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Tini a Tangaroa

Estimated captures of New Zealand fur seal, common dolphin, and turtles in New Zealand commercial fisheries, to 2017–18

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E.R. Abraham,
L. Tremblay-Boyer,
K. Berkenbusch

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Ministry for Primary Industries
PO Box 2526
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Protected species such as seabirds and marine mammals frequently interact with commercial fishing operations, with some interactions leading to their capture and mortality. In New Zealand's Exclusive Economic Zone, fisheries observers onboard commercial fishing vessels record these interactions to provide an independent record of protected species bycatch across different fisheries. Because observer coverage only extends to a proportion of the total fishing effort, bycatch assessments rely on the estimation of the total number of captures that would have been observed, if every vessel carried an observer. For protected species with sufficient numbers of observed captures, the estimation is based on the development of statistical models that incorporate observer and fishing effort data to derive the total number of captures in different fisheries.

This report documents the application of statistical models to provide total capture estimates of common dolphin (*Delphinus delphi*) in large-vessel mackerel trawl fisheries, New Zealand fur seal (*Arctocephalus forsteri*) in all trawl fisheries, and New Zealand fur seal and sea turtles (several species) in surface-longline fisheries.

For common dolphin, the estimation of total captures in trawl fisheries included data for the 16 fishing years between 2002–03 and 2017–18. Throughout this period, common dolphin were frequently observed caught in the large-vessel (90 m length and longer) mackerel trawl fishery off North Island's west coast. Estimates of common dolphin captures were derived for this fishery. In 2017–18, there were no (0; 95% c.i.: 0 to 4) estimated common dolphin captures in the North Island large-vessel mackerel trawl fishery; the corresponding capture rate was 0.03 (95% c.i.: 0.00 to 0.24) common dolphin per 100 tows. Observer coverage in this fishery was high, at almost 90%.

Over the 16-year assessment period, there was a marked reduction (85%) in common dolphin capture rates in the large-vessel North Island west coast mackerel trawl fishery following the introduction of the Marine Mammals Operational Procedures. This code of conduct for mitigating marine mammal bycatch was introduced in the mackerel trawl fishery in October 2008; the lower common dolphin captures subsequent to its introduction likely indicate that these mitigation measures have been successful. Nevertheless, common dolphin are also captured in small-vessel fisheries, particularly in the northern South Island area (Taranaki to Golden Bay), but observer coverage in these fisheries is limited. It is possible that common dolphin captures in these small-vessel fisheries are considerably higher than in the mackerel trawl fishery, and increased observer coverage, in the Taranaki area in particular, would be necessary to reduce the uncertainty in estimated common dolphin captures in these trawl fisheries.

For New Zealand fur seal, capture estimates were based on observer data from trawl and surface-longline fisheries covering the 16-year period from 2002–03 to 2017–18. Updating the structure of the model for estimating fur seal captures in trawl fisheries led to improved characterisation of variability, which in turn resulted in a reduction in the uncertainty in the predictions. Across all trawl fisheries, there were an estimated 324 (95% c.i.: 233–462) fur seal captures in 2017–18, with an estimated capture rate of 0.44 (95% c.i.: 0.31–0.62) fur seals per 100 tows. The highest capture estimates were in hoki and southern blue whiting target fisheries. In hoki target fisheries, there were 190 (95% c.i.: 128–283) estimated fur seal captures in 2017–18, with a corresponding capture rate of 1.38 (95% c.i.: 0.93–2.05) fur seals per 100 tows. This target fishery had high capture estimates throughout the reporting period, particularly in the Cook Strait area. The southern blue whiting fishery had 100% observer coverage, so that the estimated captures were equal to observed captures. In this trawl fishery, there were 17 total fur seal captures in 2017–18, at a capture rate of 3.74 fur seals per 100 tows.

In surface-longline fisheries, there were an estimated 60 (95% c.i.: 32 to 96) New Zealand fur seal captures in 2017–18, at a capture rate of 0.026 (95% c.i.: 0.014 to 0.042) fur seals per 1000 hooks. The estimated captures were largely in fisheries targeting southern bluefin tuna.

Observers recorded four sea turtle captures in 2017–18, with all observed captures in surface-longline fisheries. These captures included the first record of loggerhead turtle (*Caretta caretta*) in New Zealand fisheries, in addition to one capture of green turtle (*Chelonia mydas*) and two captures of leatherback turtle (*Dermochelys coriacea*). Throughout the assessment period, observed turtle captures occurred exclusively in northern waters, around North Island and Kermadec Islands. The estimation of turtle captures focused on surface-longline fisheries, with observer data from 2002–03 to 2017–18. The model was updated to include area, chlorophyll, fishery, sea surface temperature, and vessel size covariates. In 2017–18, there were an estimated 53 (95% c.i.: 27 to 86) turtle captures, and the estimated capture rate was 0.023 (95% c.i.: 0.012 to 0.038) turtles per 1000 hooks. Estimated captures of sea turtle occurred mainly in bigeye tuna and swordfish target fisheries. The change in the model structure, particularly the inclusion of sea surface temperature as a covariate, increased the estimated number of captures relative to previous estimates.

1. INTRODUCTION

Incidental captures in commercial fishing gear can have significant impacts on non-target and protected species, such as seabirds, marine mammals and turtles (Moore et al. 2009, Burgess et al. 2018). In New Zealand, this bycatch is monitored by fisheries observers onboard commercial fishing vessels, who record the number and identity of protected species that are captured. The observer data provide an independent and reliable record of captures, but often only cover a proportion of the total fishing effort. For this reason, bycatch assessments rely on estimations to determine the number of captures that would have been recorded if observers had been on every vessel, i.e., the number of "observable captures".

Observer records of protected species captures in New Zealand's Exclusive Economic Zone (EEZ) include seabirds, marine mammals and turtles in different commercial fisheries. For fisheries with sufficient observer coverage, observer data have been used to estimate the total number of captures by developing statistical models that integrate observer and fishing effort data (e.g., for seabirds, see Abraham et al. 2016, Abraham & Richard 2018; for marine mammals, see Abraham & Berkenbusch 2017). The present study updates previous estimates, and provides the most recent assessment of the total number of captures of common dolphin (*Delphinus delphis*), New Zealand fur seal (*Arctocephalus forsteri*) and turtles (without distinguishing species) in selected commercial fisheries in New Zealand waters.

For common dolphin and New Zealand fur seal, captures were observed sufficiently frequently to allow estimations of the total number of individuals that were captured in trawl fisheries. For New Zealand fur seal, estimates were also derived of captures in surface-longline fisheries. For turtles, the present study assessed the total number of captures in surface-longline fisheries in New Zealand waters. The estimates reflect the total number of observable captures (i.e., captures that would have been recorded by observers if an observer were present at every fishing event). The mortality of animals that were caught but lost from the fishing gear before it was brought onboard is not considered.

Previous assessments of common dolphin captures in trawl fisheries have focused on vessels that target jack mackerel (*Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae* or blue mackerel *Scomber australasicus*) on the North Island west coast, as there have been frequent observer records of common dolphin captures in this fishery. The preceding assessments of this fishery included data from 1995–96 to the most recent fishing year at the time of the assessment (i.e., to 2006–07, 2008–09, 2009–10, 2010–11, 2011–12, 2012–13 and 2014–15; Thompson & Abraham 2009, Thompson et al. 2010a, Thompson et al. 2011, Thompson et al. 2013b, 2016, Abraham et al. 2016, Abraham & Berkenbusch 2017), In the current assessment, the model for dolphin captures in large-vessel mackerel fisheries was updated, using 23 years of data from 1995–96 to 2017–18.

Previously, an estimate was derived of common dolphin captures in all other trawl fisheries, up to the 2014–15 fishing year (Abraham & Berkenbusch 2017). This model had low statistical power, due to low observer coverage in small-vessel fisheries and the corresponding low number of observed captures. This model was not updated.

Observer records of New Zealand fur seal captures have been frequent in some middle-depth trawl fisheries, particularly in hoki (*Macruronus novaezelandiae*) and southern blue whiting (*Micromesistius australis*) target fisheries. Previous capture estimates of this species in trawl fisheries included data from different periods between 2002–03 and 2014–15 (i.e., from 2002–03 to 2007–08, 2008–09, 2009–10, 2010–11, 2011–12, 2012–13 and 2014–15; Thompson et al. 2010b, Thompson & Abraham 2010, Thompson et al. 2011, Thompson et al. 2013b, 2016, Abraham et al. 2016, Abraham & Berkenbusch 2017). In the current assessment, the model used for estimating captures of New Zealand fur seal in trawl fisheries was re-developed, and the new model was applied to trawl data for the period between 2002–03 and 2017–18.

Captures of New Zealand fur seal and turtles (all species combined) were also estimated for surface-longline fisheries, following methods used previously (e.g., Abraham & Berkenbusch 2017). New Zealand sea lion *Phocarctos hookeri* captures in trawl fisheries have previously been estimated using a similar method (Abraham & Berkenbusch 2017). Previous estimation of New Zealand sea lion captures included interactions, i.e., the number of sea lions that would have been caught if no tows had used Sea Lion Exclusion Devices (SLEDs). The current assessment did not estimate sea lion captures or interactions. Instead, fatalities of female sea lion in subantarctic scampi and squid trawl fisheries in the Auckland Islands area were estimated in a risk assessment by Large et al. (2019), for the period between 1992–93 and 2016–17.

2. METHODS

2.1 General approach

Observer data were used to estimate captures of common dolphin and New Zealand fur seal in trawl fisheries (Table 1). Estimates of New Zealand fur seal and sea turtle captures were also derived for surface-longline fisheries, covering 16 fishing years between 2002–03 and 2017–18. The estimation of sea turtle captures did not distinguish species.

For each species and fleet category, a hierarchical generalised linear model (GLM) was used to estimate total captures from observed captures, following methods similar to those used in previous capture estimation (most recently Abraham & Berkenbusch 2017). The models were fitted to observer data and then used to estimate the observable captures on unobserved fishing effort. The estimated total captures were calculated as the sum of the observed captures on observed fishing events and the model-estimated captures on unobserved fishing events.

The models were fitted using Bayesian Markov chain Monte Carlo (MCMC) methods. The common dolphin model was coded using the BUGS language (Spiegelhalter et al. 2003), with model fitting carried out with the software package JAGS (Just Another Gibbs Sampler; Plummer 2005), following previous methods (Abraham & Berkenbusch 2017). For fur seal captures in trawl fisheries, the model was redeveloped using the R package BRMS (Bürkner 2017). This package provides a simple interface for fitting GLMs in the Stan language (Carpenter et al. 2017). There are several features of BRMS and Stan that make them more suited for these models. First, the negative binomial distribution, used for representing the distribution of protected species captures, is implemented natively in Stan. This implementation improves the convergence properties of the models. Second, Stan implements the no-U-turn sampler (NUTS; Hoffman & Gelman 2014), which allows model fitting times to be reduced by an order of magnitude (from days to hours). Finally, the simple interface provided by BRMS reduces the opportunity for coding errors, with tasks such as centering of covariates and coding of factor levels conducted automatically.

Table 1: Models used to estimate the total number of captures of marine mammals and turtles in New Zealand commercial fisheries. Models were fitted to data from the period 1995–96 to 2017–18 for common dolphin, and 2002–03 to 2017–18 for New Zealand fur and turtles.

Species	Fishing method	Strata	Software
Common dolphin	Trawl	West coast North Island mackerel, vessels $\geq$ 90 m	JAGS
New Zealand fur seal	Trawl	All trawl, other than flatfish	BRMS
	Surface longline	All	BRMS
Turtles (all species)	Surface longline	All	BRMS

2.2 Data preparation

Fisheries observers record the captures of protected species when they are onboard commercial fishing vessels. The capture events were entered into a database maintained by the National Institute of Water and Atmospheric Research (NIWA) on behalf of Fisheries New Zealand (previously Ministry for

Primary Industries). Currently, data are housed in the Centralised Observer Database (COD), and data used in the current analysis included the species identification, the capture method, life status and station details (Table 2). A summary of steps followed during the data preparation of observed protected species captures was provided by Thompson et al. (2017), with summaries of the preparation of data reported by Abraham & Berkenbusch (2019a) for the 2016–17 year, and by Abraham & Berkenbusch (2019b) for the 2017–18 year.

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 occurred in the net or through entanglement in the line. Additional information from observer comments was also used to identify the capture method.
Life status	Observers record whether the animal was alive, dead, 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 was no protected species bycatch.

In addition to observer data, the estimation required fishing effort data to scale observed captures to total fishing effort. Effort data are recorded by fishers on reporting forms, which are provided to Fisheries New Zealand, because fishers are required to record all fishing effort on each trip. The data preparation included the allocation of each fishing event to a fishery on the basis of the fishing method and the fisher-declared target species (Table 3). There were some unusual target species codes for 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 fisher-reported effort data. 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 loosened 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 97.5% of observed surface-longline sets, and over 98.7% of observed trawl tows were able to be linked to effort reported by the fisher (Abraham & Berkenbusch 2019b). Between 2002–03 and 2017–18, there were nine observed fur seal captures in trawl or surface-longline fisheries that could not be linked to the fisher-reported effort, and so were not included in the estimation. All observed common dolphin captures and all observed turtle captures could be associated with fisher-reported fishing effort.

Non-fishing related captures (such as fur seal that climbed onto the vessel) were excluded from the estimation. Similarly, any animals that were reported by the observer as decomposed were excluded.

2.3 Estimation of common dolphin captures in mackerel trawl fisheries

About 90% of observed common dolphin captures in all trawl fisheries were in the large-vessel mackerel trawl fishery off North Island's west coast that targets mackerel species (*Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae*) or blue mackerel (*Scomber australasicus*). The estimation of common dolphin captures in this mackerel trawl fishery used a model that was similar to the model

Table 3: Definition of target trawl fisheries used in the estimation and reporting of protected species captures, with common names and three-letter codes used by Fisheries New Zealand. Only species and codes that were used on more than 100 fishing events were included. In multi-species target fisheries, species are listed in decreasing order of how frequently they were targeted. Tows targeting hoki, hake, and ling were combined into one group during estimation of New Zealand fur seal captures (estimated captures are reported separately for each of these target species).

Method	Target fishery	Target species
Trawl	Squid	Squid (SQU).
	Hoki	Hoki (HOK).
	Hake	Hake (HAK).
	Ling	Ling (LIN).
	Deepwater	Orange roughy (ORH), oreos (OEO, SSO, BOE), cardinalfish (CDL), Patagonian toothfish (PTO).
	Southern blue whiting	Southern blue whiting (SBW).
	Mackerel	Jack mackerel (JMA), blue mackerel (EMA).
	Scampi	Scampi (SCI).
	Middle depth	Barracouta (BAR), warehou (WAR, WWA, SWA), alfonsino (BYX), gemfish (SKI), bluenose (BNS), sea perch (SPE), ghost shark (GSH), spiny dogfish (SPD), rubyfish (RBY), frostfish (FRO).
	Inshore	Tarakihi (TAR), snapper (SNA), gurnard (GUR), red cod (RCO), trevally (TRE), John dory (JDO), giant stargazer (STA), elephant fish (ELE), queen scallop (QSC), leatherjacket (LEA), school shark (SCH), blue moki (MOK), blue cod (BCO), rig (SPO), hāpuku (HPB).
	Flatfish	Flatfish (FLA), lemon sole (LSO), sand flounder (SFL), New Zealand sole (ESO), yellow-belly flounder (YBF), flounder (FLO), greenback flounder (GFL), turbot (TUR), brill (BRI), black flounder (BFL).

used previously (e.g., Thompson et al. 2011, Thompson et al. 2013b, Abraham et al. 2016, Abraham & Berkenbusch 2017). The mackerel trawl model selected fishing effort based on whole trips, with all effort within the North Island west coast and Taranaki areas (Figure 1) from trips by vessels 90 m or longer that reported targeting mackerel species on at least one tow. Because of the way the effort was selected, there were some non-mackerel target tows included in the mackerel model. The full dataset included 32 100 jack mackerel target tows, 1043 barracouta (*Thyrsites atun*) target tows, 279 blue mackerel tows and 8 tows targeting other species.

There were two key differences from the previous model (Abraham & Berkenbusch 2017). First, the current model included an effect for the introduction of a code of conduct for bycatch mitigation by the vessels in this fishery on 1 October 2008, the Marine Mammals Operational Procedures (MMOP) (Deepwater Group 2016). Practices required under the MMOP include the deployment of fishing gear only when no dolphins are present; having the officer on watch assessing that the area around the vessel is clear of dolphin activity before shooting gear; ensuring trawl gear is closed during turns (by keeping doors at or above surface); using acoustic dissuasive devices attached to the net on night-time tows for jack mackerel species; and (north of 40° 30′ S) refraining from deploying trawl gear between 0230 and 0430 h. Additionally, under the MMOP, all vessel officers are briefed annually on the risk factors regarding common dolphin captures especially area, depth and temporal factors (Ministry for Primary Industries 2017). There was no information available on a tow by tow basis on which fishing events these procedures were implemented. For this reason, a covariate was introduced and applied to all fishing from 1 October 2008 onwards (compared with fishing before this date).

Second, there was a vessel that fished in this fishery for two years only (vessel A, fishing in 2013–14 and 2014–15). Fishing by this vessel was 100% observed, and during the 2013–14 fishing year, it caught

25 dolphins, and during 2014–15, it caught 13 dolphins. Practices followed by this vessel were not considered representative of the rest of the fleet, and this vessel was not included in the data set used for model fitting. (Note, however, that the observed captures that occurred on this vessel were included in the estimated total captures, because estimates include observed captures on observed tows.) Because the observed captures were not included in the model fit, they had no influence on the estimated captures by other vessels.

The model of common dolphin captures in the mackerel fishery separately estimated the probability of capture events occurring and the number of captures in each capture event. Models of this kind are called hurdle models (Mullahy 1986, Ridout et al. 1998) and are appropriate when different processes are influencing the occurrence of captures and the number of animals caught in each capture event. In the first stage, a logistic GLM estimated the probability of capturing common dolphin on a given tow as a linear function of a number of covariates. Given that there was a capture event, the number of captures was then estimated in the second stage by sampling from a zero-truncated Poisson distribution.

The present study updated the model to include data from the large-vessel mackerel fishery to the end of the 2017–18 fishing year, covering the 23-year period between 1 October 1995 and 30 September 2018. Data for modelling and analysis were selected from the West Coast North Island and Taranaki areas (Figure 1(c)), because these are the areas where all common dolphin captures were observed in mackerel target tows. The region was divided into northern and southern sub-areas by a line at latitude $39°18'$ S.

The model estimated the probability, π_i, of capturing dolphins on a tow, i. An annual base rate or year effect, λ_y, was estimated for each year, y, allowing for annual variation in the capture event rates (the year effects include the intercept). The contribution of each covariate, x, was governed by a regression coefficient, β_x, that was estimated by the model. The logit transform of the capture event probability was defined as the sum of the year effect, λ_y, and the covariates:

$$\text{logit}(\pi_i) = \lambda_y + \sum_x \beta_x[x_i]. \tag{1}$$

Non-informative normal priors were given to the regression coefficients, β_x, and to the mean of the year effects, λ_y. A half-Cauchy prior, with a scale of 25, was given to the standard deviation of the year effects.

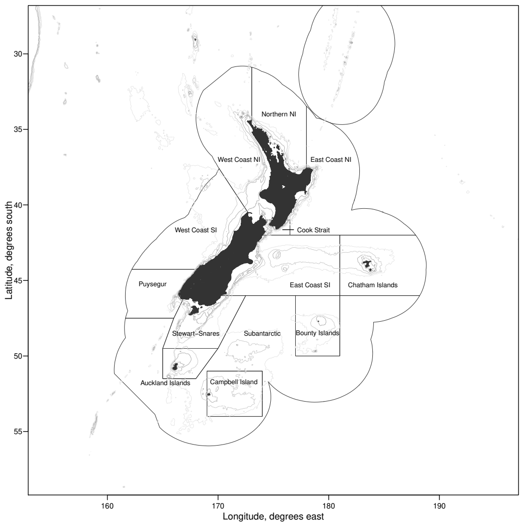
On tows where common dolphin captures occurred, the captures were assumed to follow a zero-truncated Poisson distribution with size μ. The use of a zero-truncated distribution reflected the structure of the hurdle model (if a capture event occurred, the number of dolphins caught must have been one or more). The probability that c_i dolphins were captured on tow i was given by

$$\Pr(c_i = c) = \begin{cases} (1 - \pi_i) & \text{if} \quad c = 0, \\ \pi_i \frac{e^{-\mu}\mu^c}{(1-e^{-\mu})c!} & \text{if} \quad c > 0. \end{cases} \tag{2}$$

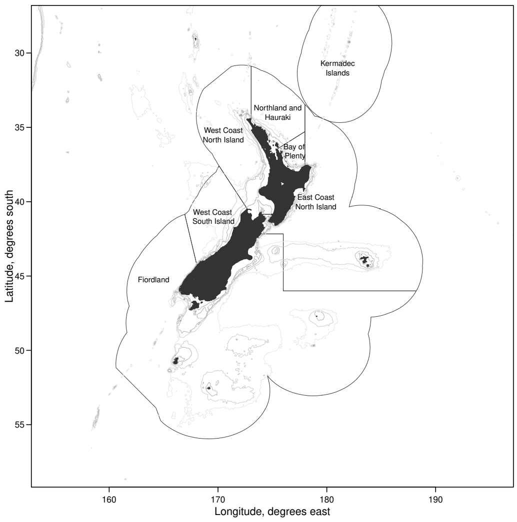
The size, μ, was given a prior that was uniform between 0.5 and 30. It would be possible for the size of the truncated Poisson distribution, μ, to vary with the value of covariates on each tow. Nevertheless, previous exploration found that there was no consistent variation of the size μ with any available covariates.

The model structure allowed for the dolphin capture event probability to depend on covariates. The covariates included trawl duration, headline depth, sub-area, light condition, and period (see definitions in Table 4). The same covariates were used previously (see Thompson & Abraham 2009, Thompson et al. 2010a, Thompson et al. 2011, Thompson et al. 2013b, Abraham et al. 2016, Abraham & Berkenbusch 2017), with the exception of "period" (before and after 1 October 2008, reflecting the introduction of the MMOP).

(a) New Zealand fur seal trawl



(b) Surface longline



(c) PSC reporting areas

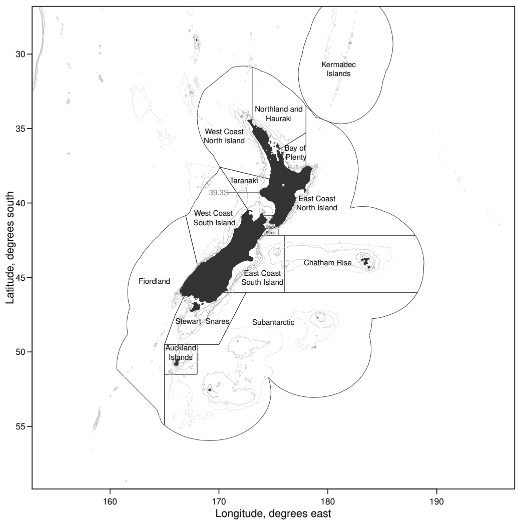


Figure 1: Areas used in the estimation of common dolphin, New Zealand fur seal and turtle captures in New Zealand commercial fisheries. Shown are: (a) areas for estimating fur seal captures in trawl fisheries, (b) areas for estimating fur seal and turtle captures in surface-longline fisheries, (c) areas for reporting protected species captures (PSC reporting areas, see https://data.dragonfly.co.nz/psc/). In (c), the line at 39°18′ S divides the large-vessel mackerel trawl fishery in the Taranaki area into southern and northern sub-areas, used in estimating common dolphin captures.

Table 4: Covariates in the common dolphin capture model for the large-vessel (≥90 m length) mackerel trawl fishery off the west coast of North Island.

Covariate	Description
Trawl duration	Duration of trawls in hours from start and end times recorded on Trawl Catch Effort Processing Return (TCEPR) forms.
Headline depth	Depth in metres of the top of the net, derived by subtracting the headline height from the ground line depth (both recorded on TCEPR forms). Indicates the depth of the top of the net.
Sub-area	The model region was divided into two sub-areas (north and south of 39°18′ S; West Coast North Island and Taranaki, respectively) that were included as a factor variable.
Light condition	Three-level factor characterising the time of the haul and the phase of the moon: light (net hauled between dawn and dusk, or between dusk and midnight on a moonlit night), dark (net hauled between dusk and midnight on a dark night, or between midnight and dawn on a moonlit night), and black (net hauled between midnight and dawn on a dark night). The illumination of the moon and time of dawn and dusk were calculated using algorithms from Meeus (1991). Night was classified as moonlit if more than 17% of the moon's disc was illuminated. Dawn and dusk were defined as when the centre of the sun's disk was 6° below the horizon (civil dawn and dusk).
Period	Two-level factor (before or after 1 October 2008), representing the capture rate before and after the introduction of Marine Mammals Operational Procedures, aimed at mitigating common dolphin (and other marine mammal) bycatch (Deepwater Group 2018).

2.4 Estimation of New Zealand fur seal captures in trawl fisheries

A Bayesian capture model was developed to predict fur seal captures in commercial trawl fisheries for the 16-year period between 2002–03 and 2017–18. The development was based on a model that was previously used to estimate the total number of fur seal captures per fishing year for the periods from 2002–03 to 2007–08, 2008–09, 2009–10, 2010–11, 2012–13 and 2014–15, respectively (Thompson & Abraham 2010, Thompson et al. 2010b, Thompson et al. 2011, Thompson et al. 2013b, Abraham et al. 2016, Abraham & Berkenbusch 2017). These models used a negative binomial error distribution to represent the distribution of the number of of fur seal captures per capture event.

In a preliminary fit of the previous model to new data, a discrepancy was identified in the prediction of fur seal captures in the Bounty Islands southern blue-whiting (*Micromesistius australis*) fishery, with an implausibly high number of captures. The observed fishery in this area accounted for less than 1% of observed tows, but almost 25% of observed fur seal captures. One vessel (vessel A, fishing in 2013–14 and 2014–15) had notably high capture rates when fishing for southern blue whiting in this area (26 captures in 18 tows). The high observed fur seal capture rates appeared to be causing difficulties with the model fit and estimates of uncertainty. This limitation was in part addressed by adding a random vessel effect to the model. We also allowed for the overdispersion of the negative binomial model to take a different value for specific area and target combinations. These values were chosen on the basis of the relationship between the variance and the mean of the observed fur seal captures in area-fishery strata. An additional model selection process was also undertaken to test the inclusion of covariate interactions.

The model was first translated into Stan, through BRMS (Bürkner 2017). Stan has a native implementation of the negative binomial distribution which improves the estimation of overdispersion parameters. No changes were otherwise made to the definition of the covariates. The description that follows first describes the dataset that was used, the structure of the model and the definition of the covariates.

We then outline the model selection process that was undertaken, and the approach to modelling the additional shape parameters of the capture distribution.

The model was fitted to all observed trawl data for the 16-year period between 2002–03 and 2017–18, with the exception of flatfish trawl fisheries. Captures by vessels targeting flatfish were assumed to be zero, because no fur seals have been observed caught in these fisheries. Because the number of observed tows greatly exceeded the number of tows that could be easily fitted by the model, trawl events were aggregated to reduce the computational load. Tow groups were defined as trawls by the same vessel, in the same statistical area, fishing for species in the same target fishery, observed or unobserved, and in the same calendar month. The aggregation of trawl events into groups reduced the accuracy of representation of some covariates, but allowed the simultaneous fitting of all trawl data from New Zealand's EEZ between 2002–03 and 2017–18 by the model using Bayesian methods.

In the model, captures, c_i, in a trawl group, i, were modelled as samples from a negative-binomial distribution:

$$c_i \sim \text{NegativeBinomial}(\text{mean} = \mu_i n_i,\ \text{shape} = \theta n_i), \tag{3}$$

where n_i is the number of tows in a trawl group. The shape parameter, θ, allows for extra dispersion in the number of captures, relative to a Poisson distribution. The negative-binomial distribution has the property that the mean of n samples from a negative-binomial distribution (NegativeBinomial(μ, θ)) is itself negative-binomially distributed, with mean μn and shape θn. For this reason, while c_i is the number of captures per group, μ_i should be interpreted as the mean capture rate per tow. The custom distribution facility of BRMS was used to code the negative binomial distribution for groups of events.

The mean capture rate within each group was estimated as the exponential of the linear predictor, which was the sum of fixed and random effects. In previous modelling of fur seal captures (Thompson & Abraham 2010, Thompson et al. 2010b, Thompson et al. 2011, Thompson et al. 2013b, Abraham et al. 2016, Abraham & Berkenbusch 2017), the fixed effects included fishing area, target fishery, day of year, and distance from shore (see definitions in Table 5). A single area–target interaction term was included in the model, following Thompson & Abraham (2010), for the subantarctic area and the deepwater target group. The previous modelling also included a random year effect, and a random vessel-year effect.

Using the model formula notation of BRMS, the previous model may be written as:

```
count | trials(events) ~ area + target + sin_doy + cos_doy + distance +
        deepwater_suba + (1 | year) + (1 | vessel:year).
```

Here "count'' is the number of observed fur seal captures (c); "trials(events)" indicates that the number of fishing events in a group is to be treated as a number of trials when parametrising the distribution; "area", "target", "sin_doy", "cos_doy", and "distance" are the fixed covariates, "deepwater_suba" is the single area-target interaction; "(1 | year)" indicates the year random effect, and "(1 | vessel:year)" indicates the vessel-year interaction term. This model was fitted using BRMS.

We allowed θ to take a separate value for fishing targeting southern blue whiting in the Bounty Islands area and for fishing targeting hoki (*Macruronus novaezelandiae*), hake (*Merluccius australis*), or ling (*Genypterus blacodes*) in the Cook Strait area, compared with all other trawl fishing. These two area-target fisheries were selected because they had the highest ratio of the variance to the mean number of fur seal caught per tow (a ratio of 3.0 and 2.0, respectively) compared with the ratio in all other area-target strata (1.59 or less) (Figure 2). For a Poisson distribution, the variance is equal to the mean, so by this measure, the overdispersion was highest in these two area-target fisheries. The extended model was sufficiently flexible to capture this overdisperson. These fisheries were influential in the predictions, because they contributed about 40% of the fur seal captures in about 3% of the observed trawl effort.

With the new model configuration for fitting dispersion, a structured approach was carried out to explore the interaction terms. The previous modelling included a vessel-year interaction, allowing the capture rate by a vessel to vary from year to year. A potential limitation with vessel-year interactions is that they tend to be proxies for other processes, due to the large number of degrees of freedom they introduce into the model. Variance associated with other processes can be masked by the vessel-year effect instead of being attributed to other covariates. This limitation is particularly relevant when making predictions outside of the training dataset, as in the current analysis for unobserved events.

Here, we trialled different combinations of interactions and retained the best-performing model for final predictions.

Table 5: Covariates included in the fur seal capture model.

Fishing area	New Zealand's Exclusive Economic Zone was divided into 13 fishing areas (see Figure 1(b)).
Target fishery	Defined by individual target species and species groups: hoki, hake, ling (grouped together); southern blue whiting; squid; jack (and blue) mackerel; scampi; middle-depth species (barracouta, ribaldo, rubyfish, alfonsino, bluenose, frostfish, ghost shark, gemfish, spiny dogfish, sea perch, and warehou); deepwater species (orange roughy, oreos, and cardinalfish); inshore species (tarakihi, snapper, gurnard, red cod, trevally, John dory, giant stargazer, elephant fish, leatherjacket, school shark, blue moki, blue cod, rig, hāpuku).
Vessel key	Unique identifier for vessels occurring in the trawl fleet as overall proxy for vessel-specific features such as boat size or configuration, skipper and/or crew habits, strategies around gear setting.
Day of year	Calculated from the mean day of the year of the tows in a group. Used to account for any seasonal variation. Harmonic functions were used to ensure that the seasonal effects were truly periodic.
Distance from shore	Four-level factor calculated using the distance from shore: coastal ($\leq$ 25 km), near (between 25 km and 90 km), far (between 90 km and 180 km), and ocean ($>$ 180 km)(see map provided by Thompson & Abraham 2010).

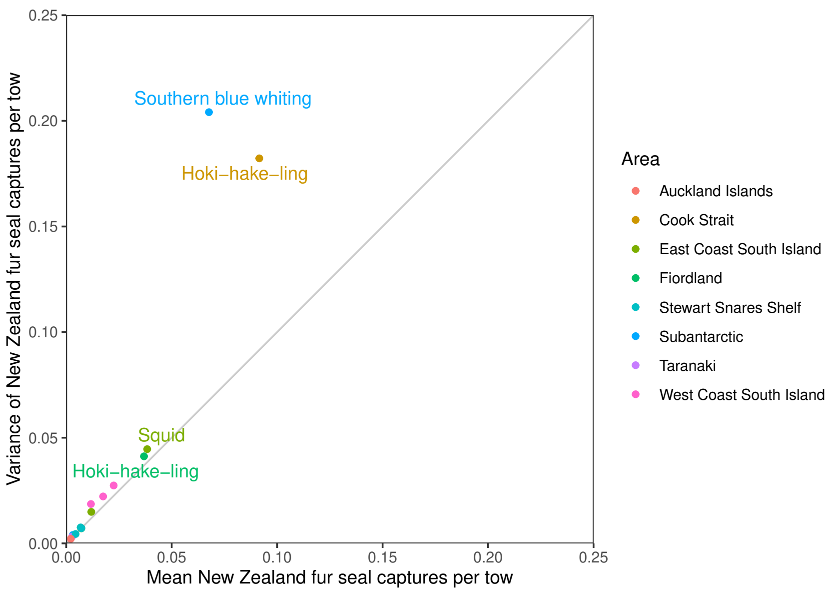


Figure 2: Mean to variance of observed New Zealand fur seal captures per tow, summarised by area and target trawl fishery (as used in the current estimation of New Zealand fur seal captures). Points are coloured by area, with targets indicated for area-fishery strata with a mean of more than 0.03 fur seal captures per tow (used in the estimation).

In extending the previous modelling, we first included all the main effects, with the year effect and the vessel effect being included as random effects:

```
count | trials(events) ~ area + target + sin_doy + cos_doy + distance +
        (1 | year) + (1 | vessel).
```

We then extended the model to add both an area-year interaction and a target-year interaction. An area-year interaction accounts for changes in fur seal capture rates over time for each area, instead of assuming that capture rates change at the same rate in all areas; for example, a specific trend in fur seal capture rates over time in a target fishery could be due to changes in practice within that fishery:

```
count | trials(events) ~ area + target + sin_doy + cos_doy + distance +
        (1 | year) + (1 | vessel) + (1| area:year) + (1| target:year).
```

We included a target-fishery-vessel interaction, which allowed for vessels to have different fur seal capture rates (relative to other vessels), when targeting different species. This interaction is appropriate for vessels that change target fisheries during the year or that moved between fisheries over the period covered by the model:

```
count | trials(events) ~ area + target + sin_doy + cos_doy + distance +
        (1 | year) + (1 | vessel) + (1| area:year) + (1| target:year) +
        (1 | vessel:target).
```

Finally, we tested the inclusion of an interaction between the area and the target, allowing for variation in relative capture rate between target fisheries in different areas (such as hoki fisheries in the East Coast South Island, Cook Strait, and the West Coast South Island areas):

```
count | trials(events) ~ area + target + sin_doy + cos_doy + distance +
        (1 | year) + (1 | vessel) + (1| area:year) + (1| target:year) +
        (1 | vessel:target) + (1 | area:target).
```

The priors for the weights of the fixed effects were normal distributions with mean 0 and standard deviation 3; the priors for the standard deviation of the random effects were half-normal distributions with standard deviation 1. For the intercept and the priors of the shape parameters, default priors from BRMS were used (a Student's t-distribution with three degrees of freedom, a mean of -2 and a scale parameter of 10 for the intercept; a gamma(0.01, 0.01) distribution for the base shape parameter; and an improper uniform prior for the relative weights of the other shape parameters). During model selection, the models were run with four chains for 500 iterations, using the no-U-turn sampler (NUTS; Hoffman & Gelman 2014). For the final run, the model was run for 2000 iterations, and the first 1000 iterations were discarded, resulting in a total of 4000 samples from the posterior distribution for each parameter. Model convergence was tested using the $\hat{R}$ measure (Brooks & Gelman 1998, Vehtari et al. 2020), which is the ratio of the variance between and within chains. If this ratio is close to one (i.e., less than 1.1) for all parameters in the model, then the model can be considered to have converged. Model selection was carried out taking into account the approximate leave-one-out information criterion (LOOIC; Vehtari et al. 2016). The LOOIC is similar to the Aikake Information Criterion (AIC), measuring model performance against model complexity, but the LOOIC is more suited to Bayesian frameworks using non-normal distributions. Comparatively small LOOIC values indicate better model fit.

2.5 Estimation of New Zealand fur seal and turtle captures in surface-longline fisheries

2.5.1 Surface-longline fishing effort

Surface-longline fishing in New Zealand can be divided into two fleets based on the length of the vessel. In general, vessels over 45 m in length were Japanese charter vessels (there was a single New Zealand registered vessel over 45 m long that fished with the Japanese fleet and that stopped fishing in 2003–04). The large vessels targeted southern bluefin tuna on 90.1% of sets between 2002–03 and 2014–15, and targeted albacore on 7.2% of sets. There were a total of 10 vessels in this fleet that were active in the period between 2002–03 and 2014–15. Due to changes in the regulation of foreign vessels, this fleet left New Zealand in June 2015.

The second fleet active between 2002–03 and 2017–18 comprised surface-longline vessels of less than 45 m in length. There were 177 vessels in this fleet, and these were all New Zealand registered, with the exception of a single Australian registered vessel that fished during 2006–07. During the period targeted by the estimation, these vessels targeted bigeye tuna on 50.1% of sets, southern bluefin tuna on 37.0% of sets, and swordfish on 8.1% of sets.

A summary of surface-longline fishing effort, showing the fishing effort and observer coverage by fishing year, the spatial distribution during the 2017–18 fishing year, and the monthly distribution of the fishing effort is shown in Appendix A (Section A.2.12). There was a marked decline in the number of hooks set over the period (Figure 3). In 2002–03, large vessels set around 2 000 000 hooks. This effort reduced to around 500 000 hooks set annually from 2009–10 until the large vessels left New Zealand during the 2014–15 fishing year. With the exception of 2006–07 and 2007–08, observer coverage on the large vessels was close to 100%. The small vessels initially set over 8 000 000 hooks, with this reducing to around 2 000 000 hooks set annually from 2006–07. Observer coverage of small vessel surface-longline fishing increased from zero in 2002–03 to around 15% between 2015–16 and 2017–18.

Fishing by Japanese and domestic vessels targeting southern bluefin tuna had a different spatial distribution (Figure 4). The Japanese fleet was highly localised, fishing offshore from the South Island south-west coast. The domestic fleet fished more inshore and also targeted southern bluefin tuna in North Island waters. After the Japanese fleet left New Zealand (in the 2014–15 fishing year), there was an increase in the number of hooks set by domestic vessels. There was no substantial increase in fishing effort in the statistical areas where the Japanese vessels had previously fished.

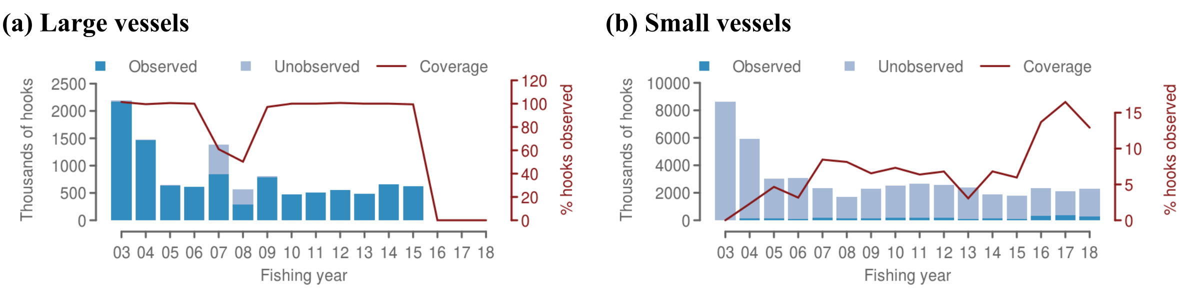


Figure 3: Surface-longline fishing effort for (a) large vessels (≥45 m) and (b) small vessels (<45 m). For each fishing year the bar indicates the number of thousands of hooks set, the number observed, and the observer coverage rate (% hooks observed).

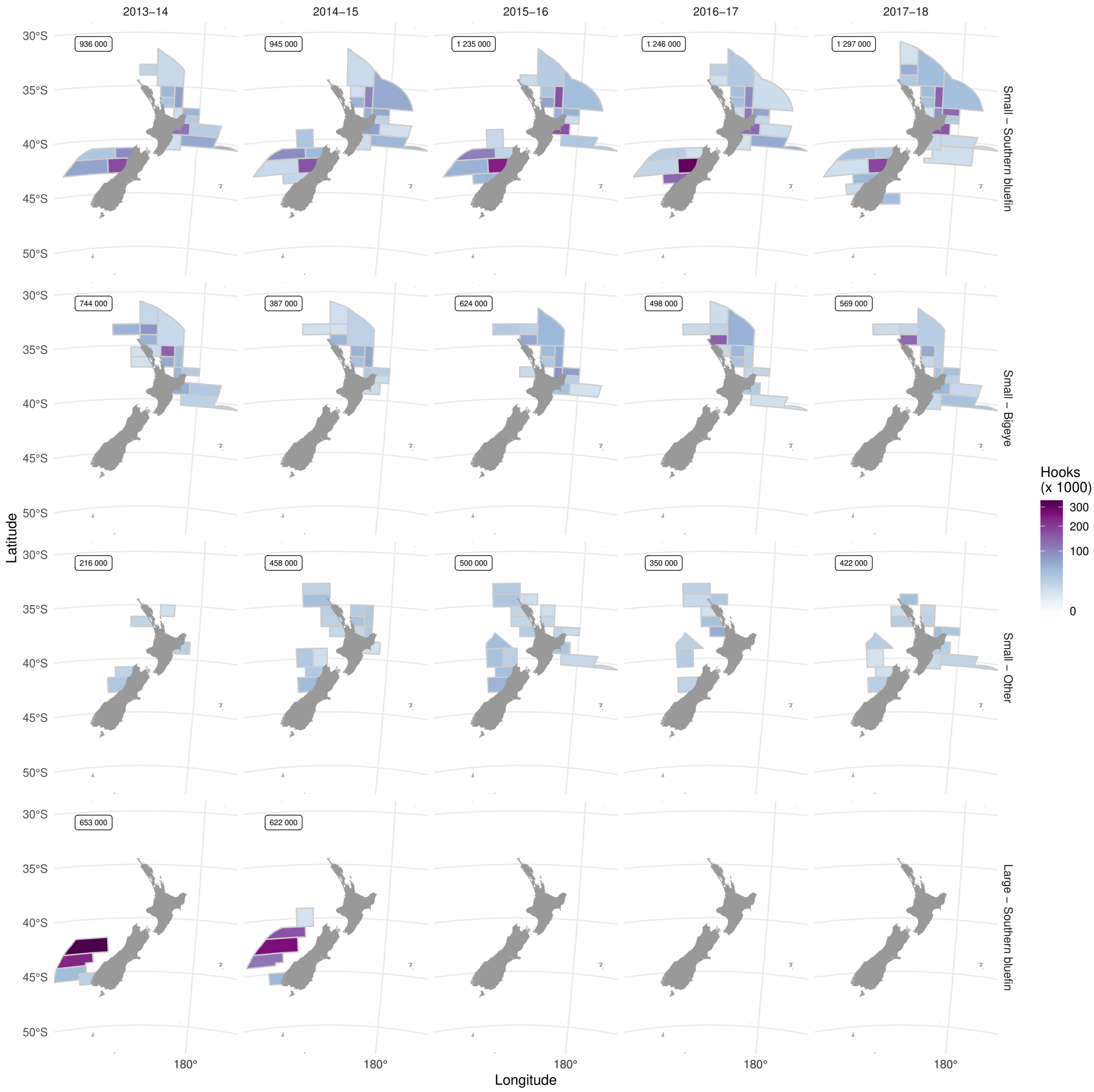


Figure 4: Change in the spatial distribution of surface-longline fishing effort over time, for the fishing years 2013–14 to 2017–18. The distributions are shown for fishing by small vessels (< 45 m long) targeting bluefin tuna, bigeye tuna, and other species; and for large vessels ($\geq$ 45 m) targeting southern bluefin. The intensity of colour within each statistical area indicates the number of hooks set (in thousands of hooks). The total number of hooks set in that fishery and year is shown in the label above each plot.

2.5.2 Statistical modelling of captures in surface-longline fisheries

The estimation of New Zealand fur seal and sea turtle captures in surface-longline fisheries used an extension of the generalised linear modelling approach that was used previously (e.g., Abraham & Berkenbusch 2017), with data including the period between the 2002–03 and 2017–18 fishing years. The same approach was followed for estimating of captures of New Zealand fur seal and sea turtles (all turtle species grouped together). The number of observed captures (including both live and dead animals) at each observed fishing events was assumed to be drawn from a Poisson distribution, with the logarithm of the mean capture rate being a linear function of the covariates (Table 6). A model was fitted to the observed data, and was then used to estimate captures on unobserved fishing, with the total estimates being the combination of the observed captures and the estimated captures on unobserved fishing. The model dataset had a total of 50 344 sets (58 501 785 hooks). There were 27 sets (16 300 hooks) that had either the sea surface temperature or chlorophyll covariate undefined. This fishing effort (representing 0.028% of the total fishing effort) was not included when estimating either New Zealand fur seal or turtle captures.

The model was fitted within a Bayesian framework, using the software BRMS (Bürkner 2017). The full model (including all covariates) had the model formula (in BRMS notation):

```
captures ~ offset(log(effort/1000)) + vessel_size + sst + (1|fishery) +
(1|area) + (1|year) + s(month, bs="cc", k=6) + s(log(chl)).
```

The captures were assumed to be proportional to the number of hooks set, which was included in the model using an offset term. The two-category vessel size effect and the numerical sea surface temperature effect were both included as fixed effects; the categorical fishery, area, and year effects were included as random effects; and the numerical month and chlorophyll effects were included in the model as splines. The month effect was included as a cyclic spline, which smoothly interpolated between December (month 12) and January (month 1), wherea chlorophyll was included as a thin-plate spline, on a logarithmic scale.

The priors for the coefficients of the fixed covariates; the standard deviation of the random effects; and the standard deviation of the variability within the splines were all set to unit normal (or half-normal) distributions. The models were run for 1000 warm-up iterations, and 1000 sampling iterations from four chains. Fitted models were checked for convergence using the Gelman-Rubin diagnostic ($\hat{R}$) which compares within chain and between chain variance (Brooks & Gelman 1998, Vehtari et al. 2020). A value of $\hat{R}$ close to one indicates convergence. The total number of samples, across the four chains, was 4000. The effective number of samples may be reduced due to auto-correlation along the chains, and the bulk Effective Sample Size (ESS) is also reported (Vehtari et al. 2020). If the bulk ESS is low, than the estimates of the mean and median may be uncertain. The model fitting was also monitored for divergent transitions in the Hamiltonian Monte-Carlo (HMC) sampler. The target average acceptance rate in Stan was increased from the default value to 0.98 in order to reduce the number of divergent transitions.

A model selection process was carried out, removing and adding covariates to identify the combination of covariates that maximised the expected log predictive density (ELPD; the ELPD is equal to -2 times the LOOIC, and so maximising the ELPD is equivalent to minimising the LOOIC). Model selection began by fitting the model with all covariates included, and proceeded in a series of rounds, with a reducing number of covariates. At each round, after having identified a candidate best model, all neighbouring models (created by the removal of a single covariate) were fitted and compared with the candidate model. If a new best model was found, then the process was repeated for another round. The process stopped when the best model had a higher ELPD than all the models with one less covariate. All models included the offset term, and no interaction terms were tested. The selected model was the model with the maximum ELPD, across all the fitted models. Bayesian stacking model weights were also calculated (Yao et al. 2018), indicating the relative weights of each of the fitted models that would be used in model averaging of the posterior predictive distribution.

2.6 Presentation of model estimates and fitted models

The fitted models were used to estimate captures or each fishing event covered by the method, spatial extent and period of the model. Estimates were made at the event level (common dolphin, New Zealand fur seal and turtle in surface longline), or at the event group level (New Zealand fur seal in trawl fisheries). A database was used to hold 4000 samples from the posterior distribution for each event or event group. Because the samples are stored at an event or event-group level, they may be aggregated as required. Uncertainty of aggregated quantities may be calculated by repeating the aggregation for each sample.

Table 6: Covariates used in estimating captures in surface-longline fisheries. For each covariate, the table gives the abbreviation (Abb.) used to refer to the covariate in model names, the representation of the covariate in BRMS notation, and a description.

Covariate	Abb.	Representation	Definition
Vessel size	`v`	`vessel`	Either large (over 45 m length) or small, with large vessels chosen as the base case. With some exceptions, vessel size divided the surface-longline fleet into Japanese charter vessels and the domestic fleet. The vessel size was included in the models as a fixed effect, with large vessels being the base case.
Sea surface temperature	`t`	`sst`	The sea surface temperature (SST) was the NOAA weekly mean SST (°C) at one-degree resolution (Reynolds et al. 2002), obtained from https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.html. The start position and date of fishing events were used to obtain the corresponding sea surface temperature. The sea surface temperature was included in the model as a fixed numeric effect, with values between 9.6 and 23.4.
Fishery	`f`	`(1|fishery)`	Target fishery, either southern bluefin tuna (*Thunnus maccoyii*), bigeye tuna (*Thunnus obesus*), swordfish (*Xiphias gladius*), albacore (*Thunnus alalunga*), or other targets. There were less than 1000 sets targeting other targets across the whole dataset. The target fishery was included in the model as a random effect.
Area	`a`	`(1|area)`	Groupings of Protected Species Capture reporting areas (Figure 1), either Fiordland, West Coast South Island, West Coast North Island, Kermadec, East Coast North Island, Northland-Hauraki, or Bay of Plenty. Areas with fewer than 200 sets across the whole dataset were grouped with areas that had more surface longline effort. In particular, the Taranaki area was grouped with the West Coast North Island area; the Cook Strait and Chatham Rise areas were grouped with the East Coast North Island area; and the East Coast South Island, Stewart-Snares, and Subantarctic areas were grouped with the Fiordland area (Figure 1). The area was included in the models as a random effect.
Fishing year	`y`	`(1|year)`	Fishing year (1 October to 30 September in the following year; when represented as a four digit number, this number refers to the second year, so 2016–17 is the 2017 fishing year). The fishing year was represented as categorical variable, with 16 years from 2002–03 to 2017–18. The fishing year was included in the models as a random effect.
Month	`s`	`s(month, bs='cc', k=6)`	Month of the start date of the fishing event (an integer, with values from 1 through 12). The month was included in the models as a cyclic cubic spline (the month effect was constrained so that January and December meet smoothly). The number of knots in the spline was set to 6.
Chlorophyll	`c`	`s(log(chl))`	The sea surface chlorophyll was obtained from 9-km MODIS Aqua satellite data (NASA 2018). The chlorophyll concentration was first obtained by interpolating the monthly distribution to the time and position of the start of the fishing. If the monthly data were missing (for example, because of cloud) then the concentration from the annual distribution was used. The chlorophyll concentration was a numeric variable, with values between 0.043 and 12.9 (-3.2 and 2.6 on the logarithmic scale). Chlorophyll was included in the models as a thin-plate spline of the logarithm of the concentration, allowing for a non-linear relationship between captures and chlorophyll.

For the most recent models, the database of estimates may be queried through the protected species capture (PSC) website, which provides summaries of captures by area, fishing year, calendar year, and vessel-size strata (https://data.dragonfly.co.nz/psc/). The database also contains previous models, since the 2009–10 fishing year; however the previous models are not available through the PSC website.

Summaries of the estimates for common dolphin, New Zealand fur seal, and turtle (and for selected fisheries or groups of fisheries) from the protected species capture website are presented in Appendix A). The summaries also provide information of the fishing effort, observed effort and captures, estimated captures and estimated capture rate.

Model summaries are presented in Appendix B, including a statistical summary of the parameters (mean, median, and 95% credible interval, calculated from the 2.5% and 97.5% quantiles of the posterior distribution) for each model. Depending on the modelling software used, the diagnostic information may include the half-width and convergence tests (Heidelberger & Welch 1983), the $\hat{R}$ measure (Brooks & Gelman 1998, Vehtari et al. 2020), the reduction in the effective number of samples caused by autocorrelation in the chains, or the bulk ESS. Also included are trace plots, showing the samples from each chain, which allows visual inspection of the quality of the model fit. In these summaries of the posterior distribution, covariates associated with discrete strata may be exponentiated, so that they can be interpreted as multiplicative effects.

3. RESULTS

3.1 Observed captures of marine mammals and turtles, 2015–16 to 2017–18

3.1.1 Observed cetacean captures during 2015–16

In the 2015–16 fishing year, there were seven observed captures of common dolphin in trawl fisheries, all of the captured dolphins died (Appendix A, Table A-1). Two of these observed common dolphin captures were in the mackerel trawl fishery, two captures were in inshore trawls targeting tarakihi (*Nemadactylus macropterus* and *N. rex*) off the North Island west coast and Northland-Hauraki areas, respectively; another two captures (in one capture event) were in the Northland-Hauraki area targeting John dory (*Zeus faber*), with the remaining observed common dolphin captures in hoki trawl fishing in Cook Strait. The four common dolphin captures in trawl fisheries targeting tarakihi and John dory were in Precision Seafood Harvest (PSH) gear. This gear has been recently developed and is a type of trawl net that keeps fish actively swimming within a low water flow section of the net.

In addition to common dolphin, one dusky dolphin (*Lagenorhynchus obscurus*) was observed killed in a school shark (*Galeorhinus galeus*) set net off the South Island east coast, one dusky dolphin was observed killed in a hoki trawl in Cook Strait, and two bottlenose dolphin (*Tursiops truncatus*) were observed caught and released alive. The bottlenose dolphin captures were both in surface-longline fisheries targeting southern bluefin tuna on the North Island east coast.

3.1.2 Observed cetacean captures during 2016–17

In the 2016–17 fishing year, there were two observed captures of unidentified beaked whale (Ziphiidae) during surface-longline fishing (one capture was reported from fishing targeting swordfish off the South Island west coast, and one from fishing targeting bluefin tuna in Bay of Plenty) (Appendix A, Table A-1). Both of the whales were cut free and released alive (one by cutting the snood and one by cutting the backbone of the line). There had only been three other observed captures of beaked whales previously, all in surface-longline fisheries (Abraham et al. 2017).

There were three captures of common dolphin reported by observers during 2016–17: one common dolphin was killed during set-net fishing targeting trevally in the Taranaki area; one was killed during trawl fishing targeting snapper (*Pagrus auratus*) off the North Island east coast; and one common dolphin was caught and released alive during surface-longline fishing targeting bigeye tuna in the Northland–

Hauraki Gulf area. This fishing year was the first year since 1998–99 without observed common dolphin captures in the large-vessel jack mackerel trawl fishery off the North Island west coast.

During 2016–17, there was one observer record of a Hector's dolphin mortality during set-net fishing off the South Island east coast, targeting rig (*Mustelus lenticulatus*).

A bottlenose dolphin was also observed killed during trawling targeting snapper in the Northland–Hauraki Gulf area.

3.1.3 Observed cetacean captures during 2017–18

During the 2017–18 fishing year, there were two orca (*Orcinus orca*) captures reported by observers. These records are the only orca captures that have been documented by observers since records began in 1992. One orca was caught during surface-longline fishing for southern bluefin tuna in the Bay of Plenty area, and this individual was released alive. The observer described the capture as an "orca calf, 3m, lip hooked, broke line". The second orca was caught during trawl fishing for silver warehou (*Seriolella punctata*), in the South Island east coast area. The observer described the capture as having "extensive lacerations to body. Likely dead when caught in net. No rigor". Owing to the unusual occurrence of an orca capture in trawl, the Ministry for Primary Industries investigated this incidence, including interviews of the observer and vessel crew, and an expert workshop to ascertain the likely causes of death (Sharp & Bock 2018). Based on available information, primarily photographic evidence of extensive injuries to the body, workshop participants concluded that the orca was most likely killed by vessel strike, and was already dead at the time the carcass was recovered from the trawl net.

There were three observer records of long-beaked common dolphin (*Delphinus capensis*) being killed by trawl fishing during 2017–18. Two captures were in inshore-trawl fishing targeting tarakihi, on the same fishing trip in the Bay of Plenty area. The third capture was in the large-vessel jack-mackerel trawl fishery off the North Island west coast. This capture was not included in the estimates of common dolphin captures, because it was a different species. These three captures were reported by observers as common dolphin, with the identification changed to long-beaked common dolphin following review of photographs; they are the only observed captures of long-beaked common dolphin since records began in 1992.

There were two observer records of long-finned pilot whale (*Globicephala melas*) caught during 2017–18. One of the captures was in the bigeye surface-longline fishery in the east coast North Island area and was released alive; the other individual was killed during hoki trawl fishing in the Stewart-Snares shelf area.

There was only a single observer record of a common dolphin capture, killed during trawl fishing targeting tarakihi in the Bay of Plenty area. As in 2016–17, there were no observed captures of common dolphin in the large-vessel mackerel trawl fishery off the North Island west coast.

3.1.4 Observed pinniped captures during 2015–16

There were 109 captures of New Zealand fur seal observed in trawl fisheries during 2015–16, during 69 tows (Table A-1). Of these captures, ten fur seal were released alive. There were also three observed captures of New Zealand fur seal in surface-longline fisheries, and all of the captured animals were released alive. These fur seal captures in surface longlines were the lowest annual number of captures observed in surface-longline fisheries over all years included in the estimation. In addition, there was also one New Zealand fur seal observed caught during set-net fishing in 2015–16, targeting school shark in the Stewart-Snares shelf area.

There were four captures of New Zealand sea lion during 2015–16, and all of these captures were in trawl fishing, in three separate tows. None of the captured sea lions were released alive. Three of the four sea lion captures were on a single vessel targeting southern blue whiting, on consecutive tows, in the Campbell Islands fishery. These animals were recorded by the observer as being recovered from the SLED. Two of the animals were recorded by the observer as being female, with one animal recorded as being male. The remaining capture was of a female sea lion on a trawl vessel targeting barracouta, close to Stewart Island, with the animal recorded by the observer as being dead “in the pounds”.

3.1.5 Observed pinniped captures during 2016–17

During 2016–17, there were 79 observed captures of New Zealand fur seal in trawl fisheries, from 69 distinct tows. Of these captures, the majority (67) were killed. Around half (37) of the observed captures were in hoki trawl fisheries. In addition to the captures in trawl fisheries, 32 New Zealand fur seals were caught in surface-longline fisheries (30 of these captures were released alive); five New Zealand fur seal were killed during set-net fishing targeting school shark and rig, in the Stewart-Snares, Fiordland, and east coast South Island areas. In addition, one New Zealand fur seal was reported killed during bottom-longline fishing for school shark in the Stewart-Snares area. This record was only the fifth fur seal observed caught during bottom-longline fishing since records began in 1992.

There were three observed captures of New Zealand sea lion during 2016–17. All three individuals were killed in the Auckland Islands squid (*Nototodarus sloanii* and *N. gouldi*) trawl fishery.

3.1.6 Observed pinniped captures during 2017–18

During 2017–18, there were 80 observed captures of New Zealand fur seal in trawl fisheries, from 70 distinct tows. Of these captures, the majority (70) were killed. Around half (41) of the observed New Zealand fur seal captures were in hoki trawl fisheries. There were also 12 New Zealand fur seals caught in surface-longline fisheries (with 10 live releases); and 11 New Zealand fur seals were captured during set-net fishing (all mortalities). The set-net captures included three New Zealand fur seals that were caught during fishing targeting butterfish (*Odax pullus*) in the Fiordland area, seven fur seals were caught during fishing targeting school shark in the Fiordland, east coast South Island, and Stewart-Snares areas, and one New Zealand fur seal was caught during fishing targeting warehou (*Seriolella brama*) in the Taranaki area.

There were eight observed captures of New Zealand sea lion during 2017–18 (including seven mortalities): one capture was in ling (*Genypterus blacodes*) trawl in the subantarctic area; two captures were in southern blue whiting trawl in the subantarctic area; two captures were in scampi trawl in the Auckland Islands area; two captures were in squid trawl in the Auckland Islands area; and one capture was in squid trawl in the Stewart-Snares area.

3.1.7 Observed sea turtle captures, 2015–16 to 2017–18

There were three different sea turtle species reported by observers for the period between 2015–16 and 2017–18: nine captures of leatherback turtle (*Dermochelys coriacea*), and one capture each of green turtle (*Chelonia mydas*) and loggerhead turtle (*Caretta caretta*) (Table A-1). In addition, there were two captures of unidentified turtle species. The loggerhead turtle was the first observed capture of this species in New Zealand fisheries. One leatherback turtle was killed during trawl fishing targeting trevally in the West Coast North Island area, all of the twelve other turtle captures during this period were in surface-longline fishing and were recorded as live releases. Of the captures in surface-longline fisheries, six were in fishing targeting bigeye tuna, five were in fishing targeting swordfish, and one was in fishing targeting southern bluefin tuna. Grouped by area, seven of the surface-longline captures were in the East Coast North Island area, three were in the Northland-Hauraki area, and two were in the West Coast North Island area.

The observed turtle captures occurred in all three years, with seven captures during 2015–16, two captures during 2016–17, and four captures during 2017–18.

3.2 Common dolphin captures in mackerel trawl fisheries

3.2.1 Observed common dolphin captures included in the estimation

In the 23-year period between 1995–96 and 2017–18, there were 225 observed captures of common dolphin. The majority (188) of these captures were during trawl fishing targeting jack mackerel. Throughout the reporting period, the highest number of observed captures in the mackerel fishery were in 2013–14, when 28 common dolphin captures were recorded, coinciding with a marked increase in observer coverage (see Appendix A, Table A-2). Since then, observer effort in the jack mackerel fishery has remained high, at over 70% each fishing year, and the number of observed captures has declined: there were only two observed common dolphin captures in this fishery between 2015–16 and 2017–18 (with concomitant observer coverage of 73 to 90% in this three-year period). These two captures occurred in each of the two northern sub-areas (Figure A-1).

During the 2013–14 and 2014–15 fishing years, a single vessel (vessel A) caught 38 common dolphin in mackerel trawl. This vessel was 100% observed, and exited the fishery after these two years. (This vessel also had high numbers of fur seal captures in other fisheries, including 44 fur seal captures in 2013–14, the highest number of captures of any vessel in any year since 1998–99.)

The observed fishing effort included in the model of estimated captures in mackerel trawl was selected on the basis of trip and, therefore, included some tows that targeted other species. In addition to the captures in mackerel trawl, there were two captures during fishing targeting barracouta that were included in the mackerel trawl model. The captures included in the model were in both sub-areas of the North Island west coast (Figure 5 without captures from vessel A; see also Table A-3 and Figure A-2).

3.2.2 Estimated common dolphin captures in mackerel trawl fisheries

Model chains passed the convergence and half-width tests (Heidelberger & Welch 1983) (see Appendix B.1 for model parameters and diagnostics for the final model). The samples from the two MCMC chains overlapped, indicating that there were no considerable structural limitations with any of the models. When the models were used to estimate captures on observed fishing effort, the observed captures were within the range of the estimates (Figure 6). The observed captures were above or below the mean estimate, depending on the year. In the years when vessel A was fishing, the model that excluded vessel A had a lower mean estimate. Otherwise, the mean estimates from the three models were similar (with the mean estimate from each model well within the credible intervals of the mean estimate from the other models).

When the 2013–14 and 2014–15 fishing years were excluded, the root mean squared error between the mean estimates from the models and the observed data (Figure 6a) was 3.49 captures for the model with no vessel A and a period effect; it was 4.45 captures for the model with vessel A and a period effect, and 4.57 captures for the model with vessel A included, but with no period effect. The annual mean estimates were closest to the observed data for the model without vessel A and with a period effect.

The period effect, which allowed the base capture rate during the period 2008–09 to 2017–18 to vary relative to the earlier years, was estimated within the model as 0.135 (95% c.i.: 0.032–0.384). All other effects being equal, this period effect indicates an estimated reduction in dolphin capture events of about 87% (62 to 97%) following the implementation of the MMOP. This decrease may not be directly related to the introduction of the MMOP. For example, if there had been a decrease in the dolphin population in the area of the jack mackerel fishery, or if dolphin had learnt to not be caught in the trawl, then these would both lead to a decrease in the period effect.

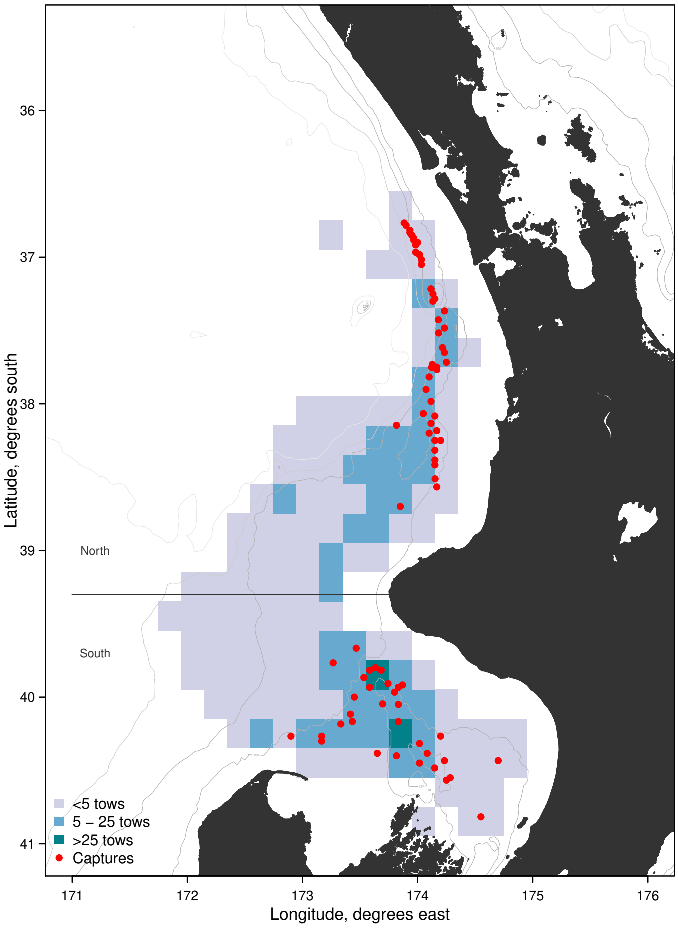
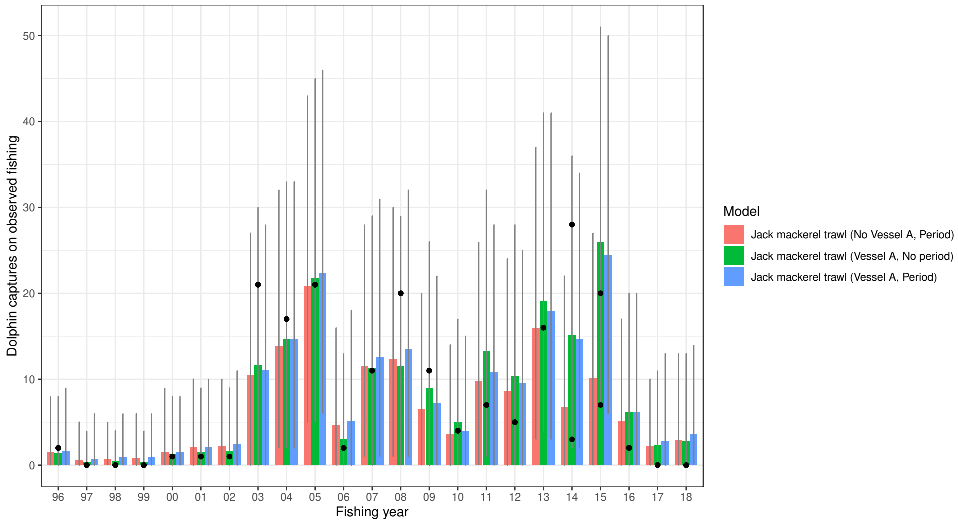


Figure 5: Spatial distribution of observed trawl effort (blue squares) and common dolphin captures (red dots) between 1995–96 and 2017–18, included in the statistical model to estimate total captures of common dolphin in the large-vessel mackerel trawl fishery. The line at 39°18′ S divides the large-vessel mackerel fishery on the North Island's west coast into northern and southern sub-areas.

(a) Observed fishing effort



(b) All fishing effort

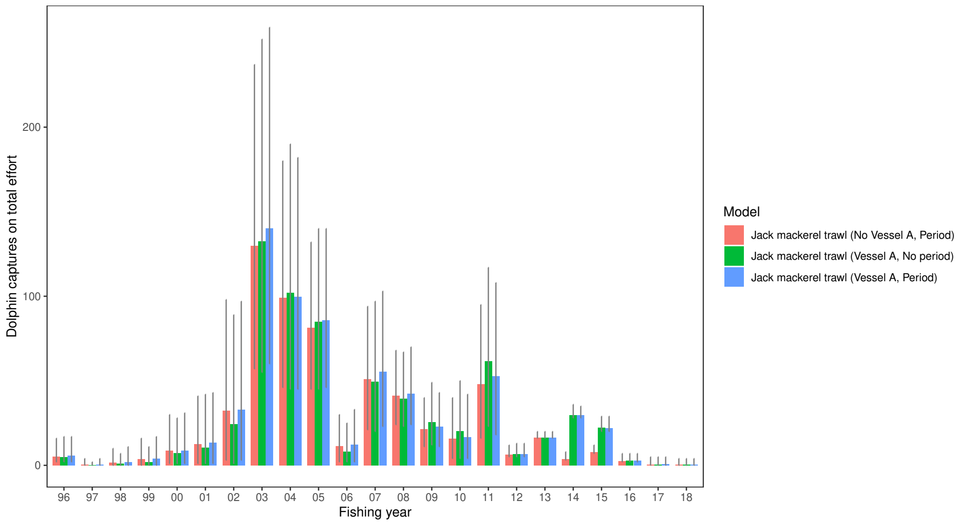


Figure 6: Comparison between the three candidate models for estimating common dolphin captures in the large-vessel mackerel trawl fisheries. Models were distinguished by inclusion or exclusion of vessel A (characterised by high numbers of observed captures in 2013–14 and 2014–15) and a "period" covariate that was introduced to the current model to account for the introduction of a code of conduct for bycatch mitigation on 1 October 2008, the Marine Mammals Operational Procedures (Deepwater Group 2018). Shown are: (a) observed fishing, and (b) all fishing in the modelled mackerel trawl fishery. For each model, the bars show the mean estimated captures, with lines indicating the 95% credible interval. In (a), dots mark the observed captures, with two values in 2013–14 and 2014–15 indicating the higher value including vessel A, which had high numbers of observed captures in these two fishing years. The higher values is to blue and green bars, with the lower value (excluding vessel A) compared to the red bar. Red bars in (b) are estimates across total fishing effort, excluding vessel A.

The other covariates in the model of common dolphin captures in large-vessel West Coast North Island mackerel trawl fisheries were similar to estimated covariates from a fit of the model to data from 1995–96 to 2010–11 (Table 7). Dolphin captures were more likely when the headline of the net was close to the surface, less likely during the day, less likely in the southern sub-area, and more likely on longer tows. This finding showed that even with an additional seven years of observer data, the parameters of the model have remained stable.

Table 7: Comparison between the model parameters from the current model (fitted on data from 1995–96 to 2017–18), and a previous model (fitted to data from 1995–96 to 2010–2011, see Thompson et al. 2013a, Thompson et al. 2013b). The "period" covariate was introduced to the current model to account for the introduction of a code of conduct for bycatch mitigation on 1 October 2008, the Marine Mammals Operational Procedures (Deepwater Group 2018).

Parameter	Data to 2010–11		Data to 2017–18	
	Mean	95% c.i.	Mean	95% c.i.
Poisson mean of dolphin caught per capture event	2.1	1.7 – 2.6	1.8	1.5 – 2.2
Headline depth, $\beta_{headline}$	-0.033	-0.045 – -0.022	-0.034	-0.045 – -0.023
Log trawl duration, $\beta_{duration}$	1.470	0.700 – 2.285	1.493	0.842 – 2.157
Light, relative to Dark, $\exp(\beta_{light})$	0.177	0.075 – 0.346	0.265	0.134 – 0.462
Black, relative to Dark, $\exp(\beta_{black})$	1.078	0.421 – 2.139	1.354	0.639 – 2.445
South, relative to North, $\exp(\beta_{south})$	0.539	0.246 – 0.996	0.607	0.331 – 1.003
Period, 2007–08 to 2017–18, relative to earlier, $\exp(\beta_{period})$			0.135	0.032 – 0.384

Common dolphin captures in mackerel trawl fishing during 2017–18 had a mean estimate of 0 (95% c.i.: 0–4) captures. This value was the lowest estimate in any fishing year that had fishing effort of more than 500 tows (Figure A-1). Dolphin captures have been routinely estimated in this fishery, with the model estimating captures over past years every time it has been re-run. The model estimates have remained stable over time, with the models consistently showing a peak in dolphin captures during 2002–03 (Figure 7). The addition of the MMOP period effect lowered the mean estimated captures during years of peak capture.

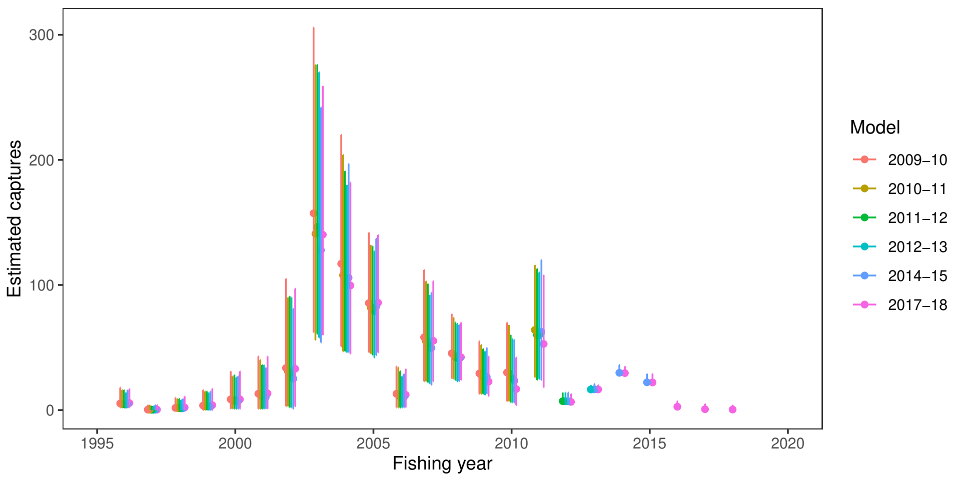


Figure 7: Comparison between models of common dolphin captures in mackerel trawl fisheries, for models fitted on data to 2009–10 (Thompson et al. 2011), 2010–11 (Thompson et al. 2013b), 2011–12 (Thompson et al. 2016), 2012–13 (Abraham et al. 2016), 2014–15 (Abraham & Berkenbusch 2017) and 2017–18 (this report). For each model, the figure shows the mean (dot) and 95% credible interval (line) of the annual estimated captures of dolphin in large-vessel west coast North Island trawl fisheries.

3.3 New Zealand fur seal captures in trawl fisheries

3.3.1 Observed fur seal captures included in the estimation

Over the 16-year assessment period, there was a total of 1691 observed New Zealand fur seal captures in trawl fisheries (Appendix C.3). Observed captures of this species were highest in 2013–14 when 159 New Zealand fur seal featured in observer records, compared with 80 observed captures in 2017–18. The recent observer records indicated a decline in New Zealand fur seal captures in trawl fisheries.

The spatial distribution of observed captures encompassed most areas off the mainland islands and in subantarctic waters, but there were relatively few observed captures in the north-eastern area (Figure 8).

Across target fisheries, the highest number of observed captures was in hoki fisheries, which had 749 records of New Zealand fur seal captures, followed by 479 observed captures in southern blue whiting trawls, and 160 observed captures in squid trawls (Appendix C.3). Other target fisheries had markedly fewer total captures, ranging between 9 and 84 observed captures over the study period (in scampi and hake targets, respectively).

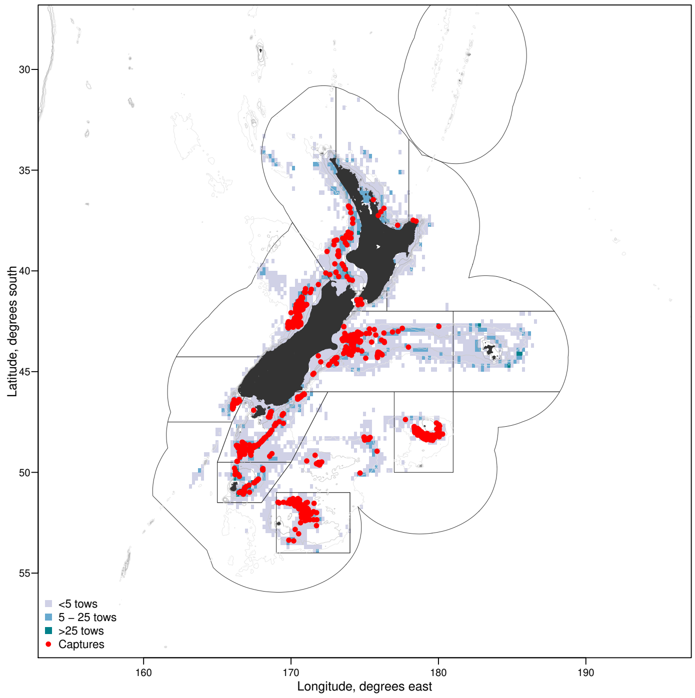


Figure 8: Spatial distribution of trawl effort (blue squares) and New Zealand fur seal captures (red dots) between 2002–03 and 2017–18, included in the statistical models to estimate total captures of fur seal in trawl fisheries in New Zealand's Exclusive Economic Zone. Annual average observed fishing effort within 0.2° squares is indicated by blue shades, model areas are indicated by lines.

3.3.2 Model of fur seal captures in trawl fisheries

The introduction of multiple overdispersion parameters improved the fit of the previous model, and the parameters were included in the base model used for exploring the interactions (Table 8). A systematic inclusion of interaction terms improved the model fit (evident in the smaller mean LOOIC values); however, when all the interaction terms were included, the model failed to converge. The model with the lowest LOOIC had target-fishery-year interactions, area:year interactions, and target-fishery-vessel interactions. The target-fishery-year interaction allowed for different changes over time in capture rates in different fisheries (for example, allowing improvements in mitigation in a fishery to be reflected in the model covariates without being extrapolated to all fisheries). The area-year interaction allowed for different trends in different areas (for example, allowing changes in the distribution of fur seal to be reflected in the data). The target-fishery-vessel interaction meant that vessels that fished in more than one target fishery may have different base capture rates in those fisheries. The model that had the lowest mean LOOIC also had the most constrained fit to the observer data, with no indication of an increase in the uncertainty.

The model was assessed by examining its ability to estimate the observed captures, when it was applied to the observed fishing effort (Figure 9). When grouped by either area or fishery, the estimated captures of New Zealand fur seal from the updated model reproduced the observed captures closely.

Table 8: Model selection for the estimation of New Zealand fur seal captures in trawl fisheries. Shown are for each of a sequence of models the mean leave-one-out information criterion (LOOIC, with a lower value indicating a better model fit), the standard error in the LOOIC, the maximum of the goodness of fit measure, $\hat{R}$, across all parameters ($\hat{R} < 1$ indicates convergence), and the upper 97.5% percentile of estimated captures on observed fishing (expressed as a percentage of the observed captures). In describing the model structures, the base model included the main covariates ("effects"), and "multiple θ" indicates that the model structure allowed for multiple overdispersion parameters. The models had different interaction terms (t: target fishery, y: year, a: area, v: vessel key); e.g., "(1 | t:y)" indicates that the model had a target-year interaction included as a random effect. The previous model used the same structure as in the preceding estimation by Abraham & Berkenbusch (2017).

Model	LOOIC mean	LOOIC s.e.	Max $\hat{R}$	Upper uncertainty
Base + (1|t:y) + (1|a:y) + (1|t:v)	6240	180	1.00	115.2
Base + (1|t:y) + (1|a:y)	6263	180	1.03	116.1
Previous, multiple θ	6296	181	1.02	121.5
Previous	6323	182	1.02	129.2
Base (includes main effects & multiple θ)	6352	183	1.02	121.8
Base + (1|t:y) + (1|a:y) + (1|t:v) + (1|a:t)	8115	233	39.23	3399397.4

(a) Fishery **(b) Area**

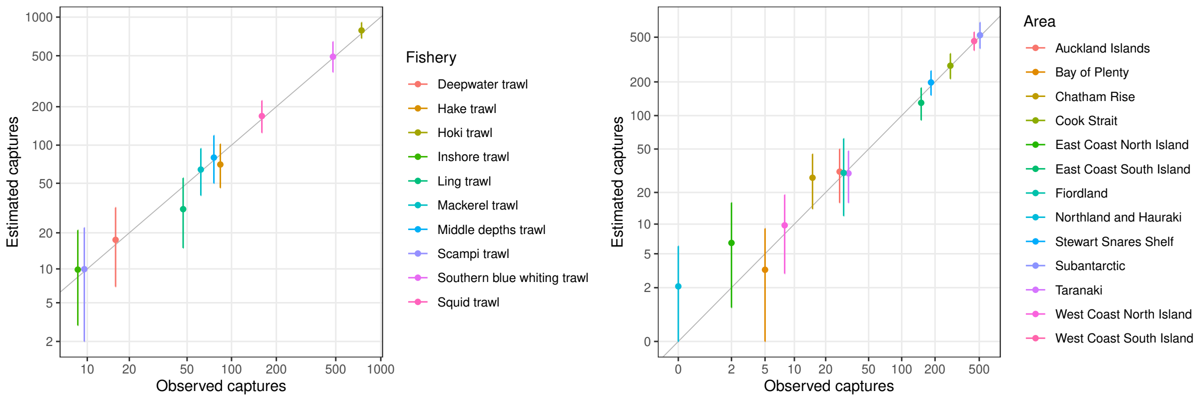


Figure 9: Comparison between the number of observed and estimated captures of New Zealand fur seal on observed fishing, by (a) target fishery and (b) summary area. Captures are totals for the model period from 2002–03 to 2017–18. Lines show the 95% credible interval of the estimated captures. Observed captures are offset to reduce overlap (note different scale on y axes).

The updated model, with interactions and with multiple overdispersion parameters, was a considerably better fit to the capture distribution, i.e., the distribution of fur seal captures on trawl groups, for trawl groups where at least one capture occurred (Figure 10). Using the previous model structure, the estimated number of New Zealand fur seal per capture event was markedly higher than was observed in southern blue whiting fisheries. Using the 90th percentile of the distribution of non-zero captures as a measure, when the model was updated, the observed 90th percentile was within the credible interval of estimates from the model. The consequence of reducing the spread of the capture distribution to improve its alignment with the observer data was a reduction in the uncertainty in the estimates (Figure 11).

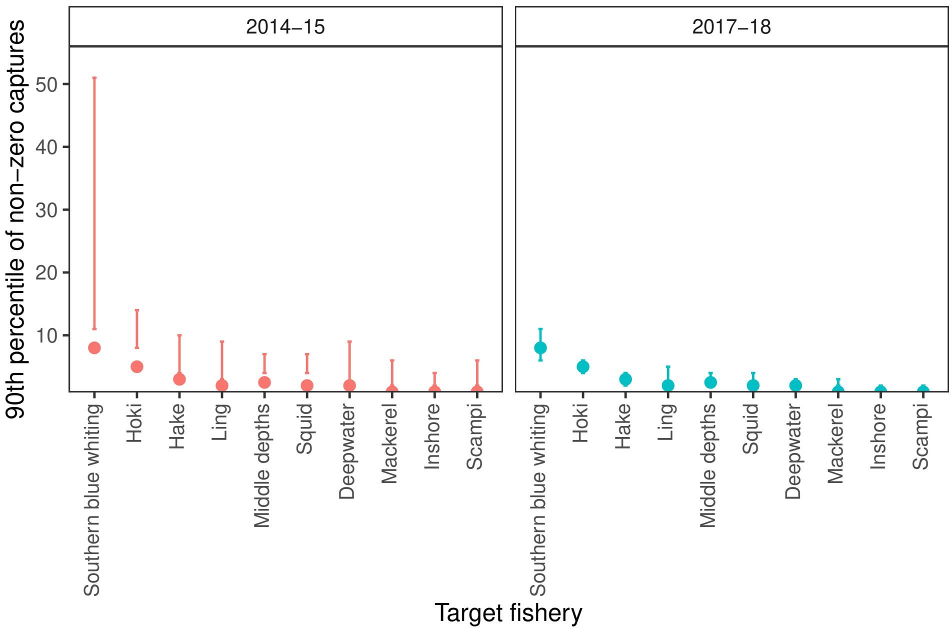


Figure 10: Comparison between estimates and observations of the 90th percentile of the number of New Zealand fur seal caught by tow group, where at least one fur seal was caught. Compared are the results from the previous model (fitted on data to 2014–15) and the current model (fitted on data to 2017–18). Dots indicate the 90th percentile of the observed number of fur seal captures (for tow groups where at least one fur seal was caught), lines indicate the 95% credible interval of the same quantity.

This effect was especially marked for southern blue whiting fisheries, which had the highest fur seal capture rate. In general, the mean estimates from the two models were aligned; however, there was a reduction in the estimated mean captures in southern blue whiting trawls, in years when the uncertainty was reduced.

New Zealand fur seal were relatively more likely to be caught in the Bounty Islands and the subantarctic areas, compared with the Stewart-Snares shelf baseline (Figure 12). Conversely, the lowest relative capture rates were from the Chatham Islands and the northern North Island areas.

Across the different target fisheries, the highest relative fur seal capture rates were in mackerel and southern blue whiting fisheries, with the lowest capture rate in trawl fisheries targeting deepwater species. Many of the covariates were correlated, and this aspect may affect interpretation of the model coefficients. For example, most of the observed tows in the subantarctic area were in deepwater species target trawl fisheries, so the high coefficient for this area was counter-balanced by the low coefficients for target fishery and distance from shore. Similarly, almost all observed tows in Cook Strait occurred in the hoki trawl target fishery, which had a high relative effect, leading to observed capture rates in this area that were higher than expected from the area coefficient alone.

There was fluctuation in the year effects over time (Figure 12). Across the time series, the median year effects were low in recent fishing years, but they were well within the 95% credible intervals of other years. There was a total of 174 vessel effects in the model. Many of the vessels had low observer coverage and no fur seal captures (see left-hand side of Figure 12(d)). Vessel A, which caught 44 fur seal in the two years it was operating, had the highest capture rate of all vessels included in the model (see far right in Figure 12(d)).

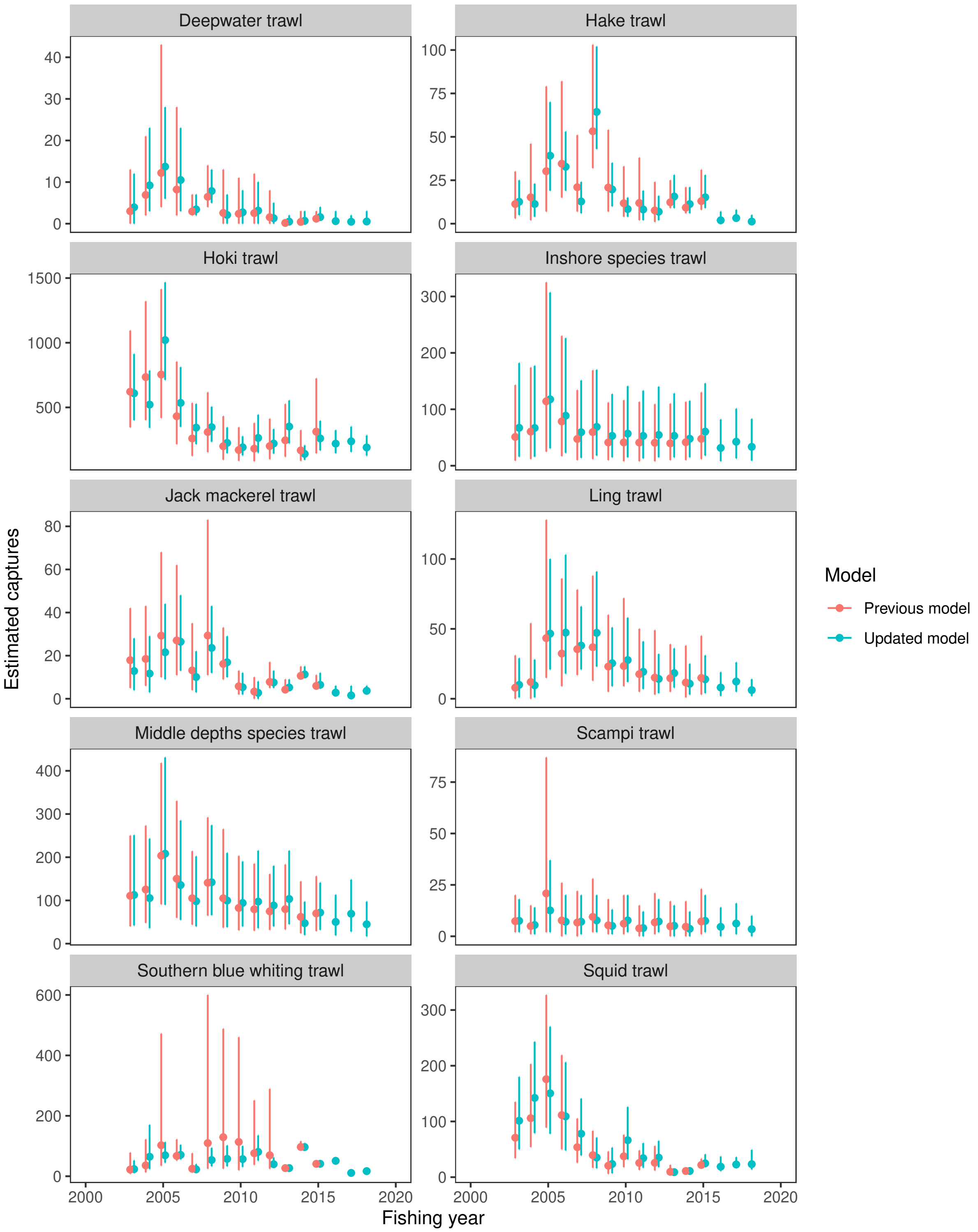


Figure 11: Comparison of the estimated number of New Zealand fur seal captures between the previous model (fitted on data to 2014–15) and the current model (fitted on data to 2017–18), by target trawl fishery and fishing year. For each of the models, dots indicate the mean estimate, lines indicate the 95% credible interval of the estimates.

The model estimated the highest relative capture rate was in the coastal zone (i.e., less than 25 km from shore) compared with a low relative capture rate at distances of 180 km or more from shore (Table B-21). Seasonal variation in the fur seal capture rate was represented through the inclusion of cosine and sine functions of the day of the year; the mean coefficient of both these terms was around 0.5 (Table B-21). These values imply higher estimated fur seal capture rates in late winter (August) relative to late summer (February).

Inspection of the interaction terms (not shown) showed a slight decrease in capture rates over time for the hoki trawl fishery and also at Bounty Islands in recent years.

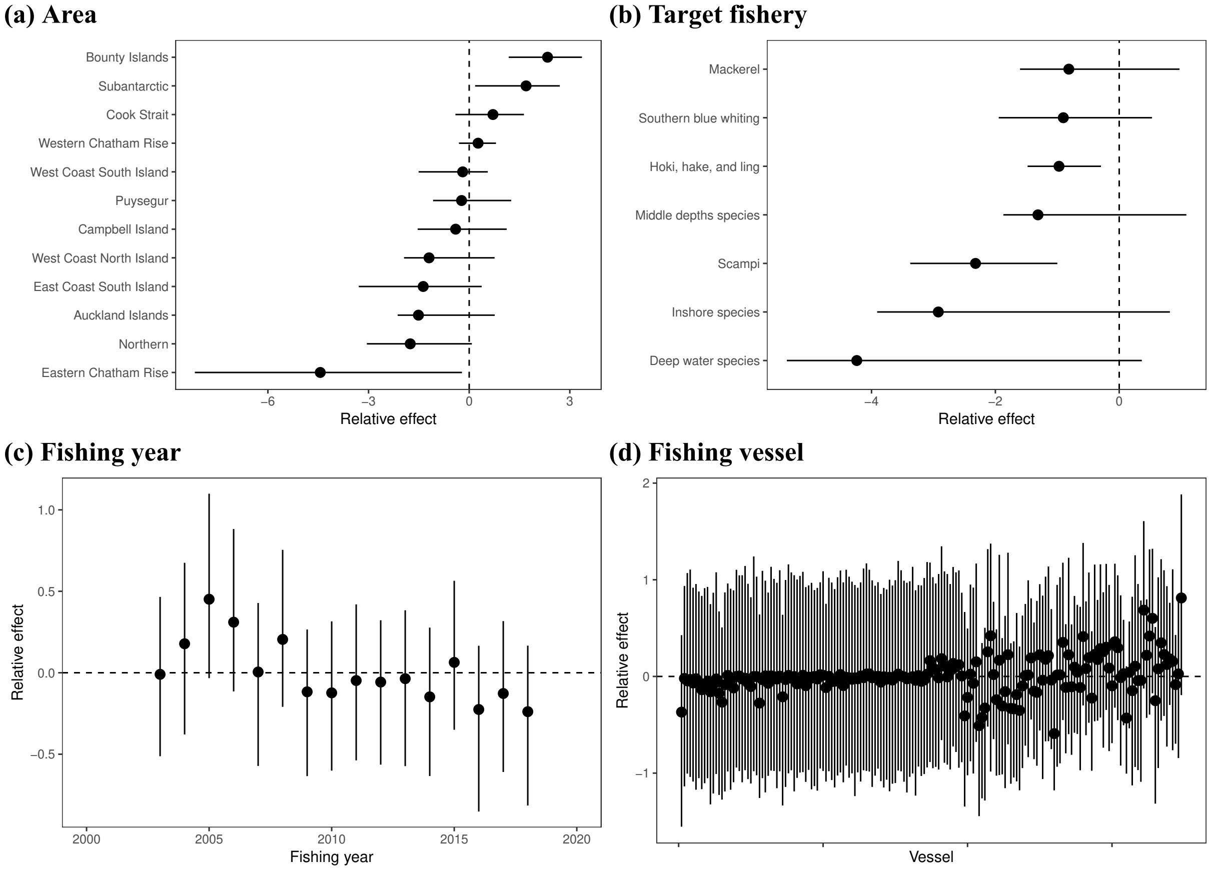


Figure 12: Summary of the posterior median (dots) and 95% credible interval (lines) of selected effects in the model of New Zealand fur seal captures in trawl fisheries. Shown are: (a) area effects (included as fixed effects, relative to the Stewart-Snares shelf), (b) target-fishery effects (included as fixed effects, relative to squid targets), (c) fishing year effects (included as random effects), and (d) vessel effects (included as random effects). In (d), the effects are ordered by the observed capture rate of each vessel.

3.3.3 Estimated captures of New Zealand fur seal in trawl fisheries

The current assessment of fur seal captures in New Zealand trawl fisheries included the period from 2002–03 to 2017–18 (see summaries in Appendix A, Section A.2; and model details in Appendix B.2). In the most recent fishing year, 2017–18, there were an estimated 324 (95% c.i.: 233 to 462) fur seal captures across all trawl fisheries (Table A-4). The corresponding capture rate was an estimated 0.44 (95% c.i.: 0.31 to 0.62) fur seals per 100 tows. Both capture estimates were the lowest values in the reporting period, and were lower than in recent years, such as in 2016–17, when there were an estimated 407 (95% c.i.: 284 to 577) fur seal captures at a capture rate of 0.52 (95% c.i.: 0.36 to 0.74) fur seals per 100 tows. Both fishing and observer effort were similar in the three most recent fishing years.

Across the different target fisheries, the highest capture estimates in 2017–18 were in hoki trawl fisheries, with an estimated 190 (95% c.i.: 128 to 283) fur seal captures and a capture rate of 1.38 (95% c.i.: 0.93 to 2.05) fur seals per 100 tows (Appendix A.2.2). Over the reporting period, this target fishery had consistently high capture estimates. Fishing effort in hoki trawl fisheries remained similar in recent years, with observed coverage between 23 and 35%. Most of the estimated fur seal captures in the hoki target fishery were in Cook Strait, with an estimated 116 (95% c.i.: 62–204) fur seal captures at a capture rate of 6.30 (95% c.i.: 3.36–11.04) fur seals per 100 tows in this area in 2017–18 (Table 9). Fur seal capture estimates were also high in the hoki trawl fishery in the West Coast South Island area.

Another trawl target fishery with high estimated fur seal captures was the southern blue whiting fishery, particularly around Bounty Islands. Across all target fisheries, fishing effort in the southern blue whiting fishery has been low, and decreased in recent years; there were 455 tows in 2017–18 (Appendix A.2.3). At the same time, this trawl fishery had 100% observer coverage, so that the 2017–18 estimates were equal to the observed captures.

Estimated fur seal captures were also high in trawl fisheries targeting middle-depth species (Appendix A.2.4). In 2017–18, the capture estimates for tows with these targets were 45 (95% c.i.: 17 to 97) fur seal and 0.72 (95% c.i.: 0.27 to 1.55) fur seals per 100 tows. Other trawl target fisheries with more than ten estimated captures in 2017–18 were inshore fisheries with 34 (95% c.i.: 9 to 83) estimated fur seal captures and squid fisheries with 23 (95% c.i.: 14 to 49) estimated captures (Appendices A.2.5 and A.2.6). The corresponding capture rates for these two latter trawl fisheries were 0.12 (95% c.i.: 0.03 to 0.30) and 0.83 (95% c.i.: 0.50 to 1.73) fur seals per 100 tows for inshore and squid targets, respectively.

Table 9: Fisheries and areas with the highest estimated New Zealand fur seal captures during the 2017–18 fishing year. Included for each fishery area are: total fishing effort, observer coverage, observed fur seal captures and capture rate, and estimated captures and capture rate (showing the mean and 95% credible interval, c.i.). Effort is reported in tows for trawl fisheries and hooks for surface-longline fisheries; capture rates are reported as fur seal per 100 tows.

Target fishery	Area	Effort	Observed			Est. captures		Est. rate	
			%	Cap.	Rate	Mean	c.i.	Mean	c.i.
Hoki trawl	Cook Strait	1847	11.5	17	8.02	116	62–204	6.30	3.36–11.04
Hoki trawl	West Coast SI	5209	45.7	22	0.92	60	39–89	1.15	0.75–1.71
Middle depths trawl	East Coast SI	2978	19.3	2	0.35	27	8–66	0.92	0.27–2.22
Southern bluefin SLL	East Coast NI	418943	11.2	6	0.13	19	8–33	0.04	0.02–0.08
Southern blue whiting trawl	Subantarctic	455	100.0	17	3.74	17	17–17	3.74	3.74–3.74

The highest estimated New Zealand fur seal captures per 0.1 degree area were in Cook Strait followed by the West Coast areas, with relatively low estimated captures around North Island (Figure 13). The Bounty Islands area, to the southwest of South Island, also had a high number of captures. The latter were observed captures from the southern blue whiting fishery, which had complete observer coverage during the 2017–18 fishing year (and in preceding recent years).

New Zealand fur seal captures have been routinely estimated in trawl fisheries, with the model estimating captures over past years every time it was re-run. The model estimates have remained stable over time, with the models consistently showing a peak in New Zealand fur seal captures during 2004–05 (Figure 14). The same model structure was used between 2009–10 and 2014–15. As additional years of data were added to the time series, the uncertainty in the model (and the mean values) tended to increase. The current change to the model structure reduced the uncertainty in the total estimated captures in each year.

The estimated capture rate (New Zealand fur seal captures per 100 tows) during 2017–18 was lower than the mean estimate for each of the trawl target fisheries (Figure 15). The rate normalises any changes in fishing effort, but may be influenced by factors such changes in the location of the fisheries, changes

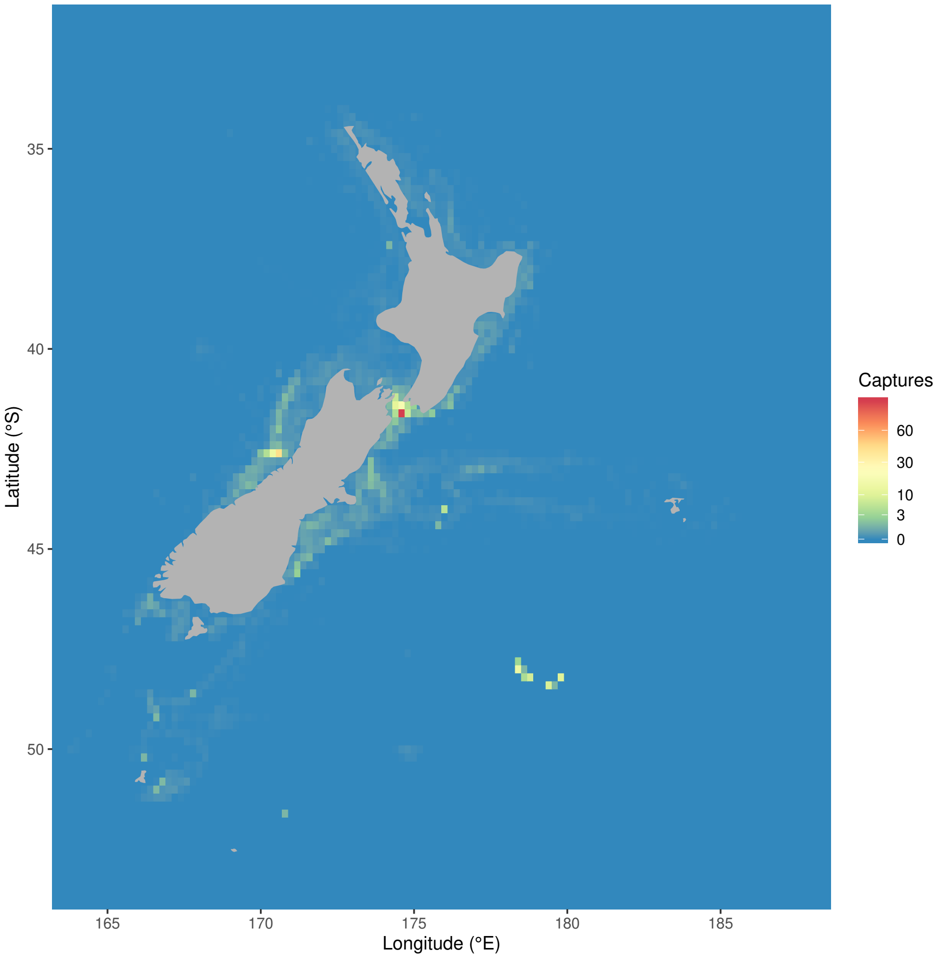


Figure 13: Estimated captures of New Zealand fur seal in trawl fisheries in New Zealand waters for the 2017–18 fishing year. The colouring indicates the mean number of fur seal that were estimated caught in trawl fisheries during 2017–18 within 0.1 degree cells. Estimates include observed captures from observed fishing.

in fur seal population or distribution, as well as by any changes in fishing practice that are aimed at reducing New Zealand fur seal captures. For southern blue whiting trawl, which has the highest mean estimated capture rate, the capture rates were variable. In recent years, they had low uncertainty, due to the high observer coverage in that fishery. Capture rates during the 2016–17 and 2017–18 fishing years were lower than the mean. For hoki trawl fisheries, the mean estimated capture rate has been lower than the overall mean for the most recent five years, indicating a decline in capture rate in those fisheries. The capture rate in the 2017–18 was significantly lower than the overall mean (the 95% credible interval of the capture rate does not span the overall mean). In many fisheries (deepwater, hoki, inshore, jack mackerel, ling, middle depths, scampi trawl), the highest mean estimated capture rate was early in the series (between 2003–04 and 2005–06).

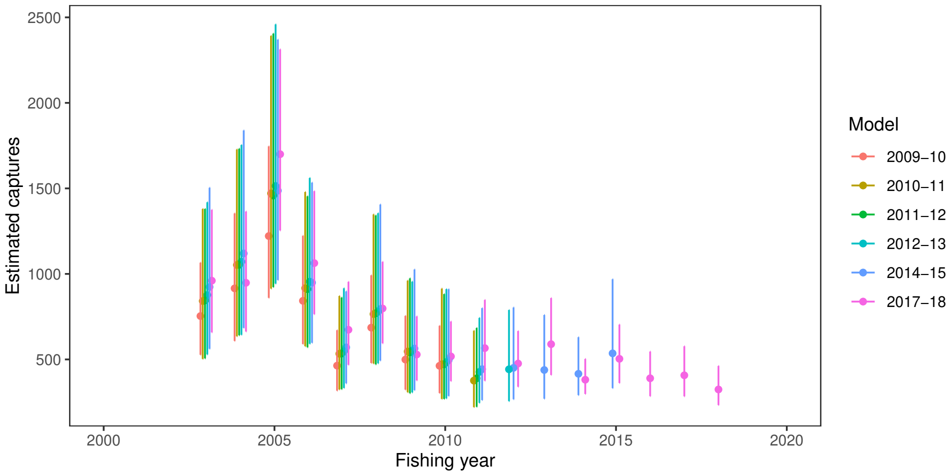


Figure 14: Comparison between models of New Zealand fur seal captures in trawl fisheries, for models fitted on data to 2009–10 (Thompson et al. 2011), 2010–11 (Thompson et al. 2013b), 2011–12 (Thompson et al. 2016), 2012–13 (Abraham et al. 2016), 2014–15 (Abraham & Berkenbusch 2017) and 2017–18 (this report). Shown for each model are the mean (dot) and 95% credible interval (line) of the annual estimated captures of New Zealand fur seal in trawl fisheries.

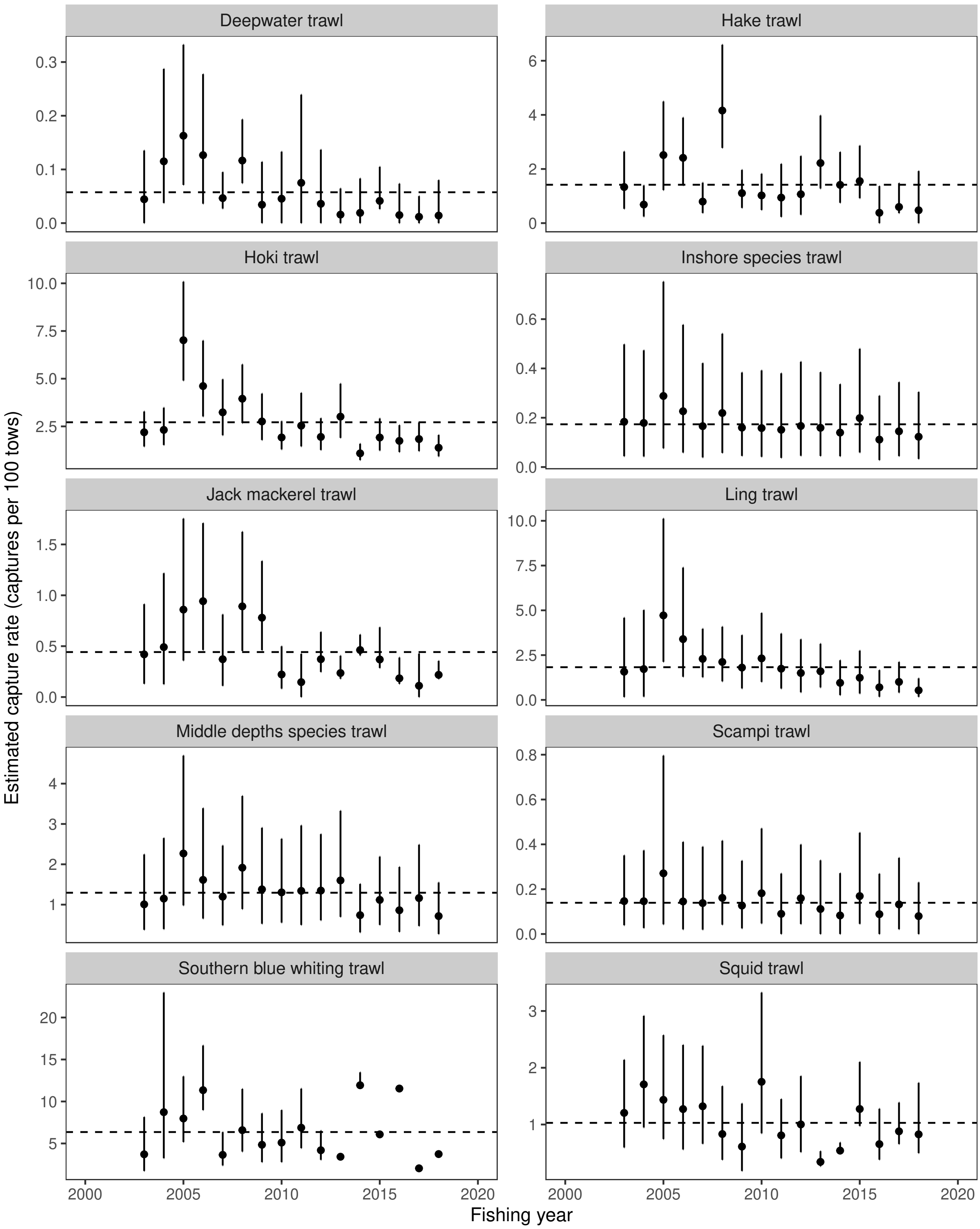


Figure 15: Estimated capture rate of New Zealand fur seal captures by target trawl fishery and fishing year. For each fishing year, dots indicate the mean estimate and vertical lines indicate the 95% credible interval of the estimates. The horizontal dashed line shows the mean capture estimate over all years, for each target fishery.

3.4 New Zealand fur seal captures in surface-longline fisheries

3.4.1 Observed New Zealand fur seal captures included in the estimation

In surface-longline fisheries, there were 408 observed New Zealand fur seal captures between 2002–03 and 2017–18. Most surface-longline effort in this period was off the South Island west coast and central North Island east coast (Figure 16).

Of the 408 total observed captures, 403 captures were recorded in southern bluefin tuna fisheries (Figure 17). This target fishery generally contributed over half of the annual surface-longline effort overall. When restricted to southern bluefin tuna fisheries, the highest number of observed captures were in the Fiordland area. Capture rates were higher in the Bay of Plenty and East Coast North Island areas, however. Although most observed captures were reported from large surface-longline vessels, capture rates were higher on small surface-longline vessels. Fur seal capture rates were lower in waters with high chlorophyll concentrations (i.e., typically coastal waters). There was no clear relationship between fur seal capture rates and sea surface temperature. Observed fishing targeting southern bluefin tuna primarily occurred in winter months (peaking in May), and fur seal capture rates were highest in July and August. Throughout the reporting period, there has been a variable number of fur seal observed caught in southern bluefin tuna fisheries, with the lowest number of fur seal captures reported in 2015–16.

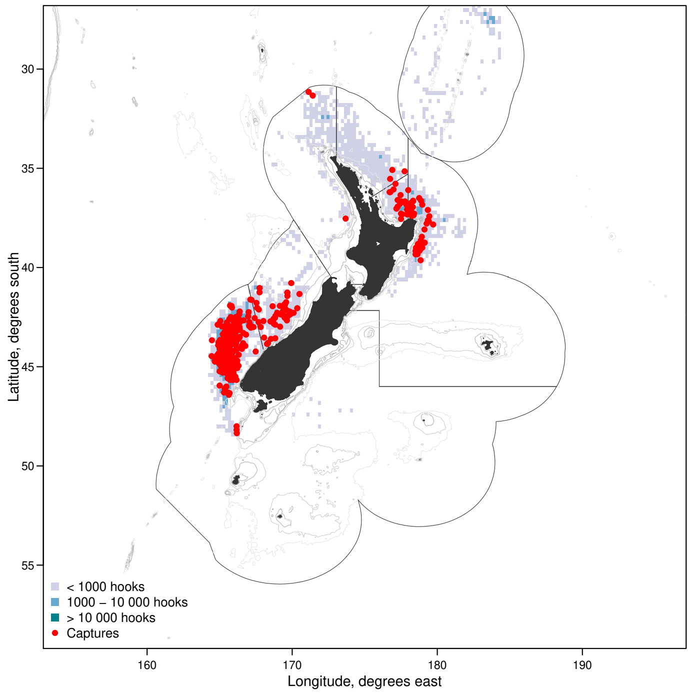


Figure 16: Spatial distribution of fishing effort (blue squares) and New Zealand fur seal captures (red dots) between 2002–03 and 2017–18, included in the statistical models to estimate total captures of fur seal in surface-longline fisheries New Zealand's Exclusive Economic Zone. Annual average observed fishing effort within 0.2° squares is indicated by blue shades, model areas are indicated by lines.

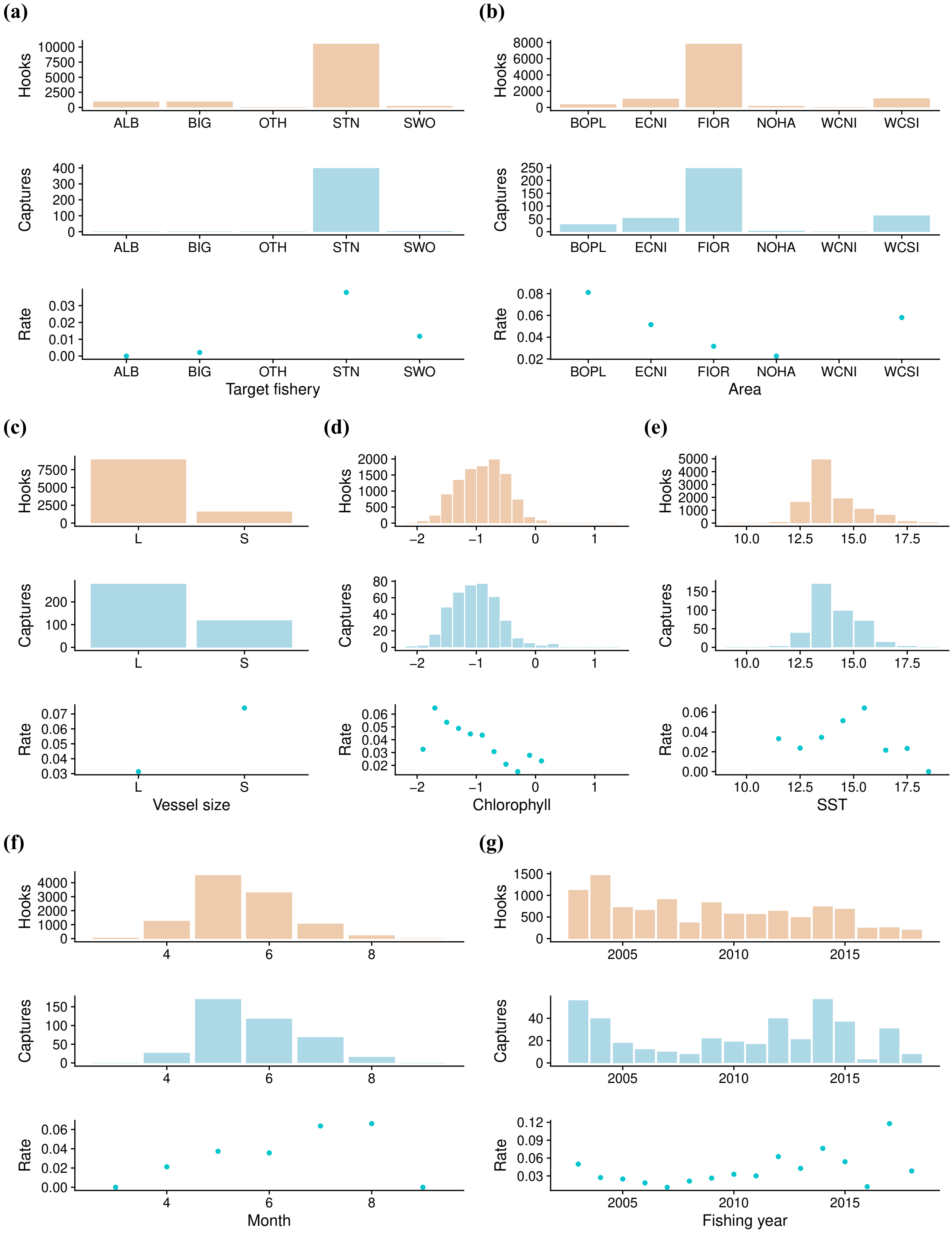


Figure 17: Relationship between covariates and fur seal captures on observed surface-longline fishing. In each sub-figure, the plots show the fishing effort (thousands of hooks observed), the number of fur seal observed caught, and the mean capture rate (observed captures per thousand hooks). The rate is not shown for groups that had fewer than 20 000 hooks observed. In (a) all target fisheries were included, whereas (b)—(g) are restricted to surface longline targeting southern bluefin tuna. The values of the covariates are (a) ALB: albacore, BIG: bigeye, STN: southern bluefin, SWO: swordfish, and OTH: other tuna; (b) BOPL: Bay of Plenty, ECNI: East Coast North Island, FIOR: Fiordland, NOHA: Northland and Hauraki, WCNI: West Coast North Island, ECNI: East Coast North Island; (c) L: large (≥45 m), S: small (<45 m). Chlorophyll (d) is in units of log(mg m^{-3}) and grouped in intervals of 0.2; sea surface temperature (SST, e) is in units of °C and grouped in intervals of 1 °C; month (f) is number in calendar year (e.g., January = 1).

3.4.2 Model of fur seal captures in surface-longline fisheries

There were no convergence issues in fitting the models: in all cases the maximum $\hat{R}$ value was 1.01 or less, and there were no divergent transitions in any of the models (Table 10). Of all models with six covariates, the model 'bafstvy' had the highest ELPD of all the models that were derived from this model by removing a single covariate; the model 'bfstvy' had the highest ELPD; and none of the four covariate models derived from this model by removing covariates had a higher ELPD. The seven models with the highest ELPD all had the fishery, temperature, vessel size, and fishing year covariates. The three models with the lowest ELPD were all missing the year covariate.

Following the previously established approach, the model with highest ELPD (equivalent to the lowest LOOIC) was selected. This model ('bfstvy') had fishery, month, temperature, vessel size, and fishing year covariates. From this model there were estimated to be 60 (95% c.i.: 32–96) fur seal captures in surface-longline fisheries during 2017–18. Across the 16 models that included sea surface temperature as a covariate, the mean number of estimated fur seal captures ranged between 51 and 62 (the lower credible interval ranged between 27 and 34, and the upper credible interval ranged between 87 and 103). Although different covariates were included within each model, the estimated captures were consistent.

If model weights were calculated across all the models included in the model selection process, then the four models with weights higher than 10% were 'baftvy', 'bfsvy', 'bstvy', 'bacfstv'. All covariates were included in at least one of these models, and all covariates (other than vessel size) were left out of at least one of these models. Even though models without year had low ELPD, one of them ('bacfstv') was included in the model weighted stacking with a weight of around 11%. The model-averaged estimated captures during 2017–18 were 64 (95% c.i.: 32–103), the estimate was similar to the estimate from the highest ELPD model, but with a broader credible interval.

The covariates from the selected model showed a negative relationship between temperature and fur seal capture rates, with lower capture rates in higher sea surface temperature water (Figure 18, see also Appendix B: Table B-22). All other covariates being equal, capture rates were estimated to be 4.0 (95% c.i.: 2.7–6.0) times higher on small vessels than on large vessels. Strong year effects were evident, with high estimated capture rates during 2002–03 and low estimated capture rates in 2015–16 and 2017–18. The fishery effect was high for southern bluefin tuna, and low for albacore. The month effect showed a peak in the winter months with low capture rates from October to February. There was considerable uncertainty in the strength of the monthly effect, however.

When the selected model was used to estimate captures on observed fishing (Figure 19), the annual variation in the estimated captures closely followed the annual variation in the observed captures—the model had a year effect and so was able to match the annual variation in the captures. The agreement indicates, however, that the model is calibrated as expected.

Table 10: Model selection for New Zealand fur seal captures in surface-longline fisheries, showing the difference in the expected log predictive density (ELPD), compared to the highest model; the standard error in the ELPD difference; the maximum $\hat{R}$ measure across all parameters; the number of divergent transitions; and the mean and 95% credible interval in the estimated number of turtle captures during the 2017–18 fishing year (calculated by applying the model to all surface-longline fishing effort in 2017–18 for which all the covariates were defined); the model weight from Bayesian model stacking. The model names indicate which covariates are included, 'b': base terms (the offset term) included in all models, 'a': area, 'c': chlorophyll, 'f': fishery, 's': season, 't': temperature, 'v': vessel size, 'y': year. The model 'Average' shows the estimated captures during 2017–18 from the model stacking.

Model	ΔELPD		$\hat{R}_{max}$	Divergences	Estimate, 2017–18		Weight
	Mean	s.e.			Mean	95% c.i.	
bfstvy	0.0	0.0	1.00	0	60	32–96	0.000
bafstvy	-0.1	2.3	1.01	0	59	32–99	0.000
baftvy	-0.3	2.6	1.01	0	59	33–102	0.466
bacfstvy	-1.1	2.3	1.01	0	58	32–98	0.000
bcfstvy	-1.2	0.8	1.01	0	59	32–98	0.000
bacftvy	-1.4	2.6	1.00	0	60	33–103	0.000
bftvy	-1.8	1.7	1.00	0	60	33–100	0.001
bafsvy	-3.3	3.8	1.01	0	56	31–95	0.018
bacfsvy	-3.8	3.7	1.00	0	56	31–94	0.000
bfsvy	-5.0	3.7	1.01	0	55	30–92	0.186
bastvy	-7.5	4.9	1.01	0	61	34–103	0.000
bstvy	-8.4	4.3	1.00	0	61	33–102	0.130
bacstvy	-8.5	5.0	1.01	0	62	34–103	0.000
bafsty	-12.9	6.6	1.01	0	53	29–92	0.035
bacfsty	-13.5	6.7	1.00	0	53	29–92	0.000
bfsty	-19.0	7.3	1.01	0	51	27–87	0.050
bacfstv	-34.1	9.6	1.00	0	90	68–114	0.113
bfstv	-41.3	10.2	1.00	0	91	68–117	0.000
bafstv	-41.5	10.3	1.01	0	91	70–115	0.000
Average					64	32–103	

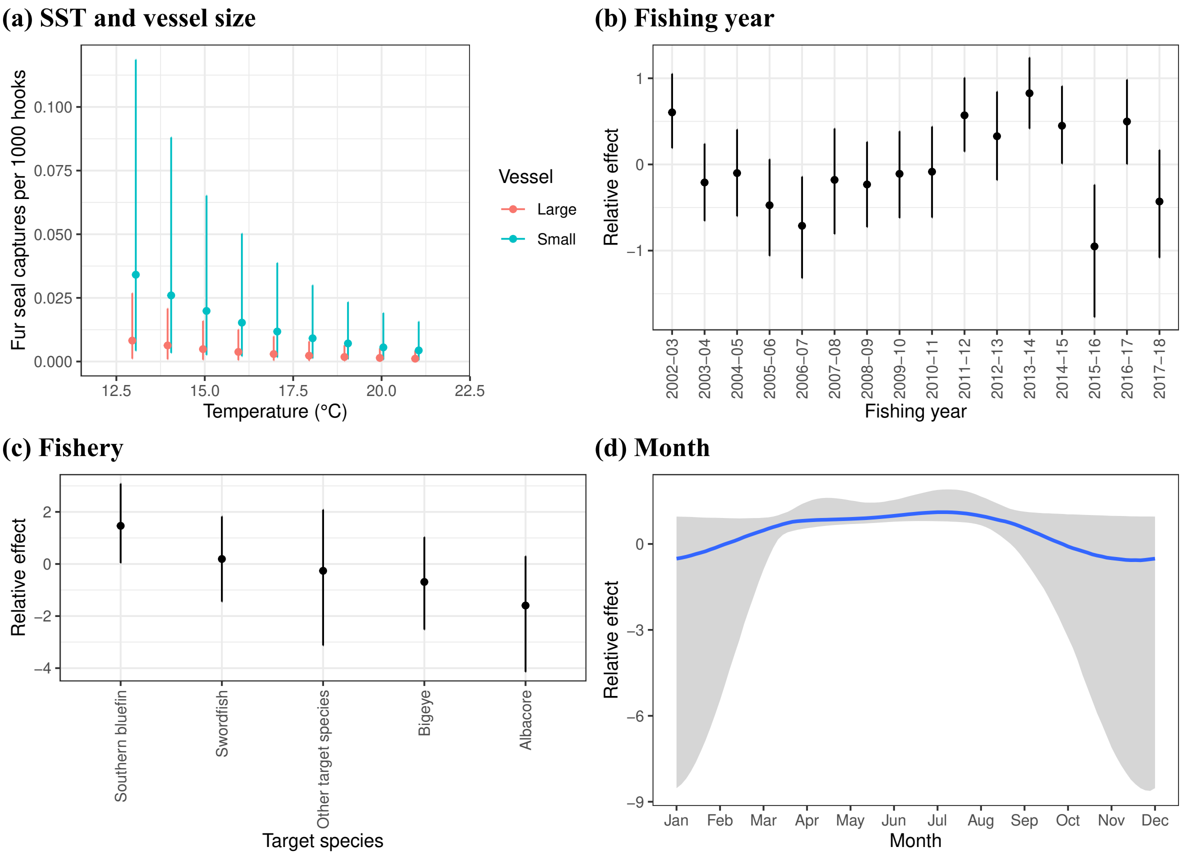


Figure 18: Fitted covariates for the model of New Zealand fur seal captures in surface-longline fisheries. Showing (a) variation in the base capture rate (fur seal captures per 1000 hooks) by sea surface temperature (SST, °C) and vessel size (large, ≥45 m; small, <45 m), (b) the relative effect of fishing year, (c) the relative effect of target fishery, and (d) the effect of month of the year, from the cyclic spline. In sub-figures (a), (b), (c), the dot marks the mean value, and lines indicate the 95% credible interval. In sub-figure (d), the blue line is the mean effect and the shading indicates the 95% credible interval.

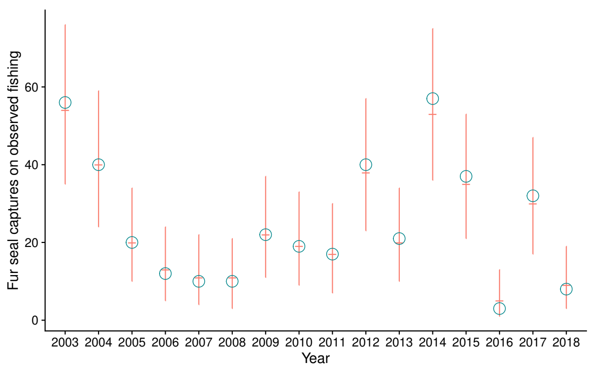


Figure 19: Estimated fur seal captures on observed surface-longline fishing. For each fishing year, the red line and bar indicate the mean and 95% credible interval of the estimates, while the circle indicates the number of observed captures.

3.4.3 Estimated captures of New Zealand fur seal in surface-longline fisheries

In 2017–18, there were an estimated 60 (95% c.i.: 32 to 96) fur seal captures in surface-longline fisheries, with an estimated capture rate 0.026 (95% c.i.: 0.014 to 0.042) fur seals per 1000 hooks. In comparison, estimates in the preceding fishing year were 150 (95% c.i.: 108 to 199) fur seal and 0.072 (95% c.i.: 0.052 to 0.095) fur seals per 1000 hooks. These recent estimates were markedly higher than the 2015–16 values, which had the lowest estimated number and capture rate over the reporting period: there were 31 (95% c.i.: 13 to 57) estimated fur seal captures in 2015–16, and the corresponding capture rate was 0.013 (95% c.i.: 0.006 to 0.024) fur seals per 1000 hooks.

Estimated captures of New Zealand fur seal in surface-longline fisheries in 2017–18 were highest in the southern bluefin tuna fishery (Table 11): all fishery-area strata with a mean estimate of one or more fur seal capture during 2017–18 were in southern bluefin tuna fisheries. West Coast South Island was the area with the highest estimated number of captures (20; 95% c.i.: 9–34), followed by East Coast North Island (17; 95% c.i.: 8–31).

Table 11: Estimated captures of New Zealand fur seal in surface-longline fisheries during 2017–18. For each target fishery and area, the mean, median and 95% credible interval of the posterior distribution is shown. Mean estimated captures are in decreasing order, and data are limited to fisheries and areas that had a mean estimate of one or more captures. The total estimate across all surface-longline fishing is also shown.

Fishery	Area	Estimated captures, 2017–18		
		Mean	Median	95% c.i.
Southern bluefin	West Coast South Island	20	20	9–34
Southern bluefin	East Coast North Island	17	16	8–31
Southern bluefin	Bay of Plenty	11	11	5–20
Southern bluefin	Northland and Hauraki	5	4	1–11
Southern bluefin	East Coast South Island	3	3	0–8
Southern bluefin	Fiordland	1	1	1–3
All	All	60	58	32–96

New Zealand fur seal captures have been regularly estimated in surface-longline fisheries, allowing comparisons between model estimates (Figure 20). The model was initially fitted with data from 1998–99 to 2010–11 (Thompson et al. 2013b). Since then, the models were fitted to data beginning with the 2002–03 fishing year, corresponding with the model of fur seal captures in trawl fisheries. Estimates from the model fitted to 2017–18 are similar to estimates from models fitted to data to 2012–13 and 2014–15. All three models estimated that there was a peak in estimated captures at the start of the series, in 2002–03, with low captures around 2006–07. The current model estimates that there was a second peak in estimated captures during 2013–14 with a subsequent decrease in the estimated captures. The annual variability in the estimated captures appears to be associated with the variation in the year effects, with low estimated captures during 2015–16 and 2017–18.

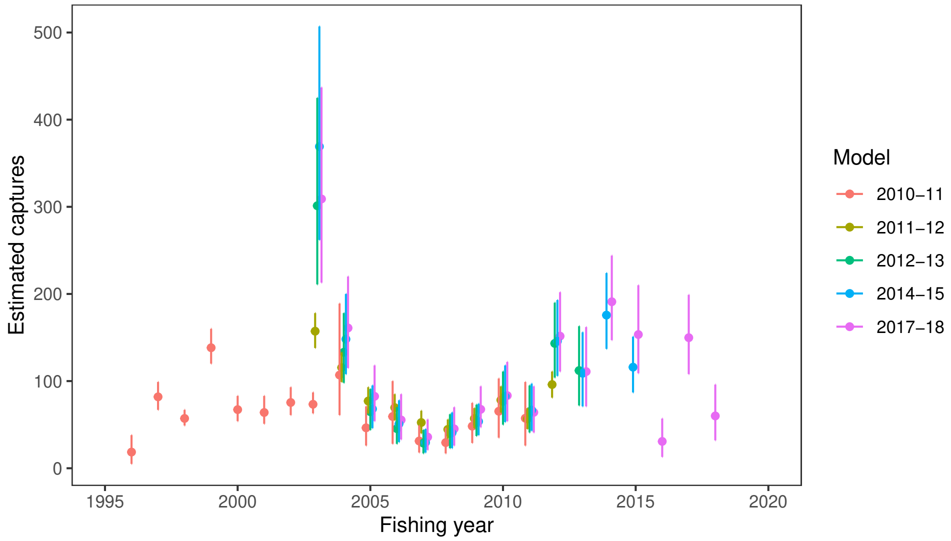


Figure 20: Comparison between models of New Zealand fur seal captures in surface-longline fisheries, for models fitted on data to 2010–11 (Thompson et al. 2013b), 2011–12 (Thompson et al. 2016), 2012–13 (Abraham et al. 2016), 2014–15 (Abraham & Berkenbusch 2017) and 2017–18 (current report). Shown are for each model, the mean (dot) and 95% credible interval (line) of the annual estimated number of captures of New Zealand fur seal in surface-longline fisheries.

3.5 Turtle captures in surface-longline fisheries

3.5.1 Observed turtle captures in surface-longline fisheries

Over the 16 years included in the estimation of turtle captures in surface-longline fisheries, there was a total of 28 observed captures (Table 12). Of these captures, 12 (42.8%) were in the three year period (2015–16 to 2017–18) that was not previously included in the estimation of turtle captures. Across the whole period, most observed captures were leatherback turtle (20 captures), with five captures of unidentified species, one capture of green turtle and one capture of loggerhead turtle. All observed turtle captures were in North Island waters, predominantly off the North Island east and west coasts, in the Northland-Hauraki and Bay of Plenty areas (Figure 21). The target surface-longline fisheries with observed captures of turtles were bigeye and southern bluefin tuna and swordfish (Figure 22). In addition to the captures in surface-longline fisheries, there have been a small number of turtles observed caught in fishing using other methods (three in trawl fisheries targeting inshore fish species, and one in bottom-longline fisheries targeting snapper).

All turtles observed caught in surface-longline fisheries were reported as released alive. Of the 28 captures, 11 captures were reported as hooked in the flipper, 7 as having no visible injuries, 4 as hooked in the mouth, 1 as having an open wound, and the remaining 9 as either having unknown injuries or no injury record.

Table 12: Observed captures of turtles in New Zealand commercial fisheries, 2002–03 to 2017–18. Shown are the number of each species caught in each target fishery. Of the turtle captures in surface-longline fisheries during this period, one was from a large vessel (≥ 45 m) that was targeting bigeye tuna in the West Coast North Island area; the remainder were from small vessels.

Method	Target fishery	Species	Number
Surface longline	Bigeye surface longline	Leatherback turtle	10
		Unidentified turtle	5
		Green turtle	1
		Loggerhead turtle	1
	Southern-bluefin surface longline	Leatherback turtle	3
		Green turtle	1
	Swordfish surface longline	Leatherback turtle	7
Trawl	Inshore trawl	Green turtle	2
		Leatherback turtle	1
Bottom longline	Snapper bottom longline	Green turtle	1

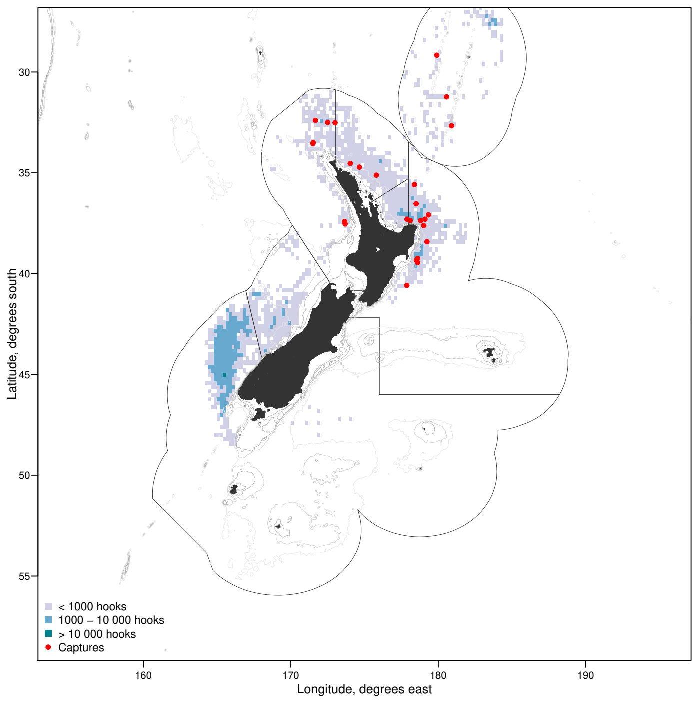


Figure 21: Spatial distribution of surface-longline fishing effort (blue squares) and sea turtle captures (red dots) between 2002–03 and 2017–18, included in the statistical model to estimate total captures of sea turtles in New Zealand's Exclusive Economic Zone. Annual average observed fishing effort within 0.2° squares is indicated by blue shades, model areas are indicated by lines.

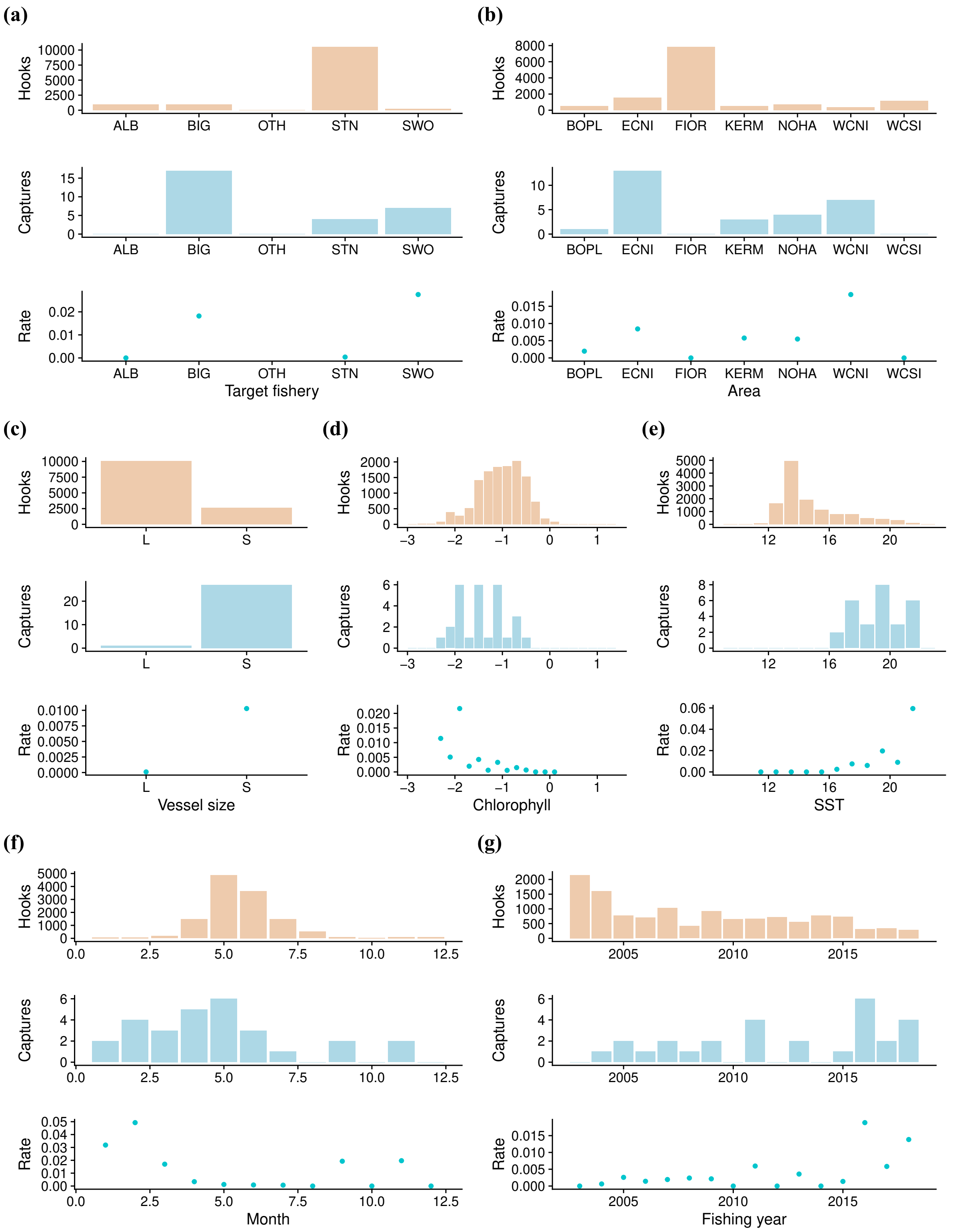


Figure 22: Relationship between covariates and turtle captures on observed surface-longline fishing. In each sub-figure, the plots show the fishing effort (thousands of hooks observed), the number of turtles observed caught, and the mean capture rate (observed captures per thousand hooks). The rate is not shown for groups that had fewer than 20 000 hooks observed. The values of the covariates are (a) ALB: albacore, BIG: bigeye, STN: southern bluefin, SWO: swordfish, and OTH: other tuna; (b) BOPL: Bay of Plenty, ECNI: East Coast North Island, FIOR: Fiordland, NOHA: Northland and Hauraki, WCNI: West Coast North Island, ECNI: East Coast North Island; (c) L: large ($\geq$45 m), S: small ($<$45 m). Chlorophyll (d) is in units of log(mg m^{-3}) and grouped in intervals of 0.2; sea surface temperature (SST, e) is in units of $^{\circ}$C and grouped in intervals of 1 $^{\circ}$C; month (f) is number in calendar year (e.g., January = 1).

3.5.2 Model of sea turtle captures in surface-longline fisheries

There were no convergence issues in fitting the models: in all cases the maximum $\hat{R}$ value was 1.01 or less, and there was a maximum of a single divergent transition in any of the models. Out of all models with six covariates, the model 'bacfstv' had the highest ELPD, of all the models that were derived from this model by removing a single covariate, the model 'bacftv' had the highest ELPD, and none of the four covariate models derived from this model by removing covariates had a higher ELPD. All models that included the temperature covariate had a standard error in the ELPD difference of less than three, and all the models that did not include the temperature covariate had a standard error in the ELPD difference of over four, indicating the importance of sea surface temperature as a variable explaining patterns in sea turtle bycatch. Surface chlorophyll was included in each of the ten models with the highest ELPD.

Following the previously established approach, the model with highest ELPD (equivalent to the lowest LOOIC) was selected. Across the 16 models that included sea surface temperature as a covariate, the mean number of estimated sea turtle captures ranged between 47 and 55 (the lower credible interval ranged between 19 and 28, while the upper credible interval ranged between 83 and 103). Although different covariates were included within each model, the estimated captures were consistent. If model weights were calculated across all the models included in the model selection process, the four models with weights higher than 10% are 'bactv', 'bacfst', 'bcftv', 'bacfv'. All covariates were included in at least one of these models, and all covariates (other than chlorophyll) were left out of at least one of these models. Even though models without temperature had low ELPD, one of them ('bacfv') was included in the model weighted stacking with a weight of around 20%. The model-averaged estimated captures during 2017–18 were 45 (95% c.i.: 15–86), the mean was lower than the estimate from the highest ELPD model due to the inclusion of a model without temperature in the model average.

The model with the lowest LOOIC value included the area, chlorophyll, fishery, temperature, and vessel-size covariates (Table 13). Of the set of models with six out of the seven covariates, the model that left out the year effect performed the best, whereas the model without the temperature performed the worst.

The turtle capture rate was strongly associated with sea surface temperature, with the mean capture rate reaching around 0.05 turtle captures per 1000 hooks in water with a sea surface temperature of 21°C (Figure 23). Capture rates were higher on the small vessels, relative to large vessels. The area effect was highest in the East Coast North Island and West Coast North Island areas, and lowest in the West Coast South Island and Bay of Plenty areas. The fishery effect was highest for fishing targeting swordfish and bigeye tuna, and lowest for fishing targeting albacore. There appeared to be a humped relationship between turtle captures and the chlorophyll concentration, with lower values at low concentrations (less than 0.1 mg m^{-3} and higher concentrations (over 1.0 mg m^{-3}), although there was considerable uncertainty in this relationship. In interpreting this covariates, it is important to recognise that the covariates themselves are correlated; for example, there was a strong association between sea surface temperature and area, so estimated capture rates may be higher in areas with higher sea surface temperatures, even if the area effects are similar.

When the selected model was used to estimate captures on observed fishing, the observed captures lay within the credible interval of the estimated captures (Figure 24).

Table 13: Model selection for turtle captures in surface-longline fisheries, showing the difference in the expected log predictive density (ELPD), compared to the highest model; the standard error in the ELPD difference; the maximum $\hat{R}$ measure across all parameters; the number of divergent transitions; and the mean and 95% credible interval in the estimated number of turtle captures during the 2017–18 fishing year (calculated by applying the model to all surface-longline fishing effort in 2017–18 for which all the covariates were defined); the model weight from Bayesian model stacking. The model names indicate which covariates are included, 'b': base terms (the offset term) included in all models, 'a': area, 'c': chlorophyll, 'f': fishery, 's': season, 't': temperature, 'v': vessel size, 'y': year. The model 'Average' shows the estimated captures during 2017–18 from the model stacking.

Model	ΔELPD		$\hat{R}_{max}$	Divergences	Estimate, 2017–18		Weight
	Mean	s.e.			Mean	95% c.i.	
bacftv	0.0	0.0	1.00	0	53	27–86	0.000
bacfstv	-0.2	1.0	1.00	0	52	29–86	0.000
bactv	-0.5	1.5	1.00	0	50	28–81	0.275
bacft	-0.8	1.9	1.00	0	54	29–92	0.068
bacfst	-1.0	2.1	1.00	0	54	30–92	0.223
bacftvy	-1.1	0.7	1.00	0	48	22–92	0.000
bacfstvy	-1.3	1.2	1.01	0	50	23–95	0.000
bcftv	-1.4	2.5	1.00	1	53	30–87	0.165
bacstv	-1.5	1.7	1.00	0	50	28–82	0.000
bcfstv	-1.7	2.6	1.00	0	55	32–89	0.045
baftv	-2.2	2.4	1.00	1	48	26–81	0.001
bacstvy	-2.2	2.0	1.00	0	48	22–91	0.000
bcfstvy	-2.6	2.8	1.00	0	53	24–101	0.000
bafstv	-2.6	2.7	1.00	0	48	26–83	0.015
bacfsty	-2.7	2.2	1.01	0	50	22–100	0.000
bafstvy	-3.2	2.7	1.00	0	48	21–94	0.000
bacfv	-7.6	5.9	1.00	0	26	15–43	0.208
bacfsvy	-7.7	4.8	1.01	0	33	14–77	0.000
bacfsv	-7.7	5.1	1.00	0	29	16–49	0.000
Average					46	18–83	

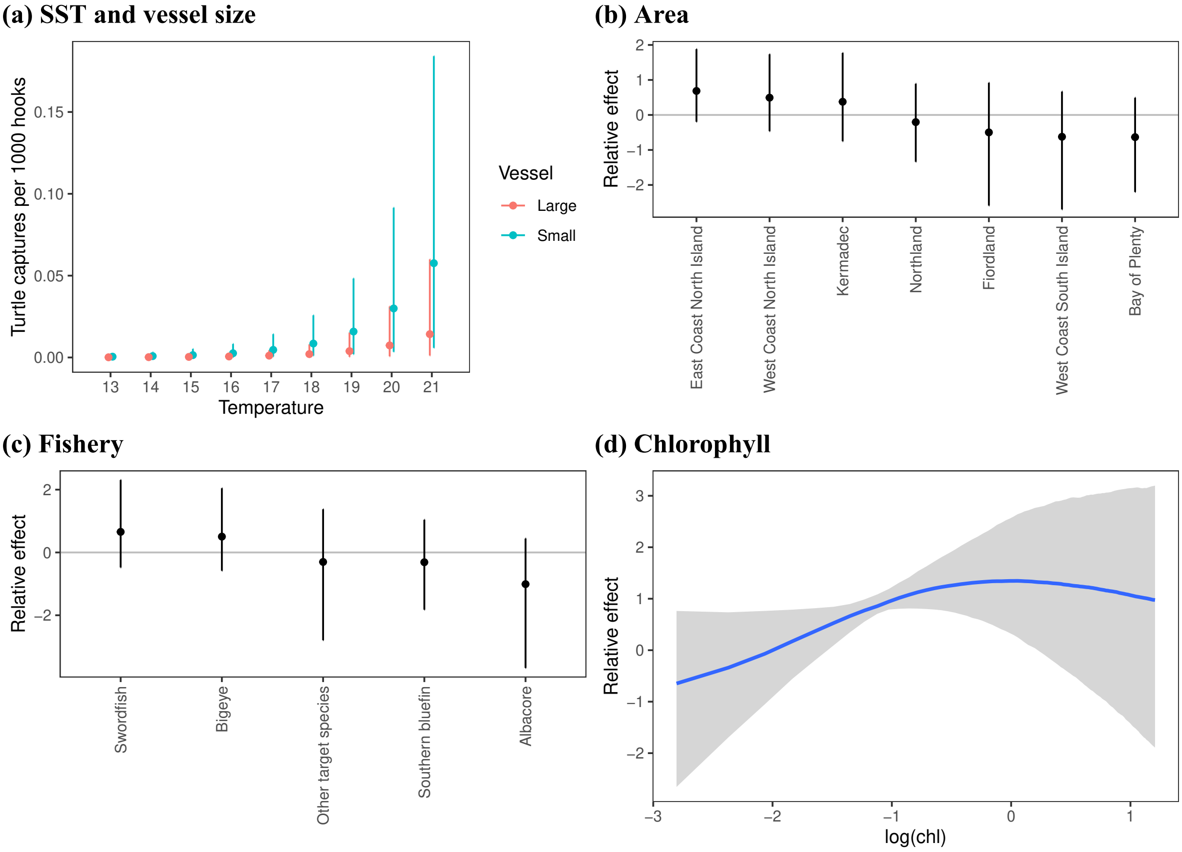


Figure 23: Fitted covariates for the model of turtle captures in surface-longline fisheries. Showing (a) variation in the base capture rate (turtle captures per 1000 hooks) by sea surface temperature (SST, °C) and vessel size (large, ≥45 m; small, <45 m), (b) the relative effect of area, (c) the relative effect of target fishery, and (d) the effect of the logarithm of the chlorophyll concentration, from the thin plate spline. In sub-figures (a), (b), (c), the dot marks the mean value, and lines indicate the 95% credible interval. In sub-figure (d), the blue line is the mean effect and the shading indicates the 95% credible interval.

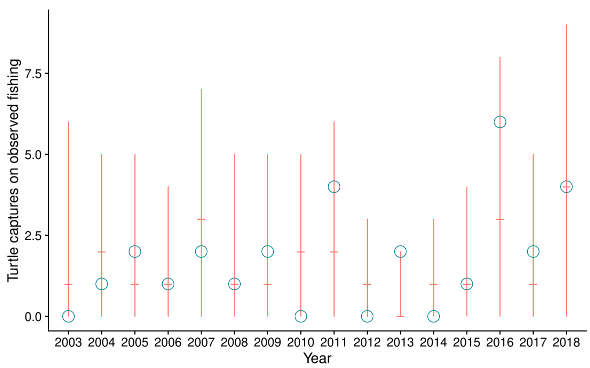


Figure 24: Estimated turtle captures on observed surface-longline fishing. For each fishing year, the red line and bar indicate the mean and 95% credible interval of estimates, while the circle indicates the number of observed captures.

3.5.3 Estimated captures of turtles in surface-longline fisheries

In the most recent fishing year, 2017–18, there were an estimated 53 (95% c.i.: 27 to 86) sea turtle captures in New Zealand surface-longline fisheries (see Appendix A, Section A.3). The corresponding capture rate was 0.023 (95% c.i.: 0.012 to 0.038) turtle captures per thousand hooks.

During 2017–18, there were 17 (95% c.i.: 7–31) estimated turtle captures in surface-longline fishing targeting bigeye tuna in East Coast North Island, and 10 (95% c.i.: 3–26) estimated turtle captures in surface-longline fishing targeting broadbill swordfish in East Coast North Island (Table 14). Over half of the estimated turtle captures during 2017–18 were in East Coast North Island. Across the fishery-area strata with a mean estimate of more than one turtle capture during 2017–18, there was a mean of only two captures in southern bluefin target fisheries, and no estimated captures in albacore or other target fisheries.

Table 14: Estimated captures of turtles in surface-longline fisheries during 2017–18. For each target fishery and area, the mean, median and 95% credible interval of the posterior distribution is shown. Mean estimated captures are in decreasing order, and data are limited to fisheries and areas that had a mean estimate of one or more captures. The total estimate across all surface-longline fishing is also shown.

Fishery	Area	Estimated captures, 2017–18		
		Mean	Median	95% c.i.
Bigeye	East Coast North Island	17	16	7–31
Swordfish	East Coast North Island	10	9	3–26
Bigeye	Northland and Hauraki	7	6	1–17
Swordfish	West Coast North Island	4	4	0–12
Swordfish	Northland and Hauraki	3	3	0–10
Swordfish	Bay of Plenty	3	2	0–10
Southern bluefin	East Coast North Island	2	2	0–6
Bigeye	Bay of Plenty	2	1	0–6
Bigeye	West Coast North Island	1	1	0–4
All	All	53	51	27–86

Turtle captures have been routinely estimated in surface-longline fisheries, with considerable variability in the estimated captures over time (Figure 25). The total number of observed captures was low, so that the estimates are sensitive to additional years of data and to changes in the model structure. The model fitted with data to the end of 2012–13 only included area effects (Abraham et al. 2016); the model to the end of 2014–15 included area and vessel-size effects, and also random year effects; whereas the current model included area, chlorophyll, fishery, temperature, and vessel-size effects. The model fitted to data to the end of 2017–18 had higher estimated captures in early years than the previous models. During the selection of the current model, models that included the temperature effect had around twice as many estimated captures during 2017–18 than models without the temperature effect (see Table 13). This finding is consistent with the increase in estimated captures evident in the current model, compared with the previous two models (neither of which included sea surface temperature as a covariate).

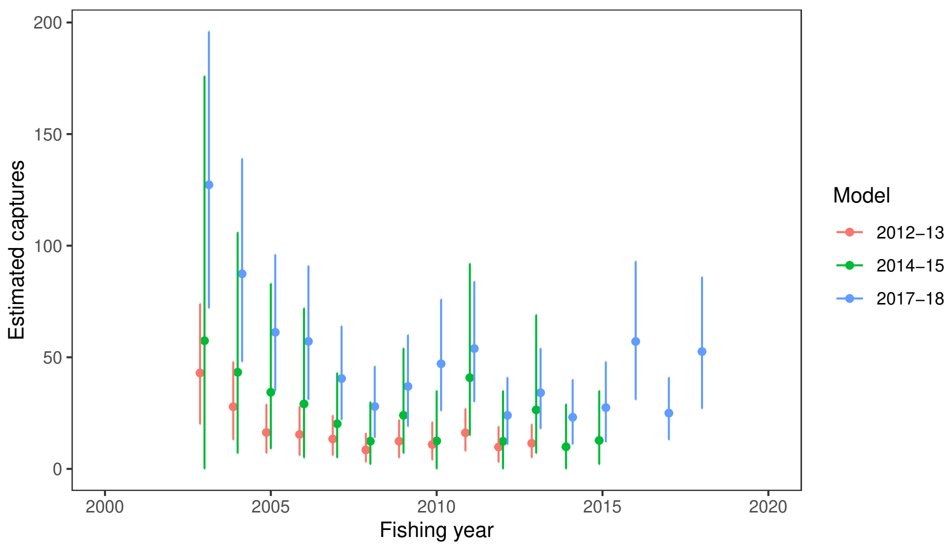


Figure 25: Comparison between models of turtle captures in surface-longline fisheries, for models fitted on data to 2012–13 (Abraham et al. 2016), 2014–15 (Abraham & Berkenbusch 2017) and 2017–18 (current report). Shown for each model are the mean (dot) and 95% credible interval (line) of the annual estimated captures of turtles in surface-longline fisheries.

4. DISCUSSION

This assessment of the capture of common dolphin, New Zealand fur seal and sea turtles in New Zealand waters provides information for monitoring the impact of New Zealand commercial fisheries on these species. The estimates represent the total number of observable captures (i.e., the number of captures that would have been reported had an observer been on every vessel). The estimates do not account for cryptic mortality, i.e., animals that may die as a result of their interaction with fishing gear but do not become captured in a way that can be seen by observers or that requires physical intervention by the vessel crew; nor do the estimates account for post-release survival of live captures. Both of these factors were included in an assessment of the risk of commercial fisheries to New Zealand marine mammals that estimated the annual potential fatalities of common dolphin and New Zealand fur seal for the period between 2012–13 and 2014–15 (Abraham et al. 2017).

4.1 Common dolphin captures

Common dolphin are frequently captured in New Zealand trawl fisheries, particularly in the large-vessel jack mackerel target fishery off the North Island west coast. There was a reduction of around 85% in capture rates following the introduction of the MMOP. In the most recent fishing year, 2017–18, there were seven vessels active in this fishery, and all vessels were observed. There were no observed common dolphin captures (although a long-beaked common dolphin was observed caught in this fishery), and the mean number of estimated captures was less than 0.5 dolphin. This estimate was a marked reduction from the estimated 99 (95% c.i.: 45–180) common dolphin captures during the 2003–04 fishing year, before the introduction of the MMOP. The model period covariate indicated that, all other covariates being equal, there was a reduction in the frequency of dolphin capture events rate of about 87% (62 to 97%) following the implementation of the MMOP. This decrease may not be directly related to the introduction of the MMOP. For example, if there had been a decrease in the dolphin population in the area of the jack mackerel fishery, or if dolphin had learnt to not be caught in the trawl, then these would also have led to a decrease in the period effect.

There were 35 observed common dolphin captures between 1995–96 and 2017–18 that were not included in the estimation. These captures included nine common dolphin observed caught during five events by two small vessels (22 m and 23 m in length) trawl fishing to the south of the Taranaki area, in Golden Bay (Figure 26). The capture locations were close to the area where common dolphin have been caught in mackerel trawl fisheries (see Appendix A, Figure A-2). Observer coverage on small trawl vessels in this area has been low: between 2002–03 and 2017–18, 865 out of 122 247 tows were observed, reflecting 0.71% observer coverage. Using a simple ratio estimate based on the observer coverage and captures would lead to an estimate of around 80 common dolphin being caught annually. In previous reporting, it was estimated that there were 63 (95% c.i.: 15–143) common dolphin caught annually by small vessels in this area (Abraham & Berkenbusch 2017). This estimate, in turn, contributed to a high estimated risk of population impacts on common dolphin from commercial fishing (Abraham et al. 2017). The estimation of common dolphin captures in other trawl fisheries was not repeated during the current analysis, because the high uncertainty and the ongoing lack of observer coverage meant that the models had low statistical power. Alternative approaches for data-poor situations include spatially-explicit risk assessments that allow the estimation of the risk of fisheries even when observer data are scarce; these types of analyses were recently conducted for New Zealand sea lion and Hector's dolphin (Large et al. 2019, Roberts et al. 2019).

In the highly-observed mackerel fishery, management of the fishery to avoid dolphin captures appears to have successfully led to the reduction of captures to a low level. In adjacent small-vessel fisheries, however, there was little information available. It is possible, based on the limited observer data, that common dolphin captures in small-vessel fisheries are considerably higher than in the mackerel trawl fishery. Increased observer coverage, in the Taranaki area in particular (which includes Golden Bay, see Figure 1), would reduce the uncertainty in estimated common dolphin captures in small-vessel fisheries.

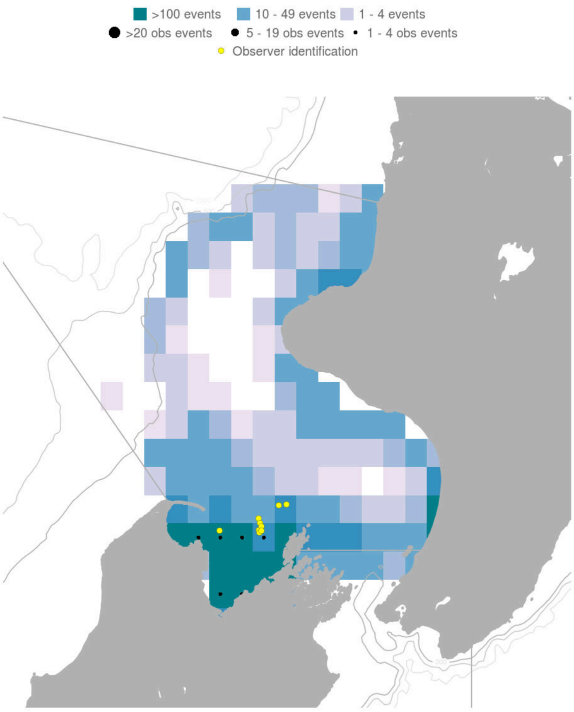


Figure 26: Observed common dolphin captures by small vessels trawl fishing in the Taranaki area (indicated by lines). Yello dots indicate observed captures; blue squares show annual average fishing effort within 0.2 degree cells; and black dots indicate observed fishing effort. Data are from the period between 2002–03 and 2017–18.

4.2 New Zealand fur seal captures

New Zealand fur seal is the most frequently caught marine mammal species in New Zealand waters. In 2017–18, there were 324 (95% c.i.: 233–462) estimated fur seal captures in trawl fisheries. The estimated captures in trawl fisheries were the lowest mean estimates in the period covered by the model.

Most estimated fur seal captures were in the hoki trawl fishery (mean captures of 190 fur seal, 95% c.i.: 128–283 during 2017–18). Mean estimated capture rates in hoki trawl fisheries were 1.38 fur seal per 100 tows, which was the lowest mean capture rate estimated over the 16 years covered by the model. The highest estimated captures, by area, in the hoki trawl fishery were in Cook Strait, with 117 (95% c.i.: 63–204) estimated captures in that area during 2017–18. When considering the estimated captures in all New Zealand trawl fisheries, Cook Strait was highlighted as the area with the highest estimated captures (see Figure 13). Capture estimates of New Zealand fur seal in this area have been persistently high compared with other areas, whereas observer coverage has remained comparatively low.

The trawl fisheries with the next highest estimated captures were the fisheries targeting middle-depths species (see Table 3). A mean of 45 (95% c.i.: 17–97) captures was estimated for 2017–18. The mean capture rate was 0.72 (95% c.i.:0.27–1.55) fur seal per 100 tows, and this estimate was the lowest mean capture rate over the 16 years of data included in the estimation. The capture rate of New Zealand fur seal in the southern blue whiting trawl fishery has been variable and, in 2017–18, this rate was 3.74 fur seal per 100 tows, with a total of 17 observed captures (all tows in this fishery were observed).

In inshore trawl fisheries, capture rates were low (0.12 fur seal per 100 tows, 95% c.i.: 0.03–0.30); however, because of the high trawl effort targeting inshore species, this capture rate corresponded with an estimated 34 (95% c.i.: 9–83) fur seal captures during 2017–18. Furthermore, observer coverage in inshore trawl fisheries has been consistently lower than in middle-depths and deepwater target fisheries, even though there has been an increase in latter part of this reporting period. In 2017–18, 7.8% of all tows targeting inshore species were observed.

This assessment updated the structure of the model for estimating fur seal captures in trawl fisheries, with key differences to the estimation approach that was taken previously. First, the model structure had additional flexibility to account for variations in capture rates due to any potential changes in fur seal abundance in some areas but not others, variations in the capture rates of specific trawl fisheries over time, and changes in average capture rates by vessels when they targeted different species. Second, the shape of the distribution used for describing the number of fur seal caught per capture event was allowed to differ for specific area-target fishery combinations that had frequent high capture events. This improved characterisation of variability led to a reduction in the uncertainty in the predictions. For example, the prediction of captures for 2014–15 in the previous analysis was 536 (95% c.i.: 332–969) fur seal (Abraham & Berkenbusch 2017), and this estimate decreased to 503 (95% c.i.: 362–704) individuals in the current analysis.

The model for fur seal captures in surface longline fisheries included sea surface temperature, with an increased fur seal capture rate being associated with colder sea surface temperatures. Chlorophyll concentration was tested as an covariate, but was not included in the selected model. There was a strong effect associated with vessel size, and small vessels had a fur seal capture around four times higher than large vessels fishing for the same species at a similar place and time. It is unclear why the capture rate is higher on small vessels. A similar increased capture rate for small vessels was found for turtles.

There were 60 (95% c.i.: 32–96) estimated fur seal captures in surface-longline fisheries during 2017–18. The estimated number of captures, and the estimated capture rate, has fluctuated since the departure of the Japanese fleet. Within the model, these inter-annual fluctuations are associated with variation in the random year effect, and so the reason for the fluctuations is not clear. It is possible that there were changes in the location of the fishing at a scale that was smaller than the model areas.

Understanding the impact of fisheries captures on the New Zealand fur seal population would require an estimation of the population size, spatial distribution, and productivity. Of the observed fur seal captures between 2002–03 and 2017–18, 11.8% of animals caught in trawl fisheries were released alive, whereas 94.4% of animals caught in surface-longline fisheries were released alive. The impact of the captures on the populations would also depend on the post release survival, particularly of the captures in surface-longline fisheries. The potential impact of fur seal captures on their populations was not considered here, but should be carried out within an integrated risk assessment framework (e.g., Abraham et al. 2017).

4.3 Sea turtle captures

Over the reporting period, leatherback, loggerhead and green turtles were reported caught in New Zealand small-vessel surface-longline fisheries, and most captures were observed in open water in northeastern New Zealand. This area is characterised by warm water of the East Auckland current and its extension between East Cape and Cook Strait. Turtle captures have also been recorded in the Kermadec Islands area and on the North Island west coast. There were an estimated total capture of 53 (95% c.i.: 27–86) turtles during 2017–18, with captures occurring mainly in bigeye tuna and swordfish target fisheries. All observed sea turtles that were caught in surface-longline fisheries were released alive, so understanding of the post-release survival of sea turtle would be essential to understanding the impact of these captures on their populations.

Capture estimates for the turtle model varied between subsequent updates of the model. The low number of captures meant that the model was sensitive to new data (42.9% of all observed turtle captures in the model dataset occurred in the three years from 2015–16 to 2017–18). Sea surface temperature and chlorophyll were introduced into the model, and there was a strong relationship between sea surface temperature and the turtle capture rate, with increasing temperatures being associated with higher sea surface temperatures. The introduction of sea surface temperature into the model as an explanatory covariate resulted in higher estimated captures of sea turtles during 2017–18, relative to models that did not include temperature. The sea surface temperature associated with bigeye and swordfish tuna fishing has been increasing (Figure 27). The trend associated with bigeye target fishing was 1.3 (95% confidence interval: 1.0 to 1.6, from a linear model) °C per decade. In 2017–18, the average sea surface temperature at the location of surface-longline fishing targeting bigeye tuna was 20.4 °C, which was 1.5 °C above the long term (2002–03 to 2017–18) mean. The anomaly was also high (1.4 °C above the long term mean) during 2015–16, and these times were the only two years with sea surface temperature anomalies over 1 °C. Both of these years were associated with estimated sea turtle capture rates in bigeye tuna fisheries of a mean of over 0.04 turtle per 1000 hooks, higher than in any other fishing year. The observed sea turtle capture rates in bigeye tuna fisheries during these years were over 0.05 turtle per 1000 hooks, higher than in any other year.

As sea surface temperatures increase with climate change, then the capture rates of sea turtle may also continue to increase. Between 1981 and 2017, the highest increase in sea surface temperature in the New Zealand region was off the North Island east coast, south of East Cape (Sutton & Bowen 2019), with a long-term average increase of around 0.3°C per decade. The changes in temperature seen in the bigeye and swordfish fisheries will include this temperature increase, along with changes arising from the change in location and seasonality of the fishery.

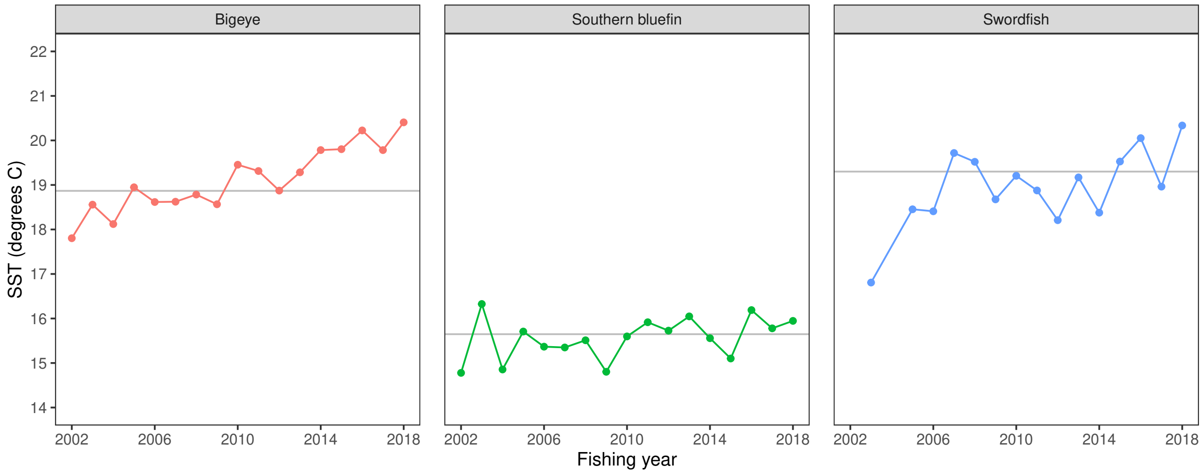


Figure 27: Change in annual average sea surface temperature (SST) at the time and location of surface longline fishing events, averaged for each target fishery. The horizontal line indicates the long term mean (2002–03 to 2017–18).

4.4 Future directions

In this report, and in previous analyses (e.g., Thompson et al. 2011, Thompson et al. 2013b, Abraham et al. 2016, Abraham & Berkenbusch 2017), a model selection process has been used to choose the covariates of the models. This selection has been based on finding the model that minimises an information criterion (such as the AIC or more recently the LOOIC). Selecting a single model from a set of tested models does not consider any uncertainty associated with the model selection. A recent approach is Bayesian model stacking, which uses model weights to sample the posterior distribution from a set of models (Yao et al. 2018). The model weights are chosen so as to maximise the predictive skill of the stacked models. Although the model selection process followed the previous process of maximising the ELPD (or equivalently of maximising the LOOIC), we also tested model stacking in the estimation of turtle and fur seal captures in surface longline fisheries. In neither case did the model with the highest ELPD have a high model weight, and the model stacking weighted some models that were far from maximising the ELPD. Rather than selecting a particular model, the model stacking allows uncertainty between models to be carried through into generating the estimates. Model stacking is implemented within the Bayesian model fitting software used here (BRMS) and provides a way of moving beyond the selection of single models based on a single criterion.

Strong patterns in the spatial distribution of captures were observed across models fitted for common dolphin, New Zealand fur seal, and turtles. Spatial variability in captures rates can occur because of changes in local population abundance or operational characteristics of a target fishery active in specific areas. Here, spatial effects were modelled directly through area covariates and indirectly through covariates (such as fishery) that were not distributed evenly over the spatial domain for the analysis. The area covariate encompassed broad regions that were modelled as independent of one another; for example, in the model of New Zealand fur seal captures, capture rates in the Bounty Islands area were treated independently from capture rates in the subantarctic area, even though Bounty Islands are nested within the subantarctic region.

The next step in the progression of the modelling approach would be to develop an explicit spatial model with a spatial surface fitted to observed captures. Ideally, this model structure would further be informed by environmental covariates likely to be related to local population abundance (such as distance to shore, or sea surface temperature). A simple approach would be to use a conditional autoregressive model (Gelfand & Vounatsou 2003, Jin et al. 2005) which fits spatial models by estimating the correlation between adjacent areas. For species with sufficient observed captures, this model approach is likely to reduce the uncertainty in the estimates. The spatial model would allow estimation of fur seal captures in surface-longline and trawl fisheries within the same framework. Spatial distributions, such as those developed by Stephenson et al. (2020) for cetaceans, may also be used to represent spatial variation in the captures, through the use of the risk assessment methodology (Abraham et al. 2017, Sharp 2017).

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6. REFERENCES

Abraham, E.R.; Berkenbusch, K. (2017). Estimated captures of New Zealand fur seal, New Zealand sea lion, common dolphin and turtles in New Zealand commercial fisheries, 1995–96 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report No. 188*. 66 p. Retrieved from http://fs.fish.govt.nz/Page.aspx?pk=113&dk=24557.

Abraham, E.R.; Berkenbusch, K. (2019a). Preparation of data for protected species capture estimation, updated to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report No. 233*. 49 p.

Abraham, E.R.; Berkenbusch, K. (2019b). Preparation of data for protected species capture estimation, updated to 2017–18. *New Zealand Aquatic Environment and Biodiversity Report No. 234*. 49 p. Retrieved from https://fs.fish.govt.nz/Page.aspx?pk=113&dk=24767.

Abraham, E.R.; Neubauer, P.; Berkenbusch, K.; Richard, Y. (2017). Assessment of the risk to New Zealand marine mammals from commercial fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 189*. 123 p. Retrieved from http://fs.fish.govt.nz/Page.aspx?pk=113&dk=24554.

Abraham, E.R.; Richard, Y. (2018). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report 197*. 97 p. Retrieved from https://www.mpi.govt.nz/dmsdocument/27588/.

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 from http://mpi.govt.nz/document-vault/12180.

Brooks, S.P.; Gelman, A. (1998). General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statistics 7 (4)*: 434–455.

Burgess, M.G.; McDermott, G.R.; Owashi, B.; Reeves, L.E.P.; Clavelle, T.; Ovando, D.; Wallace, B.P.; Lewison, R.L.; Gaines, S.D.; Costello, C. (2018). Protecting marine mammals, turtles, and birds by rebuilding global fisheries. *Science 359 (6381)*: 1255–1258.

Bürkner, P.-C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software 80*: 1–28. doi:10.18637/jss.v080.i01.

Carpenter, B.; Gelman, A.; Hoffman, M.; Lee, D.; Goodrich, B.; Betancourt, M.; Brubaker, M.A.; Guo, J.; Li, P.; Riddell, A. (2017). Stan: A probabilistic programming language. *Journal of Statistical Software 76*.

Deepwater Group (2016). Marine mammals, operational procedures. Updated September 2016. 22 p. Retrieved from https://deepwatergroup.org/wp-content/uploads/2016/11/Marin%20e-Mammals-Operational-Procedures-2016-17.pdf.

Deepwater Group (2018). Marine mammals, operational procedures. Version 9.0. 23 p. Retrieved from https://deepwatergroup.org/wp-content/uploads/2018/11/MMOP-Version-9-2.pdf.

Gelfand, A.E.; Vounatsou, P. (2003). Proper multivariate conditional autoregressive models for spatial data analysis. *Biostatistics 4 (1)*: 11–15.

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

Hoffman, M.D.; Gelman, A. (2014). The no-u-turn sampler: Adaptively setting path lengths in hamiltonian monte carlo. *Journal of Machine Learning Research 15 (1)*: 1593–1623.

Jin, X.; Carlin, B.P.; Banerjee, S. (2005). Generalized hierarchical multivariate CAR models for areal data. *Biometrics 61 (4)*: 950–961.

Large, K.; Roberts, J.; Francis, M.; Webber, D. (2019). Spatial assessment of fisheries risk for New Zealand sea lions at the Auckland Islands. *New Zealand Aquatic Environment and Biodiversity Report No. 224*. 85 p. Retrieved from https://fs.fish.govt.nz/Page.aspx?pk=113&dk=24724.

Meeus, J.H. (1991). Astronomical algorithms. 389 p. Willmann-Bell, Richmond, Virginia.

Ministry for Primary Industries (2017). Aquatic environment and biodiversity annual review 2017. Compiled by the Fisheries Management Science Team. Ministry for Primary Industries, Wellington.

Moore, J.E.; Wallace, B.P.; Lewison, R.L.; Žydelis, R.; Cox, T.M.; Crowder, L.B. (2009). A review of marine mammal, sea turtle and seabird bycatch in USA fisheries and the role of policy in shaping management. *Marine Policy 33 (3)*: 435–451.

Mullahy, J. (1986). Specification and testing of some modified count data models. *Journal of Econometrics 33 (3)*: 341–365.

NASA (2018). NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group. Moderate-resolution Imaging Spectroradiometer (MODIS) Aqua Chlorophyll Data; 2018 Reprocessing. NASA OB.DAAC, Greenbelt, MD, USA. doi:data/10.5067/AQUA/MODIS/L3M/CHL/2018.

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

Reynolds, R.W.; Rayner, N.A.; Smith, T.M.; Stokes, D.C.; Wang, W. (2002). An improved in situ and satellite SST analysis for climate. *Journal of climate 15 (13)*: 1609–1625.

Ridout, M.; Demetrio, C.G.B.; Hinde, J. (1998). Models for count data with many zeros. *In*: Proceedings of the XIXth international biometric conference (pp. 179–192). International Biometric Society. Washington.

Roberts, J.; Webber, D.; Roe, W.; Edwards, C.; Doonan, I. (2019). Spatial risk assessment of threats to Hector's and Māui dolphins (*Cephalorhynchus hectori)*. *New Zealand Aquatic Environment and Biodiversity Report No. 214*. 168 p. Retrieved from https://www.mpi.govt.nz/dmsdocument/35007/direct.

Sharp, B.R. (2017). Spatially Explicit Fisheries Risk Assessment (SEFRA): A framework for quantifying and managing incidental commercial fisheries impacts on non-target species and habitats. Chapter 3. *In*: Aquatic Environment and Biodiversity Annual Review 2016. 38 p. Compiled by the Fisheries Management Science Team, Ministry for Primary Industries, Wellington, New Zealand.

Sharp, B.R.; Bock, T. (2018). Orca capture incident workshop. Final workshop report. *MPI Technical Paper No.: 2018/02*. 27 p. Retrieved from https://www.mpi.govt.nz/dmsdocument/29057/send.

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

Stephenson, F.; Goetz, K.; Mouton, T.; Beets, F.; Hailes, S.; Roberts, J.; Pinkerton, M. (2020). Spatial distribution modelling of New Zealand cetacean species. *New Zealand Aquatic Environment and Biodiversity Report No. 240*. 217 p. Retrieved from https://fs.fish.govt.nz/Page.aspx?pk=113&dk=24798.

Sutton, P.J.; Bowen, M. (2019). Ocean temperature change around New Zealand over the last 36 years. *New Zealand Journal of Marine and Freshwater Research 53 (3)*: 305–326.

Thompson, F.N.; Abraham, E.R.; Berkenbusch, K. (2011). Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. Final Research Report for research project PRO2010-01. (Unpublished report held by Ministry for Primary Industries, Wellington). Retrieved from http://fs.fish.govt.nz/Doc/22390/AEBR_61.pdf.ashx.

Thompson, F.N.; Abraham, E.R. (2009). Dolphin bycatch in New Zealand trawl fisheries, 1995–96 to 2006–07. *New Zealand Aquatic Environment and Biodiversity Report No. 36*. 24 p. Retrieved from http://fs.fish.govt.nz/Doc/22002/AEBR_36.pdf.ashx.

Thompson, F.N.; Abraham, E.R. (2010). Estimation of fur seal (*Arctocephalus forsteri*) bycatch in New Zealand trawl fisheries, 2002–03 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 61*. 37 p. Retrieved from http://fs.fish.govt.nz/Doc/22390/AEBR_61.pdf.ashx.

Thompson, F.N.; Abraham, E.R.; Berkenbusch, K. (2010a). Common dolphin (*Delphinus delphis*) bycatch in New Zealand mackerel trawl fisheries, 1995–96 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 63*. 20 p.

Thompson, F.N.; Abraham, E.R.; Berkenbusch, K. (2013a). Common dolphin (*Delphinus delphis*) bycatch in New Zealand commercial trawl fisheries. *PLoS ONE 8*: e64438. doi:10.1371/journal.pone.0064438.

Thompson, F.N.; Abraham, E.R.; Berkenbusch, K. (2017). Preparation of data on observed protected species captures, 2002–03 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report No. 192*. 24 p.

Thompson, F.N.; Abraham, E.R.; Oliver, M.D. (2010b). Estimation of fur seal bycatch in New Zealand trawl fisheries, 2002–03 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 56*. 29 p. Retrieved from http://fs.fish.govt.nz/Doc/22314/AEBR_56%20Fur%20lion%20estimation%200708.pdf.ashx.

Thompson, F.N.; Berkenbusch, K.; Abraham, E.R. (2013b). Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. 73 p. Retrieved from https://www.mpi.govt.nz/document-vault/4241.

Thompson, F.N.; Berkenbusch, K.; Abraham, E.R. (2016). Incidental capture of marine mammals in New Zealand trawl fisheries, 1995–96 to 2011–12. *New Zealand Aquatic Environment and Biodiversity Report No. 167*. 82 p. Retrieved from http://mpi.govt.nz/document-vault/11947.

Vehtari, A.; Gelman, A.; Gabry, J. (2016). loo: Efficient leave-one-out cross-validation and WAIC for Bayesian models. R package version 0.1.6. Retrieved from https://github.com/jgabry/loo.

Vehtari, A.; Gelman, A.; Simpson, D.; Carpenter, B.; Bürkner, P.-C. (2020). Rank-normalization, folding, and localization: An improved $\hat{R}$ for assessing convergence of MCMC. Retrieved from https://arxiv.org/abs/1903.08008.

Yao, Y.; Vehtari, A.; Simpson, D.; Gelman, A., et al. (2018). Using stacking to average Bayesian predictive distributions (with discussion). *Bayesian Analysis 13 (3)*: 917–1007.

APPENDIX A: SUMMARIES OF CAPTURES BY SPECIES AND FISHERY

Table A-1: Observed marine mammal and turtle captures for the three fishing years from 2015–16 to 2017–18. Shown are the number of capture events, the number of captures, and the status (alive or dead) of captured animals in different commercial fisheries in New Zealand waters.

Fishing year	Species	Scientific name	Method	Events	Captures	Status	
						Alive	Dead
2015–16	Bottlenose dolphin	*Tursiops truncatus*	Surface longline	2	2	2	
	Common dolphin	*Delphinus delphis*	Trawl	6	7		7
	Dusky dolphin	*Lagenorhynchus obscurus*	Set net	1	1		1
			Trawl	1	1		1
	New Zealand fur seal	*Arctocephalus forsteri*	Trawl	69	109	10	99
			Surface longline	3	3	3	
			Set net	1	1		1
	New Zealand sea lion	*Phocarctos hookeri*	Trawl	3	4		4
	Leatherback turtle	*Dermochelys coriacea*	Surface longline	3	4	4	
			Trawl	1	1		1
	Turtle	*Chelonioidea*	Surface longline	2	2	2	
2016–17	Beaked whales	*Mesoplodon spp.*	Surface longline	2	2	2	
	Bottlenose dolphin	*Tursiops truncatus*	Trawl	1	1		1
	Common dolphin	*Delphinus delphis*	Set net	1	1		1
			Surface longline	1	1	1	
			Trawl	1	1		1
	Hectors dolphin	*Cephalorhynchus hectori*	Set net	1	1		1
	New Zealand fur seal	*Arctocephalus forsteri*	Trawl	67	79	12	67
			Surface longline	28	32	30	2
			Set net	5	5		5
			BLL	1	1		1
	New Zealand sea lion	*Phocarctos hookeri*	Trawl	3	3		3
	Leatherback turtle	*Dermochelys coriacea*	Surface longline	2	2	2	
2017–18	Common dolphin	*Delphinus delphis*	Trawl	1	1		1
	Long-beaked common dolphin	*Delphinus capensis*	Trawl	3	3		3
	Orca	*Orcinus orca*	Trawl	1	1		1
			Surface longline	1	1	1	
	Pilot whale long-finned	*Globicephala melas*	Trawl	1	1		1
			Surface longline	1	1	1	
	New Zealand fur seal	*Arctocephalus forsteri*	Trawl	70	80	10	70
			Surface longline	9	12	10	2
			Set net	10	11		11
	New Zealand sea lion	*Phocarctos hookeri*	Trawl	8	8	1	7
	Green turtle	*Chelonia mydas*	Surface longline	1	1	1	
	Leatherback turtle	*Dermochelys coriacea*	Surface longline	2	2	2	
	Loggerhead turtle	*Caretta caretta*	Surface longline	1	1	1	

A.1 Common dolphin

A.1.1 Common dolphin captures in jack mackerel trawl fisheries

Table A-2: Annual fishing effort (tows), and observer coverage (%) in jack mackerel trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of common dolphin; estimated captures and capture rate of common dolphin (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	3 035	11.4	21	6.07	140	60–259	4.62	1.98–8.53
2003–04	2 370	6.4	17	11.18	99	45–180	4.19	1.90–7.59
2004–05	2 506	22.3	21	3.76	85	46–139	3.39	1.84–5.55
2005–06	2 805	25.3	2	0.28	12	2–33	0.43	0.07–1.18
2006–07	2 711	29.6	11	1.37	55	23–102	2.03	0.85–3.76
2007–08	2 646	30.9	20	2.45	42	24–70	1.59	0.91–2.65
2008–09	2 168	37.5	11	1.35	23	11–42	1.04	0.51–1.94
2009–10	2 397	32.8	4	0.51	17	4–42	0.69	0.17–1.75
2010–11	1 870	31.7	7	1.18	53	18–108	2.83	0.96–5.78
2011–12	2 029	76.3	5	0.32	7	5–13	0.32	0.25–0.64
2012–13	2 209	88.0	15	0.77	15	15–19	0.70	0.68–0.86
2013–14	2 443	89.4	28	1.28	29	28–35	1.20	1.15–1.43
2014–15	1 744	86.6	19	1.26	21	19–28	1.21	1.09–1.61
2015–16	1 541	89.7	2	0.14	3	2–7	0.17	0.13–0.45
2016–17	1 398	73.0	0	0.00	1	0–5	0.05	0.00–0.36
2017–18	1 687	87.4	0	0.00	0	0–4	0.03	0.00–0.24

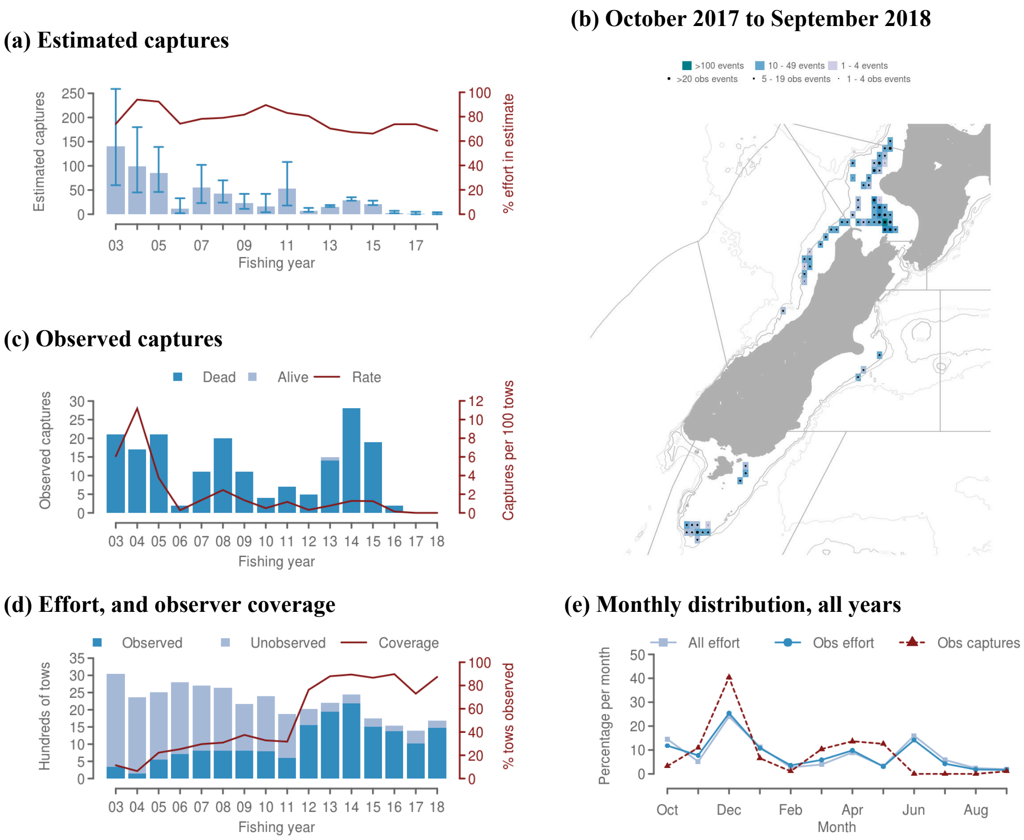


Figure A-1: Common dolphin captures in jack mackerel trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.1.2 Common dolphin captures in the large-vessel mackerel trawl model

Table A-3: Annual fishing effort (tows), and observer coverage (%) included in the model of common dolphin captures in the large-vessel west-coast North Island mackerel trawl model; number of observed captures and observed capture rate (captures per 100 tows) of common dolphin; estimated captures and capture rate (mean and 95% credible interval). The trips included in the model had 32 100 jack mackerel, 1043 barracouta, 279 blue mackerel tows and 8 other species target tows.

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995–96	406	29.6	2	1.67	5	2–16	1.29	0.49–3.94
1996–97	231	70.6	0	0.00	0	0–4	0.15	0.00–1.73
1997–98	562	38.8	0	0.00	2	0–10	0.31	0.00–1.78
1998–99	351	23.9	0	0.00	4	0–16	1.03	0.00–4.56
1999–00	413	17.2	1	1.41	9	1–30	2.08	0.24–7.26
2000–01	978	12.2	1	0.84	13	1–41	1.30	0.10–4.19
2001–02	1 586	7.0	1	0.90	32	3–98	2.04	0.19–6.18
2002–03	2 249	9.9	21	9.42	130	57–237	5.77	2.53–10.54
2003–04	2 309	7.1	17	10.37	99	46–180	4.29	1.99–7.80
2004–05	2 424	23.1	21	3.74	81	45–132	3.36	1.86–5.45
2005–06	2 117	30.6	2	0.31	11	2–30	0.53	0.09–1.42
2006–07	2 168	28.6	11	1.78	51	21–94	2.35	0.97–4.34
2007–08	2 164	34.0	20	2.72	41	24–68	1.90	1.11–3.14
2008–09	1 820	38.1	11	1.59	21	11–40	1.18	0.60–2.20
2009–10	2 189	30.1	4	0.61	16	4–40	0.72	0.18–1.83
2010–11	1 554	29.8	7	1.51	48	16–95	3.09	1.03–6.11
2011–12	1 650	79.0	5	0.38	6	5–12	0.39	0.30–0.73
2012–13	1 568	93.1	16	1.10	16	16–20	1.05	1.02–1.28
2013–14	1 808	93.0	28	1.66	29	28–33	1.59	1.55–1.83
2014–15	1 483	93.5	20	1.44	21	20–25	1.41	1.35–1.69
2015–16	1 171	89.8	2	0.19	3	2–7	0.23	0.17–0.60
2016–17	1 053	78.3	0	0.00	1	0–5	0.05	0.00–0.47
2017–18	1 176	88.0	0	0.00	0	0–4	0.03	0.00–0.34

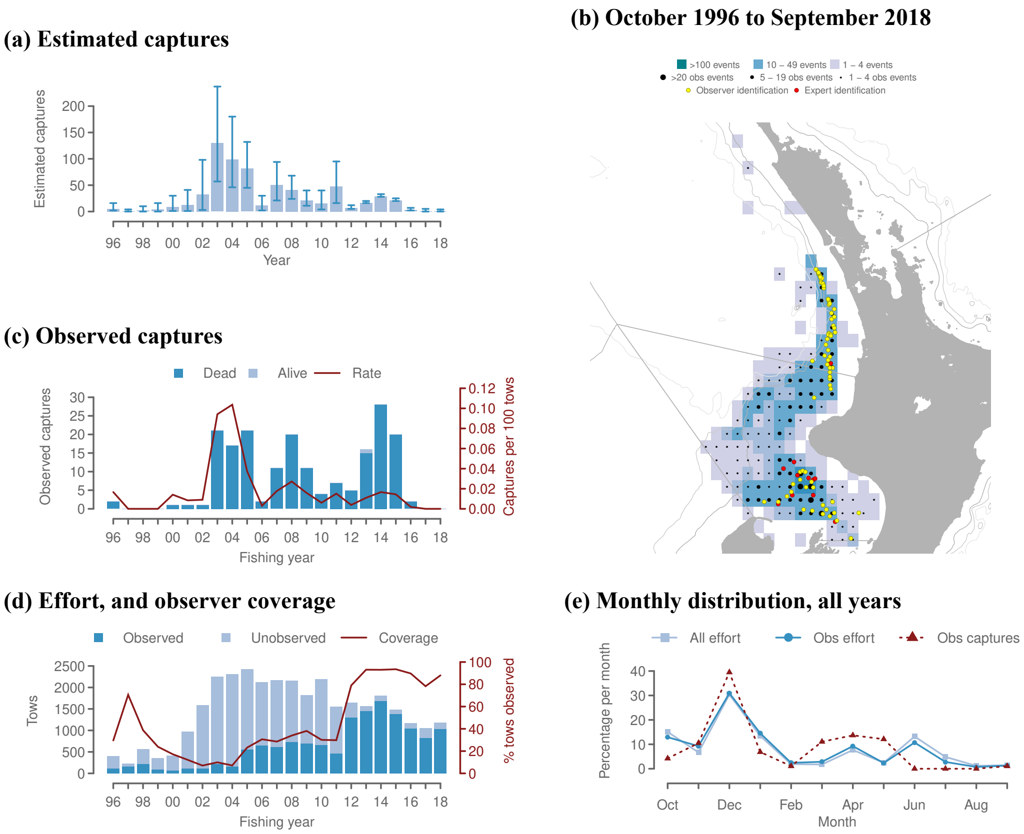


Figure A-2: Common dolphin captures in fishing effort included in the mackerel trawl model. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures between 1995–96 and 2017–18, coloured dots indicate observed captures, and the blue squares show annual average fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2 New Zealand fur seal

A.2.1 New Zealand fur seal captures in all trawl fisheries

Table A-4: Annual fishing effort (tows), and observer coverage (%) in all trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	130 148	5.3	68	0.99	960	658–1375	0.74	0.51–1.06
2003–04	120 821	5.4	90	1.37	948	663–1365	0.78	0.55–1.13
2004–05	120 437	6.4	199	2.58	1700	1254–2313	1.41	1.04–1.92
2005–06	109 931	6.0	143	2.16	1063	764–1484	0.97	0.69–1.35
2006–07	103 311	7.7	74	0.93	673	468–954	0.65	0.45–0.92
2007–08	89 531	10.1	142	1.57	798	594–1071	0.89	0.66–1.20
2008–09	87 549	11.2	72	0.74	529	377–752	0.60	0.43–0.86
2009–10	92 893	9.7	72	0.80	517	373–722	0.56	0.40–0.78
2010–11	86 079	8.7	73	0.98	566	375–848	0.66	0.44–0.99
2011–12	84 420	11.1	83	0.89	476	340–666	0.56	0.40–0.79
2012–13	83 849	14.8	121	0.98	589	409–859	0.70	0.49–1.02
2013–14	85 111	15.6	159	1.20	381	298–503	0.45	0.35–0.59
2014–15	78 765	17.2	127	0.94	503	362–704	0.64	0.46–0.89
2015–16	78 029	16.6	109	0.84	390	285–546	0.50	0.37–0.70
2016–17	78 173	17.6	79	0.58	407	284–577	0.52	0.36–0.74
2017–18	74 207	20.1	80	0.54	324	233–462	0.44	0.31–0.62

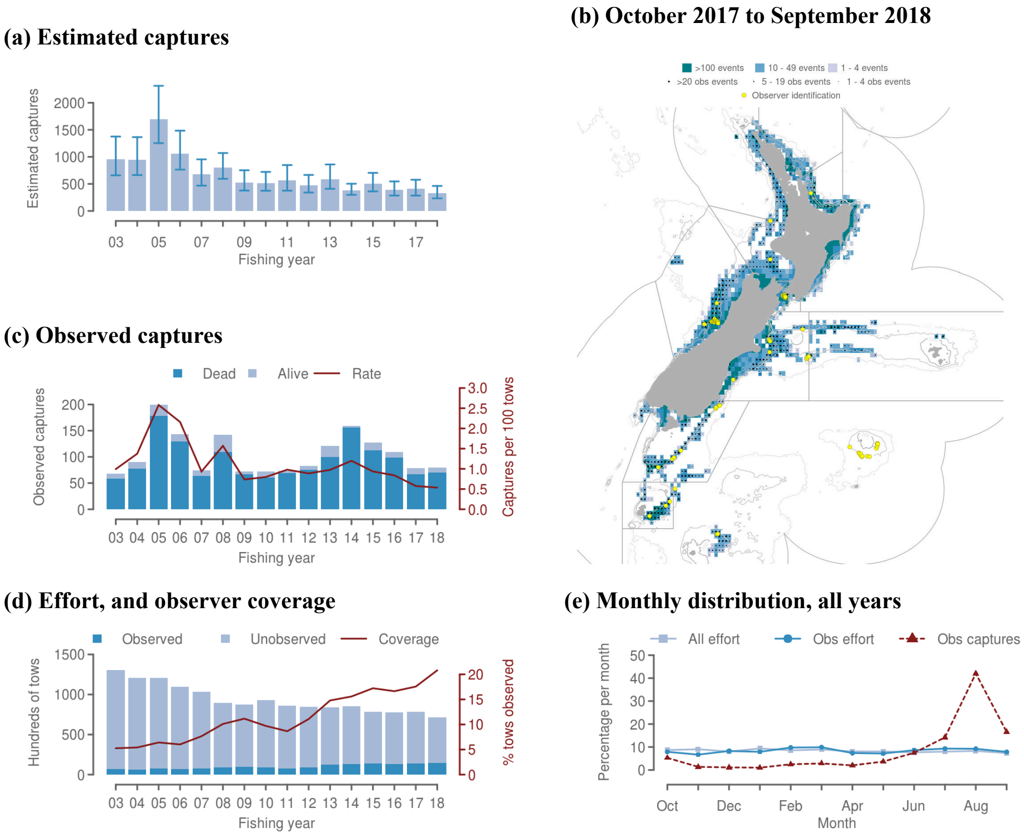


Figure A-3: New Zealand fur seal captures in all trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.2 New Zealand fur seal captures in hoki trawl fisheries

Table A-5: Annual fishing effort (tows), and observer coverage (%) in hoki trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	27 785	9.3	45	1.74	609	401–912	2.19	1.44–3.28
2003–04	22 524	10.4	56	2.39	522	343–784	2.32	1.52–3.48
2004–05	14 544	14.7	120	5.62	1021	713–1467	7.02	4.90–10.09
2005–06	11 590	15.3	62	3.49	535	350–811	4.61	3.02–7.00
2006–07	10 610	16.5	29	1.65	343	216–527	3.24	2.04–4.97
2007–08	8 787	21.4	58	3.09	347	235–505	3.95	2.67–5.75
2008–09	8 176	20.3	37	2.23	226	146–345	2.76	1.79–4.22
2009–10	9 965	20.7	30	1.45	191	129–276	1.92	1.29–2.77
2010–11	10 404	16.6	24	1.39	264	151–443	2.54	1.45–4.26
2011–12	11 333	23.8	34	1.26	221	143–332	1.95	1.26–2.93
2012–13	11 689	38.6	60	1.33	352	222–554	3.01	1.90–4.74
2013–14	12 948	30.7	32	0.80	141	95–206	1.09	0.73–1.59
2014–15	13 588	26.6	42	1.16	261	168–396	1.92	1.24–2.91
2015–16	12 636	27.5	42	1.21	220	146–324	1.74	1.16–2.56
2016–17	12 952	22.5	37	1.27	238	156–351	1.84	1.20–2.71
2017–18	13 792	34.6	41	0.86	190	128–283	1.38	0.93–2.05

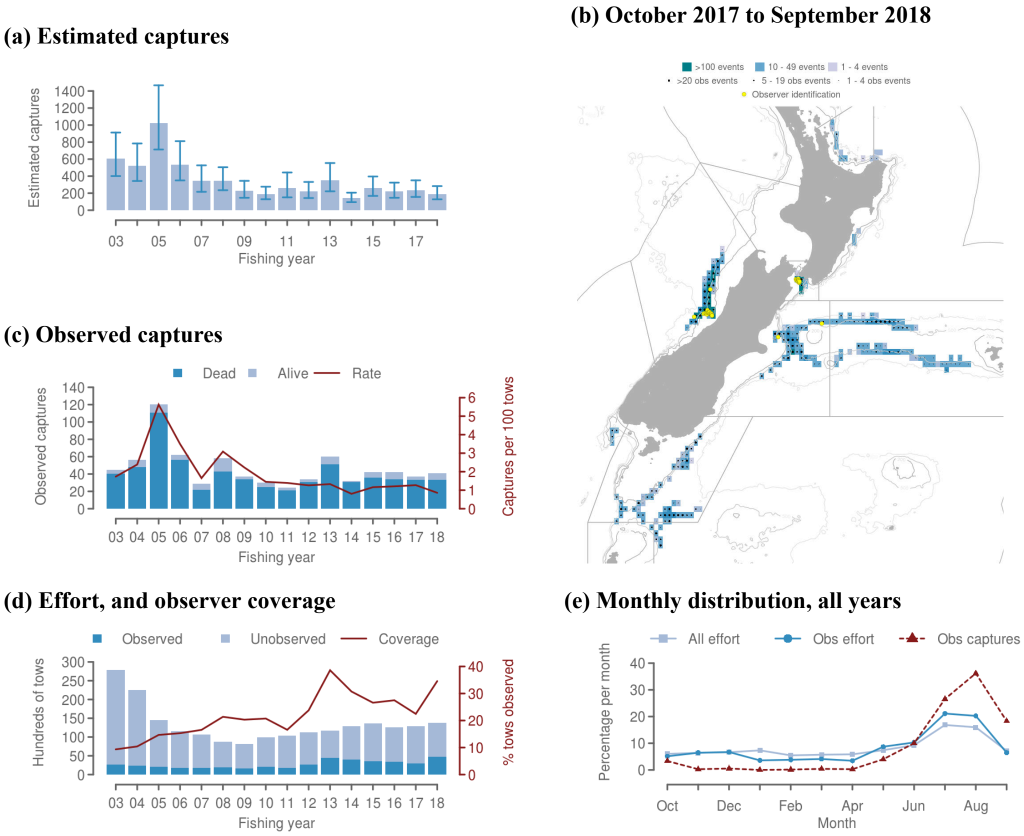


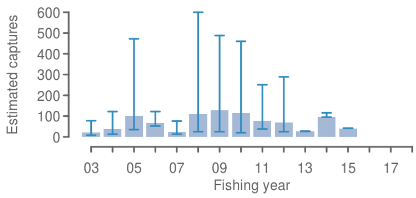
Figure A-4: New Zealand fur seal captures in hoki trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.3 New Zealand fur seal captures in southern blue whiting trawl fisheries

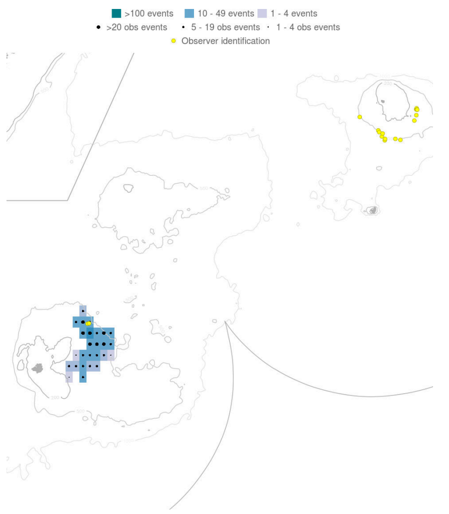
Table A-6: Annual fishing effort (tows), and observer coverage (%) in southern blue whiting trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	638	43.1	8	2.91	22	8–78	3.47	1.25–12.23
2003–04	740	32.6	13	5.39	36	13–122	4.88	1.76–16.49
2004–05	870	38.5	33	9.85	103	35–472	11.80	4.02–54.25
2005–06	624	34.8	52	23.96	67	52–122	10.77	8.33–19.55
2006–07	630	35.6	13	5.80	25	13–76	3.96	2.06–12.06
2007–08	818	40.5	24	7.25	110	25–600	13.41	3.06–73.35
2008–09	1 188	25.3	17	5.67	129	25–488	10.88	2.10–41.08
2009–10	1 114	35.5	16	4.04	114	20–460	10.20	1.80–41.29
2010–11	1 171	37.0	36	8.31	76	38–251	6.50	3.25–21.43
2011–12	951	70.3	25	3.74	69	25–289	7.30	2.63–30.39
2012–13	790	100.0	27	3.42	27	27–27	3.42	3.42–3.42
2013–14	809	99.9	95	11.76	97	95–116	11.98	11.74–14.34
2014–15	677	99.0	41	6.12	41	41–42	6.07	6.06–6.20
2015–16	442	100.0	51	11.54		–		–
2016–17	539	100.0	11	2.04		–		–
2017–18	455	100.0	17	3.74		–		–

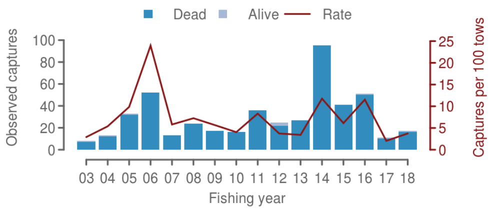
(a) Estimated captures



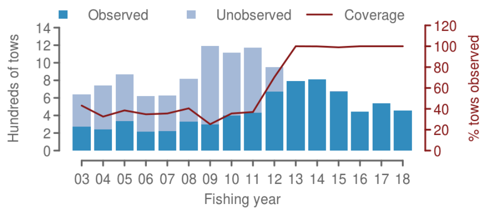
(b) October 2017 to September 2018



(c) Observed captures



(d) Effort, and observer coverage



(e) Monthly distribution, all years

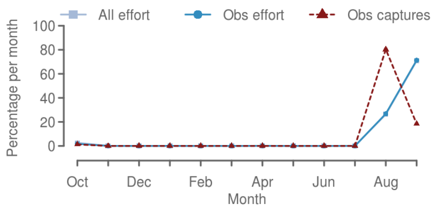


Figure A-5: New Zealand fur seal captures in southern blue whiting trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.4 New Zealand fur seal captures in middle depths species trawl fisheries

Table A-7: Annual fishing effort (tows), and observer coverage (%) in middle depths species trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	11 182	3.1	1	0.29	113	42–251	1.01	0.38–2.24
2003–04	9 167	2.1	0	0.00	105	36–243	1.15	0.39–2.65
2004–05	9 178	2.4	10	4.50	208	90–431	2.27	0.98–4.70
2005–06	8 403	5.8	4	0.82	136	55–285	1.61	0.65–3.39
2006–07	8 196	4.8	3	0.76	98	40–202	1.20	0.49–2.46
2007–08	7 416	6.1	9	2.00	142	66–274	1.92	0.89–3.69
2008–09	7 227	10.0	2	0.28	100	38–210	1.38	0.53–2.91
2009–10	7 216	12.2	5	0.57	94	40–190	1.30	0.55–2.63
2010–11	7 255	8.5	2	0.33	97	36–215	1.34	0.50–2.96
2011–12	6 549	11.7	8	1.05	88	40–180	1.35	0.61–2.75
2012–13	6 462	19.3	9	0.72	103	45–215	1.60	0.70–3.33
2013–14	6 409	21.8	4	0.29	47	20–97	0.74	0.31–1.51
2014–15	6 436	27.5	7	0.40	72	32–141	1.12	0.50–2.19
2015–16	5 841	20.8	3	0.25	50	19–113	0.86	0.33–1.93
2016–17	5 952	28.6	6	0.35	69	28–148	1.16	0.47–2.49
2017–18	6 263	25.4	3	0.19	45	17–97	0.72	0.27–1.55

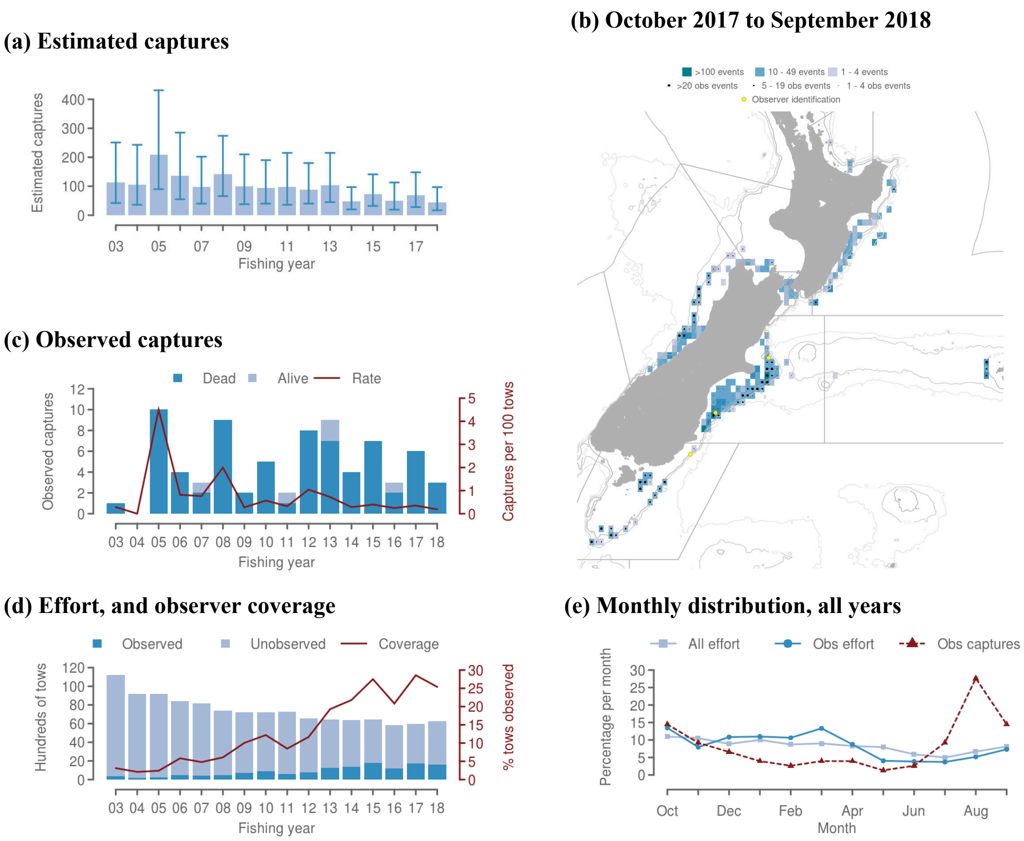


Figure A-6: New Zealand fur seal captures in middle depths species trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.5 New Zealand fur seal captures in inshore species trawl fisheries

Table A-8: Annual fishing effort (tows), and observer coverage (%) in inshore species trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	36 564	0.0	0	0.00	67	16–182	0.18	0.04–0.50
2003–04	37 378	0.0	0	0.00	67	16–177	0.18	0.04–0.47
2004–05	40 819	0.0	0	0.00	118	31–307	0.29	0.08–0.75
2005–06	39 155	0.3	0	0.00	89	23–226	0.23	0.06–0.58
2006–07	35 823	0.8	0	0.00	59	14–151	0.17	0.04–0.42
2007–08	31 417	0.4	0	0.00	69	18–170	0.22	0.06–0.54
2008–09	33 100	3.4	1	0.09	53	15–127	0.16	0.05–0.38
2009–10	35 971	1.4	0	0.00	57	15–141	0.16	0.04–0.39
2010–11	34 969	1.3	0	0.00	53	13–133	0.15	0.04–0.38
2011–12	32 775	0.6	0	0.00	55	15–140	0.17	0.05–0.43
2012–13	33 262	0.5	1	0.59	53	15–128	0.16	0.05–0.38
2013–14	34 210	4.9	2	0.12	48	15–115	0.14	0.04–0.34
2014–15	30 427	6.8	2	0.10	60	18–146	0.20	0.06–0.48
2015–16	28 340	6.6	0	0.00	32	8–82	0.11	0.03–0.29
2016–17	29 330	11.0	2	0.06	43	13–101	0.15	0.04–0.34
2017–18	27 253	7.8	1	0.05	34	9–83	0.12	0.03–0.30

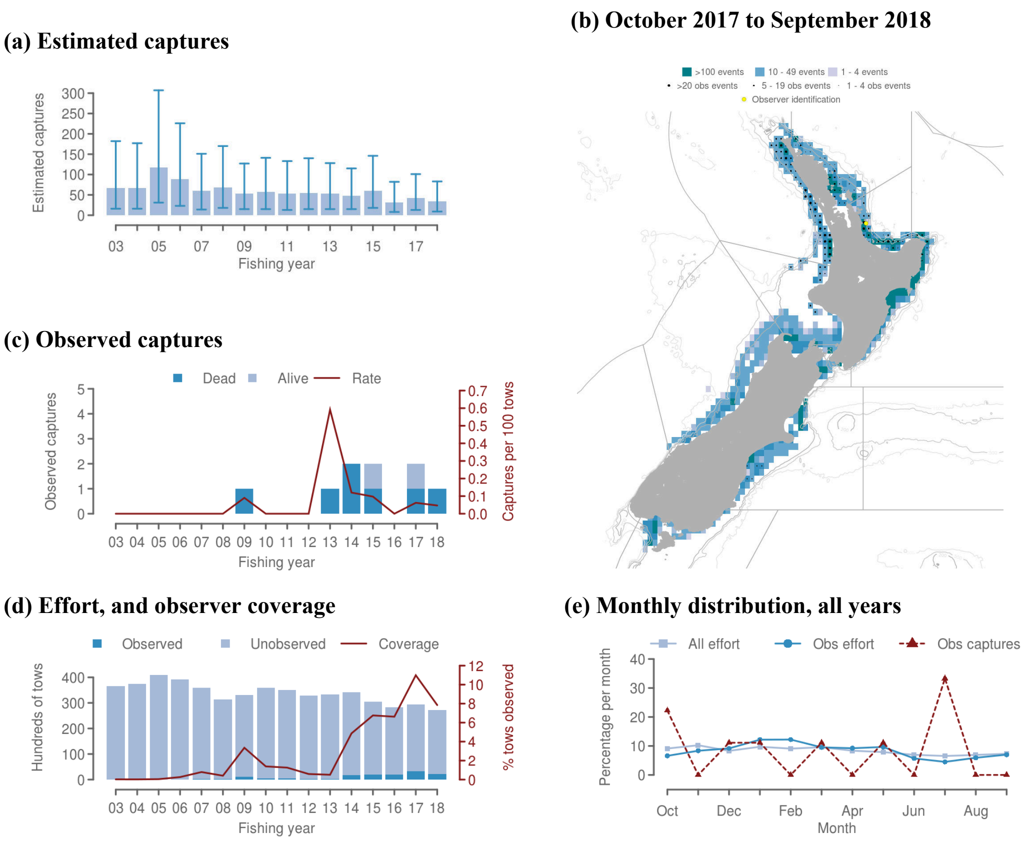


Figure A-7: New Zealand fur seal captures in inshore species trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.6 New Zealand fur seal captures in squid trawl fisheries

Table A-9: Annual fishing effort (tows), and observer coverage (%) in squid trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 410	15.6	8	0.61	101	50–180	1.20	0.59–2.14
2003–04	8 336	21.2	16	0.90	142	79–243	1.71	0.95–2.92
2004–05	10 489	23.9	15	0.60	150	78–270	1.43	0.74–2.57
2005–06	8 576	12.9	4	0.36	109	48–206	1.27	0.56–2.40
2006–07	5 905	21.8	9	0.70	78	39–141	1.32	0.66–2.39
2007–08	4 236	34.4	6	0.41	35	16–71	0.83	0.38–1.68
2008–09	3 868	33.6	1	0.08	24	7–53	0.61	0.18–1.37
2009–10	3 789	28.3	8	0.75	66	32–126	1.75	0.84–3.33
2010–11	4 213	30.0	8	0.63	34	17–61	0.81	0.40–1.45
2011–12	3 507	39.4	8	0.58	35	18–65	1.00	0.51–1.85
2012–13	2 643	85.9	7	0.31	9	7–14	0.34	0.26–0.53
2013–14	2 051	87.2	10	0.56	11	10–14	0.54	0.49–0.68
2014–15	1 950	86.9	19	1.12	25	19–41	1.27	0.97–2.10
2015–16	2 896	81.6	10	0.42	19	11–37	0.65	0.38–1.28
2016–17	2 595	74.2	17	0.88	23	17–36	0.88	0.66–1.39
2017–18	2 825	89.0	14	0.56	23	14–49	0.83	0.50–1.73

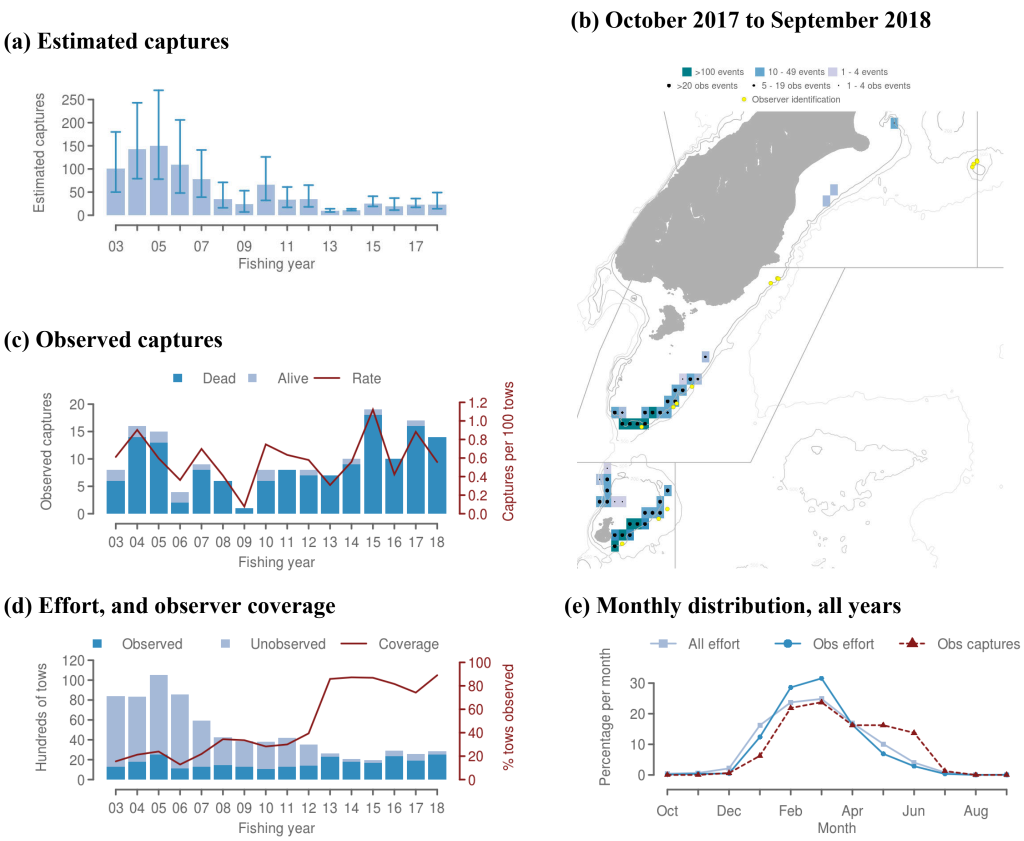


Figure A-8: New Zealand fur seal captures in squid trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.7 New Zealand fur seal captures in ling trawl fisheries

Table A-10: Annual fishing effort (tows), and observer coverage (%) in ling trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	632	2.5	0	0.00	10	1–29	1.57	0.16–4.59
2003–04	558	3.9	0	0.00	10	1–28	1.72	0.18–5.02
2004–05	988	7.7	10	13.16	47	21–100	4.72	2.13–10.12
2005–06	1 394	8.1	2	1.77	47	18–103	3.39	1.29–7.39
2006–07	1 662	9.4	12	7.64	38	21–66	2.29	1.26–3.97
2007–08	2 227	10.8	4	1.66	47	23–91	2.12	1.03–4.09
2008–09	1 410	10.3	0	0.00	25	9–51	1.80	0.64–3.62
2009–10	1 195	16.7	6	3.02	28	12–58	2.32	1.00–4.85
2010–11	1 107	9.4	2	1.92	19	7–41	1.74	0.63–3.70
2011–12	946	16.8	1	0.63	14	4–32	1.50	0.42–3.38
2012–13	1 149	23.3	4	1.49	18	8–36	1.60	0.70–3.13
2013–14	1 130	10.6	0	0.00	11	3–25	0.95	0.27–2.21
2014–15	1 127	16.1	1	0.55	14	4–31	1.24	0.35–2.75
2015–16	1 144	14.2	1	0.61	8	2–19	0.70	0.17–1.66
2016–17	1 227	20.5	3	1.19	12	5–26	1.00	0.41–2.12
2017–18	1 164	29.8	1	0.29	6	2–14	0.53	0.17–1.20

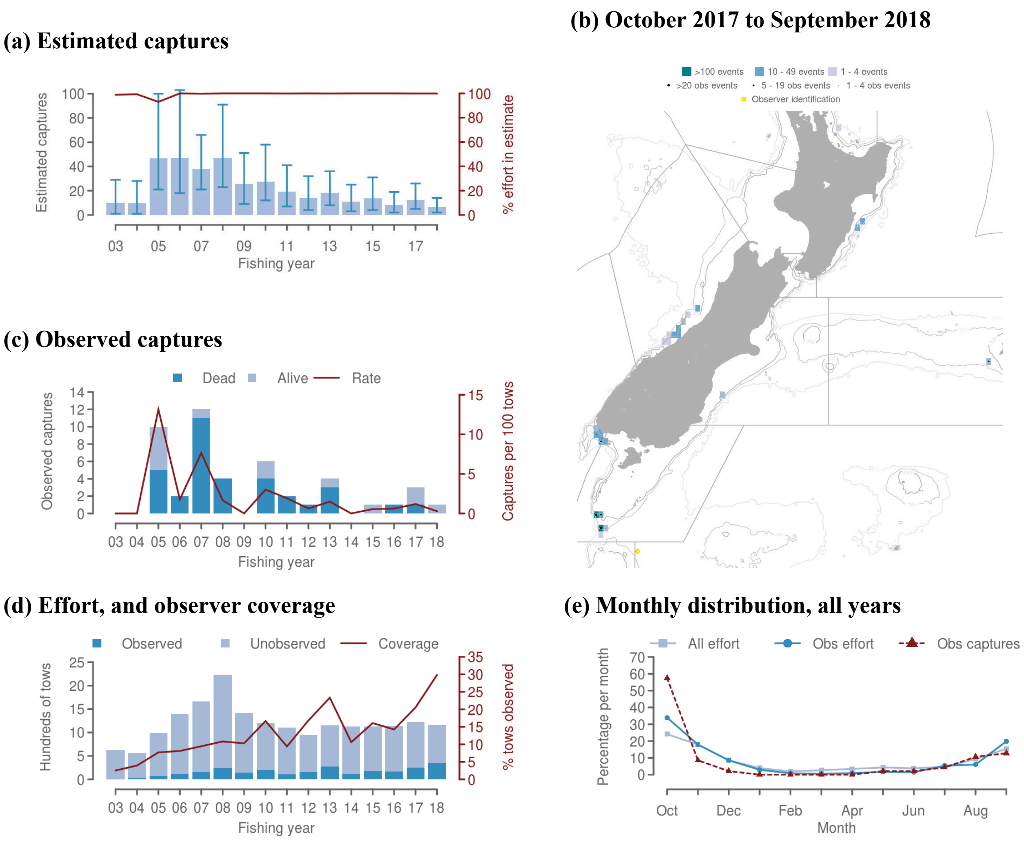


Figure A-9: New Zealand fur seal captures in ling trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.8 New Zealand fur seal captures in scampi trawl fisheries

Table A-11: Annual fishing effort (tows), and observer coverage (%) in scampi trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	5 130	10.0	2	0.39	8	2–18	0.15	0.04–0.35
2003–04	3 753	11.0	1	0.24	5	1–14	0.15	0.03–0.37
2004–05	4 648	3.1	0	0.00	13	2–37	0.27	0.04–0.80
2005–06	4 867	6.8	0	0.00	7	1–20	0.15	0.02–0.41
2006–07	5 135	7.6	0	0.00	7	1–20	0.14	0.02–0.39
2007–08	4 804	10.9	1	0.19	8	2–20	0.16	0.04–0.42
2008–09	3 975	10.0	1	0.25	5	1–13	0.13	0.03–0.33
2009–10	4 248	8.2	1	0.29	8	2–20	0.18	0.05–0.47
2010–11	4 447	12.1	0	0.00	4	0–12	0.09	0.00–0.27
2011–12	4 509	10.2	1	0.22	7	2–18	0.16	0.04–0.40
2012–13	4 565	5.9	0	0.00	5	0–15	0.11	0.00–0.33
2013–14	4 421	5.7	0	0.00	4	0–12	0.08	0.00–0.27
2014–15	4 423	7.7	1	0.29	7	2–20	0.17	0.05–0.45
2015–16	5 210	2.8	0	0.00	5	0–14	0.09	0.00–0.27
2016–17	4 707	9.5	1	0.22	6	1–16	0.13	0.02–0.34
2017–18	4 345	12.5	0	0.00	3	0–10	0.08	0.00–0.23

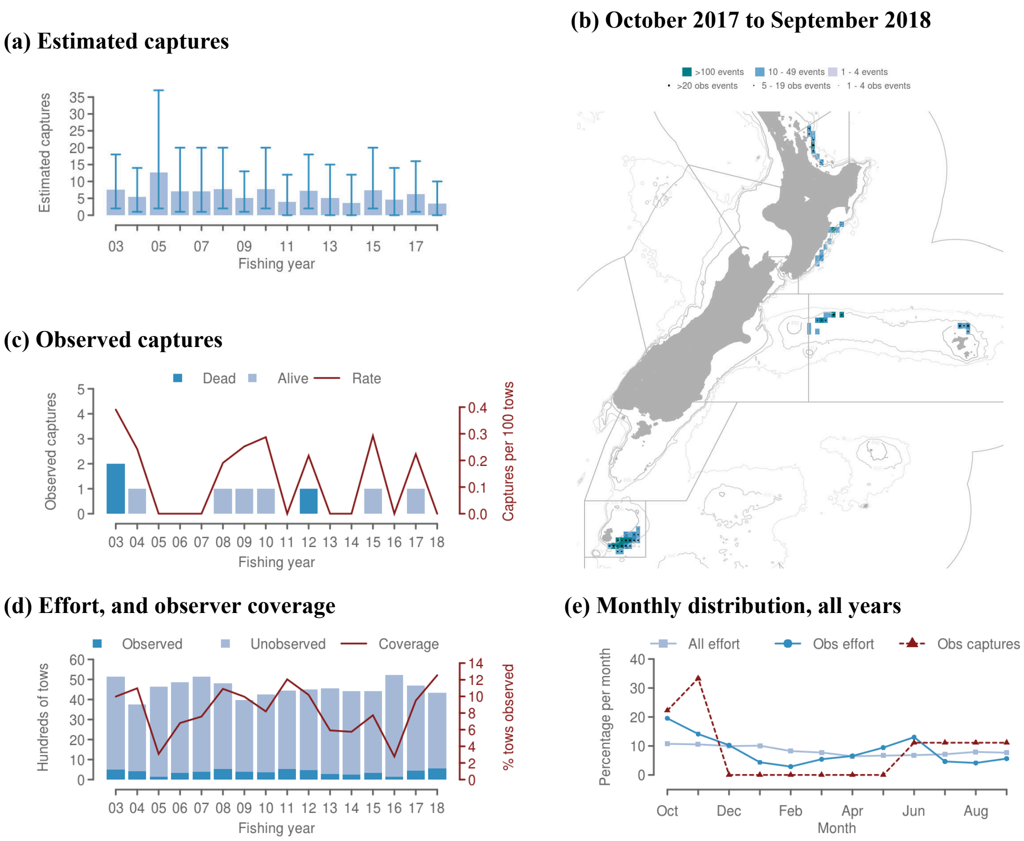


Figure A-10: New Zealand fur seal captures in scampi trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.9 New Zealand fur seal captures in jack mackerel trawl fisheries

Table A-12: Annual fishing effort (tows), and observer coverage (%) in jack mackerel trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	3 067	11.3	1	0.29	13	4–28	0.42	0.13–0.91
2003–04	2 383	6.4	2	1.32	12	3–29	0.49	0.13–1.22
2004–05	2 509	22.2	5	0.90	22	9–44	0.86	0.36–1.75
2005–06	2 808	25.2	6	0.85	26	13–48	0.94	0.46–1.71
2006–07	2 711	29.6	2	0.25	10	3–22	0.37	0.11–0.81
2007–08	2 647	30.9	7	0.86	24	12–43	0.89	0.45–1.62
2008–09	2 169	37.5	8	0.98	17	10–29	0.78	0.46–1.34
2009–10	2 406	32.7	2	0.25	5	2–12	0.22	0.08–0.50
2010–11	1 881	31.5	0	0.00	3	0–8	0.15	0.00–0.43
2011–12	2 031	76.2	5	0.32	8	5–13	0.37	0.25–0.64
2012–13	2 217	87.6	4	0.21	5	4–9	0.24	0.18–0.41
2013–14	2 444	89.4	10	0.46	11	10–15	0.46	0.41–0.61
2014–15	1 750	86.4	5	0.33	6	5–12	0.37	0.29–0.69
2015–16	1 544	89.6	2	0.14	3	2–6	0.18	0.13–0.39
2016–17	1 403	72.7	0	0.00	2	0–6	0.11	0.00–0.43
2017–18	1 688	87.3	3	0.20	4	3–6	0.22	0.18–0.36

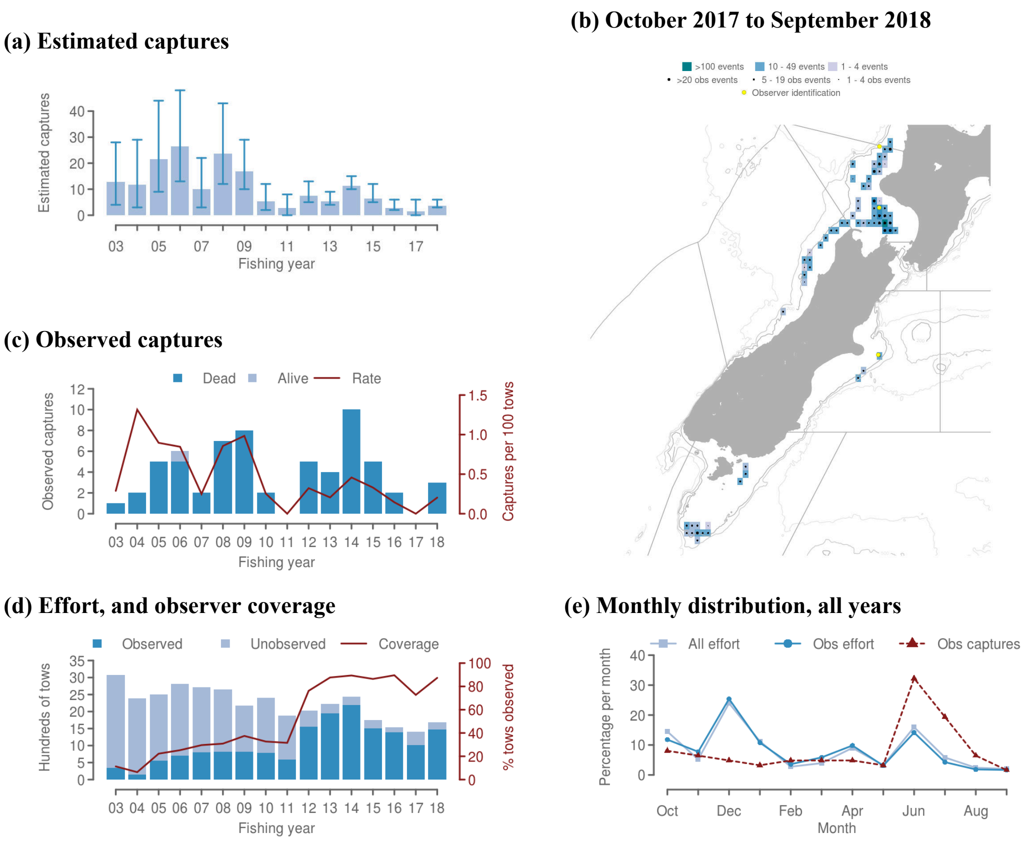


Figure A-11: New Zealand fur seal captures in jack mackerel trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.10 New Zealand fur seal captures in hake trawl fisheries

Table A-13: Annual fishing effort (tows), and observer coverage (%) in hake trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	945	5.2	3	6.12	13	5–25	1.33	0.53–2.65
2003–04	1 651	8.5	0	0.00	11	4–23	0.69	0.24–1.39
2004–05	1 557	6.2	2	2.08	39	19–70	2.52	1.22–4.50
2005–06	1 359	31.0	11	2.61	33	19–53	2.41	1.40–3.90
2006–07	1 606	18.4	4	1.35	13	6–24	0.80	0.37–1.49
2007–08	1 547	25.5	28	7.11	64	43–102	4.16	2.78–6.59
2008–09	1 779	19.7	5	1.42	20	10–35	1.11	0.56–1.97
2009–10	822	40.1	4	1.21	8	4–15	1.02	0.49–1.82
2010–11	868	26.2	1	0.44	8	2–19	0.94	0.23–2.19
2011–12	645	35.0	1	0.44	7	2–16	1.07	0.31–2.48
2012–13	704	75.0	9	1.70	16	9–28	2.22	1.28–3.98
2013–14	799	73.0	6	1.03	11	6–21	1.41	0.75–2.63
2014–15	978	76.2	8	1.07	15	9–28	1.55	0.92–2.86
2015–16	512	71.5	0	0.00	2	0–7	0.38	0.00–1.37
2016–17	542	84.1	2	0.44	3	2–8	0.60	0.37–1.48
2017–18	260	57.7	0	0.00	1	0–5	0.48	0.00–1.92

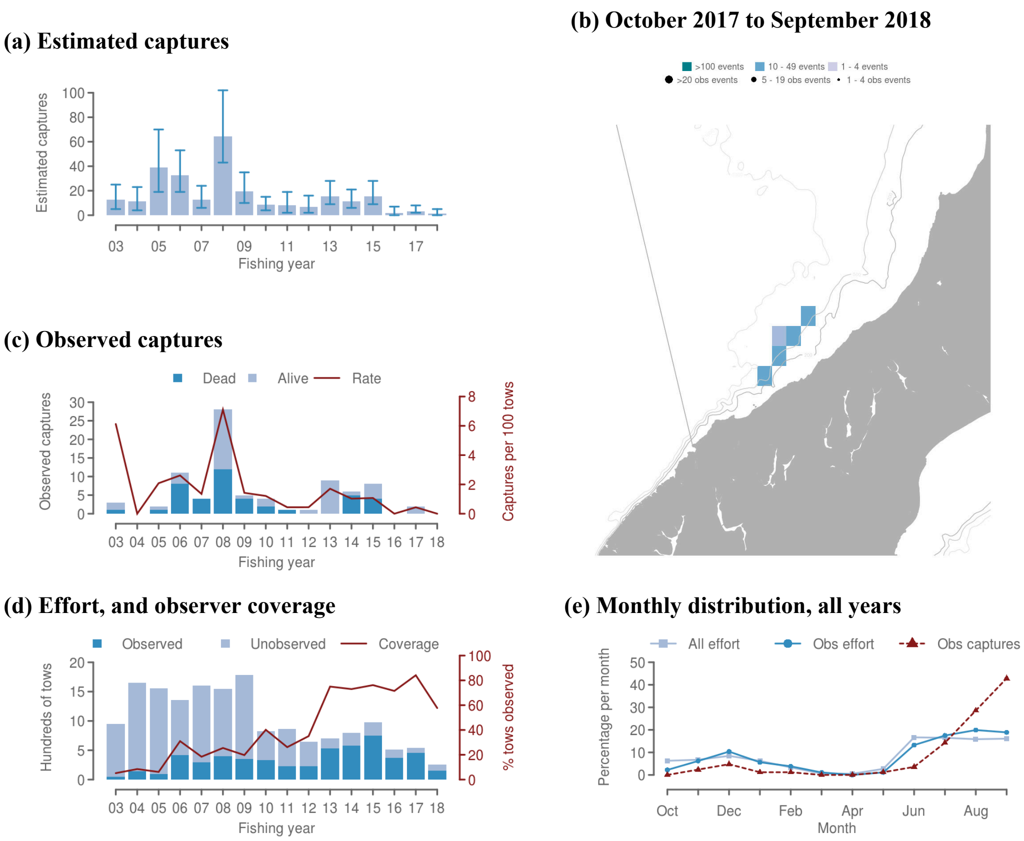


Figure A-12: New Zealand fur seal captures in hake trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.11 New Zealand fur seal captures in deepwater trawl fisheries

Table A-14: Annual fishing effort (tows), and observer coverage (%) in deepwater trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 871	15.6	0	0.00	4	0–12	0.04	0.00–0.14
2003–04	8 005	15.8	2	0.16	9	3–23	0.12	0.04–0.29
2004–05	8 425	19.2	4	0.25	14	6–28	0.16	0.07–0.33
2005–06	8 289	16.4	2	0.15	10	3–23	0.13	0.04–0.28
2006–07	7 368	31.5	2	0.09	3	2–7	0.05	0.03–0.10
2007–08	6 730	41.8	5	0.18	8	5–13	0.12	0.07–0.19
2008–09	6 134	38.7	0	0.00	2	0–7	0.03	0.00–0.11
2009–10	6 011	35.5	0	0.00	3	0–8	0.05	0.00–0.13
2010–11	4 178	28.8	0	0.00	3	0–10	0.08	0.00–0.24
2011–12	3 654	25.2	0	0.00	1	0–5	0.04	0.00–0.14
2012–13	3 098	11.2	0	0.00	0	0–2	0.02	0.00–0.06
2013–14	3 606	12.0	0	0.00	1	0–3	0.02	0.00–0.08
2014–15	3 812	25.7	1	0.10	2	1–4	0.04	0.03–0.10
2015–16	4 083	34.8	0	0.00	1	0–3	0.01	0.00–0.07
2016–17	3 972	30.9	0	0.00	0	0–2	0.01	0.00–0.05
2017–18	3 744	24.1	0	0.00	1	0–3	0.01	0.00–0.08

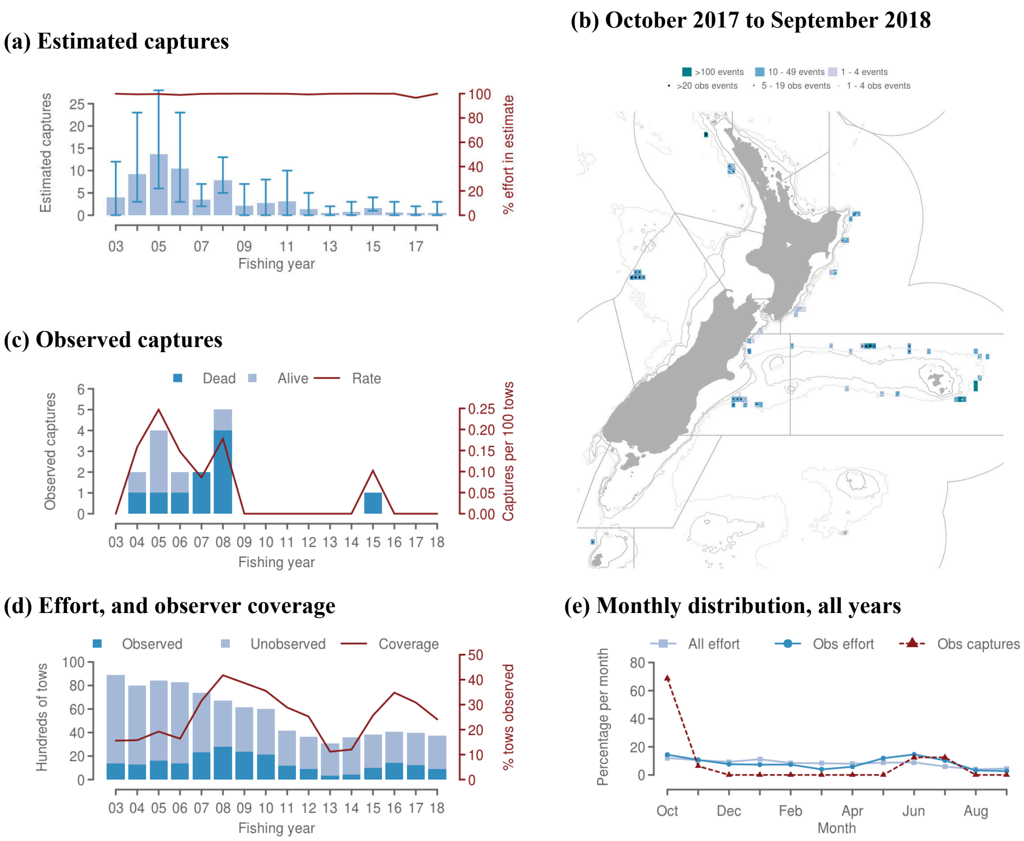


Figure A-13: New Zealand fur seal captures in deepwater trawl fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.12 New Zealand fur seal captures in surface-longline fisheries

Table A-15: Annual fishing effort (hooks), and observer coverage (%) in surface-longline fisheries; number of observed captures and observed capture rate (captures per thousand hooks) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	10 770 038	20.4	56	0.026	309	213–437	0.029	0.020–0.041
2003–04	7 386 059	21.8	40	0.025	161	115–220	0.022	0.016–0.030
2004–05	3 682 895	21.3	20	0.026	83	54–118	0.022	0.015–0.032
2005–06	3 692 109	19.1	12	0.017	55	33–85	0.015	0.009–0.023
2006–07	3 739 882	27.8	10	0.010	36	21–56	0.010	0.006–0.015
2007–08	2 245 589	18.8	10	0.024	45	26–70	0.020	0.012–0.031
2008–09	3 115 633	30.1	22	0.023	68	47–94	0.022	0.015–0.030
2009–10	2 995 264	22.1	19	0.029	83	54–122	0.028	0.018–0.041
2010–11	3 188 179	21.2	17	0.025	64	41–94	0.020	0.013–0.029
2011–12	3 100 227	23.5	40	0.055	152	111–202	0.049	0.036–0.065
2012–13	2 876 782	19.5	21	0.037	111	71–162	0.039	0.025–0.056
2013–14	2 549 764	30.7	57	0.073	191	147–244	0.075	0.058–0.096
2014–15	2 412 336	30.1	37	0.051	153	109–210	0.064	0.045–0.087
2015–16	2 358 541	13.7	3	0.009	31	13–57	0.013	0.006–0.024
2016–17	2 094 236	16.5	32	0.093	150	108–199	0.072	0.052–0.095
2017–18	2 288 051	12.9	12	0.041	60	32–96	0.026	0.014–0.042

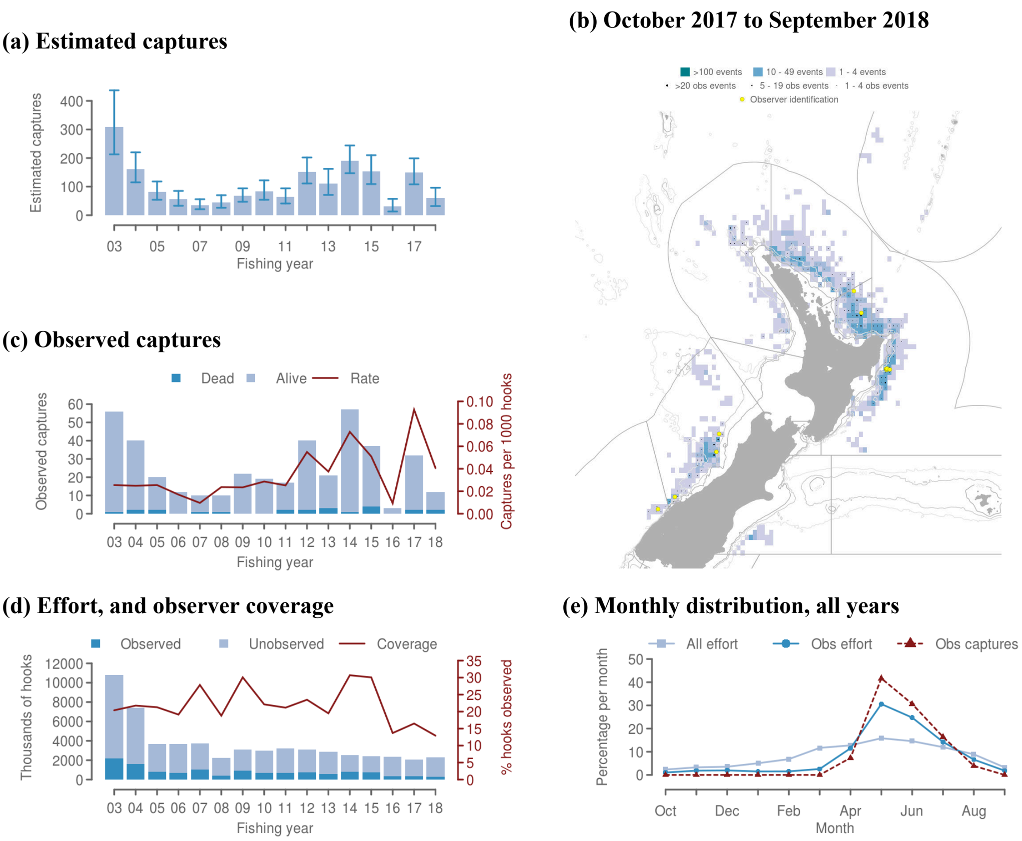


Figure A-14: New Zealand fur seal captures in surface-longline fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.2.13 New Zealand fur seal captures in southern bluefin surface-longline fisheries

Table A-16: Annual fishing effort (hooks), and observer coverage (%) in southern bluefin surface-longline fisheries; number of observed captures and observed capture rate (captures per thousand hooks) of New Zealand fur seal; estimated captures and capture rate of New Zealand fur seal (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	3 512 911	32.3	56	0.049	270	188–378	0.077	0.054–0.108
2003–04	3 195 071	46.1	40	0.027	146	105–198	0.046	0.033–0.062
2004–05	1 665 009	44.1	18	0.025	73	48–105	0.044	0.029–0.063
2005–06	1 493 868	43.9	12	0.018	49	30–75	0.033	0.020–0.050
2006–07	1 938 111	47.3	10	0.011	33	20–50	0.017	0.010–0.026
2007–08	1 104 825	34.0	8	0.021	40	22–62	0.036	0.020–0.056
2008–09	1 484 438	56.6	22	0.026	63	45–87	0.042	0.030–0.059
2009–10	1 559 858	37.2	19	0.033	80	52–116	0.051	0.033–0.074
2010–11	1 330 265	42.6	17	0.030	58	38–85	0.044	0.029–0.064
2011–12	1 593 754	40.5	40	0.062	142	104–188	0.089	0.065–0.118
2012–13	1 516 247	32.4	21	0.043	104	67–151	0.069	0.044–0.100
2013–14	1 589 620	47.0	57	0.076	184	141–234	0.116	0.089–0.147
2014–15	1 566 919	43.6	37	0.054	148	105–203	0.094	0.067–0.130
2015–16	1 234 822	20.8	3	0.012	29	12–54	0.024	0.010–0.044
2016–17	1 246 229	21.2	31	0.117	142	103–190	0.114	0.083–0.152
2017–18	1 296 591	16.6	12	0.056	58	31–93	0.045	0.024–0.072

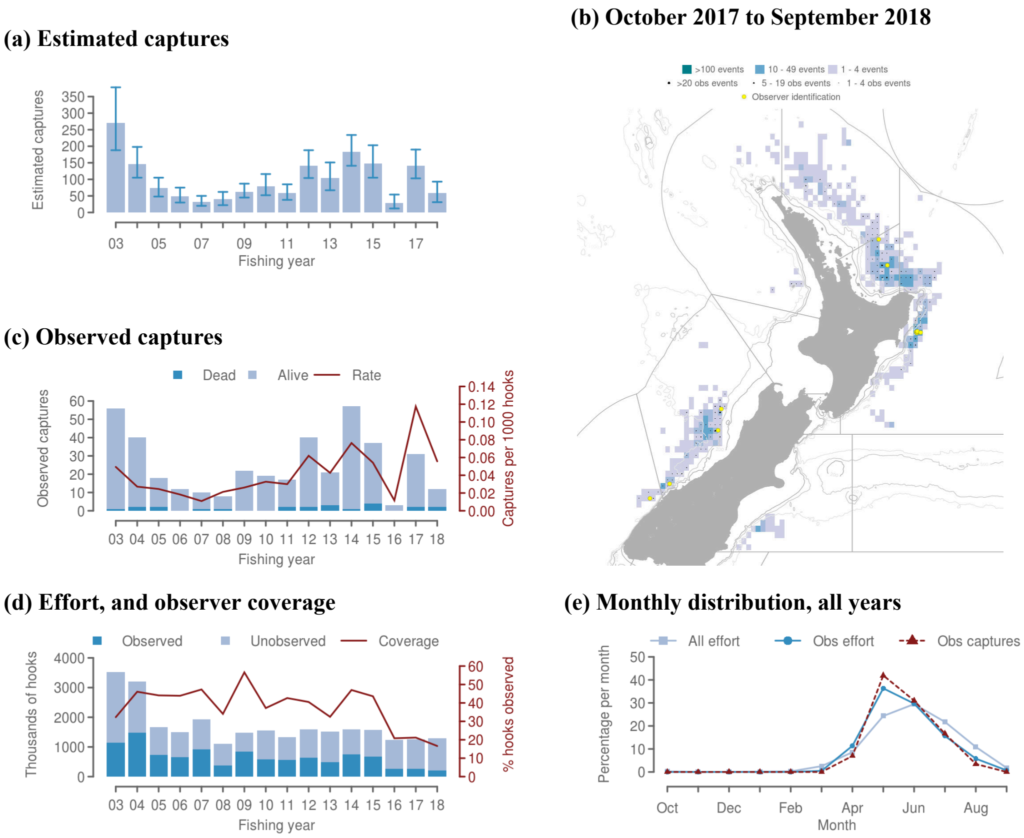


Figure A-15: New Zealand fur seal captures in southern bluefin surface-longline fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.3 Turtles

A.3.1 Turtle captures in surface-longline fisheries

Table A-17: Annual fishing effort (hooks), and observer coverage (%) in surface-longline fisheries; number of observed captures and observed capture rate (captures per thousand hooks) of turtles; estimated captures and capture rate of turtles (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	10 770 038	20.4	0	0.000	127	72–196	0.012	0.007–0.018
2003–04	7 386 059	21.8	1	0.001	87	48–139	0.012	0.006–0.019
2004–05	3 682 895	21.3	2	0.003	61	35–96	0.017	0.010–0.026
2005–06	3 692 109	19.1	1	0.001	57	31–91	0.015	0.008–0.025
2006–07	3 739 882	27.8	2	0.002	40	22–64	0.011	0.006–0.017
2007–08	2 245 589	18.8	1	0.002	28	14–46	0.012	0.006–0.020
2008–09	3 115 633	30.1	2	0.002	37	19–60	0.012	0.006–0.019
2009–10	2 995 264	22.1	0	0.000	47	26–76	0.016	0.009–0.025
2010–11	3 188 179	21.2	4	0.006	54	30–84	0.017	0.009–0.026
2011–12	3 100 227	23.5	0	0.000	24	11–41	0.008	0.004–0.013
2012–13	2 876 782	19.5	2	0.004	34	18–54	0.012	0.006–0.019
2013–14	2 549 764	30.7	0	0.000	23	11–40	0.009	0.004–0.016
2014–15	2 412 336	30.1	1	0.001	27	12–48	0.011	0.005–0.020
2015–16	2 358 541	13.7	6	0.019	57	31–93	0.024	0.013–0.039
2016–17	2 094 236	16.5	2	0.006	25	13–41	0.012	0.006–0.020
2017–18	2 288 051	12.9	4	0.014	53	27–86	0.023	0.012–0.038

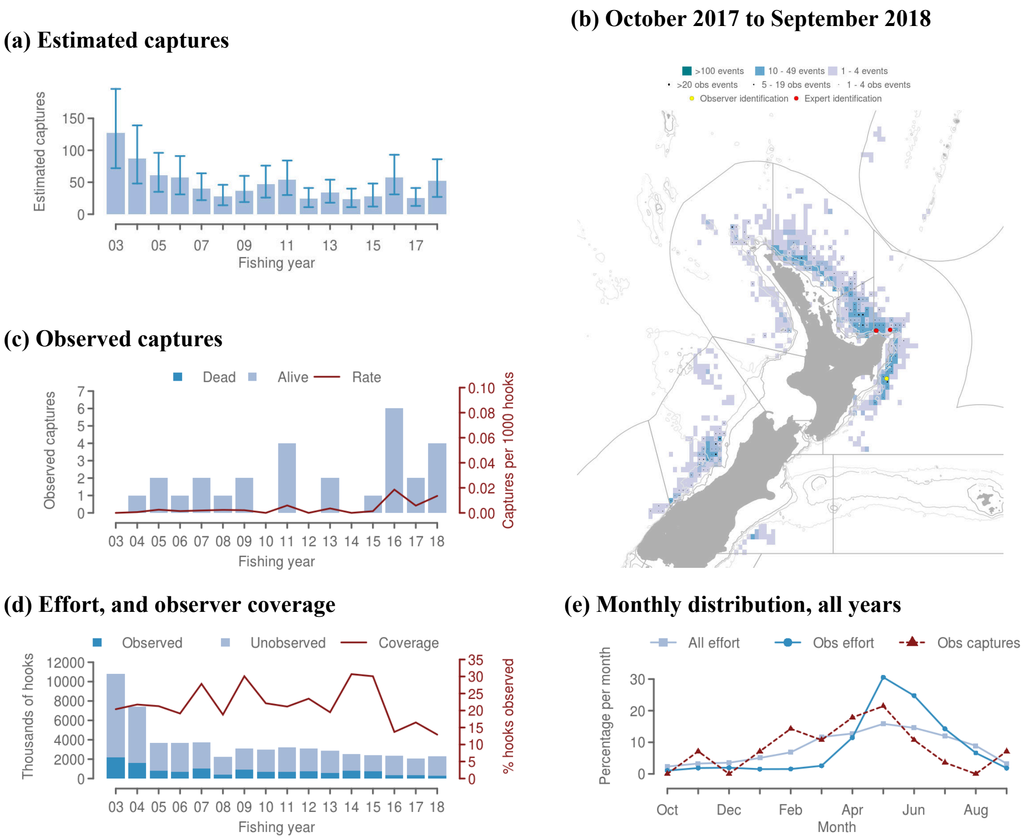


Figure A-16: Turtle captures in surface-longline fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.3.2 Turtle captures in bigeye tuna surface-longline fisheries

Table A-18: Annual fishing effort (hooks), and observer coverage (%) in bigeye tuna surface-longline fisheries; number of observed captures and observed capture rate (captures per thousand hooks) of turtles; estimated captures and capture rate of turtles (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	5 188 307	1.6	0	0.000	101	54–163	0.019	0.010–0.031
2003–04	3 507 137	3.4	1	0.008	76	39–124	0.022	0.011–0.035
2004–05	1 648 281	2.0	2	0.060	50	26–81	0.030	0.016–0.049
2005–06	1 869 486	2.4	1	0.022	49	25–81	0.026	0.013–0.043
2006–07	1 532 071	5.5	1	0.012	31	15–53	0.021	0.010–0.035
2007–08	967 829	2.5	0	0.000	21	9–37	0.022	0.009–0.038
2008–09	1 565 517	5.8	2	0.022	34	18–57	0.022	0.011–0.036
2009–10	1 247 437	6.2	0	0.000	37	17–64	0.029	0.014–0.051
2010–11	1 646 956	5.3	1	0.011	41	19–69	0.025	0.012–0.042
2011–12	1 291 923	3.0	0	0.000	19	8–35	0.015	0.006–0.027
2012–13	994 535	6.1	2	0.033	21	10–37	0.021	0.010–0.037
2013–14	743 981	4.0	0	0.000	17	6–31	0.022	0.008–0.042
2014–15	387 005	6.3	1	0.041	11	4–21	0.029	0.010–0.054
2015–16	623 659	6.5	3	0.074	29	14–51	0.047	0.022–0.082
2016–17	497 967	11.1	0	0.000	12	4–23	0.023	0.008–0.046
2017–18	569 223	9.0	3	0.059	27	13–46	0.047	0.023–0.081

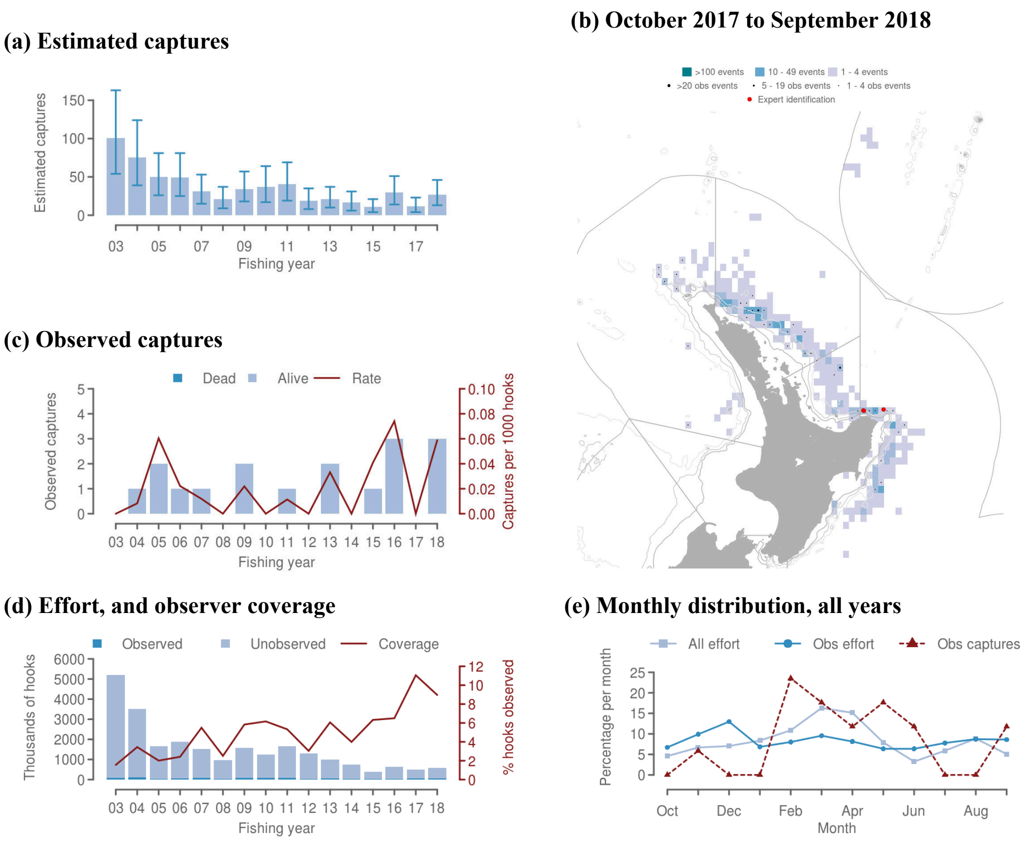


Figure A-17: Turtle captures in bigeye tuna surface-longline fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

A.3.3 Turtle captures in swordfish surface-longline fisheries

Table A-19: Annual fishing effort (hooks), and observer coverage (%) in swordfish surface-longline fisheries; number of observed captures and observed capture rate (captures per thousand hooks) of turtles; estimated captures and capture rate of turtles (mean and 95% credible interval).

Fishing year	Effort	Observed			Est. captures		Est. capture rate	
		% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	NA		0		0	0–1		–
2003–04	0		0			–		–
2004–05	132 503	8.7	0	0.000	4	0–10	0.028	0.000–0.075
2005–06	228 305	2.1	0	0.000	5	1–13	0.022	0.004–0.057
2006–07	210 175	19.1	1	0.025	7	2–15	0.031	0.010–0.071
2007–08	125 330	17.3	1	0.046	5	1–12	0.042	0.008–0.096
2008–09	41 700	9.6	0	0.000	1	0–4	0.033	0.000–0.096
2009–10	137 840	0.4	0	0.000	6	1–15	0.046	0.007–0.109
2010–11	177 248	10.5	0	0.000	6	1–13	0.032	0.006–0.073
2011–12	195 400	22.2	0	0.000	3	0–9	0.017	0.000–0.046
2012–13	316 390	2.6	0	0.000	9	2–20	0.028	0.006–0.063
2013–14	192 963	2.5	0	0.000	4	0–10	0.021	0.000–0.052
2014–15	447 962	3.9	0	0.000	14	4–31	0.032	0.009–0.069
2015–16	447 220	5.4	2	0.083	23	8–47	0.050	0.018–0.105
2016–17	324 040	8.1	2	0.076	10	4–21	0.032	0.012–0.065
2017–18	390 220	7.5	1	0.034	22	7–46	0.056	0.018–0.118

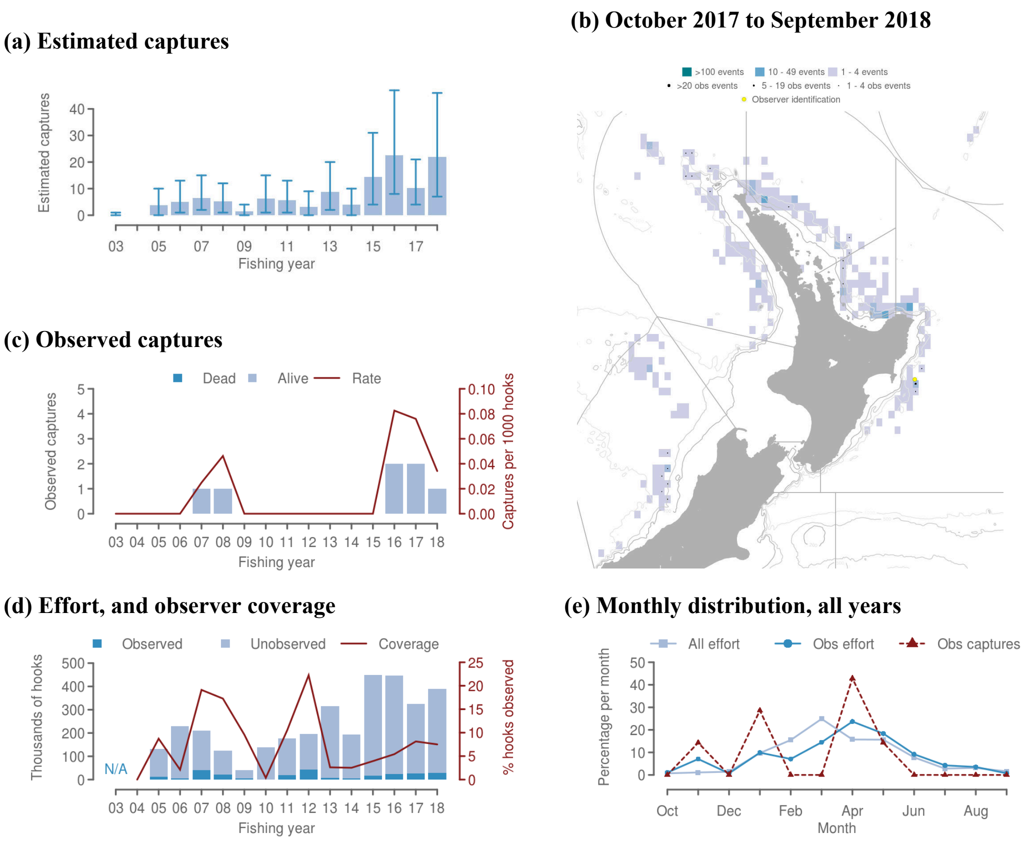


Figure A-18: Turtle captures in swordfish surface-longline fisheries. (a) Estimated captures, with 95% credible intervals, (b) Mapped effort and captures in 2017–18, coloured dots indicate observed captures, and the blue squares show fishing effort within 0.2 degree cells (because of confidentiality rules, some effort may not be displayed), (c) Observed captures, (d) Effort and observed effort, and (e) Monthly distribution of fishing effort, observed effort, and observed captures.

APPENDIX B: SUMMARIES OF MODEL PARAMETERS

B.1 Common dolphin model parameters

Table B-20: Summary of model parameters, for common dolphin captures in large-vessel West Coast North Island mackerel trawl for the final model (not including observed fishing from vessel A in the model, and including a covariate for the period 2008–09 and on, relative to before). For each parameter, the table gives summary statistics of the posterior distribution (mean, median, and 95% credible interval, based on the 2.5% and 97.5% quantiles), and diagnostics (the number of chains that fail convergence and half-width tests)(Heidelberger & Welch 1983), and the reduction in the effective length of the chains due to autocorrelation. Trace plots of the chains are also shown.

Parameter	Statistic			Diagnostics			
	Mean	Median	95% c.i.	Conv.	H.W.	Loss (%)	Trace
Number of dolphin caught per capture event							
Poisson mean	1.836	1.829	1.491 – 2.205				
Base rates (events per 100 tows)							
Mean rate	0.575	0.546	0.236 – 1.073			72.1	
1995–96	1.075	0.797	0.118 – 3.599			20.4	
1996–97	0.597	0.398	0.030 – 2.298			27.9	
1997–98	0.570	0.387	0.034 – 2.227			30.5	
1998–99	0.511	0.354	0.029 – 1.933			33.8	
1999–00	1.069	0.787	0.117 – 3.755			17.1	
2000–01	0.834	0.648	0.103 – 2.616			16.8	
2001–02	0.700	0.557	0.094 – 2.110			18.5	
2002–03	2.109	1.930	0.704 – 4.541			6.4	
2003–04	1.340	1.231	0.471 – 2.863			7.1	
2004–05	0.991	0.935	0.426 – 1.875				
2005–06	0.198	0.171	0.032 – 0.516			20.7	
2006–07	0.441	0.407	0.156 – 0.903			7.3	
2007–08	0.329	0.302	0.112 – 0.690			2.3	
2008–09	2.061	1.560	0.352 – 6.741			53.3	
2009–10	1.153	0.838	0.144 – 3.988			49.1	
2010–11	3.199	2.499	0.594 – 9.991			56.8	
2011–12	0.764	0.601	0.133 – 2.302			58.6	
2012–13	1.129	0.895	0.225 – 3.411			62.0	
2013–14	0.339	0.262	0.043 – 1.066			56.7	
2014–15	0.708	0.548	0.123 – 2.194			60.8	
2015–16	0.449	0.342	0.059 – 1.491			54.9	
2016–17	0.256	0.184	0.016 – 0.907			48.3	
2017–18	0.196	0.140	0.012 – 0.718			57.0	
Headline depth, $\beta_{headline}$	-0.034	-0.034	-0.045 – -0.023			10.3	
Log trawl duration, $\beta_{duration}$	1.493	1.487	0.842 – 2.157				
Light condition, relative to Dark							
Light, exp(β_{light})	0.265	0.253	0.134 – 0.462				
Black, exp(β_{black})	1.354	1.291	0.639 – 2.445				
Sub-area, relative to North							
South, exp(β_{south})	0.607	0.585	0.331 – 1.003				
Period, relative to 1995–96 to 2007–08							
2008–09 to 2017–18	0.135	0.110	0.032 – 0.384			66.0	
Deviance	229.763	229.231	228.779 – 233.820				

B.2 Fur seal trawl model parameters

Table B-21: Summary of model parameters, for New Zealand fur seal captures in trawl fisheries. For each parameter, the table gives summary statistics of the posterior distribution (mean, median, and 95% credible interval, based on the 2.5% and 97.5% quantiles), and diagnostics ($\hat{R}$, Brooks & Gelman 1998), and the reduction in the effective length of the chains due to autocorrelation. Trace plots of the chains are also shown.

Parameter	Statistic			Diagnostics		
	Mean	Median	95% c.i.	$\hat{R}$	Loss (%)	Trace
Base rate (captures per 100 tows)						
2002–03	1.013	0.990	0.643 – 1.532	1.000		
2003–04	1.245	1.187	0.807 – 1.974	1.001		
2004–05	1.640	1.564	0.994 – 2.746	1.000	40.9	
2005–06	1.428	1.372	0.926 – 2.273	1.002	20.6	
2006–07	1.038	1.015	0.654 – 1.530	1.000		
2007–08	1.274	1.219	0.832 – 2.004	1.000		
2008–09	0.902	0.892	0.570 – 1.308	1.000		
2009–10	0.883	0.878	0.541 – 1.282	1.000		
2010–11	0.959	0.948	0.607 – 1.413	1.000		
2011–12	0.953	0.945	0.616 – 1.376	1.000		
2012–13	0.978	0.965	0.621 – 1.435	0.999		
2013–14	0.862	0.854	0.540 – 1.226	1.000		
2014–15	1.108	1.071	0.733 – 1.654	0.999		
2015–16	0.813	0.805	0.488 – 1.182	1.000		
2016–17	0.876	0.871	0.545 – 1.268	1.000		
2017–18	0.792	0.784	0.470 – 1.148	1.000	7.4	
Day of year coefficient						
Sine coefficient	0.503	0.502	0.445 – 0.567	1.000		
Cosine coefficient	0.503	0.503	0.440 – 0.570	1.000		
Area effect, relative to Stewart-Snares shelf						
East Coast SI	1.360	1.319	0.801 – 2.182	1.000	9.8	
West Coast SI	0.851	0.822	0.475 – 1.391	1.000	16.9	
Auckland Islands	0.229	0.219	0.119 – 0.403	1.000		
West Coast NI	0.313	0.293	0.147 – 0.592	0.999	1.5	
Subantarctic	6.448	5.675	2.125 – 14.385	1.000		
Campbell Island	0.739	0.649	0.231 – 1.731	1.000	0.1	
Cook Strait	2.121	2.018	1.082 – 3.797	1.000		
Puysegur	0.839	0.783	0.374 – 1.658	1.000		
Bounty Islands	12.113	10.724	4.021 – 28.666	0.999		
Northern NI	0.200	0.168	0.047 – 0.535	0.999		
East Coast NI	0.306	0.234	0.038 – 0.981	1.000		
Chatham Islands	0.020	0.011	0.000 – 0.098	1.001		
Fishery effect, relative to Squid						
Hoki/Hake/Ling	0.392	0.377	0.234 – 0.628	1.000	0.2	
Deepwater	0.016	0.014	0.005 – 0.038	0.999		
Middle depth	0.275	0.264	0.156 – 0.460	0.999		
Jack mackerel	0.467	0.439	0.215 – 0.896	1.000	5.8	
Southern blue whiting	0.460	0.399	0.143 – 1.141	0.999		
Scampi	0.107	0.096	0.032 – 0.243	1.000		
Inshore	0.058	0.052	0.020 – 0.132	1.000		
Distance coefficients relative to Near (between 25 km and 90 km)						
Coastal (< 25 km)	1.781	1.766	1.299 – 2.361	1.000		
Far (> 90 km & < 180 km)	0.844	0.835	0.632 – 1.111	0.999		
Ocean (> 180 km)	0.510	0.495	0.307 – 0.787	0.999		
Overdispersion						
$1/\theta$	0.034	0.034	0.027 – 0.044	1.000		
$1/\theta$ (SBWT in Bounty Islands)	0.120	0.116	0.057 – 0.207	1.000		
$1/\theta$ (Hoki/Hake/Ling in Cook Strait)	0.132	0.122	0.057 – 0.258	1.000	19.9	
Random effects (sd)						
Year	0.303	0.300	0.062 – 0.561	1.003	60.3	
Vessel	0.473	0.475	0.236 – 0.693	1.002	72.1	
Target by year	0.234	0.239	0.032 – 0.417	1.002	74.4	
Area by year	0.530	0.528	0.391 – 0.685	1.002	51.8	
Target by vessel	0.481	0.478	0.303 – 0.674	1.003	72.6	

B.3 Fur seal surface-longline model parameters

Table B-22: Summary of model parameters, for New Zealand fur seal captures in surface-longline fisheries. For each parameter, the table gives summary statistics of the posterior distribution (mean, median, and 95% credible interval, based on the 2.5% and 97.5% quantiles), and diagnostics ($\hat{R}$, Brooks & Gelman 1998, and the bulk effective sample size (ESS)). Trace plots of the chains are also shown.

Parameter	Statistic			Diagnostics		
	Mean	Median	95% c.i.	$\hat{R}$	Bulk ESS	Trace
Base capture rate (log captures per 1000 hooks)						
Intercept	-1.777	-1.733	-4.482 – 0.679	1.00	2109	
Vessel size effect (relative to large vessels)						
Small vessels (< 45 m)	1.394	1.398	0.997 – 1.791	1.00	2087	
Sea surface temperature effect						
Sea surface temperature	-0.257	-0.257	-0.383 – -0.126	1.00	2411	
Month (cyclic spline of the month)						
Standard deviation	0.746	0.532	0.021 – 2.402	1.00	574	
Fishery random effect						
Albacore	-1.594	-1.451	-4.142 – 0.297	1.00	2510	
Bigeye	-0.689	-0.674	-2.519 – 1.031	1.00	1852	
Other target species	-0.262	-0.197	-3.128 – 2.083	1.00	3291	
Southern bluefin	1.465	1.432	0.039 – 3.081	1.00	1702	
Swordfish	0.192	0.185	-1.446 – 1.823	1.00	1942	
Fishing year random effect						
2002–03	0.604	0.597	0.189 – 1.052	1.00	1750	
2003–04	-0.209	-0.212	-0.655 – 0.239	1.00	1716	
2004–05	-0.100	-0.100	-0.601 – 0.405	1.00	2114	
2005–06	-0.473	-0.470	-1.060 – 0.060	1.00	2691	
2006–07	-0.712	-0.705	-1.320 – -0.142	1.00	2509	
2007–08	-0.179	-0.173	-0.807 – 0.416	1.00	2614	
2008–09	-0.232	-0.230	-0.727 – 0.262	1.00	1965	
2009–10	-0.109	-0.105	-0.620 – 0.385	1.00	2202	
2010–11	-0.084	-0.078	-0.616 – 0.439	1.00	2165	
2011–12	0.570	0.568	0.149 – 1.007	1.00	2034	
2012–13	0.327	0.327	-0.182 – 0.844	1.00	2413	
2013–14	0.826	0.825	0.416 – 1.240	1.00	1707	
2014–15	0.449	0.449	0.009 – 0.909	1.00	1847	
2015–16	-0.951	-0.929	-1.772 – -0.236	1.00	2978	
2016–17	0.498	0.494	0.003 – 0.985	1.00	2165	
2017–18	-0.430	-0.421	-1.082 – 0.168	1.00	2819	
Random effects (standard deviation)						
Fishing year	0.593	0.574	0.382 – 0.905	1.00	1108	
Fishery	1.340	1.274	0.583 – 2.520	1.00	1936	

B.4 Turtle surface-longline model parameters

Table B-23: Summary of model parameters, for turtle captures in surface-longline fisheries. For each parameter, the table gives summary statistics of the posterior distribution (mean, median, and 95% credible interval, based on the 2.5% and 97.5% quantiles), and diagnostics ($\hat{R}$, Brooks & Gelman 1998, and the bulk effective sample size (ESS)). Trace plots of the chains are also shown.

Parameter	Statistic			Diagnostics		
	Mean	Median	95% c.i.	$\hat{R}$	Bulk ESS	Trace
Base capture rate (log captures per 1000 hooks)						
Intercept	-17.677	-17.683	-22.485 – -12.700	1.00	2825	
Vessel size effect (relative to large vessels)						
Small vessels (< 45 m)	1.544	1.547	0.255 – 2.924	1.00	3326	
Sea surface temperature effect						
Sea surface temperature	0.616	0.617	0.348 – 0.867	1.00	3071	
Chlorophyll (thin-plate spline of the log chlorophyll concentration)						
Intercept	0.512	0.515	-1.468 – 2.500	1.00	4135	
Standard deviation	1.300	1.282	0.124 – 2.649	1.00	1669	
Area random effect						
Bay of Plenty	-0.634	-0.549	-2.202 – 0.493	1.00	2971	
East Coast North Island	0.686	0.634	-0.195 – 1.881	1.00	2221	
Fiordland	-0.498	-0.325	-2.590 – 0.920	1.00	3190	
Kermadec	0.377	0.303	-0.751 – 1.773	1.00	3263	
Northland	-0.205	-0.177	-1.338 – 0.892	1.00	3305	
West Coast North Island	0.494	0.417	-0.464 – 1.734	1.00	2867	
West Coast South Island	-0.624	-0.465	-2.699 – 0.668	1.00	3064	
Fishery random effect						
Albacore	-1.009	-0.774	-3.678 – 0.444	1.00	2416	
Bigeye	0.504	0.407	-0.583 – 2.045	1.00	2173	
Other target species	-0.303	-0.140	-2.795 – 1.376	1.00	4641	
Southern bluefin	-0.311	-0.249	-1.822 – 1.042	1.00	2544	
Swordfish	0.655	0.547	-0.478 – 2.308	1.00	2026	
Random effects (standard deviation)						
Area	0.833	0.783	0.095 – 1.840	1.00	1658	
Fishery	0.926	0.855	0.082 – 2.146	1.00	1673	

APPENDIX C: NEW ZEALAND FUR SEAL CAPTURES IN TRAWL FISHERIES

C.1 Estimate of New Zealand fur seal captures by target fishery

Table C-24: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seal in trawl fisheries, organised by target group, for eight fishing years from 2010–11 to 2017–18.

		Observed				Est. captures		Est. capture rate	
	Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2010–11									
Hoki	10 397	1 717	16.5	24	1.40	264	151–443	2.54	1.45–4.26
Hake	866	227	26.2	1	0.44	8	2–19	0.95	0.23–2.19
SBW	1 171	432	36.9	36	8.33	81	52–135	6.88	4.44–11.53
Middle depth	7 250	615	8.5	2	0.33	97	36–215	1.34	0.50–2.97
Squid	4 212	1 257	29.8	8	0.64	34	17–61	0.81	0.40–1.45
Ling	1 106	103	9.3	2	1.94	19	7–41	1.74	0.63–3.71
Jack mackerel	1 881	593	31.5	0	0.00	3	0–8	0.15	0.00–0.43
Scampi	4 445	531	11.9	0	0.00	4	0–12	0.09	0.00–0.27
Deepwater	4 173	1 192	28.6	0	0.00	3	0–10	0.08	0.00–0.24
Inshore	34 928	440	1.3	0	0.00	53	13–133	0.15	0.04–0.38
2011–12									
Hoki	11 326	2 691	23.8	34	1.26	221	143–332	1.95	1.26–2.93
Hake	645	225	34.9	1	0.44	7	2–16	1.07	0.31–2.48
SBW	951	668	70.2	25	3.74	40	29–62	4.19	3.05–6.52
Middle depth	6 545	763	11.7	8	1.05	88	40–180	1.35	0.61–2.75
Squid	3 507	1 379	39.3	8	0.58	35	18–65	1.00	0.51–1.85
Ling	946	159	16.8	1	0.63	14	4–32	1.50	0.42–3.38
Jack mackerel	2 031	1 546	76.1	5	0.32	8	5–13	0.37	0.25–0.64
Scampi	4 496	445	9.9	1	0.22	7	2–18	0.16	0.04–0.40
Deepwater	3 629	895	24.7	0	0.00	1	0–5	0.04	0.00–0.14
Inshore	32 717	192	0.6	0	0.00	55	15–140	0.17	0.05–0.43
2012–13									
Hoki	11 665	4 490	38.5	58	1.29	352	222–554	3.02	1.90–4.75
Hake	704	528	75.0	9	1.70	16	9–28	2.22	1.28–3.98
SBW	790	790	100.0	27	3.42	27	27–27	3.42	3.42–3.42
Middle depth	6 446	1 230	19.1	9	0.73	103	45–215	1.60	0.70–3.34
Squid	2 643	2 270	85.9	7	0.31	9	7–14	0.34	0.26–0.53
Ling	1 148	267	23.3	4	1.50	18	8–36	1.60	0.70–3.14
Jack mackerel	2 191	1 912	87.3	4	0.21	5	4–9	0.24	0.18–0.41
Scampi	4 522	244	5.4	0	0.00	5	0–15	0.11	0.00–0.33
Deepwater	3 095	340	11.0	0	0.00	0	0–2	0.02	0.00–0.06
Inshore	33 186	169	0.5	1	0.59	53	15–128	0.16	0.05–0.39
2013–14									
Hoki	12 941	3 961	30.6	32	0.81	141	95–206	1.09	0.73–1.59
Hake	799	580	72.6	6	1.03	11	6–21	1.41	0.75–2.63
SBW	809	808	99.9	95	11.76	97	95–109	11.93	11.74–13.47
Middle depth	6 402	1 392	21.7	4	0.29	47	20–97	0.74	0.31–1.52
Squid	2 051	1 785	87.0	10	0.56	11	10–14	0.54	0.49–0.68
Ling	1 130	120	10.6	0	0.00	11	3–25	0.95	0.27–2.21
Jack mackerel	2 444	2 178	89.1	10	0.46	11	10–15	0.46	0.41–0.61
Scampi	4 419	253	5.7	0	0.00	4	0–12	0.08	0.00–0.27
Deepwater	3 605	433	12.0	0	0.00	1	0–3	0.02	0.00–0.08
Inshore	34 145	1 661	4.9	2	0.12	48	15–115	0.14	0.04–0.34
2014–15									
Hoki	13 580	3 608	26.6	42	1.16	261	168–396	1.92	1.24–2.92
Hake	978	745	76.2	8	1.07	15	9–28	1.55	0.92–2.87
SBW	677	669	98.8	41	6.13	41	41–43	6.08	6.06–6.35
Middle depth	6 433	1 732	26.9	7	0.40	72	32–141	1.12	0.50–2.19
Squid	1 939	1 680	86.6	19	1.13	25	19–41	1.28	0.98–2.11
Ling	1 127	181	16.1	1	0.55	14	4–31	1.24	0.35–2.75
Jack mackerel	1 750	1 510	86.3	5	0.33	6	5–12	0.37	0.29–0.69
Scampi	4 420	342	7.7	1	0.29	7	2–20	0.17	0.05–0.45
Deepwater	3 811	965	25.3	1	0.10	2	1–4	0.04	0.03–0.10
Inshore	30 374	2 051	6.8	2	0.10	60	18–146	0.20	0.06–0.48
2015–16									
Hoki	12 632	3 458	27.4	41	1.19	220	146–324	1.74	1.16–2.57
Hake	512	366	71.5	0	0.00	2	0–7	0.38	0.00–1.37
SBW	442	441	99.8	51	11.56	51	51–51	11.54	11.54–11.54
Middle depth	5 836	1 211	20.8	3	0.25	50	19–113	0.86	0.33–1.94
Squid	2 879	2 341	81.3	10	0.43	19	11–37	0.66	0.38–1.29
Ling	1 144	163	14.2	1	0.61	8	2–19	0.70	0.17–1.66
Jack mackerel	1 544	1 381	89.4	2	0.14	3	2–6	0.18	0.13–0.39
Scampi	5 200	143	2.8	0	0.00	5	0–14	0.09	0.00–0.27
Deepwater	4 081	1 413	34.6	0	0.00	1	0–3	0.01	0.00–0.07
Inshore	28 302	1 874	6.6	0	0.00	32	8–82	0.11	0.03–0.29
2016–17									
Hoki	12 898	2 848	22.1	36	1.26	238	156–351	1.84	1.21–2.72
Hake	542	456	84.1	2	0.44	3	2–8	0.60	0.37–1.48
SBW	539	537	99.6	11	2.05	11	11–11	2.04	2.04–2.04
Middle depth	5 938	1 684	28.4	6	0.36	69	28–148	1.17	0.47–2.49
Squid	2 594	1 925	74.2	17	0.88	23	17–36	0.88	0.66–1.39
Ling	1 226	252	20.6	3	1.19	12	5–26	1.00	0.41–2.12
Jack mackerel	1 398	1 015	72.6	0	0.00	2	0–6	0.11	0.00–0.43
Scampi	4 697	447	9.5	1	0.22	6	1–16	0.13	0.02–0.34
Deepwater	3 835	1 082	28.2	0	0.00	0	0–2	0.01	0.00–0.05
Inshore	29 298	3 214	11.0	2	0.06	43	13–101	0.15	0.04–0.34
2017–18									
Hoki	13 790	4 761	34.5	40	0.84	190	128–283	1.38	0.93–2.05
Hake	260	150	57.7	0	0.00	1	0–5	0.48	0.00–1.92
SBW	455	455	100.0	17	3.74	17	17–17	3.74	3.74–3.74
Middle depth	6 248	1 585	25.4	3	0.19	45	17–97	0.72	0.27–1.55
Squid	2 825	2 514	89.0	14	0.56	23	14–49	0.83	0.50–1.73
Ling	1 163	342	29.4	1	0.29	6	2–14	0.53	0.17–1.20
Jack mackerel	1 688	1 473	87.3	3	0.20	4	3–6	0.22	0.18–0.36
Scampi	4 320	524	12.1	0	0.00	3	0–10	0.08	0.00–0.23
Deepwater	3 744	897	24.0	0	0.00	1	0–3	0.01	0.00–0.08
Inshore	27 216	2 126	7.8	1	0.05	34	9–83	0.12	0.03–0.30

C.2 Estimate of New Zealand fur seal captures by summary area

Table C-25: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seal in trawl fisheries, organised by area, for eight fishing years from 2010–11 to 2017–18.

		Observed				Est. captures		Est. capture rate	
	Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2010–11									
Cook Strait	4 680	148	3.2	18	12.16	251	120–485	5.36	2.56–10.36
West coast South Island	8 268	804	9.7	3	0.37	68	25–147	0.82	0.30–1.78
East coast South Island	13 883	1 302	9.4	4	0.31	83	29–182	0.59	0.21–1.31
Stewart-Snares	6 070	1 317	21.7	11	0.84	43	23–74	0.70	0.38–1.22
Bounty Islands	420	155	36.9	31	20.00	65	41–112	15.56	9.76–26.67
Campbell Island	968	364	37.6	4	1.10	10	5–20	1.05	0.52–2.07
West coast North Island	8 658	604	7.0	0	0.00	8	1–24	0.09	0.01–0.28
Subantarctic islands	886	306	34.5	1	0.33	9	1–33	0.99	0.11–3.72
Auckland Islands	3 312	854	25.8	1	0.12	5	1–14	0.16	0.03–0.42
Puysegur	622	56	9.0	0	0.00	8	0–27	1.25	0.00–4.34
2011–12									
Cook Strait	4 571	233	5.1	16	6.87	161	82–293	3.52	1.79–6.41
West coast South Island	8 369	1 533	18.3	22	1.44	109	64–177	1.30	0.76–2.11
East coast South Island	13 377	1 322	9.9	6	0.45	86	35–174	0.64	0.26–1.30
Stewart-Snares	6 300	1 706	27.1	9	0.53	41	20–73	0.65	0.32–1.16
Bounty Islands	224	100	44.6	12	12.00	25	15–47	11.22	6.70–20.98
Campbell Island	646	458	70.9	4	0.87	6	4–10	0.89	0.62–1.55
West coast North Island	9 364	1 488	15.9	3	0.20	13	4–31	0.14	0.04–0.33
Subantarctic islands	745	330	44.3	9	2.73	10	9–14	1.36	1.21–1.88
Auckland Islands	2 615	716	27.4	2	0.28	6	2–14	0.24	0.08–0.54
Puysegur	498	90	18.1	0	0.00	4	0–16	0.87	0.00–3.21
2012–13									
Cook Strait	5 144	202	3.9	28	13.86	317	164–567	6.16	3.19–11.02
West coast South Island	8 733	2 573	29.5	38	1.48	127	83–201	1.45	0.95–2.30
East coast South Island	13 897	2 447	17.6	9	0.37	62	29–115	0.44	0.21–0.83
Stewart-Snares	6 214	3 032	48.8	11	0.36	20	13–33	0.33	0.21–0.53
Bounty Islands	77	77	100.0	18	23.38	18	18–18	23.38	23.38–23.38
Campbell Island	869	791	91.0	9	1.14	9	9–10	1.04	1.04–1.15
West coast North Island	9 892	1 515	15.3	3	0.20	12	4–30	0.12	0.04–0.30
Subantarctic islands	164	107	65.2	0	0.00	1	0–3	0.32	0.00–1.83
Auckland Islands	2 190	1 040	47.5	3	0.29	4	3–8	0.20	0.14–0.37
Puysegur	459	173	37.7	0	0.00	3	0–13	0.68	0.00–2.83
2013–14									
Cook Strait	4 955	230	4.6	5	2.17	69	29–133	1.39	0.59–2.68
West coast South Island	9 765	2 522	25.8	33	1.31	110	72–170	1.13	0.74–1.74
East coast South Island	14 528	2 018	13.9	3	0.15	40	14–85	0.28	0.10–0.59
Stewart-Snares	5 913	2 469	41.8	10	0.41	21	12–35	0.35	0.20–0.59
Bounty Islands	190	189	99.5	91	48.15	93	91–105	48.71	47.89–55.26
Campbell Island	715	662	92.6	4	0.60	4	4–5	0.58	0.56–0.70
West coast North Island	9 306	2 094	22.5	10	0.48	23	12–44	0.24	0.13–0.47
Subantarctic islands	322	68	21.1	1	1.47	2	1–5	0.58	0.31–1.55
Auckland Islands	1 885	778	41.3	1	0.13	2	1–4	0.09	0.05–0.21
Puysegur	519	145	27.9	0	0.00	4	0–14	0.69	0.00–2.70
2014–15									
Cook Strait	4 500	475	10.6	6	1.26	143	59–288	3.18	1.31–6.40
West coast South Island	10 723	2 936	27.4	45	1.53	164	109–243	1.53	1.02–2.27
East coast South Island	13 777	1 611	11.7	10	0.62	85	40–168	0.62	0.29–1.22
Stewart-Snares	5 704	2 417	42.4	21	0.87	39	26–62	0.68	0.46–1.09
Bounty Islands	25	25	100.0	33	132.00	33	33–33	132.00	132.00–132.00
Campbell Island	668	641	96.0	8	1.25	8	8–9	1.20	1.20–1.35
West coast North Island	8 611	2 324	27.0	1	0.04	6	1–16	0.07	0.01–0.19
Subantarctic islands	59	36	61.0	0	0.00	0	0–2	0.30	0.00–3.39
Auckland Islands	1 567	649	41.4	0	0.00	1	0–4	0.05	0.00–0.26
Puysegur	474	123	25.9	0	0.00	3	0–13	0.73	0.00–2.74
2015–16									
Cook Strait	4 325	153	3.5	24	15.69	171	92–303	3.96	2.13–7.01
West coast South Island	10 551	2 527	24.0	21	0.83	90	54–140	0.85	0.51–1.33
East coast South Island	12 979	1 568	12.1	6	0.38	48	20–98	0.37	0.15–0.76
Stewart-Snares	4 610	1 998	43.3	2	0.10	6	2–13	0.12	0.04–0.28
Bounty Islands	62	62	100.0	50	80.65	50	50–50	80.65	80.65–80.65
Campbell Island	397	397	100.0	1	0.25	1	1–1	0.25	0.25–0.25
West coast North Island	7 680	2 425	31.6	1	0.04	5	1–13	0.06	0.01–0.17
Subantarctic islands	196	88	44.9	0	0.00	0	0–1	0.07	0.00–0.51
Auckland Islands	2 981	1 365	45.8	3	0.22	4	3–8	0.15	0.10–0.27
Puysegur	469	160	34.1	0	0.00	3	0–11	0.61	0.00–2.35
2016–17									
Cook Strait	3 705	140	3.8	23	16.43	172	91–302	4.65	2.46–8.15
West coast South Island	10 745	2 364	22.0	17	0.72	84	50–137	0.78	0.47–1.28
East coast South Island	13 394	1 849	13.8	11	0.59	89	42–173	0.67	0.31–1.29
Stewart-Snares	5 032	1 977	39.3	11	0.56	22	13–35	0.43	0.26–0.70
Bounty Islands	73	73	100.0	8	10.96	8	8–8	10.96	10.96–10.96
Campbell Island	540	499	92.4	3	0.60	3	3–4	0.56	0.56–0.74
West coast North Island	7 144	2 539	35.5	0	0.00	3	0–9	0.04	0.00–0.13
Subantarctic islands	214	191	89.3	0	0.00	0	0–3	0.17	0.00–1.40
Auckland Islands	3 209	1 415	44.1	3	0.21	5	3–10	0.16	0.09–0.31
Puysegur	422	154	36.5	0	0.00	3	0–12	0.69	0.00–2.84
2017–18									
Cook Strait	3 680	216	5.9	16	7.41	130	68–231	3.54	1.85–6.28
West coast South Island	9 805	3 160	32.2	22	0.70	71	46–107	0.72	0.47–1.09
East coast South Island	14 021	2 132	15.2	9	0.42	65	29–131	0.47	0.21–0.93
Stewart-Snares	5 448	2 881	52.9	8	0.28	14	9–23	0.25	0.17–0.42
Bounty Islands	132	129	97.7	15	11.63	15	15–15	11.38	11.36–11.36
Campbell Island	542	501	92.4	2	0.40	2	2–3	0.38	0.37–0.55
West coast North Island	7 522	2 791	37.1	2	0.07	7	2–16	0.09	0.03–0.21
Subantarctic islands	348	217	62.4	0	0.00	0	0–2	0.06	0.00–0.57
Auckland Islands	3 308	1 626	49.2	4	0.25	6	4–10	0.18	0.12–0.30
Puysegur	371	171	46.1	0	0.00	1	0–6	0.34	0.00–1.62

C.3 Estimate of New Zealand fur seal captures by target fishery and summary area

Table C-26: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area and target, for fishing years from 2002–03 to 2017–18. Area/target combinations are included in the table if, across all years, more than one fur seal capture was estimated, or if the total fishing effort exceeded 1000 tows. The area/target combinations are ordered by decreasing number of estimated captures.

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03										
Hoki	Cook Strait	4 103	135	3.3	4	2.96	190	75–395	4.64	1.83–9.63
Hoki	West coast SI.	7 862	924	11.8	18	1.95	212	115–361	2.70	1.46–4.59
Hoki	East coast SI.	9 946	863	8.7	13	1.51	155	79–276	1.56	0.79–2.78
SBW	Bounty Islands	24	-	-	-	-	9	0–35	38.28	0.00–145.83
Middle depth	East coast SI.	2 812	30	1.1	0	0.00	45	13–114	1.60	0.46–4.05
Squid	Stewart-Snares	3 279	503	15.3	7	1.39	32	15–61	0.98	0.46–1.86
Middle depth	Cook Strait	1 194	1	0.1	0	0.00	15	2–48	1.30	0.17–4.02
Middle depth	West coast SI.	1 829	-	-	-	-	24	5–66	1.31	0.27–3.61
Squid	East coast SI.	1 753	50	2.9	0	0.00	47	14–107	2.67	0.80–6.10
Inshore	East coast SI.	7 642	1	0.0	0	0.00	34	6–99	0.44	0.08–1.30
Hake	West coast SI.	516	36	7.0	3	8.33	10	4–20	1.84	0.78–3.88
SBW	Campbell Island	606	269	44.4	8	2.97	14	9–26	2.38	1.49–4.29
Inshore	West coast SI.	1 622	-	-	-	-	3	0–12	0.21	0.00–0.74
Middle depth	Stewart-Snares	978	138	14.1	1	0.72	11	3–27	1.12	0.31–2.76
Inshore	Cook Strait	1 866	-	-	-	-	6	0–22	0.32	0.00–1.18
Hoki	Stewart-Snares	2 393	429	17.9	3	0.70	20	7–41	0.82	0.29–1.71
Ling	West coast SI.	27	-	-	-	-	1	0–4	2.29	0.00–14.81
Jack mackerel	West coast NI.	2 293	218	9.5	0	0.00	5	0–15	0.22	0.00–0.65
Inshore	West coast NI.	6 590	-	-	-	-	5	0–17	0.07	0.00–0.26
Ling	Stewart-Snares	115	-	-	-	-	1	0–5	1.15	0.00–4.35
Inshore	Stewart-Snares	1 497	-	-	-	-	6	0–23	0.42	0.00–1.54
Squid	Auckland Islands	1 466	416	28.4	0	0.00	2	0–5	0.10	0.00–0.34
Ling	Puysegur	93	-	-	-	-	3	0–15	3.45	0.00–16.13
Middle depth	West coast NI.	1 675	74	4.4	0	0.00	8	0–27	0.45	0.00–1.61
Hoki	Puysegur	496	55	11.1	6	10.91	20	8–44	3.97	1.61–8.87
Jack mackerel	West coast SI.	386	53	13.7	0	0.00	5	0–15	1.29	0.00–3.89
Squid	Puysegur	1 420	311	21.9	1	0.32	16	4–38	1.10	0.28–2.68
Scampi	East coast SI.	910	257	28.2	2	0.78	5	2–12	0.55	0.22–1.32
Ling	East coast SI.	37	-	-	-	-	1	0–7	3.50	0.00–18.92
Squid	Subantarctic	236	19	8.1	0	0.00	4	0–15	1.66	0.00–6.36
Deepwater	Subantarctic	1 164	141	12.1	0	0.00	1	0–4	0.07	0.00–0.34
Scampi	Auckland Islands	1 399	149	10.7	0	0.00	0	0–2	0.03	0.00–0.14
Jack mackerel	East coast SI.	175	32	18.3	1	3.12	2	1–6	1.23	0.57–3.43
Middle depth	Subantarctic	37	5	13.5	0	0.00	2	0–14	6.31	0.00–37.84
Hake	Stewart-Snares	149	-	-	-	-	1	0–4	0.63	0.00–2.68
Scampi	Cook Strait	247	7	2.8	0	0.00	0	0–2	0.14	0.00–0.81
Middle depth	Puysegur	136	7	5.1	0	0.00	1	0–4	0.52	0.00–2.94
Deepwater	East coast SI.	1 557	214	13.7	0	0.00	1	0–3	0.04	0.00–0.19
Ling	West coast NI.	16	-	-	-	-	0	0–2	1.02	0.00–12.50
Hoki	Auckland Islands	1 151	63	5.5	0	0.00	0	0–2	0.04	0.00–0.17
Jack mackerel	Stewart-Snares	202	42	20.8	0	0.00	1	0–4	0.39	0.00–1.98
Inshore	Puysegur	126	-	-	-	-	1	0–3	0.45	0.00–2.38
Deepwater	Cook Strait	168	-	-	-	-	0	0–1	0.09	0.00–0.60
Deepwater	Stewart-Snares	622	34	5.5	0	0.00	0	0–2	0.06	0.00–0.32
Deepwater	West coast NI.	290	125	43.1	0	0.00	0	0–0	0.00	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2003–04										
Hoki	Cook Strait	4 221	130	3.1	1	0.77	159	52–349	3.77	1.23–8.27
Hoki	West coast SI.	6 843	1 336	19.5	34	2.54	230	141–361	3.36	2.06–5.28
Hoki	East coast SI.	7 134	550	7.7	17	3.09	96	50–174	1.35	0.70–2.44
SBW	Bounty Islands	34	9	26.5	9	100.00	48	13–155	142.42	38.24–455.88
Middle depth	East coast SI.	1 725	11	0.6	0	0.00	35	8–91	2.01	0.46–5.28
Squid	Stewart-Snares	4 531	950	21.0	10	1.05	65	31–122	1.43	0.68–2.69
Middle depth	Cook Strait	1 351	-	-	-	-	15	2–51	1.14	0.15–3.77
Middle depth	West coast SI.	1 531	3	0.2	0	0.00	32	7–86	2.06	0.46–5.62
Squid	East coast SI.	581	3	0.5	0	0.00	28	5–77	4.74	0.86–13.26
Inshore	East coast SI.	6 837	7	0.1	0	0.00	27	5–78	0.40	0.07–1.14
Hake	West coast SI.	608	53	8.7	0	0.00	7	1–17	1.23	0.16–2.80
SBW	Campbell Island	706	229	32.4	4	1.75	16	6–37	2.29	0.85–5.24
Inshore	West coast SI.	1 967	-	-	-	-	6	0–20	0.31	0.00–1.02
Middle depth	Stewart-Snares	622	29	4.7	0	0.00	8	1–23	1.24	0.16–3.70
Inshore	Cook Strait	1 763	-	-	-	-	5	0–22	0.31	0.00–1.25
Hoki	Stewart-Snares	1 900	94	4.9	0	0.00	15	4–35	0.78	0.21–1.84
Ling	West coast SI.	44	-	-	-	-	1	0–4	1.87	0.00–9.09
Jack mackerel	West coast NI.	2 247	140	6.2	0	0.00	8	1–23	0.34	0.04–1.02
Inshore	West coast NI.	7 001	-	-	-	-	6	0–21	0.08	0.00–0.30
Ling	Stewart-Snares	158	8	5.1	0	0.00	1	0–5	0.76	0.00–3.16
Inshore	Stewart-Snares	2 040	-	-	-	-	7	0–26	0.36	0.00–1.27
Squid	Auckland Islands	2 597	793	30.5	6	0.76	21	9–41	0.81	0.35–1.58
Ling	Puysegur	134	-	-	-	-	5	0–21	3.75	0.00–15.67
Middle depth	West coast NI.	1 650	53	3.2	0	0.00	7	0–27	0.45	0.00–1.64
Hoki	Puysegur	147	32	21.8	3	9.38	6	3–16	4.12	2.04–10.88
Jack mackerel	West coast SI.	87	9	10.3	2	22.22	4	2–9	4.32	2.30–10.34
Squid	Puysegur	253	-	-	-	-	9	1–32	3.65	0.40–12.65
Scampi	East coast SI.	623	205	32.9	0	0.00	2	0–7	0.32	0.00–1.12
Ling	East coast SI.	20	-	-	-	-	1	0–5	3.77	0.00–25.00
Squid	Subantarctic	330	17	5.2	0	0.00	18	2–61	5.34	0.61–18.48
Deepwater	Subantarctic	1 072	201	18.8	2	1.00	3	2–8	0.33	0.19–0.75
Scampi	Auckland Islands	1 450	169	11.7	1	0.59	2	1–6	0.16	0.07–0.41
Jack mackerel	East coast SI.	11	-	-	-	-	0	0–1	0.89	0.00–9.09
Middle depth	Subantarctic	66	8	12.1	0	0.00	4	0–19	5.81	0.00–28.83
Hake	Stewart-Snares	166	53	31.9	0	0.00	1	0–3	0.45	0.00–1.81
Scampi	Cook Strait	45	-	-	-	-	0	0–1	0.14	0.00–2.22
Middle depth	Puysegur	122	27	22.1	0	0.00	0	0–3	0.31	0.00–2.46
Deepwater	East coast SI.	1 426	96	6.7	0	0.00	1	0–3	0.04	0.00–0.21
Ling	West coast NI.	12	-	-	-	-	0	0–1	0.73	0.00–8.33
Hoki	Auckland Islands	723	139	19.2	1	0.72	2	1–6	0.33	0.14–0.83
Jack mackerel	Stewart-Snares	38	3	7.9	0	0.00	0	0–2	0.49	0.00–5.26
Inshore	Puysegur	27	-	-	-	-	0	0–1	0.36	0.00–3.70
Deepwater	Cook Strait	102	-	-	-	-	0	0–1	0.10	0.00–0.98
Deepwater	Stewart-Snares	362	84	23.2	0	0.00	0	0–2	0.08	0.00–0.55
Deepwater	West coast NI.	350	152	43.4	0	0.00	0	0–0	0.01	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2004–05										
Hoki	Cook Strait	3 082	135	4.4	32	23.70	499	270–865	16.20	8.76–28.07
Hoki	West coast SI.	3 942	1 013	25.7	63	6.22	376	235–601	9.55	5.96–15.25
Hoki	East coast SI.	5 121	714	13.9	14	1.96	96	50–174	1.88	0.98–3.40
SBW	Bounty Islands	100	52	52.0	24	46.15	42	27–76	41.83	27.00–76.00
Middle depth	East coast SI.	1 701	7	0.4	0	0.00	40	10–102	2.34	0.59–6.00
Squid	Stewart-Snares	5 858	1 573	26.9	8	0.51	59	28–110	1.00	0.48–1.88
Middle depth	Cook Strait	1 093	1	0.1	0	0.00	51	11–142	4.64	1.01–12.99
Middle depth	West coast SI.	1 555	74	4.8	9	12.16	68	27–151	4.39	1.74–9.71
Squid	East coast SI.	1 515	61	4.0	3	4.92	54	17–127	3.55	1.12–8.38
Inshore	East coast SI.	7 022	-	-	-	-	36	7–107	0.52	0.10–1.52
Hake	West coast SI.	784	86	11.0	2	2.33	33	14–64	4.26	1.79–8.16
SBW	Campbell Island	758	280	36.9	9	3.21	27	13–53	3.55	1.72–6.99
Inshore	West coast SI.	2 552	-	-	-	-	17	2–51	0.67	0.08–2.00
Middle depth	Stewart-Snares	1 004	46	4.6	0	0.00	18	4–48	1.77	0.40–4.78
Inshore	Cook Strait	1 539	11	0.7	0	0.00	14	1–46	0.91	0.06–2.99
Hoki	Stewart-Snares	948	109	11.5	2	1.83	16	5–36	1.69	0.53–3.80
Ling	West coast SI.	128	-	-	-	-	13	1–46	10.30	0.78–35.94
Jack mackerel	West coast NI.	2 378	528	22.2	5	0.95	19	8–39	0.80	0.34–1.64
Inshore	West coast NI.	6 649	-	-	-	-	14	1–45	0.21	0.02–0.68
Ling	Stewart-Snares	386	67	17.4	3	4.48	7	3–17	1.87	0.78–4.40
Inshore	Stewart-Snares	2 359	-	-	-	-	9	0–34	0.40	0.00–1.44
Squid	Auckland Islands	2 693	805	29.9	0	0.00	4	0–13	0.16	0.00–0.48
Ling	Puysegur	177	4	2.3	0	0.00	9	1–31	4.95	0.56–17.51
Middle depth	West coast NI.	1 640	48	2.9	1	2.08	18	4–50	1.11	0.24–3.05
Hoki	Puysegur	292	58	19.9	9	15.52	18	10–36	6.23	3.42–12.33
Jack mackerel	West coast SI.	68	17	25.0	0	0.00	2	0–9	2.94	0.00–13.24
Squid	Puysegur	296	63	21.3	4	6.35	14	5–36	4.64	1.69–12.16
Scampi	East coast SI.	1 247	63	5.1	0	0.00	3	0–11	0.26	0.00–0.88
Ling	East coast SI.	51	-	-	-	-	4	0–19	7.41	0.00–37.25
Squid	Subantarctic	67	1	1.5	0	0.00	11	0–53	16.77	0.00–79.10
Deepwater	Subantarctic	1 158	323	27.9	4	1.24	8	4–18	0.73	0.35–1.55
Scampi	Auckland Islands	1 275	-	-	-	-	2	0–8	0.14	0.00–0.63
Jack mackerel	East coast SI.	9	4	44.4	0	0.00	0	0–1	0.90	0.00–11.11
Middle depth	Subantarctic	60	5	8.3	0	0.00	5	0–28	9.16	0.00–46.71
Hake	Stewart-Snares	105	-	-	-	-	1	0–5	1.10	0.00–4.76
Scampi	Cook Strait	186	-	-	-	-	5	0–22	2.88	0.00–11.83
Middle depth	Puysegur	129	-	-	-	-	1	0–5	0.78	0.00–3.88
Deepwater	East coast SI.	1 364	121	8.9	0	0.00	1	0–4	0.07	0.00–0.29
Ling	West coast NI.	9	-	-	-	-	0	0–3	4.37	0.00–33.33
Hoki	Auckland Islands	376	2	0.5	0	0.00	0	0–2	0.10	0.00–0.53
Jack mackerel	Stewart-Snares	53	8	15.1	0	0.00	0	0–3	0.78	0.00–5.66
Inshore	Puysegur	22	-	-	-	-	0	0–1	0.26	0.00–4.55
Deepwater	Cook Strait	110	-	-	-	-	0	0–2	0.23	0.00–1.82
Deepwater	Stewart-Snares	237	66	27.8	0	0.00	0	0–1	0.02	0.00–0.42
Deepwater	West coast NI.	323	67	20.7	0	0.00	0	0–1	0.01	0.00–0.31

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2005–06										
Hoki	Cook Strait	1 969	64	3.3	19	29.69	280	139–523	14.24	7.06–26.56
Hoki	West coast SI.	3 545	802	22.6	23	2.87	173	99–290	4.88	2.79–8.18
Hoki	East coast SI.	4 902	724	14.8	12	1.66	62	32–111	1.27	0.65–2.26
SBW	Bounty Islands	94	82	87.2	51	62.20	59	51–82	62.86	54.26–87.23
Middle depth	East coast SI.	2 129	57	2.7	1	1.75	48	13–116	2.23	0.61–5.45
Squid	Stewart-Snares	4 477	644	14.4	2	0.31	51	19–104	1.14	0.42–2.32
Middle depth	Cook Strait	697	-	-	-	-	20	3–63	2.93	0.43–9.04
Middle depth	West coast SI.	1 170	28	2.4	0	0.00	31	7–81	2.64	0.60–6.93
Squid	East coast SI.	1 361	9	0.7	0	0.00	36	9–88	2.64	0.66–6.47
Inshore	East coast SI.	6 721	-	-	-	-	26	4–77	0.39	0.06–1.15
Hake	West coast SI.	1 145	332	29.0	8	2.41	29	16–49	2.54	1.40–4.28
SBW	Campbell Island	510	135	26.5	1	0.74	8	1–23	1.64	0.20–4.51
Inshore	West coast SI.	2 607	10	0.4	0	0.00	12	1–35	0.47	0.04–1.34
Middle depth	Stewart-Snares	1 210	303	25.0	2	0.66	16	5–38	1.29	0.41–3.14
Inshore	Cook Strait	1 783	7	0.4	0	0.00	13	1–46	0.75	0.06–2.58
Hoki	Stewart-Snares	774	136	17.6	1	0.74	8	2–19	1.04	0.26–2.45
Ling	West coast SI.	148	-	-	-	-	11	1–34	7.48	0.68–22.99
Jack mackerel	West coast NI.	2 067	641	31.0	4	0.62	14	6–28	0.67	0.29–1.35
Inshore	West coast NI.	5 481	74	1.4	0	0.00	8	1–28	0.15	0.02–0.51
Ling	Stewart-Snares	600	97	16.2	2	2.06	10	3–22	1.60	0.50–3.67
Inshore	Stewart-Snares	1 878	-	-	-	-	6	0–22	0.34	0.00–1.17
Squid	Auckland Islands	2 462	685	27.8	2	0.29	7	2–16	0.29	0.08–0.65
Ling	Puysegur	239	15	6.3	0	0.00	17	2–60	7.26	0.84–25.10
Middle depth	West coast NI.	783	12	1.5	1	8.33	9	2–27	1.14	0.26–3.45
Hoki	Puysegur	108	34	31.5	7	20.59	11	7–22	9.74	6.48–20.37
Jack mackerel	West coast SI.	209	6	2.9	0	0.00	6	0–18	2.96	0.00–8.61
Squid	Puysegur	203	6	3.0	0	0.00	9	0–29	4.28	0.00–14.29
Scampi	East coast SI.	1 511	96	6.4	0	0.00	2	0–8	0.15	0.00–0.53
Ling	East coast SI.	99	-	-	-	-	4	0–16	3.73	0.00–16.16
Squid	Subantarctic	41	-	-	-	-	6	0–34	14.87	0.00–82.93
Deepwater	Subantarctic	987	134	13.6	1	0.75	4	1–10	0.37	0.10–1.01
Scampi	Auckland Islands	1 332	116	8.7	0	0.00	2	0–6	0.12	0.00–0.45
Jack mackerel	East coast SI.	436	58	13.3	2	3.45	5	2–13	1.25	0.46–2.98
Middle depth	Subantarctic	22	2	9.1	0	0.00	3	0–20	14.19	0.00–90.91
Hake	Stewart-Snares	174	87	50.0	3	3.45	3	3–5	1.95	1.72–2.87
Scampi	Cook Strait	71	-	-	-	-	1	0–5	1.20	0.00–7.04
Middle depth	Puysegur	157	2	1.3	0	0.00	3	0–12	1.95	0.00–7.66
Deepwater	East coast SI.	1 298	224	17.3	0	0.00	1	0–3	0.06	0.00–0.23
Ling	West coast NI.	46	-	-	-	-	1	0–8	3.24	0.00–17.39
Hoki	Auckland Islands	20	3	15.0	0	0.00	0	0–1	0.14	0.00–5.00
Jack mackerel	Stewart-Snares	86	3	3.5	0	0.00	1	0–4	0.96	0.00–4.65
Inshore	Puysegur	194	-	-	-	-	1	0–4	0.33	0.00–2.06
Deepwater	Cook Strait	148	4	2.7	0	0.00	0	0–2	0.16	0.00–1.35
Deepwater	Stewart-Snares	275	7	2.5	0	0.00	0	0–1	0.06	0.00–0.36
Deepwater	West coast NI.	331	114	34.4	0	0.00	0	0–1	0.03	0.00–0.30

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2006–07										
Hoki	Cook Strait	2 078	225	10.8	23	10.22	251	141–416	12.07	6.79–20.02
Hoki	West coast SI.	2 121	515	24.3	0	0.00	27	8–64	1.30	0.38–3.02
Hoki	East coast SI.	4 724	639	13.5	4	0.63	46	18–92	0.97	0.38–1.95
SBW	Bounty Islands	51	38	74.5	8	21.05	10	8–16	19.27	15.69–31.37
Middle depth	East coast SI.	1 968	51	2.6	1	1.96	34	9–85	1.74	0.46–4.32
Squid	Stewart-Snares	2 925	705	24.1	6	0.85	40	18–77	1.37	0.62–2.63
Middle depth	Cook Strait	747	2	0.3	0	0.00	21	4–61	2.79	0.54–8.17
Middle depth	West coast SI.	1 716	24	1.4	0	0.00	19	4–51	1.11	0.23–2.97
Squid	East coast SI.	1 490	37	2.5	2	5.41	31	9–75	2.08	0.60–5.03
Inshore	East coast SI.	5 476	26	0.5	0	0.00	20	3–57	0.37	0.05–1.04
Hake	West coast SI.	1 069	160	15.0	4	2.50	11	5–21	1.03	0.47–1.96
SBW	Campbell Island	559	181	32.4	5	2.76	11	5–24	2.05	0.89–4.29
Inshore	West coast SI.	2 914	56	1.9	0	0.00	4	0–13	0.14	0.00–0.45
Middle depth	Stewart-Snares	1 316	142	10.8	2	1.41	17	5–38	1.30	0.38–2.89
Inshore	Cook Strait	1 392	1	0.1	0	0.00	7	0–25	0.49	0.00–1.80
Hoki	Stewart-Snares	1 194	205	17.2	2	0.98	18	7–39	1.54	0.59–3.27
Ling	West coast SI.	80	-	-	-	-	2	0–7	1.93	0.00–8.75
Jack mackerel	West coast NI.	2 136	585	27.4	1	0.17	4	1–12	0.21	0.05–0.56
Inshore	West coast NI.	5 558	85	1.5	0	0.00	4	0–14	0.07	0.00–0.25
Ling	Stewart-Snares	619	122	19.7	11	9.02	23	13–39	3.66	2.10–6.30
Inshore	Stewart-Snares	1 740	-	-	-	-	10	1–34	0.56	0.06–1.95
Squid	Auckland Islands	1 318	537	40.7	1	0.19	3	1–7	0.19	0.08–0.53
Ling	Puysegur	222	18	8.1	1	5.56	5	1–16	2.05	0.45–7.22
Middle depth	West coast NI.	707	54	7.6	0	0.00	2	0–9	0.33	0.00–1.27
Hoki	Puysegur	24	3	12.5	0	0.00	0	0–2	0.74	0.00–8.33
Jack mackerel	West coast SI.	432	183	42.4	1	0.55	3	1–8	0.73	0.23–1.85
Squid	Puysegur	19	2	10.5	0	0.00	0	0–4	2.13	0.00–21.05
Scampi	East coast SI.	1 989	107	5.4	0	0.00	4	0–14	0.22	0.00–0.70
Ling	East coast SI.	230	-	-	-	-	4	0–11	1.56	0.00–4.78
Squid	Subantarctic	109	-	-	-	-	3	0–12	2.86	0.00–11.01
Deepwater	Subantarctic	1 222	824	67.4	2	0.24	2	2–4	0.19	0.16–0.33
Scampi	Auckland Islands	1 329	95	7.1	0	0.00	1	0–5	0.09	0.00–0.38
Jack mackerel	East coast SI.	110	17	15.5	0	0.00	2	0–7	1.46	0.00–6.36
Middle depth	Subantarctic	18	10	55.6	0	0.00	0	0–1	0.63	0.00–5.56
Hake	Stewart-Snares	166	55	33.1	0	0.00	1	0–4	0.57	0.00–2.41
Scampi	Cook Strait	78	17	21.8	0	0.00	0	0–2	0.35	0.00–2.56
Middle depth	Puysegur	97	20	20.6	0	0.00	0	0–3	0.50	0.00–3.09
Deepwater	East coast SI.	755	92	12.2	0	0.00	0	0–2	0.04	0.00–0.26
Ling	West coast NI.	26	6	23.1	0	0.00	0	0–1	0.54	0.00–3.85
Hoki	Auckland Islands	15	5	33.3	0	0.00	0	0–0	0.06	0.00–0.00
Jack mackerel	Stewart-Snares	22	-	-	-	-	0	0–4	2.24	0.00–18.18
Inshore	Puysegur	112	-	-	-	-	0	0–2	0.17	0.00–1.79
Deepwater	Cook Strait	152	4	2.6	0	0.00	0	0–2	0.15	0.00–1.32
Deepwater	Stewart-Snares	163	127	77.9	0	0.00	0	0–1	0.02	0.00–0.61
Deepwater	West coast NI.	313	310	99.0	0	0.00	0	0–0	0.00	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2007–08										
Hoki	Cook Strait	1 845	201	10.9	24	11.94	210	120–353	11.39	6.50–19.13
Hoki	West coast SI.	1 388	462	33.3	23	4.98	81	48–137	5.86	3.46–9.87
Hoki	East coast SI.	4 157	696	16.7	7	1.01	48	23–89	1.15	0.55–2.14
SBW	Bounty Islands	200	98	49.0	17	17.35	31	20–52	15.59	10.00–26.00
Middle depth	East coast SI.	1 882	154	8.2	6	3.90	35	14–75	1.87	0.74–3.99
Squid	Stewart-Snares	2 412	861	35.7	6	0.70	18	9–33	0.73	0.37–1.37
Middle depth	Cook Strait	599	7	1.2	0	0.00	18	3–53	2.95	0.50–8.85
Middle depth	West coast SI.	1 348	72	5.3	3	4.17	70	24–159	5.17	1.78–11.80
Squid	East coast SI.	539	-	-	-	-	15	2–45	2.82	0.37–8.35
Inshore	East coast SI.	3 777	8	0.2	0	0.00	15	2–42	0.40	0.05–1.11
Hake	West coast SI.	1 072	319	29.8	25	7.84	60	39–97	5.62	3.64–9.05
SBW	Campbell Island	559	230	41.1	7	3.04	12	7–22	2.21	1.25–3.94
Inshore	West coast SI.	2 565	14	0.5	0	0.00	22	4–60	0.85	0.16–2.34
Middle depth	Stewart-Snares	1 013	81	8.0	0	0.00	11	2–29	1.07	0.20–2.86
Inshore	Cook Strait	1 146	-	-	-	-	5	0–18	0.47	0.00–1.57
Hoki	Stewart-Snares	746	332	44.5	3	0.90	6	3–11	0.80	0.40–1.48
Ling	West coast SI.	315	-	-	-	-	25	6–62	7.95	1.90–19.68
Jack mackerel	West coast NI.	2 191	715	32.6	1	0.14	6	1–15	0.27	0.05–0.68
Inshore	West coast NI.	5 987	53	0.9	0	0.00	5	0–18	0.09	0.00–0.30
Ling	Stewart-Snares	691	134	19.4	3	2.24	8	3–16	1.16	0.43–2.32
Inshore	Stewart-Snares	1 319	-	-	-	-	7	0–24	0.51	0.00–1.82
Squid	Auckland Islands	1 265	589	46.6	0	0.00	2	0–7	0.18	0.00–0.56
Ling	Puysegur	217	13	6.0	0	0.00	2	0–8	0.83	0.00–3.69
Middle depth	West coast NI.	968	22	2.3	0	0.00	4	0–14	0.43	0.00–1.45
Hoki	Puysegur	10	-	-	-	-	0	0–1	1.16	0.00–10.00
Jack mackerel	West coast SI.	260	77	29.6	6	7.79	14	7–29	5.45	2.69–11.15
Squid	Puysegur	15	-	-	-	-	0	0–1	0.41	0.00–6.67
Scampi	East coast SI.	1 891	182	9.6	0	0.00	4	0–12	0.19	0.00–0.63
Ling	East coast SI.	251	3	1.2	0	0.00	8	1–23	2.99	0.40–9.16
Squid	Subantarctic	2	2	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	Subantarctic	1 696	833	49.1	5	0.60	7	5–12	0.41	0.29–0.71
Scampi	Auckland Islands	1 326	93	7.0	1	1.08	3	1–8	0.21	0.08–0.60
Jack mackerel	East coast SI.	169	14	8.3	0	0.00	3	0–11	1.99	0.00–6.51
Middle depth	Subantarctic	21	11	52.4	0	0.00	1	0–5	2.79	0.00–23.81
Hake	Stewart-Snares	157	49	31.2	1	2.04	1	1–3	0.91	0.64–1.91
Scampi	Cook Strait	65	23	35.4	0	0.00	0	0–2	0.27	0.00–3.08
Middle depth	Puysegur	80	-	-	-	-	1	0–3	0.68	0.00–3.75
Deepwater	East coast SI.	1 061	281	26.5	0	0.00	0	0–2	0.04	0.00–0.19
Ling	West coast NI.	64	-	-	-	-	1	0–5	1.45	0.00–7.81
Hoki	Auckland Islands	203	124	61.1	1	0.81	1	1–2	0.55	0.49–0.99
Jack mackerel	Stewart-Snares	14	3	21.4	0	0.00	0	0–1	0.33	0.00–7.14
Inshore	Puysegur	51	-	-	-	-	0	0–1	0.15	0.00–1.96
Deepwater	Cook Strait	127	19	15.0	0	0.00	0	0–1	0.07	0.00–0.79
Deepwater	Stewart-Snares	136	67	49.3	0	0.00	0	0–1	0.07	0.00–0.74
Deepwater	West coast NI.	233	131	56.2	0	0.00	0	0–0	0.00	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2008–09										
Hoki	Cook Strait	1 944	168	8.6	19	11.31	164	91–279	8.44	4.68–14.35
Hoki	West coast SI.	1 172	501	42.7	11	2.20	31	17–55	2.63	1.45–4.69
Hoki	East coast SI.	3 860	570	14.8	4	0.70	24	10–48	0.63	0.26–1.24
SBW	Bounty Islands	403	120	29.8	17	14.17	50	28–92	12.42	6.95–22.83
Middle depth	East coast SI.	2 080	230	11.1	2	0.87	35	11–82	1.68	0.53–3.94
Squid	Stewart-Snares	1 809	531	29.4	1	0.19	13	3–32	0.70	0.17–1.77
Middle depth	Cook Strait	841	4	0.5	0	0.00	31	6–90	3.68	0.71–10.70
Middle depth	West coast SI.	994	37	3.7	0	0.00	22	5–58	2.25	0.50–5.84
Squid	East coast SI.	121	3	2.5	0	0.00	6	0–24	5.22	0.00–19.83
Inshore	East coast SI.	4 424	299	6.8	0	0.00	16	3–46	0.37	0.07–1.04
Hake	West coast SI.	1 004	210	20.9	3	1.43	16	6–30	1.56	0.60–2.99
SBW	Campbell Island	620	124	20.0	0	0.00	3	0–11	0.52	0.00–1.77
Inshore	West coast SI.	2 805	290	10.3	0	0.00	8	1–24	0.30	0.04–0.86
Middle depth	Stewart-Snares	1 003	251	25.0	0	0.00	5	0–15	0.49	0.00–1.50
Inshore	Cook Strait	1 278	-	-	-	-	6	0–21	0.47	0.00–1.64
Hoki	Stewart-Snares	806	299	37.1	3	1.00	6	3–11	0.70	0.37–1.36
Ling	West coast SI.	266	-	-	-	-	10	1–27	3.69	0.38–10.15
Jack mackerel	West coast NI.	1 817	696	38.3	4	0.57	9	4–17	0.48	0.22–0.94
Inshore	West coast NI.	5 833	178	3.1	0	0.00	6	0–19	0.10	0.00–0.33
Ling	Stewart-Snares	375	72	19.2	0	0.00	2	0–6	0.48	0.00–1.60
Inshore	Stewart-Snares	1 522	83	5.5	1	1.20	5	1–15	0.32	0.07–0.99
Squid	Auckland Islands	1 925	761	39.5	0	0.00	4	0–14	0.23	0.00–0.73
Ling	Puysegur	166	-	-	-	-	2	0–10	1.32	0.00–6.02
Middle depth	West coast NI.	767	70	9.1	0	0.00	3	0–11	0.42	0.00–1.43
Hoki	Puysegur	8	-	-	-	-	0	0–1	1.03	0.00–12.50
Jack mackerel	West coast SI.	204	81	39.7	4	4.94	7	4–15	3.47	1.96–7.35
Squid	Puysegur	4	1	25.0	0	0.00	0	0–1	1.58	0.00–25.00
Scampi	East coast SI.	1 306	204	15.6	0	0.00	2	0–8	0.17	0.00–0.61
Ling	East coast SI.	207	16	7.7	0	0.00	6	0–19	2.76	0.00–9.18
Squid	Subantarctic	1	-	-	-	-	0	0–0	1.50	0.00–0.00
Deepwater	Subantarctic	1 217	415	34.1	0	0.00	1	0–4	0.08	0.00–0.33
Scampi	Auckland Islands	1 457	61	4.2	1	1.64	2	1–6	0.15	0.07–0.41
Jack mackerel	East coast SI.	52	1	1.9	0	0.00	1	0–5	1.70	0.00–9.62
Middle depth	Subantarctic	65	6	9.2	0	0.00	0	0–2	0.37	0.00–3.08
Hake	Stewart-Snares	274	78	28.5	0	0.00	0	0–2	0.10	0.00–0.73
Scampi	Cook Strait	29	2	6.9	0	0.00	0	0–1	0.21	0.00–3.45
Middle depth	Puysegur	59	41	69.5	0	0.00	0	0–1	0.11	0.00–1.69
Deepwater	East coast SI.	743	233	31.4	0	0.00	0	0–2	0.03	0.00–0.27
Ling	West coast NI.	56	1	1.8	0	0.00	1	0–4	1.30	0.00–7.14
Hoki	Auckland Islands	157	114	72.6	0	0.00	0	0–1	0.03	0.00–0.64
Jack mackerel	Stewart-Snares	80	34	42.5	0	0.00	0	0–1	0.19	0.00–1.25
Inshore	Puysegur	21	-	-	-	-	0	0–1	0.16	0.00–4.76
Deepwater	Cook Strait	118	3	2.5	0	0.00	0	0–1	0.11	0.00–0.85
Deepwater	Stewart-Snares	148	77	52.0	0	0.00	0	0–0	0.01	0.00–0.00
Deepwater	West coast NI.	236	166	70.3	0	0.00	0	0–0	0.00	0.00–0.00

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Table C-26: (*continued*)

		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
						Observed		Est. captures		Est. capture rate
2009–10										
Hoki	Cook Strait	1 631	341	20.9	17	4.99	109	62–178	6.67	3.80–10.91
Hoki	West coast SI.	2 096	658	31.4	4	0.61	29	11–60	1.38	0.52–2.86
Hoki	East coast SI.	4 370	617	14.1	7	1.13	42	20–81	0.96	0.46–1.85
SBW	Bounty Islands	394	89	22.6	10	11.24	43	20–85	10.94	5.08–21.57
Middle depth	East coast SI.	2 263	243	10.7	1	0.41	48	14–115	2.12	0.62–5.08
Squid	Stewart-Snares	2 259	760	33.6	8	1.05	41	19–80	1.83	0.84–3.54
Middle depth	Cook Strait	1 023	76	7.4	0	0.00	19	3–54	1.83	0.29–5.28
Middle depth	West coast SI.	854	78	9.1	0	0.00	9	1–27	1.07	0.12–3.16
Squid	East coast SI.	299	2	0.7	0	0.00	20	3–58	6.83	1.00–19.40
Inshore	East coast SI.	5 079	254	5.0	0	0.00	22	4–60	0.44	0.08–1.18
Hake	West coast SI.	546	135	24.7	3	2.22	7	3–14	1.28	0.55–2.56
SBW	Campbell Island	535	226	42.2	2	0.88	5	2–11	0.89	0.37–2.06
Inshore	West coast SI.	3 300	99	3.0	0	0.00	6	0–18	0.17	0.00–0.55
Middle depth	Stewart-Snares	887	235	26.5	4	1.70	13	5–30	1.48	0.56–3.38
Inshore	Cook Strait	1 589	-	-	-	-	4	0–16	0.28	0.00–1.01
Hoki	Stewart-Snares	1 238	433	35.0	2	0.46	10	4–22	0.83	0.32–1.78
Ling	West coast SI.	284	9	3.2	0	0.00	4	0–13	1.56	0.00–4.58
Jack mackerel	West coast NI.	2 213	710	32.1	2	0.28	4	2–9	0.20	0.09–0.41
Inshore	West coast NI.	6 293	4	0.1	0	0.00	5	0–18	0.08	0.00–0.29
Ling	Stewart-Snares	295	128	43.4	3	2.34	7	3–22	2.52	1.02–7.46
Inshore	Stewart-Snares	1 681	68	4.0	0	0.00	7	0–26	0.45	0.00–1.55
Squid	Auckland Islands	1 189	303	25.5	0	0.00	4	0–12	0.31	0.00–1.01
Ling	Puysegur	124	6	4.8	0	0.00	2	0–12	1.96	0.00–9.68
Middle depth	West coast NI.	475	4	0.8	0	0.00	2	0–7	0.33	0.00–1.47
Hoki	Puysegur	5	2	40.0	0	0.00	0	0–1	1.58	0.00–20.00
Jack mackerel	West coast SI.	63	26	41.3	0	0.00	0	0–3	0.72	0.00–4.76
Squid	Puysegur	34	1	2.9	0	0.00	1	0–4	1.77	0.00–11.76
Scampi	East coast SI.	1 446	106	7.3	1	0.94	6	1–15	0.39	0.07–1.04
Ling	East coast SI.	225	37	16.4	3	8.11	11	3–32	4.91	1.33–14.22
Squid	Subantarctic	4	-	-	-	-	0	0–3	6.46	0.00–75.00
Deepwater	Subantarctic	1 383	568	41.1	0	0.00	1	0–5	0.09	0.00–0.36
Scampi	Auckland Islands	941	92	9.8	0	0.00	0	0–3	0.05	0.00–0.32
Jack mackerel	East coast SI.	52	17	32.7	0	0.00	0	0–3	0.79	0.00–5.77
Middle depth	Subantarctic	42	10	23.8	0	0.00	0	0–3	0.83	0.00–7.14
Hake	Stewart-Snares	226	187	82.7	1	0.53	1	1–2	0.49	0.44–0.88
Scampi	Cook Strait	73	5	6.8	0	0.00	0	0–3	0.49	0.00–4.11
Middle depth	Puysegur	100	45	45.0	0	0.00	0	0–2	0.18	0.00–2.00
Deepwater	East coast SI.	985	189	19.2	0	0.00	0	0–2	0.04	0.00–0.20
Ling	West coast NI.	15	-	-	-	-	0	0–1	0.93	0.00–6.67
Hoki	Auckland Islands	62	3	4.8	0	0.00	0	0–1	0.18	0.00–1.61
Jack mackerel	Stewart-Snares	73	28	38.4	0	0.00	0	0–1	0.19	0.00–1.37
Inshore	Puysegur	102	-	-	-	-	0	0–2	0.28	0.00–1.96
Deepwater	Cook Strait	125	12	9.6	0	0.00	0	0–1	0.06	0.00–0.80
Deepwater	Stewart-Snares	91	57	62.6	0	0.00	0	0–1	0.06	0.00–1.10
Deepwater	West coast NI.	162	92	56.8	0	0.00	0	0–0	0.00	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2010–11										
Hoki	Cook Strait	1 592	90	5.7	18	20.00	192	93–360	12.05	5.84–22.61
Hoki	West coast SI.	2 810	552	19.6	3	0.54	43	15–93	1.53	0.53–3.31
Hoki	East coast SI.	4 133	737	17.8	3	0.41	24	8–52	0.57	0.19–1.26
SBW	Bounty Islands	175	61	34.9	31	50.82	64	41–110	36.43	23.43–62.86
Middle depth	East coast SI.	2 323	177	7.6	0	0.00	31	7–87	1.34	0.30–3.75
Squid	Stewart-Snares	2 174	683	31.4	7	1.02	23	11–44	1.07	0.51–2.02
Middle depth	Cook Strait	1 106	26	2.4	0	0.00	43	9–125	3.87	0.81–11.30
Middle depth	West coast SI.	887	17	1.9	0	0.00	10	1–29	1.10	0.11–3.27
Squid	East coast SI.	394	15	3.8	0	0.00	6	0–22	1.62	0.00–5.58
Inshore	East coast SI.	4 695	-	-	-	-	14	2–43	0.30	0.04–0.92
Hake	West coast SI.	682	127	18.6	0	0.00	5	0–14	0.76	0.00–2.05
SBW	Campbell Island	928	364	39.2	4	1.10	10	5–20	1.09	0.54–2.16
Inshore	West coast SI.	3 315	4	0.1	0	0.00	6	0–19	0.17	0.00–0.57
Middle depth	Stewart-Snares	770	147	19.1	2	1.36	8	3–20	1.08	0.39–2.60
Inshore	Cook Strait	1 790	-	-	-	-	12	1–41	0.68	0.06–2.29
Hoki	Stewart-Snares	984	226	23.0	0	0.00	4	0–10	0.37	0.00–1.02
Ling	West coast SI.	343	-	-	-	-	4	0–13	1.13	0.00–3.79
Jack mackerel	West coast NI.	1 570	474	30.2	0	0.00	2	0–6	0.10	0.00–0.38
Inshore	West coast NI.	6 386	73	1.1	0	0.00	5	0–17	0.07	0.00–0.27
Ling	Stewart-Snares	263	92	35.0	2	2.17	3	2–6	1.20	0.76–2.28
Inshore	Stewart-Snares	1 594	-	-	-	-	4	0–15	0.25	0.00–0.94
Squid	Auckland Islands	1 585	543	34.3	1	0.18	4	1–11	0.26	0.06–0.69
Ling	Puysegur	231	7	3.0	0	0.00	6	0–22	2.46	0.00–9.52
Middle depth	West coast NI.	512	-	-	-	-	1	0–6	0.29	0.00–1.17
Hoki	Puysegur	76	1	1.3	0	0.00	1	0–4	1.08	0.00–5.26
Jack mackerel	West coast SI.	118	32	27.1	0	0.00	1	0–3	0.58	0.00–2.54
Squid	Puysegur	57	16	28.1	0	0.00	0	0–2	0.60	0.00–3.51
Scampi	East coast SI.	1 198	115	9.6	0	0.00	2	0–6	0.14	0.00–0.50
Ling	East coast SI.	96	-	-	-	-	3	0–12	2.81	0.00–12.50
Squid	Subantarctic	2	-	-	-	-	0	0–1	3.11	0.00–50.00
Deepwater	Subantarctic	767	293	38.2	0	0.00	1	0–4	0.13	0.00–0.52
Scampi	Auckland Islands	1 401	205	14.6	0	0.00	1	0–5	0.08	0.00–0.36
Jack mackerel	East coast SI.	73	28	38.4	0	0.00	0	0–2	0.37	0.00–2.74
Middle depth	Subantarctic	32	3	9.4	0	0.00	1	0–5	2.27	0.00–15.62
Hake	Stewart-Snares	94	90	95.7	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	Cook Strait	27	2	7.4	0	0.00	0	0–3	1.40	0.00–11.11
Middle depth	Puysegur	63	31	49.2	0	0.00	1	0–4	0.90	0.00–6.35
Deepwater	East coast SI.	914	224	24.5	0	0.00	0	0–2	0.03	0.00–0.22
Ling	West coast NI.	19	-	-	-	-	0	0–1	0.73	0.00–5.26
Hoki	Auckland Islands	270	88	32.6	0	0.00	0	0–1	0.05	0.00–0.37
Jack mackerel	Stewart-Snares	118	59	50.0	0	0.00	0	0–2	0.20	0.00–1.69
Inshore	Puysegur	172	-	-	-	-	0	0–2	0.17	0.00–1.16
Deepwater	Cook Strait	94	30	31.9	0	0.00	0	0–1	0.08	0.00–1.06
Deepwater	Stewart-Snares	73	20	27.4	0	0.00	0	0–0	0.03	0.00–0.00
Deepwater	West coast NI.	169	57	33.7	0	0.00	0	0–0	0.01	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2011–12										
Hoki	Cook Strait	1 747	197	11.3	16	8.12	125	65–226	7.17	3.72–12.94
Hoki	West coast SI.	3 209	1 155	36.0	13	1.13	65	36–112	2.04	1.12–3.49
Hoki	East coast SI.	4 325	874	20.2	5	0.57	26	11–52	0.60	0.25–1.20
SBW	Bounty Islands	173	80	46.2	12	15.00	25	15–47	14.47	8.67–27.17
Middle depth	East coast SI.	2 051	202	9.8	0	0.00	30	7–76	1.44	0.34–3.71
Squid	Stewart-Snares	1 984	800	40.3	6	0.75	21	10–42	1.06	0.50–2.12
Middle depth	Cook Strait	870	7	0.8	0	0.00	26	5–76	2.94	0.57–8.74
Middle depth	West coast SI.	929	85	9.1	7	8.24	21	10–42	2.21	1.08–4.52
Squid	East coast SI.	219	6	2.7	0	0.00	9	1–29	4.09	0.46–13.24
Inshore	East coast SI.	4 077	20	0.5	0	0.00	14	2–42	0.34	0.05–1.03
Hake	West coast SI.	505	85	16.8	1	1.18	7	2–16	1.36	0.40–3.17
SBW	Campbell Island	646	458	70.9	4	0.87	6	4–10	0.89	0.62–1.55
Inshore	West coast SI.	3 239	32	1.0	0	0.00	11	1–31	0.33	0.03–0.96
Middle depth	Stewart-Snares	824	243	29.5	1	0.41	8	2–23	1.03	0.24–2.79
Inshore	Cook Strait	1 798	-	-	-	-	8	0–29	0.47	0.00–1.61
Hoki	Stewart-Snares	1 224	285	23.3	0	0.00	3	0–9	0.26	0.00–0.74
Ling	West coast SI.	232	20	8.6	0	0.00	4	0–12	1.59	0.00–5.17
Jack mackerel	West coast NI.	1 640	1 288	78.5	3	0.23	4	3–7	0.24	0.18–0.43
Inshore	West coast NI.	6 904	39	0.6	0	0.00	7	0–22	0.09	0.00–0.32
Ling	Stewart-Snares	241	89	36.9	1	1.12	2	1–7	0.96	0.41–2.90
Inshore	Stewart-Snares	1 628	26	1.6	0	0.00	4	0–17	0.27	0.00–1.04
Squid	Auckland Islands	1 283	570	44.4	2	0.35	5	2–11	0.38	0.16–0.86
Ling	Puysegur	241	12	5.0	0	0.00	4	0–15	1.53	0.00–6.22
Middle depth	West coast NI.	515	17	3.3	0	0.00	2	0–8	0.38	0.00–1.55
Hoki	Puysegur	98	49	50.0	0	0.00	0	0–2	0.34	0.00–2.04
Jack mackerel	West coast SI.	124	87	70.2	1	1.15	2	1–5	1.31	0.81–4.03
Squid	Puysegur	19	1	5.3	0	0.00	0	0–2	1.04	0.00–10.53
Scampi	East coast SI.	1 681	43	2.6	1	2.33	5	1–12	0.27	0.06–0.71
Ling	East coast SI.	67	-	-	-	-	2	0–11	3.46	0.00–16.42
Squid	Subantarctic	2	2	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	Subantarctic	563	196	34.8	0	0.00	1	0–3	0.12	0.00–0.53
Scampi	Auckland Islands	1 247	119	9.5	0	0.00	1	0–6	0.11	0.00–0.48
Jack mackerel	East coast SI.	120	65	54.2	0	0.00	1	0–5	0.67	0.00–4.17
Middle depth	Subantarctic	33	-	-	-	-	0	0–2	0.83	0.00–6.06
Hake	Stewart-Snares	139	139	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	Cook Strait	51	21	41.2	0	0.00	0	0–2	0.58	0.00–3.92
Middle depth	Puysegur	45	28	62.2	0	0.00	0	0–1	0.11	0.00–2.22
Deepwater	East coast SI.	836	111	13.3	0	0.00	0	0–2	0.03	0.00–0.24
Ling	West coast NI.	19	2	10.5	0	0.00	0	0–1	0.75	0.00–5.26
Hoki	Auckland Islands	45	5	11.1	0	0.00	0	0–0	0.06	0.00–0.00
Jack mackerel	Stewart-Snares	142	102	71.8	1	0.98	1	1–2	0.80	0.70–1.41
Inshore	Puysegur	76	-	-	-	-	0	0–1	0.10	0.00–1.32
Deepwater	Cook Strait	83	8	9.6	0	0.00	0	0–1	0.13	0.00–1.20
Deepwater	Stewart-Snares	118	22	18.6	0	0.00	0	0–1	0.03	0.00–0.85
Deepwater	West coast NI.	270	138	51.1	0	0.00	0	0–0	0.01	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2012–13										
Hoki	Cook Strait	1 940	197	10.2	28	14.21	258	137–461	13.32	7.06–23.76
Hoki	West coast SI.	3 353	1 821	54.3	28	1.54	75	49–115	2.23	1.46–3.43
Hoki	East coast SI.	4 217	1 458	34.6	2	0.14	16	6–32	0.38	0.14–0.76
SBW	Bounty Islands	77	77	100.0	18	23.38	18	18–18	23.38	23.38–23.38
Middle depth	East coast SI.	2 221	446	20.1	6	1.35	32	13–68	1.44	0.59–3.06
Squid	Stewart-Snares	1 529	1 343	87.8	4	0.30	5	4–9	0.35	0.26–0.59
Middle depth	Cook Strait	1 005	-	-	-	-	41	9–120	4.11	0.90–11.94
Middle depth	West coast SI.	1 055	57	5.4	0	0.00	21	4–56	1.96	0.38–5.31
Squid	East coast SI.	38	13	34.2	0	0.00	0	0–2	0.74	0.00–5.26
Inshore	East coast SI.	4 540	101	2.2	1	0.99	10	2–26	0.22	0.04–0.57
Hake	West coast SI.	597	423	70.9	9	2.13	16	9–28	2.61	1.51–4.69
SBW	Campbell Island	709	709	100.0	9	1.27	9	9–9	1.27	1.27–1.27
Inshore	West coast SI.	3 203	30	0.9	0	0.00	9	1–26	0.29	0.03–0.81
Middle depth	Stewart-Snares	855	613	71.7	3	0.49	5	3–11	0.61	0.35–1.29
Inshore	Cook Strait	2 087	-	-	-	-	13	1–43	0.64	0.05–2.06
Hoki	Stewart-Snares	1 084	667	61.5	0	0.00	1	0–4	0.09	0.00–0.37
Ling	West coast SI.	159	1	0.6	0	0.00	5	0–16	3.25	0.00–10.06
Jack mackerel	West coast NI.	1 696	1 445	85.2	3	0.21	4	3–7	0.23	0.18–0.41
Inshore	West coast NI.	7 362	22	0.3	0	0.00	6	0–20	0.08	0.00–0.27
Ling	Stewart-Snares	623	196	31.5	4	2.04	6	4–10	0.94	0.64–1.61
Inshore	Stewart-Snares	1 822	-	-	-	-	3	0–10	0.15	0.00–0.55
Squid	Auckland Islands	1 027	885	86.2	3	0.34	3	3–5	0.32	0.29–0.49
Ling	Puysegur	138	27	19.6	0	0.00	2	0–11	1.76	0.00–7.97
Middle depth	West coast NI.	438	16	3.7	0	0.00	2	0–7	0.37	0.00–1.60
Hoki	Puysegur	68	56	82.4	0	0.00	0	0–1	0.10	0.00–1.47
Jack mackerel	West coast SI.	181	157	86.7	1	0.64	1	1–4	0.75	0.55–2.21
Squid	Puysegur	39	26	66.7	0	0.00	0	0–1	0.21	0.00–2.56
Scampi	East coast SI.	1 791	113	6.3	0	0.00	2	0–9	0.13	0.00–0.50
Ling	East coast SI.	63	28	44.4	0	0.00	1	0–5	1.15	0.00–7.94
Squid	Subantarctic	3	3	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	Subantarctic	80	65	81.2	0	0.00	0	0–0	0.03	0.00–0.00
Scampi	Auckland Islands	1 066	110	10.3	0	0.00	1	0–5	0.10	0.00–0.47
Jack mackerel	East coast SI.	216	213	98.6	0	0.00	0	0–0	0.01	0.00–0.00
Middle depth	Subantarctic	17	14	82.4	0	0.00	0	0–2	1.23	0.00–11.76
Hake	Stewart-Snares	103	102	99.0	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	Cook Strait	36	4	11.1	0	0.00	1	0–4	1.56	0.00–11.11
Middle depth	Puysegur	60	50	83.3	0	0.00	0	0–3	0.59	0.00–5.00
Deepwater	East coast SI.	809	73	9.0	0	0.00	0	0–2	0.03	0.00–0.25
Ling	West coast NI.	33	1	3.0	0	0.00	0	0–2	0.89	0.00–6.06
Hoki	Auckland Islands	85	45	52.9	0	0.00	0	0–0	0.02	0.00–0.00
Jack mackerel	Stewart-Snares	90	90	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Inshore	Puysegur	140	-	-	-	-	0	0–1	0.12	0.00–0.71
Deepwater	Cook Strait	60	1	1.7	0	0.00	0	0–1	0.07	0.00–1.67
Deepwater	Stewart-Snares	108	21	19.4	0	0.00	0	0–1	0.02	0.00–0.93
Deepwater	West coast NI.	348	31	8.9	0	0.00	0	0–1	0.01	0.00–0.29

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2013–14										
Hoki	Cook Strait	2 183	230	10.5	5	2.17	54	22–103	2.47	1.01–4.72
Hoki	West coast SI.	4 140	1 787	43.2	26	1.45	73	48–110	1.76	1.16–2.66
Hoki	East coast SI.	3 976	986	24.8	1	0.10	10	3–24	0.26	0.08–0.60
SBW	Bounty Islands	190	189	99.5	91	48.15	93	91–105	48.71	47.89–55.26
Middle depth	East coast SI.	1 934	467	24.1	1	0.21	15	4–38	0.79	0.21–1.96
Squid	Stewart-Snares	1 221	1 081	88.5	8	0.74	9	8–11	0.71	0.66–0.90
Middle depth	Cook Strait	888	-	-	-	-	10	1–31	1.14	0.11–3.49
Middle depth	West coast SI.	917	54	5.9	0	0.00	11	1–31	1.18	0.11–3.38
Squid	East coast SI.	13	4	30.8	0	0.00	0	0–1	1.17	0.00–7.88
Inshore	East coast SI.	5 298	11	0.2	0	0.00	10	1–31	0.19	0.02–0.59
Hake	West coast SI.	653	445	68.1	6	1.35	11	6–21	1.72	0.92–3.22
SBW	Campbell Island	590	590	100.0	4	0.68	4	4–4	0.68	0.68–0.68
Inshore	West coast SI.	3 506	59	1.7	0	0.00	10	1–29	0.28	0.03–0.83
Middle depth	Stewart-Snares	819	544	66.4	2	0.37	5	2–13	0.65	0.24–1.59
Inshore	Cook Strait	1 750	-	-	-	-	5	0–16	0.26	0.00–0.91
Hoki	Stewart-Snares	1 516	540	35.6	0	0.00	2	0–6	0.12	0.00–0.40
Ling	West coast SI.	175	-	-	-	-	4	0–12	2.19	0.00–6.86
Jack mackerel	West coast NI.	1 798	1 579	87.8	8	0.51	9	8–11	0.48	0.44–0.61
Inshore	West coast NI.	6 648	318	4.8	1	0.31	10	2–28	0.15	0.03–0.42
Ling	Stewart-Snares	403	59	14.6	0	0.00	2	0–7	0.55	0.00–1.74
Inshore	Stewart-Snares	1 634	-	-	-	-	3	0–10	0.16	0.00–0.61
Squid	Auckland Islands	737	622	84.4	1	0.16	1	1–3	0.17	0.14–0.41
Ling	Puysegur	233	29	12.4	0	0.00	3	0–13	1.28	0.00–5.58
Middle depth	West coast NI.	595	126	21.2	1	0.79	4	1–10	0.59	0.17–1.68
Hoki	Puysegur	49	7	14.3	0	0.00	0	0–2	0.57	0.00–4.08
Jack mackerel	West coast SI.	202	173	85.6	1	0.58	2	1–5	0.80	0.50–2.48
Squid	Puysegur	79	77	97.5	0	0.00	0	0–0	0.01	0.00–0.00
Scampi	East coast SI.	1 829	92	5.0	0	0.00	2	0–8	0.12	0.00–0.44
Ling	East coast SI.	59	2	3.4	0	0.00	1	0–4	1.01	0.00–6.78
Squid	Subantarctic	1	1	100.0	1	100.00	1	1–1	100.00	100.00–100.00
Deepwater	Subantarctic	211	10	4.7	0	0.00	0	0–2	0.14	0.00–0.95
Scampi	Auckland Islands	884	56	6.3	0	0.00	0	0–2	0.04	0.00–0.23
Jack mackerel	East coast SI.	295	287	97.3	1	0.35	1	1–2	0.35	0.34–0.68
Middle depth	Subantarctic	47	45	95.7	0	0.00	0	0–0	0.05	0.00–0.00
Hake	Stewart-Snares	135	126	93.3	0	0.00	0	0–0	0.01	0.00–0.00
Scampi	Cook Strait	11	-	-	-	-	0	0–0	0.22	0.00–0.00
Middle depth	Puysegur	35	25	71.4	0	0.00	0	0–1	0.24	0.00–2.86
Deepwater	East coast SI.	1 094	141	12.9	0	0.00	0	0–2	0.02	0.00–0.18
Ling	West coast NI.	23	4	17.4	0	0.00	0	0–2	1.13	0.00–8.70
Hoki	Auckland Islands	187	90	48.1	0	0.00	0	0–0	0.01	0.00–0.00
Jack mackerel	Stewart-Snares	119	110	92.4	0	0.00	0	0–0	0.02	0.00–0.00
Inshore	Puysegur	110	-	-	-	-	0	0–2	0.19	0.00–1.82
Deepwater	Cook Strait	107	-	-	-	-	0	0–1	0.03	0.00–0.93
Deepwater	Stewart-Snares	66	9	13.6	0	0.00	0	0–0	0.01	0.00–0.00
Deepwater	West coast NI.	236	67	28.4	0	0.00	0	0–1	0.01	0.00–0.42

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2014–15										
Hoki	Cook Strait	2 030	443	21.8	6	1.35	119	49–239	5.86	2.41–11.77
Hoki	West coast SI.	4 708	2 026	43.0	34	1.68	115	77–174	2.44	1.64–3.70
Hoki	East coast SI.	4 367	654	15.0	1	0.15	20	6–43	0.46	0.14–0.98
SBW	Bounty Islands	25	25	100.0	33	132.00	33	33–33	132.00	132.00–132.00
Middle depth	East coast SI.	2 099	261	12.4	2	0.77	31	10–76	1.49	0.48–3.62
Squid	Stewart-Snares	1 107	1 035	93.5	14	1.35	14	14–17	1.30	1.26–1.54
Middle depth	Cook Strait	801	22	2.7	0	0.00	16	2–46	1.95	0.25–5.74
Middle depth	West coast SI.	809	71	8.8	1	1.41	15	4–37	1.80	0.49–4.57
Squid	East coast SI.	162	65	40.1	5	7.69	10	5–26	6.21	3.09–16.05
Inshore	East coast SI.	3 958	-	-	-	-	17	3–50	0.43	0.08–1.26
Hake	West coast SI.	823	596	72.4	6	1.01	13	7–26	1.60	0.85–3.16
SBW	Campbell Island	641	641	100.0	8	1.25	8	8–8	1.25	1.25–1.25
Inshore	West coast SI.	3 272	-	-	-	-	13	2–37	0.39	0.06–1.13
Middle depth	Stewart-Snares	833	674	80.9	4	0.59	6	4–12	0.73	0.48–1.44
Inshore	Cook Strait	1 506	-	-	-	-	7	0–25	0.48	0.00–1.66
Hoki	Stewart-Snares	1 436	387	26.9	1	0.26	5	1–11	0.33	0.07–0.77
Ling	West coast SI.	135	-	-	-	-	3	0–13	2.47	0.00–9.63
Jack mackerel	West coast NI.	1 274	1 085	85.2	1	0.09	1	1–3	0.10	0.08–0.24
Inshore	West coast NI.	6 389	724	11.3	0	0.00	4	0–12	0.06	0.00–0.19
Ling	Stewart-Snares	538	53	9.9	0	0.00	5	0–16	0.99	0.00–2.97
Inshore	Stewart-Snares	1 500	1	0.1	0	0.00	6	0–22	0.41	0.00–1.47
Squid	Auckland Islands	631	557	88.3	0	0.00	0	0–1	0.02	0.00–0.16
Ling	Puysegur	206	61	29.6	0	0.00	2	0–11	1.20	0.00–5.34
Middle depth	West coast NI.	683	386	56.5	0	0.00	1	0–4	0.11	0.00–0.59
Hoki	Puysegur	86	3	3.5	0	0.00	1	0–4	0.90	0.00–4.65
Jack mackerel	West coast SI.	192	184	95.8	4	2.17	4	4–6	2.23	2.08–3.12
Squid	Puysegur	22	22	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	East coast SI.	1 917	258	13.5	1	0.39	4	1–12	0.22	0.05–0.63
Ling	East coast SI.	12	2	16.7	0	0.00	0	0–3	2.58	0.00–25.00
Squid	Subantarctic	1	1	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	Subantarctic	31	20	64.5	0	0.00	0	0–1	0.16	0.00–3.23
Scampi	Auckland Islands	610	-	-	-	-	1	0–3	0.09	0.00–0.49
Jack mackerel	East coast SI.	143	118	82.5	0	0.00	1	0–5	0.51	0.00–3.50
Middle depth	Subantarctic	11	11	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Hake	Stewart-Snares	134	131	97.8	2	1.53	2	2–2	1.50	1.49–1.49
Scampi	Cook Strait	53	-	-	-	-	1	0–4	1.06	0.00–7.55
Middle depth	Puysegur	26	19	73.1	0	0.00	0	0–1	0.41	0.00–3.85
Deepwater	East coast SI.	1 088	232	21.3	1	0.43	1	1–3	0.11	0.09–0.28
Ling	West coast NI.	20	8	40.0	0	0.00	0	0–1	0.20	0.00–5.00
Hoki	Auckland Islands	226	49	21.7	0	0.00	0	0–1	0.06	0.00–0.44
Jack mackerel	Stewart-Snares	108	91	84.3	0	0.00	0	0–1	0.10	0.00–0.93
Inshore	Puysegur	105	-	-	-	-	0	0–1	0.11	0.00–0.95
Deepwater	Cook Strait	96	10	10.4	0	0.00	0	0–1	0.06	0.00–1.04
Deepwater	Stewart-Snares	48	45	93.8	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	West coast NI.	242	121	50.0	0	0.00	0	0–0	0.01	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2015–16										
Hoki	Cook Strait	1 818	153	8.4	24	15.69	137	76–233	7.55	4.18–12.82
Hoki	West coast SI.	5 036	1 876	37.3	17	0.91	71	42–114	1.41	0.83–2.26
Hoki	East coast SI.	4 275	1 004	23.5	0	0.00	10	2–25	0.24	0.05–0.58
SBW	Bounty Islands	40	40	100.0	50	125.00	50	50–50	125.00	125.00–125.00
Middle depth	East coast SI.	1 931	258	13.4	0	0.00	15	3–42	0.80	0.16–2.18
Squid	Stewart-Snares	987	918	93.0	1	0.11	1	1–2	0.12	0.10–0.20
Middle depth	Cook Strait	794	-	-	-	-	22	4–66	2.77	0.50–8.31
Middle depth	West coast SI.	821	81	9.9	3	3.70	9	3–19	1.04	0.37–2.31
Squid	East coast SI.	469	121	25.8	6	4.96	14	7–31	3.00	1.49–6.61
Inshore	East coast SI.	3 576	-	-	-	-	5	0–17	0.15	0.00–0.48
Hake	West coast SI.	372	233	62.6	0	0.00	2	0–7	0.52	0.00–1.88
SBW	Campbell Island	397	397	100.0	1	0.25	1	1–1	0.25	0.25–0.25
Inshore	West coast SI.	3 358	-	-	-	-	5	0–16	0.16	0.00–0.48
Middle depth	Stewart-Snares	652	548	84.0	0	0.00	1	0–3	0.09	0.00–0.46
Inshore	Cook Strait	1 613	-	-	-	-	10	1–35	0.64	0.06–2.17
Hoki	Stewart-Snares	729	227	31.1	0	0.00	1	0–2	0.07	0.00–0.27
Ling	West coast SI.	133	4	3.0	0	0.00	1	0–6	1.04	0.00–4.51
Jack mackerel	West coast NI.	1 145	1 054	92.1	1	0.09	1	1–2	0.10	0.09–0.17
Inshore	West coast NI.	5 752	1 082	18.8	0	0.00	3	0–9	0.05	0.00–0.16
Ling	Stewart-Snares	382	66	17.3	1	1.52	2	1–5	0.53	0.26–1.31
Inshore	Stewart-Snares	1 522	-	-	-	-	1	0–6	0.09	0.00–0.39
Squid	Auckland Islands	1 350	1 243	92.1	3	0.24	3	3–5	0.25	0.22–0.37
Ling	Puysegur	304	71	23.4	0	0.00	2	0–9	0.79	0.00–2.96
Middle depth	West coast NI.	304	53	17.4	0	0.00	1	0–4	0.29	0.00–1.32
Hoki	Puysegur	66	17	25.8	0	0.00	0	0–2	0.54	0.00–3.03
Jack mackerel	West coast SI.	258	208	80.6	1	0.48	2	1–4	0.62	0.39–1.56
Squid	Puysegur	63	57	90.5	0	0.00	0	0–1	0.10	0.00–1.59
Scampi	East coast SI.	1 726	6	0.3	0	0.00	2	0–8	0.12	0.00–0.46
Ling	East coast SI.	76	1	1.3	0	0.00	1	0–3	0.76	0.00–3.95
Squid	Subantarctic	2	2	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	Subantarctic	184	77	41.8	0	0.00	0	0–1	0.07	0.00–0.54
Scampi	Auckland Islands	1 429	65	4.5	0	0.00	1	0–4	0.06	0.00–0.28
Jack mackerel	East coast SI.	52	41	78.8	0	0.00	0	0–1	0.19	0.00–1.92
Middle depth	Subantarctic	5	5	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Hake	Stewart-Snares	132	129	97.7	0	0.00	0	0–0	0.01	0.00–0.00
Scampi	Cook Strait	45	-	-	-	-	1	0–4	1.28	0.00–8.89
Middle depth	Puysegur	18	15	83.3	0	0.00	0	0–0	0.09	0.00–0.00
Deepwater	East coast SI.	867	134	15.5	0	0.00	0	0–2	0.03	0.00–0.23
Ling	West coast NI.	11	3	27.3	0	0.00	0	0–1	0.36	0.00–9.09
Hoki	Auckland Islands	110	53	48.2	0	0.00	0	0–1	0.03	0.00–0.91
Jack mackerel	Stewart-Snares	74	74	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Inshore	Puysegur	18	-	-	-	-	0	0–0	0.15	0.00–0.14
Deepwater	Cook Strait	35	-	-	-	-	0	0–1	0.12	0.00–2.86
Deepwater	Stewart-Snares	132	36	27.3	0	0.00	0	0–0	0.01	0.00–0.00
Deepwater	West coast NI.	466	233	50.0	0	0.00	0	0–1	0.01	0.00–0.21

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2016–17										
Hoki	Cook Strait	1 701	120	7.1	23	19.17	141	77–240	8.28	4.53–14.11
Hoki	West coast SI.	4 980	1 550	31.1	12	0.77	67	38–114	1.34	0.76–2.29
Hoki	East coast SI.	4 394	900	20.5	1	0.11	26	9–58	0.59	0.20–1.32
SBW	Bounty Islands	25	25	100.0	8	32.00	8	8–8	32.00	32.00–32.00
Middle depth	East coast SI.	2 230	476	21.3	3	0.63	35	11–84	1.58	0.49–3.77
Squid	Stewart-Snares	1 116	906	81.2	9	0.99	10	9–14	0.93	0.81–1.25
Middle depth	Cook Strait	598	17	2.8	0	0.00	22	3–66	3.62	0.50–11.04
Middle depth	West coast SI.	721	151	20.9	2	1.32	5	2–12	0.72	0.28–1.66
Squid	East coast SI.	148	77	52.0	6	7.79	10	6–22	6.46	4.05–14.86
Inshore	East coast SI.	4 548	92	2.0	0	0.00	15	2–42	0.32	0.04–0.92
Hake	West coast SI.	443	361	81.5	2	0.55	3	2–8	0.72	0.45–1.81
SBW	Campbell Island	499	499	100.0	3	0.60	3	3–3	0.60	0.60–0.60
Inshore	West coast SI.	3 535	17	0.5	0	0.00	5	0–15	0.14	0.00–0.42
Middle depth	Stewart-Snares	881	712	80.8	1	0.14	3	1–9	0.35	0.11–1.02
Inshore	Cook Strait	1 291	-	-	-	-	8	0–28	0.64	0.00–2.17
Hoki	Stewart-Snares	1 106	117	10.6	0	0.00	3	0–7	0.23	0.00–0.63
Ling	West coast SI.	235	17	7.2	1	5.88	3	1–8	1.28	0.43–3.40
Jack mackerel	West coast NI.	1 050	819	78.0	0	0.00	0	0–2	0.03	0.00–0.19
Inshore	West coast NI.	5 551	1 658	29.9	0	0.00	2	0–7	0.03	0.00–0.13
Ling	Stewart-Snares	405	93	23.0	1	1.08	3	1–8	0.75	0.25–1.98
Inshore	Stewart-Snares	1 336	-	-	-	-	2	0–9	0.18	0.00–0.68
Squid	Auckland Islands	1 280	901	70.4	2	0.22	3	2–6	0.22	0.16–0.47
Ling	Puysegur	205	51	24.9	0	0.00	2	0–10	1.10	0.00–4.88
Middle depth	West coast NI.	215	48	22.3	0	0.00	0	0–3	0.19	0.00–1.40
Hoki	Puysegur	86	2	2.3	0	0.00	1	0–4	0.77	0.00–4.65
Jack mackerel	West coast SI.	255	123	48.2	0	0.00	1	0–5	0.41	0.00–1.96
Squid	Puysegur	36	36	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	East coast SI.	1 074	85	7.9	1	1.18	3	1–8	0.26	0.09–0.74
Ling	East coast SI.	54	-	-	-	-	1	0–4	1.39	0.00–7.41
Squid	Subantarctic	5	5	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	Subantarctic	182	181	99.5	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	Auckland Islands	1 680	356	21.2	0	0.00	1	0–5	0.08	0.00–0.30
Jack mackerel	East coast SI.	39	29	74.4	0	0.00	0	0–1	0.14	0.00–2.56
Middle depth	Subantarctic	2	2	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Hake	Stewart-Snares	97	95	97.9	0	0.00	0	0–0	0.01	0.00–0.00
Scampi	Cook Strait	65	-	-	-	-	1	0–4	0.92	0.00–6.15
Middle depth	Puysegur	13	13	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	East coast SI.	893	178	19.9	0	0.00	0	0–2	0.04	0.00–0.22
Ling	West coast NI.	25	13	52.0	0	0.00	0	0–1	0.20	0.00–4.00
Hoki	Auckland Islands	133	77	57.9	0	0.00	0	0–1	0.02	0.00–0.75
Jack mackerel	Stewart-Snares	31	22	71.0	0	0.00	0	0–0	0.05	0.00–0.00
Inshore	Puysegur	30	-	-	-	-	0	0–0	0.07	0.00–0.00
Deepwater	Cook Strait	41	3	7.3	0	0.00	0	0–1	0.14	0.00–2.44
Deepwater	Stewart-Snares	52	31	59.6	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	West coast NI.	279	1	0.4	0	0.00	0	0–0	0.01	0.00–0.00

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Table C-26: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2017–18										
Hoki	Cook Strait	1 979	206	10.4	16	7.77	117	63–204	5.92	3.18–10.31
Hoki	West coast SI.	5 209	2 379	45.7	22	0.92	60	39–89	1.15	0.75–1.71
Hoki	East coast SI.	3 977	942	23.7	2	0.21	11	4–22	0.27	0.10–0.55
SBW	Bounty Islands	34	34	100.0	15	44.12	15	15–15	44.12	44.12–44.12
Middle depth	East coast SI.	3 017	576	19.1	2	0.35	27	9–66	0.90	0.30–2.19
Squid	Stewart-Snares	1 229	1 190	96.8	7	0.59	7	7–8	0.58	0.57–0.65
Middle depth	Cook Strait	458	10	2.2	0	0.00	8	1–27	1.74	0.21–5.90
Middle depth	West coast SI.	951	280	29.4	0	0.00	5	0–15	0.53	0.00–1.58
Squid	East coast SI.	373	229	61.4	4	1.75	13	4–38	3.48	1.07–10.19
Inshore	East coast SI.	4 613	13	0.3	0	0.00	12	2–35	0.26	0.04–0.76
Hake	West coast SI.	200	90	45.0	0	0.00	1	0–5	0.62	0.00–2.50
SBW	Campbell Island	420	420	100.0	2	0.48	2	2–2	0.48	0.48–0.48
Inshore	West coast SI.	2 639	-	-	-	-	3	0–10	0.12	0.00–0.38
Middle depth	Stewart-Snares	508	473	93.1	1	0.21	1	1–3	0.25	0.20–0.59
Inshore	Cook Strait	1 153	-	-	-	-	4	0–17	0.39	0.00–1.47
Hoki	Stewart-Snares	1 411	820	58.1	0	0.00	1	0–4	0.08	0.00–0.28
Ling	West coast SI.	162	-	-	-	-	1	0–5	0.76	0.00–3.09
Jack mackerel	West coast NI.	1 150	1 006	87.5	2	0.20	2	2–4	0.20	0.17–0.35
Inshore	West coast NI.	5 874	1 697	28.9	0	0.00	3	0–11	0.06	0.00–0.19
Ling	Stewart-Snares	498	130	26.1	0	0.00	2	0–7	0.42	0.00–1.41
Inshore	Stewart-Snares	1 521	-	-	-	-	2	0–8	0.14	0.00–0.53
Squid	Auckland Islands	1 137	1 009	88.7	3	0.30	3	3–5	0.28	0.26–0.44
Ling	Puysegur	86	26	30.2	0	0.00	1	0–5	0.88	0.00–5.81
Middle depth	West coast NI.	184	23	12.5	0	0.00	1	0–4	0.41	0.00–2.17
Hoki	Puysegur	99	43	43.4	0	0.00	0	0–3	0.42	0.00–3.03
Jack mackerel	West coast SI.	253	202	79.8	0	0.00	0	0–2	0.14	0.00–0.79
Squid	Puysegur	64	64	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	East coast SI.	984	79	8.0	0	0.00	1	0–4	0.08	0.00–0.41
Ling	East coast SI.	40	6	15.0	0	0.00	0	0–2	0.69	0.00–5.00
Squid	Subantarctic	22	22	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	Subantarctic	264	149	56.4	0	0.00	0	0–1	0.04	0.00–0.38
Scampi	Auckland Islands	1 727	270	15.6	0	0.00	2	0–6	0.09	0.00–0.35
Jack mackerel	East coast SI.	75	69	92.0	1	1.45	1	1–2	1.42	1.33–2.67
Middle depth	Subantarctic	9	7	77.8	0	0.00	0	0–1	0.42	0.00–11.11
Hake	Stewart-Snares	59	59	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	Cook Strait	51	-	-	-	-	0	0–3	0.91	0.00–5.88
Middle depth	Puysegur	19	17	89.5	0	0.00	0	0–0	0.04	0.00–0.00
Deepwater	East coast SI.	942	218	23.1	0	0.00	0	0–2	0.03	0.00–0.21
Ling	West coast NI.	31	4	12.9	0	0.00	0	0–2	0.59	0.00–6.45
Hoki	Auckland Islands	257	173	67.3	0	0.00	0	0–1	0.03	0.00–0.39
Jack mackerel	Stewart-Snares	186	185	99.5	0	0.00	0	0–0	0.00	0.00–0.00
Inshore	Puysegur	20	-	-	-	-	0	0–1	0.30	0.00–5.00
Deepwater	Cook Strait	32	-	-	-	-	0	0–1	0.09	0.00–3.12
Deepwater	Stewart-Snares	36	24	66.7	0	0.00	0	0–0	0.01	0.00–0.00
Deepwater	West coast NI.	281	60	21.4	0	0.00	0	0–1	0.01	0.00–0.36