75	2.75	1.79–3.61	

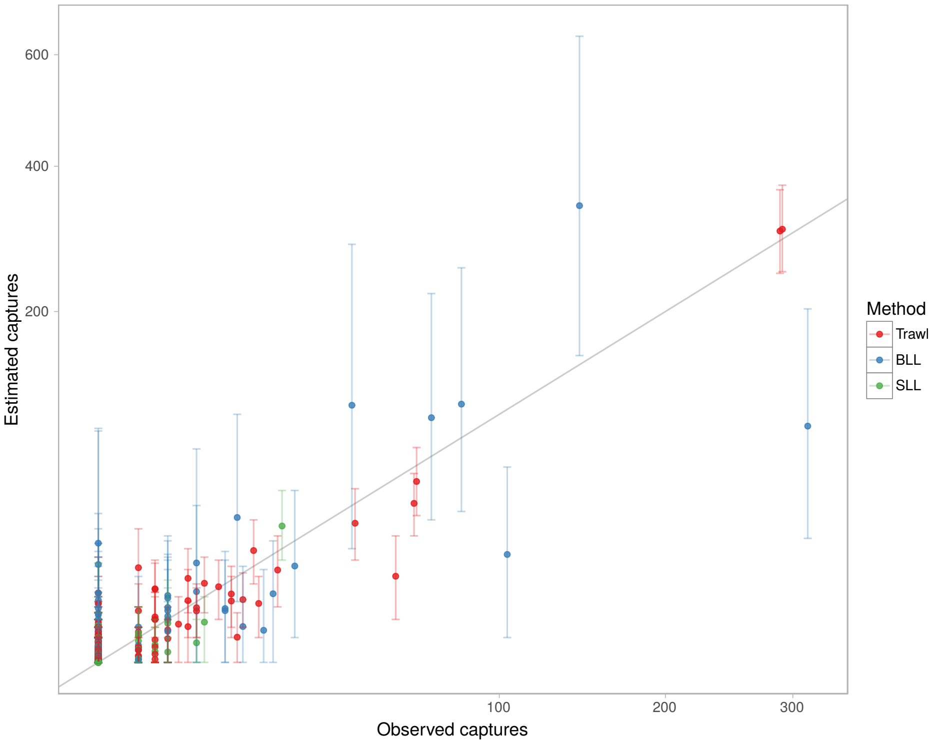


Figure B-37: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-52: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were 22 such strata, representing 3.9% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
BLL	Large-vessel ling (no IWL)	Large	South	Stewart Snares Shelf	Spring (Oct-Dec)	909	144	338.95	153–637
BLL	Large-vessel ling (no IWL)	Large	South	Eastern Chatham Rise	Spring (Oct-Dec)	290	313	90.72	25–203
Trawl	Squid	Large	South	Stewart Snares Shelf	Autumn (Apr-Jun)	2236	62	41.09	26–58
BLL	Large-vessel ling (no IWL)	Large	South	Fiordland	Spring (Oct-Dec)	78	104	18.93	1–62
Trawl	Scampi	Large	South	Auckland Islands	Spring (Oct-Dec)	413	1	14.57	5–29
Trawl	Scampi	Large	South	Auckland Islands	Summer (Jan-Mar)	111	55	12.06	3–26
Trawl	Hoki	Large	South	Eastern Chatham Rise	Summer (Jan-Mar)	1299	2	8.79	3–17
Trawl	Hoki	Large	South	Stewart Snares Shelf	Spring (Oct-Dec)	1292	2	8.72	3–16
Trawl	Scampi	Large	South	Auckland Islands	Autumn (Apr-Jun)	115	0	7.85	2–18
BLL	Large-vessel ling (IWL)	Large	South	South Subantarctic	Autumn (Apr-Jun)	437	0	7.78	1–23
Trawl	Middle depths	Large	South	Western Chatham Rise	Spring (Oct-Dec)	622	16	5.64	1–12
Trawl	Mackerel	Large	South	Western Chatham Rise	Summer (Jan-Mar)	353	0	5.57	1–12
BLL	Minor targets	Small	South	Eastern Chatham Rise	Spring (Oct-Dec)	8	17	1.67	0–14
Trawl	Scampi	Small	South	Auckland Islands	Summer (Jan-Mar)	38	12	1.03	0–4
SLL	Southern bluefin	Large	South	South Subantarctic	Autumn (Apr-Jun)	55	6	0.62	0–3
SLL	Bigeye	Small	North	West Coast North Island	Spring (Oct-Dec)	19	3	0.18	0–1
Trawl	Squid	Large	South	South Subantarctic	Summer (Jan-Mar)	11	2	0.11	0–1
BLL	Large-vessel ling (no IWL)	Large	South	Stewart Snares Shelf	Winter (Jul-Sep)	4	1	0.02	0–0
SLL	Bigeye	Small	North	North East	Winter (Jul-Sep)	94	1	0.02	0–0
Trawl	Hoki	Large	South	Fiordland	Spring (Oct-Dec)	30	2	0.02	0–0
SLL	Southern bluefin	Small	North	North East	Winter (Jul-Sep)	247	1	0.02	0–0
BLL	Bluenose	Small	North	North East	Spring (Oct-Dec)	8	1	0.01	0–0

B.6 Black petrel

Table B-53: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
BLL	Bluenose	Small	North East	Summer	7	22	0.004	1889	1359	551–2776
BLL	Snapper	Small	North East	Summer	12	506	0.015	812	1270	737–2006
BLL	Snapper	Small	North East	Autumn	21	340	0.010	2021	962	554–1538
BLL	Snapper	Small	North East	Spring	2	345	0.009	218	819	416–1413
BLL	Bluenose	Small	North East	Autumn	0	44	0.010	0	805	286–1750
BLL	Bluenose	Small	North East	Spring	4	8	0.002	2354	629	245–1401
BLL	Bluenose	Small	East of North Island	Summer	9	15	0.004	2206	481	183–1006
SLL	Bigeye	Small	North East	Summer	7	133	0.027	263	426	220–731
BLL	Bluenose	Small	East of North Island	Spring	0	0	0.000		360	110–892
SLL	Bigeye	Small	North East	Spring	11	148	0.022	491	324	164–570
SLL	Bigeye	Small	North East	Autumn	0	43	0.010	0	300	137–572
SLL	Bigeye	Small	East of North Island	Summer	14	151	0.025	550	287	150–492
BLL	Hāpuku	Small	North East	Summer	0	0	0.000		274	64–767
BLL	Bluenose	Small	East of North Island	Autumn	0	13	0.006	0	247	81–556
SLL	Bigeye	Small	East of North Island	Autumn	0	96	0.022	0	170	74–327

Table B-54: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	106	108	0	2	0.00	1.85
Half-width	106	103	104	2	3	1.89	2.83

Table B-55: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Small BLL for method, North for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.04	0.05	0.01–0.29	
Method - Small-vessel SLL	1.18	1.26	0.21–9.15	
Method - Small-vessel trawl	0.05	0.05	0.01–0.38	-
Method - Large-vessel BLL	0.01	0.01	0.00–2.28	
Method - Large-vessel SLL	0.14	0.14	0.00–3.68	
Method - Large-vessel trawl	0.00	0.00	0.00–0.07	-
Region - South	0.00	0.00	0.00–0.10	-
Season - Autumn (Apr-Jun)	0.79	0.79	0.45–1.41	
Season - Winter (Jul-Sep)	0.04	0.03	0.00–0.21	-
Season - Spring (Oct-Dec)	0.58	0.57	0.31–1.07	
CV(Year) - BLL	0.62	1.02	0.02–3.96	
CV(Year) - SLL	0.50	0.78	0.02–3.32	
CV(Year) - Trawl	0.60	0.99	0.02–4.11	
Area - North East	1.78	2.06	0.49–5.25	
Area - East of North Island	1.02	1.18	0.26–3.08	
Area - West Coast North Island	0.19	0.26	0.01–0.85	-
Area - Kermadec Islands	0.69	0.84	0.07–2.57	
Area - Eastern Chatham Rise	0.70	0.90	0.00–3.45	
Area - East Subantarctic	0.73	0.97	0.00–3.66	
Area - South Subantarctic	0.75	1.00	0.00–3.82	
Area - Western Chatham Rise	0.71	0.93	0.00–3.45	
Area - Auckland Islands	0.73	1.00	0.00–3.66	
Area - Stewart Snares Shelf	0.72	0.94	0.00–3.33	
Area - Cook Strait	0.73	0.97	0.00–3.52	
Area - Fiordland	0.75	0.99	0.00–3.59	
Area - West Coast South Island	0.73	0.97	0.00–3.47	
CV(Area)	0.92	1.01	0.32–2.20	
Fishery - Snapper	0.46	0.55	0.10–1.52	
Fishery - Bigeye	0.87	1.05	0.12–3.00	
Fishery - Bluenose	2.71	3.14	0.71–8.30	
Fishery - Inshore	1.11	1.43	0.19–4.50	
Fishery - Hāpuku	1.53	1.89	0.31–5.62	
Fishery - Minor surface longline	1.38	1.72	0.20–5.12	
Fishery - Scampi	1.05	1.37	0.16–4.47	
Fishery - Albacore	1.05	1.34	0.13–4.23	
Fishery - Swordfish	0.54	0.74	0.05–2.52	
Fishery - Large-vessel ling (IWL)	0.50	0.93	0.00–4.51	
Fishery - Large-vessel ling (no IWL)	0.51	0.92	0.00–4.31	
Fishery - Minor targets	0.07	0.17	0.00–0.93	-
Fishery - Small-vessel ling	0.09	0.21	0.00–1.05	
Fishery - Southern bluefin	0.02	0.06	0.00–0.34	-
Fishery - Flatfish	0.35	0.64	0.00–2.92	
Fishery - Hoki	0.45	0.83	0.00–3.92	
Fishery - Middle depths	0.38	0.69	0.00–3.21	
Fishery - Deepwater	0.35	0.65	0.00–2.98	
Fishery - Ling	0.52	0.91	0.00–3.86	
Fishery - Hake	0.52	0.92	0.00–4.07	
Fishery - Squid	0.52	0.94	0.00–4.29	
Fishery - Southern blue whiting	0.56	0.99	0.00–4.57	
Fishery - Mackerel	0.44	0.84	0.00–3.84	
CV(Fishery)	1.25	1.31	0.67–2.27	
CV(Overdispersion) - BLL	3.37	3.38	2.49–4.29	
CV(Overdispersion) - SLL	3.17	3.17	2.44–3.90	
CV(Overdispersion) - Trawl	0.95	1.01	0.24–2.04	

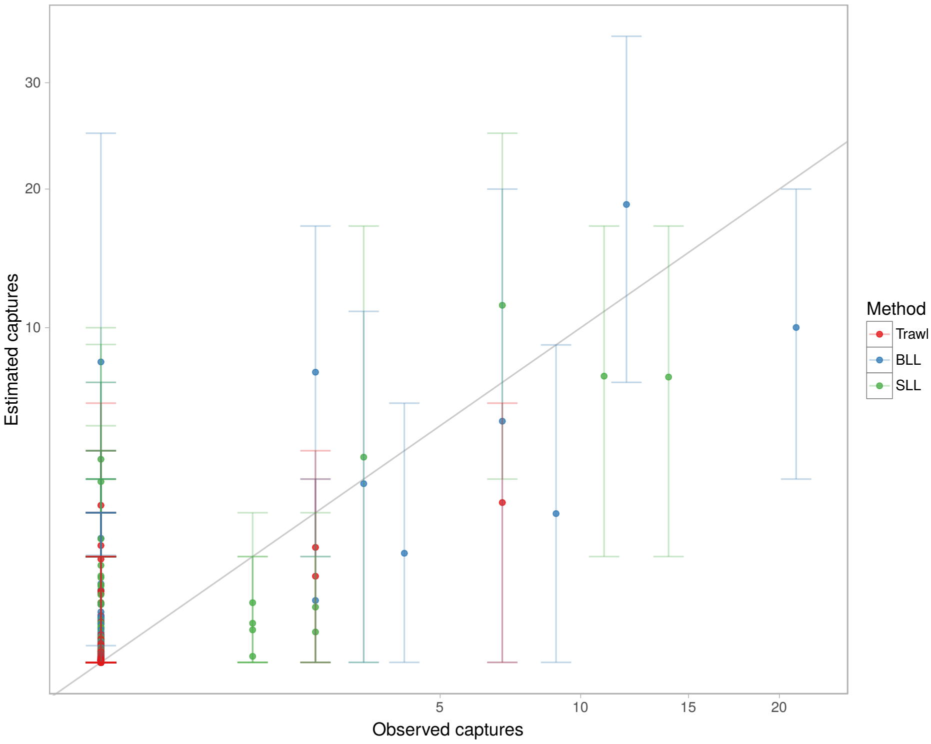


Figure B-38: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-56: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were four such strata, representing 0.7% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
BLL	Snapper	Small	North	North East	Autumn (Apr-Jun)	340	21	10.01	3–20
Trawl	Inshore	Small	North	North East	Autumn (Apr-Jun)	621	7	2.28	0–6
SLL	Albacore	Small	North	North East	Spring (Oct-Dec)	1	2	0.08	0–1
SLL	Albacore	Large	North	North East	Winter (Jul-Sep)	2	1	0.00	0–0

B.7 Grey petrel

Table B-57: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries. IWL: Integrated weight line.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
BLL	Snapper	Small	North East	Winter	0	0	0.000		2338	902–4834
BLL	Large-vessel ling (no IWL)	Large	Western Chatham Rise	Winter	10	47	0.027	373	1001	282–2542
BLL	Snapper	Small	North East	Autumn	11	340	0.010	1058	825	368–1526
BLL	Large-vessel ling (no IWL)	Large	Auckland Islands	Winter	99	165	0.359	276	464	194–1009
BLL	Large-vessel ling (no IWL)	Large	South Subantarctic	Autumn	106	355	0.202	524	412	259–638
BLL	Large-vessel ling (no IWL)	Large	Eastern Chatham Rise	Winter	9	964	0.153	58	221	98–436
SLL	Southern bluefin	Small	East of North Island	Autumn	12	263	0.035	342	217	112–363
BLL	Large-vessel ling (no IWL)	Large	South Subantarctic	Winter	101	55	0.185	545	209	100–378
BLL	Small-vessel ling	Small	East of North Island	Winter	0	46	0.010	0	153	29–434
SLL	Southern bluefin	Small	East of North Island	Winter	7	143	0.093	74	133	71–220
BLL	Large-vessel ling (no IWL)	Large	Western Chatham Rise	Autumn	2	61	0.036	55	119	30–327
BLL	Large-vessel ling (no IWL)	Large	East Subantarctic	Autumn	0	8	0.015	0	113	42–242
BLL	Large-vessel ling (no IWL)	Large	Auckland Islands	Autumn	18	20	0.062	290	93	37–189
BLL	Large-vessel ling (no IWL)	Large	East Subantarctic	Winter	0	21	0.135	0	75	21–180
BLL	Small-vessel ling	Small	Western Chatham Rise	Winter	3	90	0.033	91	63	14–159

Table B-58: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	108	108	0	0	0.00	0.00
Half-width	108	92	94	14	16	12.96	14.81

Table B-59: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Large BLL for method, South for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.00	0.00	0.00–0.02	
Method - Large-vessel SLL	0.42	0.41	0.04–5.11	
Method - Large-vessel trawl	0.01	0.01	0.00–0.08	-
Method - Small-vessel BLL	0.29	0.28	0.03–2.53	
Method - Small-vessel SLL	0.24	0.23	0.02–2.76	
Method - Small-vessel trawl	0.00	0.00	0.00–0.03	-
Region - North	1.31	1.43	0.10–42.40	
Season - Autumn (Apr-Jun)	54.95	60.03	12.90–486.96	+
Season - Winter (Jul-Sep)	166.30	180.67	38.80–1441.27	+
Season - Spring (Oct-Dec)	2.55	2.73	0.42–26.36	
CV(Year) - BLL	2.45	2.53	1.61–3.86	
CV(Year) - SLL	0.43	0.51	0.02–1.41	
CV(Year) - Trawl	0.67	0.70	0.14–1.34	
Area - South Subantarctic	1.25	1.48	0.17–4.14	
Area - Auckland Islands	2.10	2.55	0.28–7.80	
Area - East of North Island	2.12	2.84	0.07–10.01	
Area - Eastern Chatham Rise	0.15	0.19	0.02–0.59	-
Area - North East	0.46	0.66	0.01–2.53	
Area - Western Chatham Rise	1.93	2.39	0.25–7.22	
Area - East Subantarctic	1.16	1.42	0.15–4.13	
Area - Kermadec Islands	0.29	0.52	0.01–2.42	
Area - Stewart Snares Shelf	0.10	0.18	0.00–0.77	-
Area - Cook Strait	0.00	0.02	0.00–0.18	-
Area - Fiordland	0.00	0.01	0.00–0.06	-
Area - West Coast South Island	0.00	0.02	0.00–0.14	-
Area - West Coast North Island	0.01	0.07	0.00–0.53	-
CV(Area)	1.82	1.89	1.22–2.93	
Fishery - Large-vessel ling (no IWL)	0.82	0.99	0.15–2.78	
Fishery - Large-vessel ling (IWL)	1.89	2.27	0.37–6.53	
Fishery - Southern bluefin	0.85	1.07	0.12–3.24	
Fishery - Southern blue whiting	3.60	4.08	1.11–9.63	+
Fishery - Snapper	2.63	3.20	0.56–8.94	
Fishery - Albacore	0.60	0.80	0.07–2.73	
Fishery - Small-vessel ling	0.22	0.32	0.03–1.28	
Fishery - Deepwater	0.61	0.75	0.11–2.29	
Fishery - Minor targets	0.33	0.50	0.03–2.00	
Fishery - Swordfish	1.45	1.85	0.19–5.92	
Fishery - Bluenose	0.06	0.12	0.00–0.57	-
Fishery - Bigeye	0.14	0.23	0.01–0.94	-
Fishery - Hoki	0.20	0.29	0.01–1.16	
Fishery - Squid	0.36	0.51	0.02–1.83	
Fishery - Hāpuku	0.20	0.43	0.00–2.07	
Fishery - Minor surface longline	0.48	0.91	0.00–4.30	
Fishery - Flatfish	0.49	0.92	0.00–4.34	
Fishery - Inshore	0.39	0.75	0.00–3.58	
Fishery - Middle depths	0.16	0.33	0.00–1.57	
Fishery - Ling	0.38	0.73	0.00–3.37	
Fishery - Hake	0.43	0.81	0.00–3.71	
Fishery - Scampi	0.24	0.47	0.00–2.19	
Fishery - Mackerel	0.26	0.50	0.00–2.36	
CV(Fishery)	1.27	1.31	0.79–2.01	
CV(Overdispersion) - BLL	3.25	3.26	2.31–4.24	
CV(Overdispersion) - SLL	2.04	1.93	0.36–3.12	
CV(Overdispersion) - Trawl	0.98	1.04	0.19–2.10	

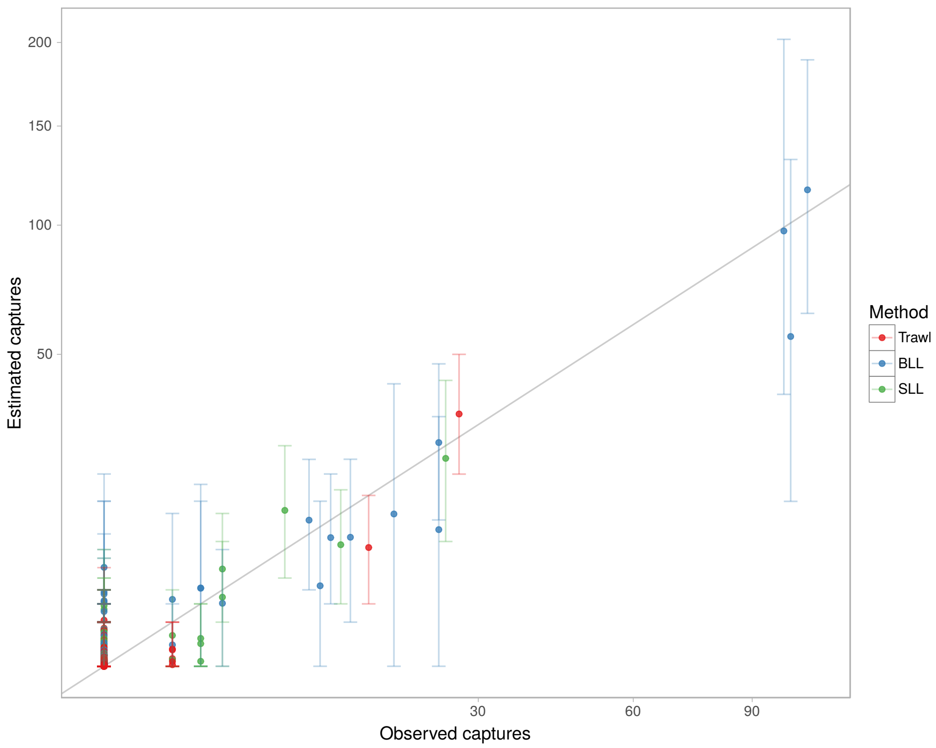


Figure B-39: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-60: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were four such strata, representing 0.7% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
SLL	Bigeye	Small	North	East of North Island	Summer (Jan-Mar)	151	1	0.02	0–0
SLL	Swordfish	Small	North	Kermadec Islands	Spring (Oct-Dec)	21	2	0.01	0–0
Trawl	Squid	Large	South	Western Chatham Rise	Winter (Jul-Sep)	5	1	0.01	0–0
Trawl	Hoki	Large	South	Stewart Snares Shelf	Spring (Oct-Dec)	1292	1	0.00	0–0

B.8 Sooty shearwater

Table B-61: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries. IWL: Integrated weight line.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
Trawl	Squid	Large	Stewart Snares Shelf	Summer	278	8014	0.326	852	936	792–1103
Trawl	Squid	Large	Stewart Snares Shelf	Autumn	212	2236	0.272	778	641	509–804
Trawl	Hoki	Large	Western Chatham Rise	Autumn	95	1820	0.142	667	543	421–682
Trawl	Middle depths	Small	Western Chatham Rise	Autumn	0	0	0.000		413	201–769
Trawl	Squid	Large	Western Chatham Rise	Autumn	17	158	0.062	275	291	199–411
Trawl	Middle depths	Small	Western Chatham Rise	Spring	0	35	0.007	0	275	132–518
Trawl	Middle depths	Small	Western Chatham Rise	Summer	10	182	0.033	307	274	138–503
Trawl	Hoki	Large	Western Chatham Rise	Spring	48	2025	0.186	258	252	186–333
Trawl	Squid	Large	Auckland Islands	Autumn	56	2099	0.308	181	227	169–297
Trawl	Squid	Small	Western Chatham Rise	Autumn	0	0	0.000		224	100–432
Trawl	Hoki	Large	Western Chatham Rise	Summer	38	1514	0.141	269	217	160–282
Trawl	Squid	Large	Auckland Islands	Summer	86	5407	0.429	200	215	164–276
Trawl	Squid	Small	Western Chatham Rise	Summer	0	2	0.001	0	189	87–354
Trawl	Hoki	Large	Stewart Snares Shelf	Autumn	24	1632	0.287	83	180	128–241
BLL	Large-vessel ling (no IWL)	Large	Western Chatham Rise	Autumn	0	61	0.036	0	165	82–296

Table B-62: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	107	108	0	1	0.00	0.93
Half-width	107	104	104	3	3	2.80	2.80

Table B-63: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Large trawl for method, South for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.01	0.01	0.00–0.02	
Method - Large-vessel BLL	4.45	4.84	0.66–50.69	
Method - Large-vessel SLL	21.72	25.15	2.03–645.27	+
Method - Small-vessel trawl	1.49	1.49	0.74–2.94	
Method - Small-vessel BLL	0.27	0.24	0.01–3.52	
Method - Small-vessel SLL	1.18	1.08	0.04–20.74	
Region - North	0.16	0.17	0.02–1.78	
Season - Autumn (Apr-Jun)	2.07	2.07	1.73–2.48	+
Season - Winter (Jul-Sep)	0.01	0.01	0.00–0.04	-
Season - Spring (Oct-Dec)	1.13	1.13	0.87–1.46	
CV(Year) - Trawl	0.48	0.49	0.31–0.78	
CV(Year) - BLL	0.82	0.85	0.31–1.56	
CV(Year) - SLL	0.57	0.73	0.02–2.35	
Area - Stewart Snares Shelf	2.52	2.71	0.87–5.66	
Area - Western Chatham Rise	3.18	3.42	1.10–7.12	+
Area - Auckland Islands	1.06	1.15	0.37–2.40	
Area - Fiordland	0.98	1.08	0.32–2.47	
Area - Eastern Chatham Rise	0.27	0.30	0.08–0.68	-
Area - East of North Island	1.22	1.56	0.14–5.05	
Area - East Subantarctic	0.05	0.07	0.01–0.22	-
Area - Cook Strait	0.20	0.26	0.03–0.83	-
Area - North East	0.30	0.44	0.02–1.68	
Area - West Coast South Island	0.07	0.09	0.01–0.30	-
Area - South Subantarctic	0.04	0.06	0.00–0.22	-
Area - West Coast North Island	0.17	0.29	0.01–1.26	
Area - Kermadec Islands	1.21	1.65	0.11–5.66	
CV(Area)	1.26	1.30	0.88–1.88	
Fishery - Squid	2.62	2.80	0.88–5.70	
Fishery - Hoki	1.07	1.14	0.35–2.33	
Fishery - Middle depths	1.70	1.81	0.56–3.79	
Fishery - Large-vessel ling (no IWL)	0.65	0.89	0.06–3.14	
Fishery - Scampi	1.03	1.13	0.30–2.62	
Fishery - Ling	1.29	1.42	0.40–3.22	
Fishery - Hake	1.11	1.24	0.35–2.81	
Fishery - Large-vessel ling (IWL)	0.69	0.95	0.05–3.31	
Fishery - Mackerel	0.44	0.49	0.13–1.17	
Fishery - Albacore	1.66	2.14	0.13–6.94	
Fishery - Southern bluefin	0.01	0.01	0.00–0.06	-
Fishery - Deepwater	0.06	0.07	0.01–0.22	-
Fishery - Bluenose	0.95	1.36	0.06–4.94	
Fishery - Hāpuku	1.84	2.46	0.17–8.58	
Fishery - Swordfish	1.44	2.02	0.09–7.61	
Fishery - Inshore	0.05	0.07	0.00–0.27	-
Fishery - Minor targets	0.09	0.26	0.00–1.51	
Fishery - Snapper	0.34	0.74	0.00–3.83	
Fishery - Small-vessel ling	0.13	0.38	0.00–2.25	
Fishery - Bigeye	0.09	0.25	0.00–1.55	
Fishery - Minor surface longline	0.46	0.92	0.00–4.60	
Fishery - Flatfish	0.01	0.03	0.00–0.15	-
Fishery - Southern blue whiting	0.24	0.56	0.00–2.86	
CV(Fishery)	1.39	1.42	0.98–2.03	
CV(Overdispersion) - Trawl	4.49	4.49	4.11–4.90	
CV(Overdispersion) - BLL	2.65	2.56	0.79–3.78	
CV(Overdispersion) - SLL	0.98	1.10	0.19–2.50	

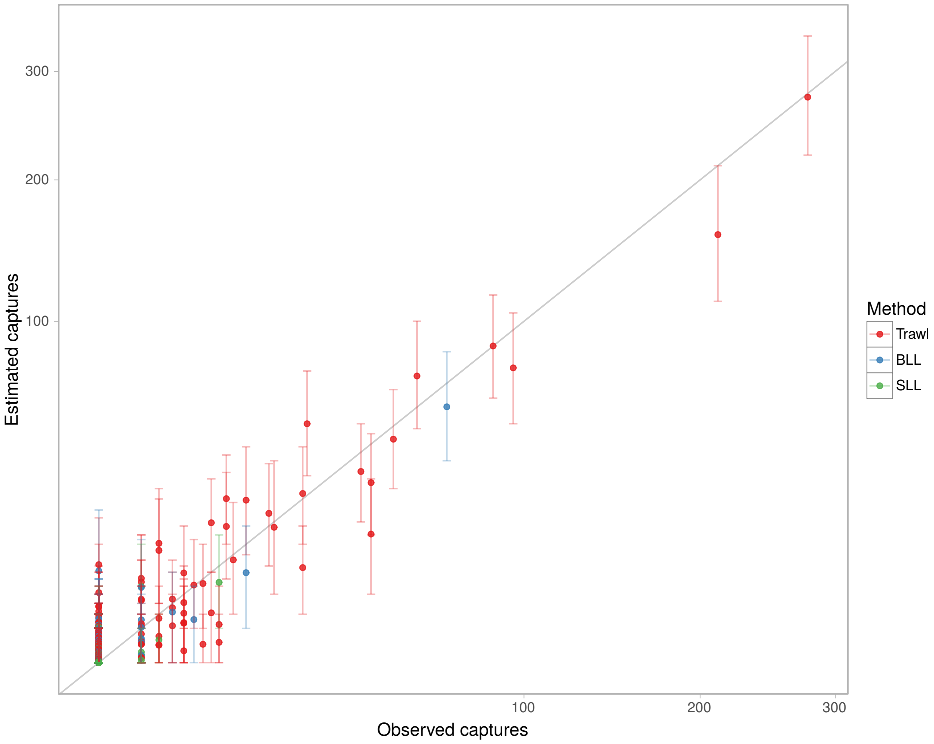


Figure B-40: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-64: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were 15 such strata, representing 2.7% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
Trawl	Hoki	Large	South	Stewart Snares Shelf	Autumn (Apr-Jun)	1632	24	48.95	30–73
Trawl	Hoki	Large	South	Stewart Snares Shelf	Spring (Oct-Dec)	1292	9	23.07	12–37
Trawl	Middle depths	Large	South	Western Chatham Rise	Autumn (Apr-Jun)	239	41	14.18	4–29
Trawl	Scampi	Small	South	Western Chatham Rise	Autumn (Apr-Jun)	206	2	12.21	3–26
Trawl	Hake	Large	South	Stewart Snares Shelf	Spring (Oct-Dec)	564	2	10.80	3–23
Trawl	Scampi	Small	South	Western Chatham Rise	Spring (Oct-Dec)	251	0	8.23	2–18
Trawl	Scampi	Small	South	Auckland Islands	Autumn (Apr-Jun)	395	23	7.74	2–16
BLL	Large-vessel ling (no IWL)	Large	South	Western Chatham Rise	Autumn (Apr-Jun)	61	0	7.21	1–20
Trawl	Ling	Large	South	Western Chatham Rise	Spring (Oct-Dec)	47	8	1.25	0–5
Trawl	Scampi	Small	South	Auckland Islands	Summer (Jan-Mar)	38	8	0.35	0–2
Trawl	Hoki	Large	South	Fiordland	Spring (Oct-Dec)	30	6	0.29	0–2
Trawl	Hake	Large	South	Eastern Chatham Rise	Summer (Jan-Mar)	69	4	0.12	0–1
Trawl	Inshore	Small	South	West Coast South Island	Summer (Jan-Mar)	452	1	0.02	0–0
Trawl	Hoki	Large	South	Cook Strait	Winter (Jul-Sep)	966	1	0.02	0–0
SLL	Southern bluefin	Large	South	South Subantarctic	Autumn (Apr-Jun)	55	1	0.01	0–0

B.9 Flesh-footed shearwater

Table B-65: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
BLL	Snapper	Small	North East	Summer	41	506	0.015	2774	2916	1969–4141
BLL	Snapper	Small	North East	Spring	5	345	0.009	547	2003	1234–3095
SLL	Bigeye	Small	North East	Summer	17	133	0.027	639	1760	1004–2969
BLL	Snapper	Small	North East	Autumn	29	340	0.010	2791	1494	955–2220
SLL	Bigeye	Small	North East	Spring	14	148	0.022	625	1460	755–2728
SLL	Bigeye	Small	East of North Island	Summer	87	151	0.025	3421	1188	757–1792
SLL	Bigeye	Small	North East	Autumn	9	43	0.010	916	830	425–1504
SLL	Bigeye	Small	East of North Island	Autumn	0	96	0.022	0	474	255–815
BLL	Hāpuku	Small	North East	Summer	0	0	0.000		339	49–1123
Trawl	Inshore	Small	North East	Summer	2	458	0.015	129	200	81–367
BLL	Hāpuku	Small	North East	Spring	0	1	0.001	0	187	26–628
Trawl	Scampi	Small	North East	Summer	4	142	0.054	74	160	91–254
SLL	Bigeye	Small	West Coast North Island	Summer	0	57	0.022	0	153	39–392
Trawl	Scampi	Small	North East	Spring	40	447	0.114	350	145	91–212
SLL	Albacore	Small	East of North Island	Autumn	0	23	0.015	0	136	23–452

Table B-66: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	105	108	0	3	0.00	2.78
Half-width	105	101	104	1	4	0.95	3.81

Table B-67: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Small SLL for method, North for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.08	0.09	0.02–0.63	
Method - Small-vessel BLL	0.51	0.54	0.07–5.67	
Method - Small-vessel trawl	0.22	0.23	0.03–1.76	
Method - Large-vessel SLL	0.01	0.00	0.00–1.23	
Method - Large-vessel BLL	0.02	0.01	0.00–3.24	
Method - Large-vessel trawl	0.01	0.01	0.00–0.26	-
Region - South	0.01	0.01	0.00–0.12	-
Season - Autumn (Apr-Jun)	0.53	0.53	0.34–0.84	-
Season - Winter (Jul-Sep)	0.00	0.00	0.00–0.04	-
Season - Spring (Oct-Dec)	0.62	0.62	0.39–0.99	-
CV(Year) - SLL	0.82	1.21	0.03–4.29	
CV(Year) - BLL	0.71	1.13	0.02–4.23	
CV(Year) - Trawl	0.73	1.16	0.02–4.33	
Area - North East	1.87	2.21	0.45–5.77	
Area - East of North Island	1.09	1.28	0.25–3.39	
Area - West Coast North Island	0.30	0.36	0.04–1.05	
Area - Western Chatham Rise	1.22	1.63	0.13–5.73	
Area - Eastern Chatham Rise	0.53	0.75	0.00–2.83	
Area - East Subantarctic	0.68	0.93	0.00–3.59	
Area - South Subantarctic	0.67	0.91	0.00–3.46	
Area - Auckland Islands	0.58	0.78	0.00–2.95	
Area - Stewart Snares Shelf	0.59	0.79	0.00–2.85	
Area - Cook Strait	0.69	0.95	0.00–3.56	
Area - Fiordland	0.71	0.98	0.00–4.05	
Area - West Coast South Island	0.65	0.88	0.00–3.38	
Area - Kermadec Islands	0.32	0.49	0.00–1.87	
CV(Area)	0.98	1.10	0.37–2.51	
Fishery - Bigeye	2.28	2.69	0.47–7.28	
Fishery - Snapper	1.09	1.36	0.13–4.15	
Fishery - Scampi	1.76	2.11	0.33–5.90	
Fishery - Inshore	0.19	0.24	0.03–0.72	-
Fishery - Albacore	1.47	1.87	0.22–6.03	
Fishery - Minor targets	0.80	1.08	0.08–3.62	
Fishery - Hāpuku	1.67	2.17	0.19–7.00	
Fishery - Minor surface longline	0.64	0.91	0.08–3.36	
Fishery - Hoki	1.73	2.19	0.26–6.86	
Fishery - Swordfish	0.30	0.49	0.01–2.00	
Fishery - Middle depths	0.46	0.67	0.03–2.42	
Fishery - Ling	1.40	1.91	0.11–7.05	
Fishery - Large-vessel ling (IWL)	0.34	0.80	0.00–4.46	
Fishery - Large-vessel ling (no IWL)	0.34	0.81	0.00–4.24	
Fishery - Bluenose	0.04	0.13	0.00–0.76	-
Fishery - Small-vessel ling	0.06	0.19	0.00–1.13	
Fishery - Southern bluefin	0.01	0.04	0.00–0.24	-
Fishery - Flatfish	0.06	0.17	0.00–0.91	-
Fishery - Deepwater	0.08	0.23	0.00–1.30	
Fishery - Hake	0.46	0.98	0.00–5.03	
Fishery - Squid	0.29	0.66	0.00–3.45	
Fishery - Southern blue whiting	0.45	1.01	0.00–5.22	
Fishery - Mackerel	0.13	0.40	0.00–2.30	
CV(Fishery)	1.43	1.47	0.87–2.37	
CV(Overdispersion) - SLL	4.11	4.12	3.47–4.79	
CV(Overdispersion) - BLL	3.47	3.47	2.55–4.41	
CV(Overdispersion) - Trawl	2.02	1.94	0.76–2.61	

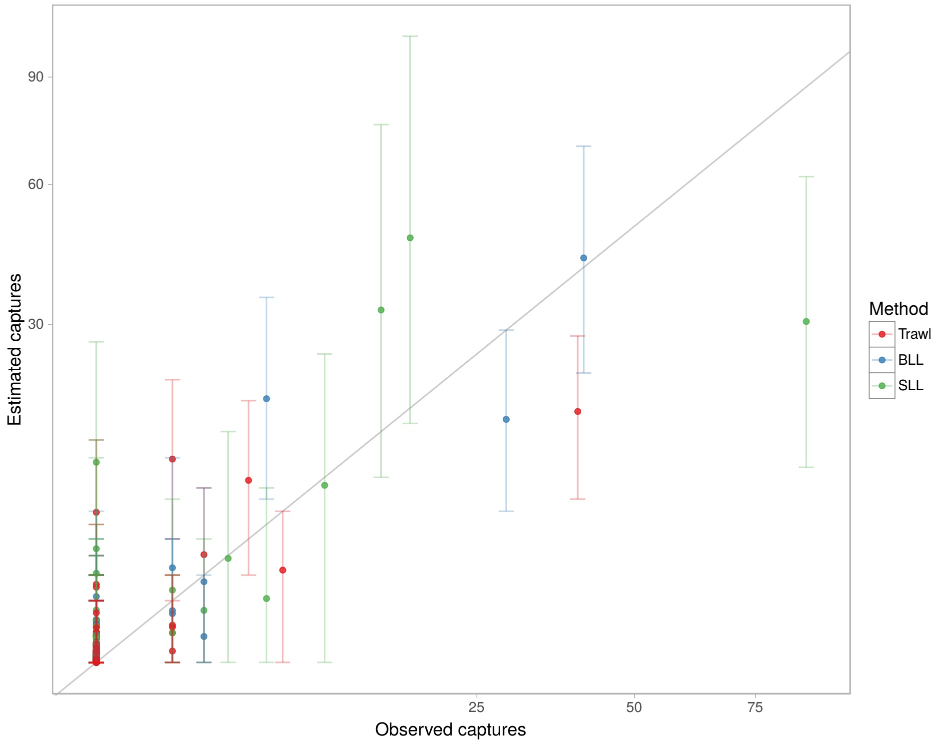


Figure B-41: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-68: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were six such strata, representing 1.1% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
SLL	Bigeye	Small	North	East of North Island	Summer (Jan-Mar)	151	87	30.53	10–62
BLL	Snapper	Small	North	North East	Spring (Oct-Dec)	345	5	18.27	7–35
Trawl	Scampi	Small	North	North East	Spring (Oct-Dec)	447	40	16.54	7–28
Trawl	Scampi	Small	North	North East	Autumn (Apr-Jun)	337	1	10.86	4–21
SLL	Bigeye	Small	North	East of North Island	Autumn (Apr-Jun)	96	0	10.52	1–27
Trawl	Scampi	Small	North	East of North Island	Spring (Oct-Dec)	272	0	5.92	1–13

B.10 Other birds

Table B-69: Model strata with the highest number of estimated captures. Only the 15 strata with the most estimated captures are shown, sorted in decreasing order of mean estimated captures. The strata were defined as combinations of fishing method, fishery, vessel size, area, and season. The number of observed captures between the fishing years 1998–99 and 2013–14 for bottom and surface longline fisheries, and between 2002–03 and 2013–14 for trawl fisheries are shown, along with the number of fishing events observed, the proportion of fishing events observed (observer coverage), the associated ratio estimate of the total number of captures, and the mean and 95% credible interval of the total estimated number of captures. The cut-off length between small and large vessels was 28 m in trawl fisheries, 34 m in bottom-longline (BLL) fisheries, and 45 m in surface-longline (SLL) fisheries.

Method	Fishery	Vessel size	Area	Season	Observations				Estimated captures	
					Captures	Events	Coverage	Ratio est.	Mean	95% c.i.
BLL	Snapper	Small	North East	Winter	0	0	0.000		1285	769–2041
BLL	Snapper	Small	North East	Spring	7	345	0.009	766	1155	717–1754
BLL	Snapper	Small	North East	Summer	21	506	0.015	1421	979	626–1443
BLL	Snapper	Small	North East	Autumn	6	340	0.010	577	915	573–1372
Trawl	Flatfish	Small	Stewart Snares Shelf	Winter	0	0	0.000		515	291–832
Trawl	Flatfish	Small	Western Chatham Rise	Winter	0	28	0.002	0	504	289–810
Trawl	Flatfish	Small	Stewart Snares Shelf	Summer	2	463	0.021	93	492	308–727
Trawl	Flatfish	Small	Stewart Snares Shelf	Spring	0	7	0.000	0	487	284–767
Trawl	Flatfish	Small	Western Chatham Rise	Summer	32	248	0.013	2546	453	283–675
Trawl	Flatfish	Small	Western Chatham Rise	Autumn	0	39	0.002	0	404	238–630
Trawl	Flatfish	Small	Western Chatham Rise	Spring	0	54	0.003	0	403	233–644
Trawl	Flatfish	Small	West Coast South Island	Winter	0	23	0.002	0	343	197–545
Trawl	Flatfish	Small	Stewart Snares Shelf	Autumn	0	32	0.002	0	324	192–502
Trawl	Flatfish	Small	West Coast South Island	Autumn	0	14	0.001	0	262	145–410
Trawl	Flatfish	Small	West Coast North Island	Winter	0	0	0.000		244	114–439

Table B-70: Model diagnostics, showing the number of tests where the test passed and failed for both MCMC chains, or for any chain. The tests consisted of the Heidelberger & Welch (1983) tests for convergence and half-width, determining whether the MCMC convergence was sufficient and that the mean of each posterior distribution can be estimated with an accuracy to at least two digits.

Test	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Convergence	108	105	108	0	3	0.00	2.78
Half-width	105	103	103	2	2	1.90	1.90

Table B-71: Summary of the posterior distributions of the model parameters. Given the large number of parameters related to annual variation (with a coefficient for each year, method and vessel size), only their coefficient of variation is shown. Base levels of the factor covariates are: Large trawl for method, South for region, and Summer (Jan-Mar) for season. Effects whose confidence interval is entirely above or below 1 are indicated by a '+' and a '-' sign respectively.

Parameter	Statistic			Significance
	Median	Mean	95% c.i.	
Intercept	0.00	0.00	0.00–0.01	
Method - Large-vessel BLL	2.91	2.94	0.75–12.58	
Method - Large-vessel SLL	6.52	6.55	1.65–26.68	+
Method - Small-vessel trawl	1.51	1.51	0.72–3.02	
Method - Small-vessel BLL	9.11	9.13	3.02–29.38	+
Method - Small-vessel SLL	9.44	9.58	2.60–38.68	+
Region - North	0.57	0.57	0.34–1.05	
Season - Autumn (Apr-Jun)	0.98	0.98	0.75–1.27	
Season - Winter (Jul-Sep)	1.49	1.49	1.08–2.05	+
Season - Spring (Oct-Dec)	1.07	1.07	0.78–1.45	
CV(Year) - Trawl	0.58	0.60	0.38–0.92	
CV(Year) - BLL	0.79	0.81	0.33–1.38	
CV(Year) - SLL	0.39	0.48	0.01–1.44	
Area - Stewart Snares Shelf	1.09	1.11	0.86–1.48	
Area - Auckland Islands	1.05	1.08	0.81–1.47	
Area - West Coast South Island	1.02	1.05	0.77–1.44	
Area - Western Chatham Rise	1.10	1.13	0.86–1.54	
Area - North East	1.03	1.07	0.71–1.52	
Area - Eastern Chatham Rise	0.84	0.83	0.54–1.06	
Area - South Subantarctic	0.92	0.90	0.53–1.20	
Area - Fiordland	1.02	1.05	0.72–1.52	
Area - West Coast North Island	0.85	0.83	0.41–1.15	
Area - Kermadec Islands	1.09	1.16	0.78–1.86	
Area - East of North Island	0.96	0.94	0.56–1.33	
Area - Cook Strait	1.01	1.04	0.72–1.50	
Area - East Subantarctic	0.81	0.78	0.37–1.09	
CV(Area)	0.20	0.22	0.01–0.49	
Fishery - Squid	1.79	1.85	0.89–3.17	
Fishery - Hoki	0.63	0.64	0.30–1.11	
Fishery - Large-vessel ling (no IWL)	1.00	1.13	0.27–2.68	
Fishery - Snapper	1.34	1.45	0.50–3.13	
Fishery - Flatfish	3.43	3.63	1.71–6.56	+
Fishery - Deepwater	0.52	0.55	0.24–1.01	
Fishery - Albacore	2.71	2.94	1.00–6.24	
Fishery - Middle depths	0.53	0.55	0.23–1.03	
Fishery - Large-vessel ling (IWL)	0.75	0.86	0.21–2.13	
Fishery - Mackerel	0.60	0.64	0.26–1.23	
Fishery - Southern bluefin	0.15	0.17	0.04–0.44	-
Fishery - Small-vessel ling	0.49	0.55	0.15–1.28	
Fishery - Ling	1.09	1.16	0.44–2.27	
Fishery - Hake	0.49	0.52	0.19–1.07	
Fishery - Southern blue whiting	0.34	0.37	0.12–0.84	-
Fishery - Scampi	0.37	0.40	0.14–0.84	-
Fishery - Bigeye	0.34	0.39	0.09–1.00	
Fishery - Inshore	0.37	0.40	0.13–0.90	-
Fishery - Minor targets	0.96	1.06	0.30–2.43	
Fishery - Hāpuku	1.48	1.67	0.51–3.85	
Fishery - Swordfish	0.85	0.97	0.23–2.43	
Fishery - Bluenose	0.30	0.37	0.05–1.14	
Fishery - Minor surface longline	0.46	0.61	0.02–2.08	
CV(Fishery)	0.84	0.85	0.60–1.19	
CV(Overdispersion) - Trawl	2.89	2.89	2.45–3.32	
CV(Overdispersion) - BLL	3.93	3.93	2.99–4.87	
CV(Overdispersion) - SLL	1.28	1.35	0.23–2.79	

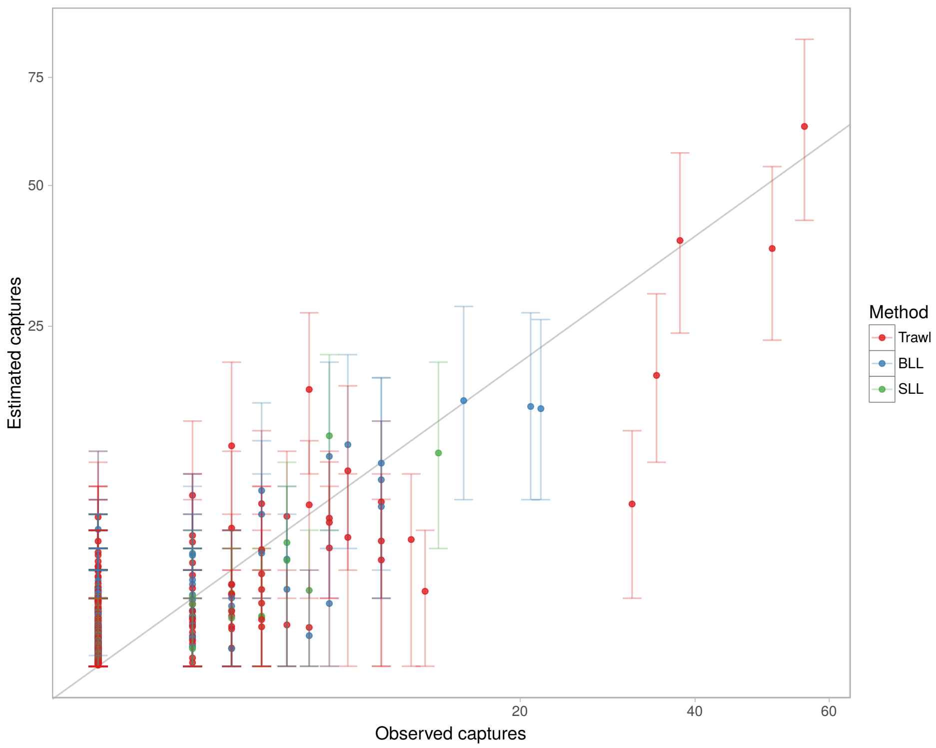


Figure B-42: Comparison between the number of captures estimated on observed fishing effort (represented by their mean and 95% credible interval) and the number of captures that was observed, for each combination of region, fishery, vessel size, area, and season. The points were coloured according to the fishing method.

Table B-72: List of strata, defined as combinations of region, fishery, vessel size, area, and season, for which the number of observed captures was outside the 95% credible interval of the number of captures estimated on the observed fishing effort. There were 22 such strata, representing 3.9% of all 561 strata.

Method	Fishery	Vessel size	Region	Area	Season	Observations	Captures	Mean	95% c.i.
Trawl	Squid	Large	South	Stewart Snares Shelf	Autumn (Apr-Jun)	2236	35	18.30	9–30
Trawl	Squid	Large	South	Auckland Islands	Autumn (Apr-Jun)	2099	5	16.57	8–27
Trawl	Flatfish	Small	South	Stewart Snares Shelf	Summer (Jan-Mar)	463	2	10.51	4–20
Trawl	Hoki	Large	South	Western Chatham Rise	Spring (Oct-Dec)	2025	1	6.32	2–13
Trawl	Flatfish	Small	South	Western Chatham Rise	Summer (Jan-Mar)	248	32	5.69	1–12
Trawl	Hoki	Large	South	Western Chatham Rise	Summer (Jan-Mar)	1514	0	4.82	1–10
Trawl	Deepwater	Large	South	Eastern Chatham Rise	Autumn (Apr-Jun)	2779	11	3.47	0–8
Trawl	Hoki	Large	South	Cook Strait	Winter (Jul-Sep)	966	9	3.39	0–8
Trawl	Middle depths	Large	South	Stewart Snares Shelf	Summer (Jan-Mar)	1006	9	2.44	0–6
SLL	Bigeye	Small	North	North East	Spring (Oct-Dec)	148	5	1.24	0–4
Trawl	Deepwater	Large	South	Western Chatham Rise	Spring (Oct-Dec)	414	12	1.22	0–4
BLL	Hāpuku	Small	North	North East	Autumn (Apr-Jun)	25	6	0.85	0–4
SLL	Southern bluefin	Large	North	East of North Island	Winter (Jul-Sep)	146	3	0.52	0–2
Trawl	Hoki	Large	South	Fiordland	Winter (Jul-Sep)	140	3	0.47	0–2
Trawl	Hoki	Large	South	Fiordland	Autumn (Apr-Jun)	127	4	0.37	0–2
Trawl	Ling	Large	South	Fiordland	Winter (Jul-Sep)	42	3	0.34	0–2
Trawl	Hoki	Small	South	West Coast South Island	Winter (Jul-Sep)	55	5	0.33	0–2
BLL	Small-vessel ling	Small	South	Stewart Snares Shelf	Winter (Jul-Sep)	7	5	0.20	0–2
Trawl	Hoki	Large	South	Fiordland	Spring (Oct-Dec)	30	2	0.07	0–1
BLL	Small-vessel ling	Small	South	Cook Strait	Summer (Jan-Mar)	4	2	0.07	0–1
Trawl	Inshore	Small	South	Cook Strait	Winter (Jul-Sep)	5	1	0.02	0–0
Trawl	Ling	Large	South	South Subantarctic	Summer (Jan-Mar)	1	1	0.00	0–0