Estimation of fur seal (*Arctocephalus forsteri*) bycatch in New Zealand trawl fisheries, 2002–03 to 2008–09

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EXECUTIVE SUMMARY

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In the 2008–09 fishing year, 72 New Zealand fur seals (*Arctocephalus forsteri*) were observed captured in commercial trawl fisheries around New Zealand. Trawls targeting hoki continued to have the highest number of observed captures, with 38 (53%) observed, 20 of these on hoki trawlers in the Cook Strait alone. The highest observed fur seal capture rate of 14.17 captures per 100 tows was on southern blue whiting trawls near the Bounty Islands, with 17 fur seal captures observed. Another 16 captures were observed in a range of other fisheries: hake, squid, scampi, jack mackerel, and other middle depth species (barracouta and silver warehou).

Observer coverage of inshore fisheries increased to over 3.4% in 2008–09, the first year it has been greater than 1%. One fur seal capture was observed on an inshore tow targeting giant stargazer west of Stewart Island, the first time a fur seal capture has been observed on an inshore trawl. Despite the recent increase in inshore observer coverage, no attempt was made to estimate fur seal captures in the inshore trawl fisheries as over the whole period coverage in these fisheries remained too low.

A Bayesian capture model was developed to predict fur seal captures in commercial trawl fisheries. The parameters from the fitted model were used to estimate fur seal captures across commercial trawl effort, excluding inshore fishing, for the seven year period from 2002–03 to 2008–09. The mean estimate in 2008–09 was 550 fur seal captures (95% c.i.: 338 to 826), lower than the estimate of 710 captures (95% c.i.: 489 to 996) in 2007–08, but higher than the estimate of 501 captures (95% c.i.: 304 to 764) in 2006–07. Trawl effort targeting hoki had the highest estimated fur seal captures amongst the different target fisheries in 2008–09, with 191 estimated captures (95% c.i.: 112 to 306). Estimated fur seal captures by hoki trawlers in Cook Strait accounted for 23% of all estimated captures. Trawls targeting middle depth species were estimated to have caught 150 fur seals (95% c.i.: 57 to 307) in 2008–09.

In 2008–09 the mean estimate of 96 fur seal captures (95% c.i.: 40 to 195) near the Bounty Islands, was greater than the mean estimate of 80 captures (95% c.i.: 47 to 125) on the west coast of the South Island. Trawl effort near the Bounty Islands, mostly southern blue whiting, reached a peak of 637 tows in 2008–09, while trawl effort on the west coast of the South Island continued a slow decline to 3726 tows. The capture rate near the Bounty Islands was estimated to be 16.16 (95% c.i.: 8.06 to 28.74) fur seal captures per 100 tows, the highest of any area.

1. INTRODUCTION

Direct interactions between marine mammals and fisheries occur world-wide (Read et al. 2006, Lyle & Wilcox 2008). For many cetacean and pinniped species these interactions are frequently fatal and pose a significant threat to local populations (Lyle & Wilcox 2008). Globally, the annual bycatch of marine mammals is estimated to be more than 600 000 animals, about 53% of which are pinnipeds and 47% are cetaceans (Read et al. 2006). In New Zealand, the marine mammal most frequently caught as bycatch in commercial fisheries is the New Zealand fur seal (*Arctocephalus forsteri*). The size and dynamics of the New Zealand population are poorly known and up-to-date counts and estimates are needed for many parts of New Zealand. The most recent census of New Zealand fur seals was in 1973, when the population was thought to be between 30 000 and 50 000. The consensus is that the population has increased since then (Lalas & Bradshaw 2001).

New Zealand fur seals are predominantly caught in trawl fisheries, with smaller numbers of observed captures reported in surface longline fisheries (Abraham & Thompson 2009, Abraham et al. 2010). In the 2008–09 fishing year, the Ministry of Fisheries observer programme recorded 72 fur seal captures in trawl fisheries. Of these observed captures, 51.4% were in the hoki trawl fishery, 23.6% in the southern blue whiting trawl fishery, and 11.1% in the jack mackerel trawl fishery. Typically, fur seals caught in trawl nets are retrieved dead (93% of fur seals caught in trawl fisheries in the 2008–09 fishing year were reported by the observer as dead). In 2008–09, 22 fur seals were observed caught in surface longline fisheries, which were all released alive. On rare occasions, fur seal captures are observed caught in bottom longline fisheries: there were 4 observed captures in the 11 year period 1998–99 to 2008–09, with no observed captures in 2006–07, 2007–08, or 2008–09. Six fur seals have been observed caught in set nets targeting school sharks and moki. All were observed since set net observer coverage began in 2005–06, with one observed caught in January 2009, on the west coast of the South Island, north of Cape Foulwind.

In fisheries where there has been sufficient observer coverage, the observed fur seal capture data provides a basis for estimating bycatch on the unobserved portion of those fisheries. Previous authors have applied ratio estimation methods to estimate fur seal captures in trawl, surface longline, and bottom longline fisheries in New Zealand's Exclusive Economic Zone (EEZ) for the fishing years 1990–91 to 1995–96 and 1998–99 to 2006–07 (Manly et al. 2002, Baird 2005a, 2005b, 2005c, Abraham & Thompson 2009, Abraham et al. 2010). However, the ratio estimation method has some limitations: it is only reliable when applied to fisheries in which there has been representative observer coverage, and it may be biased if the observer coverage is non-random with respect to factors that determine the rate at which fur seals are caught.

Smith & Baird (2009) used Bayesian models to estimate total fur seal captures and strike rates for the period 1994–95 to 2005–06 in five pre-defined areas within the EEZ (all south of 40° latitude). They considered the covariates that might influence the likelihood of fur seal captures. Overall, the factors that consistently explained some of the fur seal captures for all of New Zealand were time of day and time of year. They found that fur seals were more likely to be caught during hours of low light (dawn, dusk, and night time) and during certain times of the year, most likely related to breeding seasons. The findings of Smith & Baird (2009) were broadly similar to those of earlier studies by Manly et al. (2002) and Mormede et al. (2008), who also found that time of day, area, and day of year were correlated with likelihood of fur seal capture.

The intention of this report is to provide model-based estimates of the number of New Zealand fur seals caught as bycatch in New Zealand commercial trawl fisheries for each fishing year between 2002–03 and 2008–09.

This work was completed as part of project PRO2007/02, which has the overall objective of describing the nature and extent of marine mammal captures in New Zealand commercial fisheries. This report focuses on fur seal captures to the end of the 2008–09 fishing year. The methods used here build upon those already developed by Smith & Baird (2009) for estimating annual fur seal bycatch, and were reported by Thompson et al. (2010) for the six years 2002–03 to 2007–08. Other reports have focussed on estimating the capture of sea lions (Thompson & Abraham 2009b) and dolphins (Thompson & Abraham 2009a), with the capture of all marine mammals being reported by Abraham & Thompson (2009) and Abraham et al. (2010). The data summaries (Abraham & Thompson 2009, Abraham et al. 2010) also include estimates of the number of fur seals captured in surface longline fisheries.

2. METHODS

2.1 Data sources and preparation

Commercial trawl vessels return a record of all fishing effort to the Ministry of Fisheries. Skippers complete either a Trawl Catch Effort Processing Return (TCEPR), a Trawl Catch Effort Return (TCER), or a Catch Effort Landing Return (CELR). Data from these forms are stored in databases administered by the Ministry of Fisheries (Ministry of Fisheries 2008). Information entered on these forms by the fisher includes date, time, location, target species, tow duration, and vessel size. This information is available from the Warehou database.

Ministry of Fishery observers on commercial fishing vessels record captures of protected species, including New Zealand fur seals. The capture events are recorded on forms by the observers and entered into a database maintained by the National Institute of Water and Atmospheric Research (NIWA) on behalf of the Ministry of Fisheries. Currently, data are housed in the Centralised Observer Database (COD).

Extracts from the Warehou and COD databases were obtained, including all trawl effort within the outer boundary of New Zealand's Exclusive Economic Zone, and spanning the period from 1 October 2002 to 30 September 2009. In New Zealand, the fishing year runs from 1 October to 30 September in the following year, so the data extract covered the period from the 2002–03 to the 2008–09 fishing years. A summary of the capture of all seabird and marine mammal species in this dataset, and for the period 1998–99 to 2001–02, was given by Abraham et al. (2010). The observer records were linked to corresponding fisher reported effort, using the same rules described by Thompson & Abraham (2009b). Model covariates were derived using fisher reported data from the linked records. This ensured consistency between the data used for building the model, and the data used for making the estimation.

During the 2007–08 fishing year, inshore trawl fisheries moved to reporting fishing effort on TCER forms, rather than CELR forms. The TCER form records the latitude and longitude of fishing effort, whereas the CELR forms gave only the statistical area. Consequently, in recent years there has been more accurate information available on where inshore fishing is occurring. In order to allow the modelling to include covariates that depended on information not available on CELR forms (latitude, longitude, and time of day) the missing data were either obtained from the observer record, if possible, or were imputed. Imputed values were sampled at random from more recent fishing effort by the same vessel, in the same statistical area, targeting the same species, that had been reported on the TCER form.

Over the period covered by the data, fur seal captures were not observed to the north or east of the North Island, or in the waters around the Chatham Islands. Trawl effort in these areas was excluded, under the assumption that there were no captures by the unobserved effort in these regions. Inshore trawl fisheries accounted for more than 50% of the total trawl effort, when measured by number of tows. Across the whole period, coverage of inshore fisheries was very low, at 0.5% of tows or less, and no fur seals were observed caught in inshore trawl fisheries. Inshore trawl effort was excluded from the modelling and from the estimates, as it was expected that the characteristics of inshore trawl fisheries were different from those of the offshore fisheries.

Bayesian modelling is computationally expensive, and there were more observed tows than could be easily fitted by the model using Monte Carlo Markov chains (MCMC). Trawl events were aggregated to reduce the computational load. While grouping the data reduced the fidelity of some covariates, it allowed trawl data from the whole of New Zealand's EEZ to be fitted simultaneously. The grouping followed similar methods to those used by Manly et al. (2002). Tow groups were defined as trawls by the same vessel, in the same statistical area, targeting the same species, observed or not, occurring within five days of each other, and with no more than than 20 tows being included in each group. Tows within a group were consecutive. Covariates were calculated for each group by aggregating the value for each trawl event in an appropriate way, for example, by taking the average value within of the covariate within the group. The grouping had the additional advantage that it reduced the correlation between fur seal captures on subsequent data points.

2.2 Covariate exploration

An exhaustive exploration of covariates was made by Thompson et al. (2010) with data from the 2002–03 to 2007–08 fishing years. In this report data from 2008–09 were added, and some of the analysis repeated. The same range of potential covariates (Table 1) was explored to determine whether there was a relationship between the covariates and fur seal captures. Potential covariates included those identified by Smith & Baird (2009) and Mormede et al. (2008), aggregated appropriately to the grouped data. Covariates were restricted to quantities that could be defined from the fisher reported data.

In order to explore the functional form of the relationship between each covariate and observed New Zealand fur seal captures, generalised additive models (GAMs) were fitted to the capture data (Wood 2004). The GAMs identified the semi-parametric splines that best described the relationship between the covariate and the seal captures. Fixed target species and fishing area effects were included in each of the GAM models, to control for the influence of these factors on the fur seal capture rate. A negative binomial error relationship was used for the GAMs, with a logarithmic link function, as this is appropriate to count data (Hilbe 2007).

Thompson et al. (2010) used a step analysis to narrow the list of covariates explored in the full Bayesian models (Venables & Ripley 2002). Negative binomial general linear models were fitted using maximum likelihood methods, with covariates tried in turn. The covariate that reduced the Akaike Information Criterion (AIC) (Akaike 1976) the most at each stage was retained, and the process repeated. In this way, the covariates were ranked according to their explanatory power. The step analysis was repeated with the extra 2008–09 data.

Thompson et al. (2010) tested four candidate models by fitting the full Bayesian model using MCMCs, and then selecting the model that minimised the Deviance Information Criterion (DIC), as described by Gelman et al. (2004). The DIC was calculated as the sum of the deviance and an estimate of the effective number of parameters, derived from the variance of the MCMC samples of the deviance. This stage of analysis was not repeated because the results from the maximum likelihood step analysis did not change. The covariates selected by Thompson et al. (2010) were included again.

Fixed area and target effects are included in the model. To explore the possibility of including area–target interaction terms, another step analysis was performed. Fixing the covariates selected from the previous

Table 1: Covariates included in the step analysis.

Fishing area	New Zealand's EEZ was divided into 13 fishing areas, corresponding to areas used in previous analysis and presented in Figure 1. The 10 areas where fur seal captures have been observed were included in the model data set.
Target species group	Target species were grouped together. The groups were the same as in Abraham et al. (2010), with the difference that hake and ling tows were grouped with the middle depth species. The groups used were hoki, southern blue whiting, squid, jack (and blue) mackerel, scampi, middle depth species (ling, hake, barracouta, ribaldo, rubyfish, alfonsino, bluenose, frostfish, ghost shark, gemfish, spiny dogfish, sea perch, and warehou), deep water species (orange roughy, oreos, and cardinalfish). All inshore target species, excluding flatfish (9 species), were reported together as inshore trawl and included 89 species codes. The most frequently caught inshore fish were tarakihi, snapper, red cod, gurnard, trevally, John dory, and giant stargazer.
Tow duration	The mean tow duration of the tows in each group.
Day of year	The day of the year was used to capture any seasonal variation. Calculated from the mean day of the year of the tows in a group. Harmonic functions were used to ensure that the seasonal effects were truly periodic.
Moon illumination	The percentage of the moon illuminated was calculated from the date and location data (Meeus 1991). The average illumination was calculated over all the tows in the group.
Daytime at start (end) of the tow	The proportion of tows in a group that started (ended) in the daytime. Hours of daylight were calculated from civil dawn and dusk (Meeus 1991).
Night hours	Mean number of hours towed in the night-time. Calculated using the latitude, day of year, and start and end times of each tow. Night-time was calculated as between civil dawn and dusk (Meeus 1991).
Nation	The flag of the vessel, with five values: New Zealand, Russia, Korea, Japan, and Other.
Processor type	A three level factor covariate representing the type of processing on board, with values: meal plant, freezer, and fresher.
Gear type	A two level factor covariate describing what kind of gear was used on the tows, with values: bottom or midwater. The most frequently used gear within each group was used.
Vessel size	A four level factor covariate characterising the length of vessels, with values: small ($\leq$ 28 m), mid (between 28 m and 45 m), large (between 45 m and 85 m) and largest ($>$ 85 m).
Catch weight	The mean number of tonnes reported caught on the tows.
Bottom depth	The mean bottom depth calculated from the depth at the start of tows in each group.
Distance from shore	The mean distance from shore of the tows in each group.
Distance factor	A 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), mapped in Figure 4.

analysis, the step analysis was offered a fixed effect for each non-empty combination of area and target. In this way the potential interaction terms were ranked. The list was truncated to those that explained more than 1% of deviance. Two models were tested to select the final model, one with the interaction term included and one without the term. As above, the DIC was used to select the final model.

2.3 Model structure

Captures, y_i, in a trawl group, i, were modelled as samples from a negative-binomial distribution:

$$y_i \sim \text{NegativeBinomial}(\text{mean} = \mu_i n_i, \text{shape} = \theta n_i), \tag{1}$$

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 shape was assumed to be the same for all trawl groups. 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 y_i is the number of captures per group, μ_i should be interpreted as the mean strike rate per tow.

The mean capture rate within each group was estimated as the product of a random year effect λ_{y_i}, a random vessel-year effect $\nu_{v_i y_i}$, and the exponential of a sum over covariates,

$$\begin{aligned}
\mu_i &= \lambda_{y_i} \nu_{v_i y_i} \exp\left(\sum_c \beta_c x_i^c\right) && (2)\\
\log(\lambda_{y_i}) &\sim \text{Normal}(\mu = \mu_\lambda,\ \sigma = \sigma_\lambda) && (3)\\
\nu_{v_i y_i} &\sim \text{Gamma}(\text{shape} = \theta_\nu,\ \text{rate} = \theta_\nu) && (4)
\end{aligned}$$

The random year effect λ_{y_i} on each tow was drawn from a log normal distribution with mean μ_λ, and standard deviation σ_λ. The random vessel-year effect $\nu_{v_i y_i}$ for each observed vessel v_i and year y_i was included to account for the variation between vessels, and was drawn from a gamma distribution with shape and rate θ_ν. With this parameterisation, the gamma distribution has unit mean. The coefficient of a covariate c was denoted β_c, while the value of the covariate at tow i was denoted x_i^c.

Standard priors were used for the model (hyper-)parameters (e.g., Gelman et al. 2006). Diffuse normal priors were used for the covariate coefficients and for the logarithm of the mean year effect, μ_λ. The shape hyper-parameters were given uniform shrinkage priors, with the size parameter for the overdispersion equal to the mean number of captures, and the size parameter for the vessel-year effect equal to the mean number of captures per vessel:

$$\begin{aligned}
\log(\mu_\lambda) &\sim \text{Mean}(\mu = \bar{y}_i, \sigma = 100) && (5)\\
\sigma_\lambda &\sim \text{Half-Cauchy}(25) && (6)\\
\theta &\sim \text{Uniform-shrinkage}(\bar{y}_i) && (7)\\
\theta_\nu &\sim \text{Uniform-shrinkage}(\bar{y_{v_i}}) && (8)\\
\beta_c &\sim \text{Normal}(\mu = 0, \sigma = 100) && (9)
\end{aligned}$$

The models were coded in the BUGS language (Spiegelhalter et al. 2003), a domain specific language for describing Bayesian models. The model was fitted with the software package JAGS (Plummer 2005), using MCMC methods. To ensure that the model had converged, a burn-in of 10 000 iterations was made. From there, the model was run for another 100 000 iterations and every 20$^{\text{th}}$ iteration was kept. Two chains were fitted to the model, and the output included 5000 samples of the posterior distribution from each chain. Model convergence was checked using diagnostics provided by the CODA package for the R statistical system (Plummer et al. 2006). To test whether the model produced a suitable representation of the data, simulations of observed captures were made using randomly chosen samples from the Markov chains and visually compared with the actual observed captures (Gelman et al. 2006). Randomised quantile-quantile plots were used to compare the estimated captures on the observed tows with actual observed captures (Dunn & Smyth 1996). By calculating the quantile residuals for each sample from the chain, a distribution of residuals could be obtained. All uncertainties were calculated as the 95% percentiles of the posterior distributions, from the MCMC chains.

3. RESULTS

3.1 Data sources

Over the seven year period, 229 749 tows were reported on CELR forms, 269 977 tows reported on TCEPR forms, and 67 930 tows were reported on the newer TCER forms (all since 19 June 2006). Data from the more recent TCER forms were used to impute position information for the older CELR data, affecting 13% of tows, or 6% of grouped records. Of these imputed values, 97% were sampled from effort from the same vessel, targeting the same species, in the same statistical area. The remaining 3% were sampled from effort by the vessel in the same statistical area, but targeting other species. Most of the fishing effort reported on CELR forms was targeting inshore species (85%), and a further 10% targeting middle depth species, in particular barracouta. The effort targeting inshore species was not included in the modelled data set (Table 2), because there was not enough observer coverage to allow estimation of captures in these fisheries.

Of the 45 627 observed tows from the selected area and date range, 43 294 were used to fit the model. We excluded all observed inshore tows (1817), and 516 tows that were not linked to corresponding fisher effort. Observer data sourced from the COD database did not require any grooming. The values of covariates were taken from the fisher reported data, from TCEPR and TCER forms. There were 26 fur seal captures, 3.3% of the total, that were not linked to fisher reported effort. In 2006–07 there were 11 captures that could not be associated with fisher reported effort. In 2008–09, there was an observed fur seal capture on a inshore tow targeting giant stargazer west of Stewart Island. This was the first record of a fur seal capture from the inshore fleet. Observed captures from unlinked tows were not included in the analysis (Table 2).

The modelled data set was further compressed by grouping tows together. This reduced the size of the observed data used to fit the model from 43 294 tows to 6742 groups. The same grouping was made to the trawl effort, reducing the data from 285 143 tows to 49 939 groups.

3.2 Potential covariates

3.2.1 Areas

New Zealand fur seals were caught in trawl fisheries on the west coast of both the North and South Islands, on the east coast south of Wairarapa, and around the subantarctic islands. In Figures 1 and 2, observed captures are plotted for the seven years of data included in the model. The New Zealand region was divided into the areas shown on the maps. These areas are similar to those defined in previous work (Abraham & Thompson 2009, Abraham et al. 2010), with a few exceptions. The Chatham Rise was split into western and eastern parts, the Bounty Islands and Campbell Island areas were split off the surrounding subantarctic area, and the Cook Strait and Auckland Islands areas were increased, to give coverage of the areas where fur seals are caught. Fishing effort on the north and east sides of the North Island, and from around the Chatham Islands, were excluded from the analysis as no fur seal captures were reported in these areas in the six year period. Note that one fur seal was observed caught off the west coast of the Chatham Islands in May 2002, before the period reported here, by a trawler targeting jack mackerel.

The fishing effort, observer coverage, and observed captures for these areas is presented in Table 3. The capture rate varied considerably, with a capture rate of almost 14 animals per 100 tows in the Bounty Islands area. The area with the next highest capture rate was Cook Strait, with an observed capture rate of 9.5 animals per 100 tows, but this figure was based on low observer coverage of 3.5%. Of all observed captures, 30% occurred on the west coast of the South Island, with an observed capture rate of 3.15 fur seals per 100 tows.

Table 2: Summary of data included in the model showing all commercial effort from the study area and period, inshore trawl effort within that data, and effort included in the model dataset. The observed data include all observed tows within the study area and period, observed inshore tows, observed tows that were unable to be linked to the trawl effort, and the number of observed tows included in the model. The captures are all fur seal captures on observed tows, and the number of fur seals included in the model dataset.

	Trawl effort, tows			Observed tows				Captures	
	All	Inshore	Modelled	All	Inshore	Not linked	Modelled	All	Modelled
2002–03	101 808	45 437	56 371	5 822	1	41	5 780	67	67
2003–04	93 527	45 171	48 356	5 736	6	48	5 682	85	84
2004–05	90 042	45 690	44 352	6 639	12	58	6 569	202	193
2005–06	79 444	40 517	38 927	5 671	90	39	5 542	144	143
2006–07	75 379	39 918	35 461	6 571	170	150	6 251	72	61
2007–08	64 464	32 517	31 947	7 193	114	55	7 024	141	138
2008–09	63 072	33 343	29 729	7 995	1 424	125	6 446	72	71
All	567 736	282 593	285 143	45 627	1 817	516	43 294	783	757

Table 3: Summary of the model dataset by area. The columns show the trawl effort, observed trawl effort, observer coverage (%), observed fur seal captures, and observed fur seal capture rate (captures per 100 tows). The table includes all effort for the period 1 October 2002 to 30 September 2009, and is sorted in decreasing order of the capture rate.

		Observed tows		Fur seals	
	Tows	Tows	Coverage %	Captures	Rate
Bounty Islands	2 738	909	33.2	127	13.97
Cook Strait	27 539	1 042	3.8	99	9.50
Puysegur	6 013	804	13.4	31	3.86
West Coast South Island	47 669	7 460	15.6	235	3.15
Campbell Island	4 649	1 478	31.8	42	2.84
Western Chatham Rise	83 377	8 158	9.8	96	1.18
Stewart-Snares	48 007	9 555	19.9	81	0.85
Other subantarctic islands	11 853	3 234	27.3	14	0.43
West Coast North Island	26 178	4 887	18.7	16	0.33
Auckland Islands	26 921	5 751	21.4	15	0.26

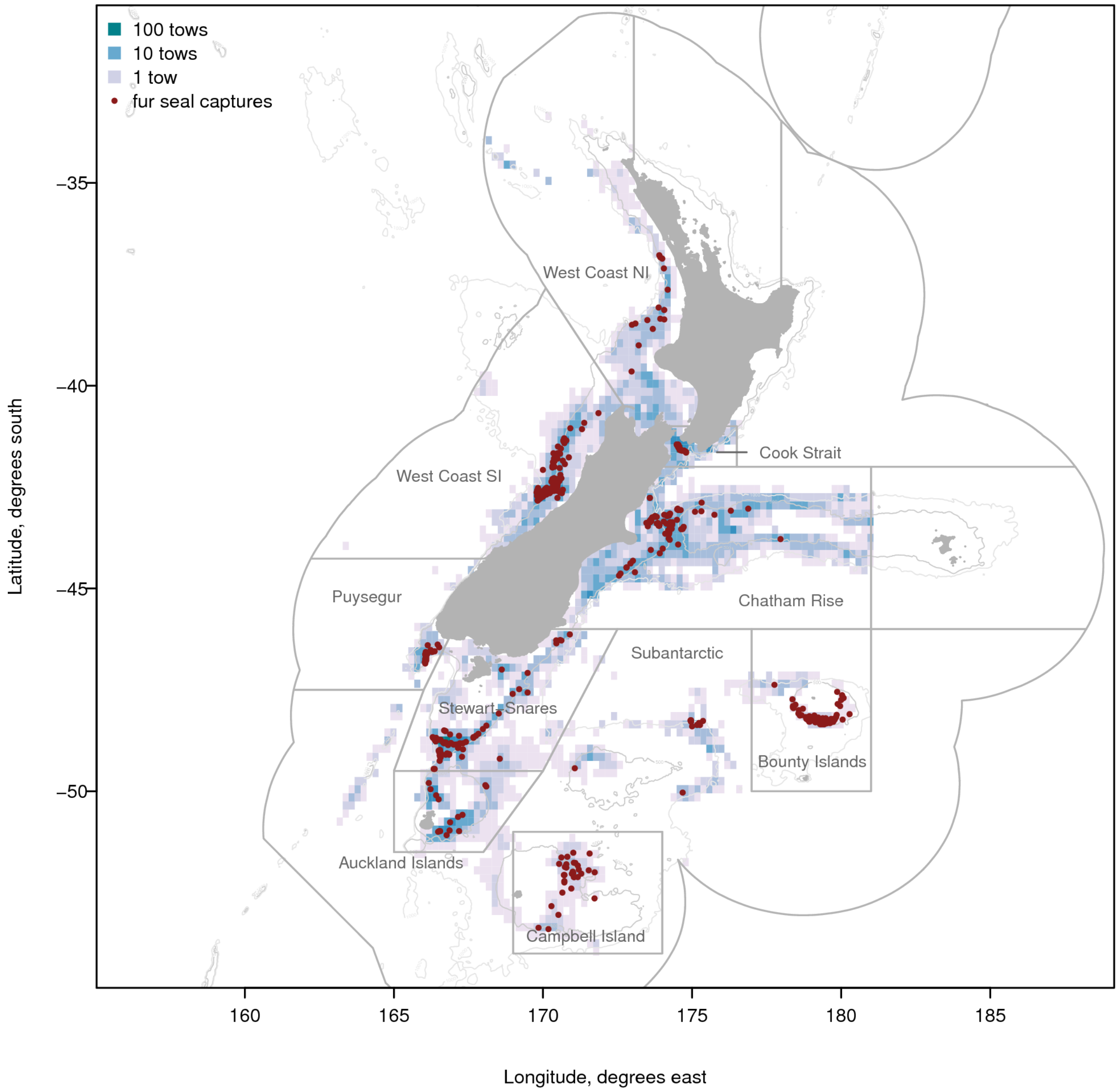


Figure 1: Map of trawl effort and fur seal captures from the model dataset, for the period 1 October 2002 to 30 September 2009. The colours of the heatmap indicate the average annual trawl effort within 0.2° × 0.2° squares. The 10 defined subareas are indicated; the areas without names are not included in models or tabulated results.

3.2.2 Target species

Target species were grouped to simplify the analysis, as in Abraham & Thompson (2009) and Abraham et al. (2010). Tows targeting hake and ling were further grouped with the middle depth targets. The effort and observations, by target species group, are shown in Table 4. The fur seal capture rate was over 8 captures per 100 tows for tows targeting southern blue whiting (Table 4). This was largely due to the high rates observed near the Bounty Islands, where southern blue whiting was the main target. Hoki and other middle depth species had observed capture rates of close to 3 captures per 100 tows.

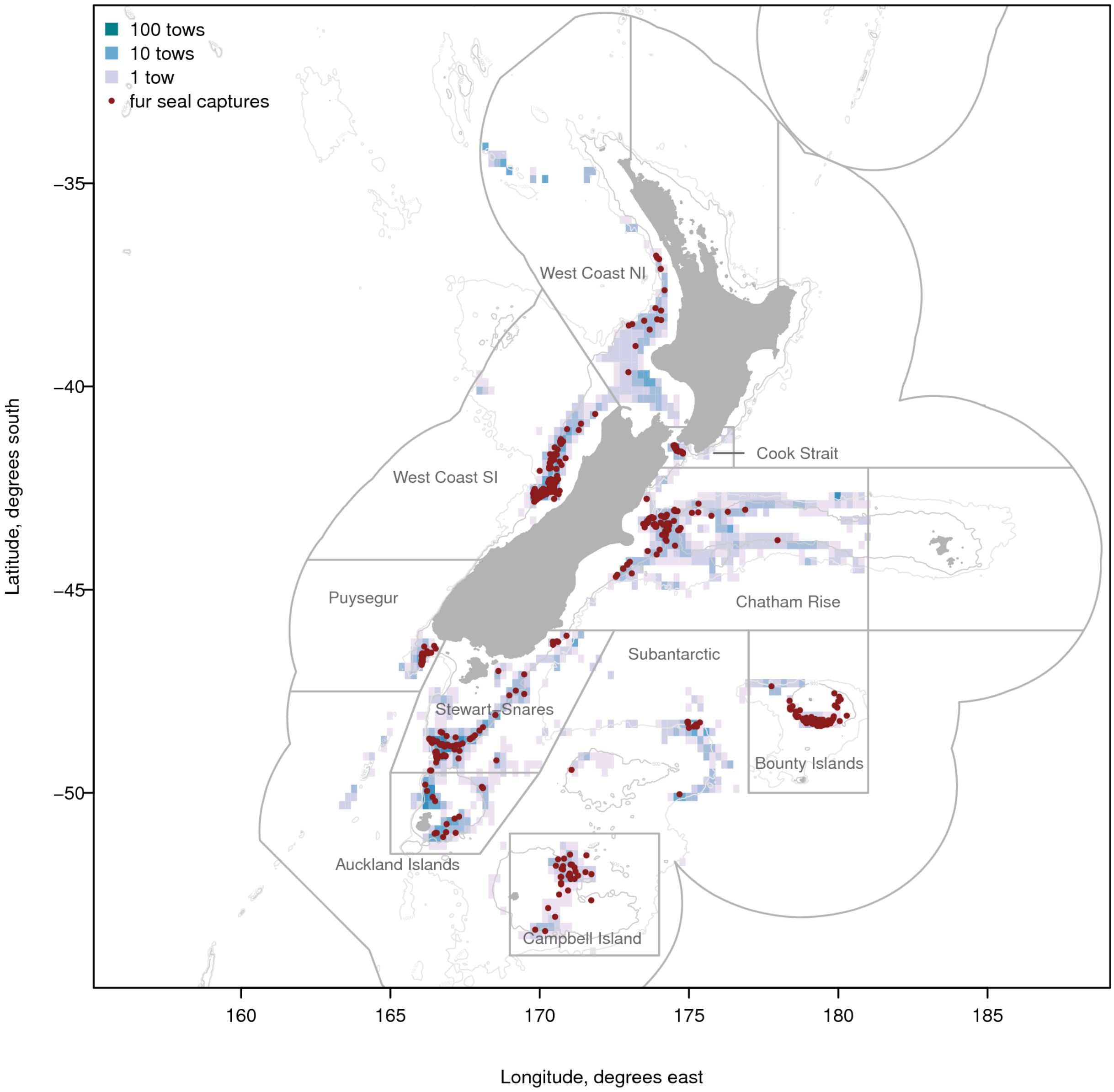


Figure 2: Map of observed tows and fur seal captures from the model dataset, for the period 1 October 2002 to 30 September 2009. The colours of the heatmap indicate the annual average number of observed tows within 0.2° × 0.2° squares.

Table 4: Summary of the model dataset by target species. The columns show the trawl effort, observed trawl effort, observer coverage (%), observed fur seal captures, and observed fur seal capture rate (captures per 100 tows). The table includes trawl effort for the period 1 October 2002 to 30 September 2009, and is sorted in decreasing order of the capture rate.

		Observed tows		Fur seals	
	Tows	Tows	Coverage	Captures	Rate %
Southern blue whiting	4 318	1 615	37.4	143	8.85
Middle depth species	56 249	3 529	6.3	103	2.92
Hoki	92 351	11 950	12.9	340	2.85
Jack mackerel	16 081	3 346	20.8	23	0.69
Squid	45 962	9 397	20.4	59	0.63
Deepwater species	23 054	5 426	23.5	14	0.26
Scampi	17 399	1 585	9.1	4	0.25

3.2.3 Distance to shore

Distance to shore was identified in previous work as being correlated with fur seal captures in some areas (Mormede et al. 2008, Smith & Baird 2009). Distance to shore was calculated using functions from PostGIS, with the New Zealand coastline being obtained from the GSHHS database (Wessel & Smith 1996). Islands with an area of less than 25 hectares were excluded when calculating the distance to shore. The distance to shore distribution of observer and fisher reported effort is compared in Figure 3(a). Observed effort was representative of all effort. The number of fishing events peaked between 40 km and 60 km from the shore, and the highest number of observed fur seal captures occurred in this range. Figure 3(b) shows the relationship been distance to shore and the fur seal capture rate, obtained from fitting a GAM. Target and area effects were accounted for in this fit. Between 25 km and 90 km the fur seal capture rate increased with increasing distance from shore. There was a reduction in fur seal capture rates until about 200 km from shore, beyond which there is no further consistent decrease in the capture rate. Before inclusion in the Bayesian model, distance to shore was converted into a four level factor. The chosen levels were closer than 25 km to shore, between 25 km and 90 km, between 90 km and 180 km, and further than 180 km. These distances are marked on Figure 3(b), and are shown in Figure 4.

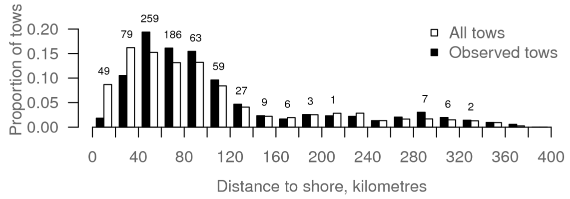
3.2.4 Other covariates

A range of other covariates was explored for a potential association with fur seal capture rates. These included bottom depth, tow duration, time of day effects, and day of year. In Figure 5 a selection of these covariates is shown. Definitions of all covariates taken through to the step analysis are given in Table 1. In general, the distributions of the covariates on observed tows were similar to the distribution on all tows. With respect to these variables, the observations appeared to be representative.

There was no strong relationship between bottom depth and the fur seal capture rate in the depth range (0 to 1000 m) where most of the observations were concentrated (Figure 5a, b), although the fur seal capture rate appeared to decrease beyond 600 m depth. Tow duration was picked as a covariate for three of the six models in Smith & Baird (2009). A priori, it might be expected that more fur seals would be caught on longer tows. There was no evidence of this from the GAM fit (Figure 5d). In Figure 5(e, f) the proportion of tows within a group that started in the daytime is shown. For approximately one-third of groups, all tows within the group started during the day. There was a clear negative association with fur seal captures: the fur seal capture rate was lower for groups that had a higher proportion of tows starting during the day.

Although observations and effort were approximately evenly distributed through the year (Figure 5(g)),

(a) Distance to shore distribution



(b) Distance to shore effect

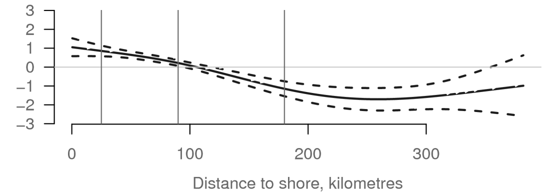


Figure 3: Relationship between fur seal captures and distance to shore. (a) The distributions of distance to shore for observed tows and all tows. The number of observed captures in each level on the distribution plots is displayed above the bars. (b) The relationship between seal capture rate and distance to shore derived from fitting a GAM. Target and area factors were also included in the GAM. The vertical lines in (b) indicate the distances used as break-points in the distance to shore factor (25 km, 90 km, and 180 km).

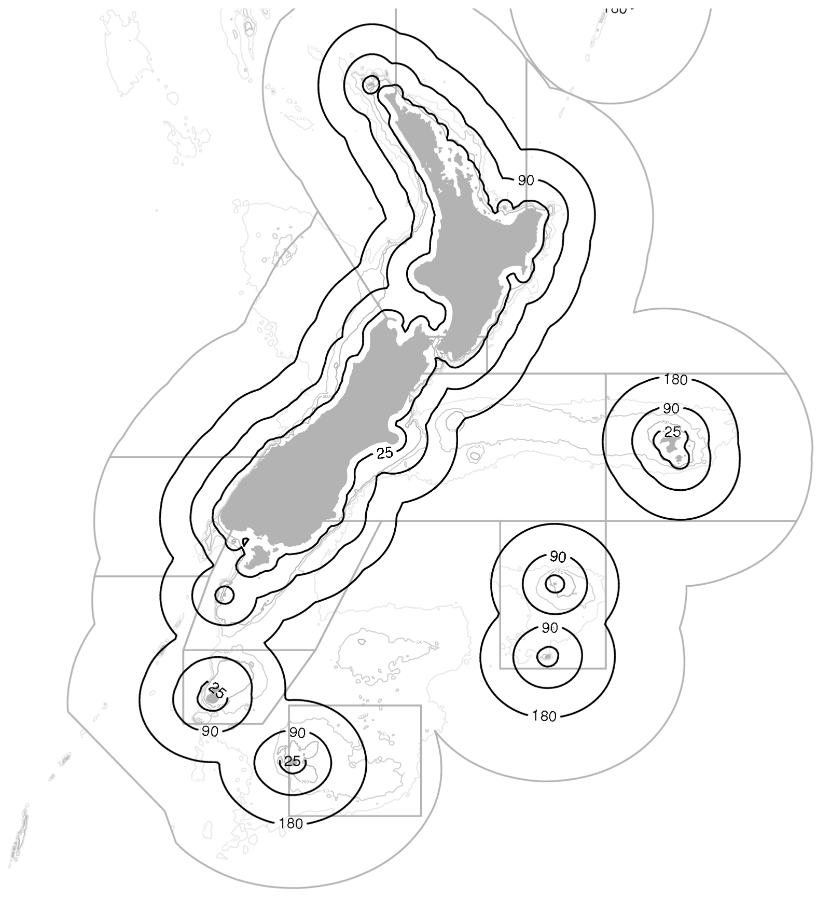


Figure 4: Map of the distance to shore factors, with contours at 25 km, 90 km, and 180 km from shore. Bathymetric contours are also shown in faint grey, marking depths of 200 m, 500 m, and 1000 m. New Zealand's EEZ was divided into four regions according to the distance to shore: coastal ($\leq$ 25 km), near (25 to 90 km), far (90 to 180 km), and ocean ($>$ 180km).

there was a clear relationship between season (time of year) and the fur seal capture rate. The seasonal effect is shown in Figure 5(h), with a peak in August and September. A harmonic function of the day of year (the sum of a sine and a cosine term, both with annual periods) was also fitted to the fur seal capture data, and had a similar form to the GAM fit (Figure 5h). This justifies using harmonic terms to represent the effect of time of year on the fur seal capture rate. Three of the six models by Smith & Baird (2009) included a day of year effect.

Another way of including the light condition variable was as the mean number of hours trawled at night. Over 60% of trawl groups had an average of less than 1 hour of fishing during the night, and there was a weak association between the average number of hours fished at night and the fur seal capture rate (Figure 5i, j).

3.3 Step analysis

The results of the step analysis are shown in Table 5. The ranking of covariates was similar to that reported by Thompson et al. (2010), with the same order and amount of deviance explained for the first six covariates.

The area factor was identified as having the most explanatory power, accounting for over 25% of the

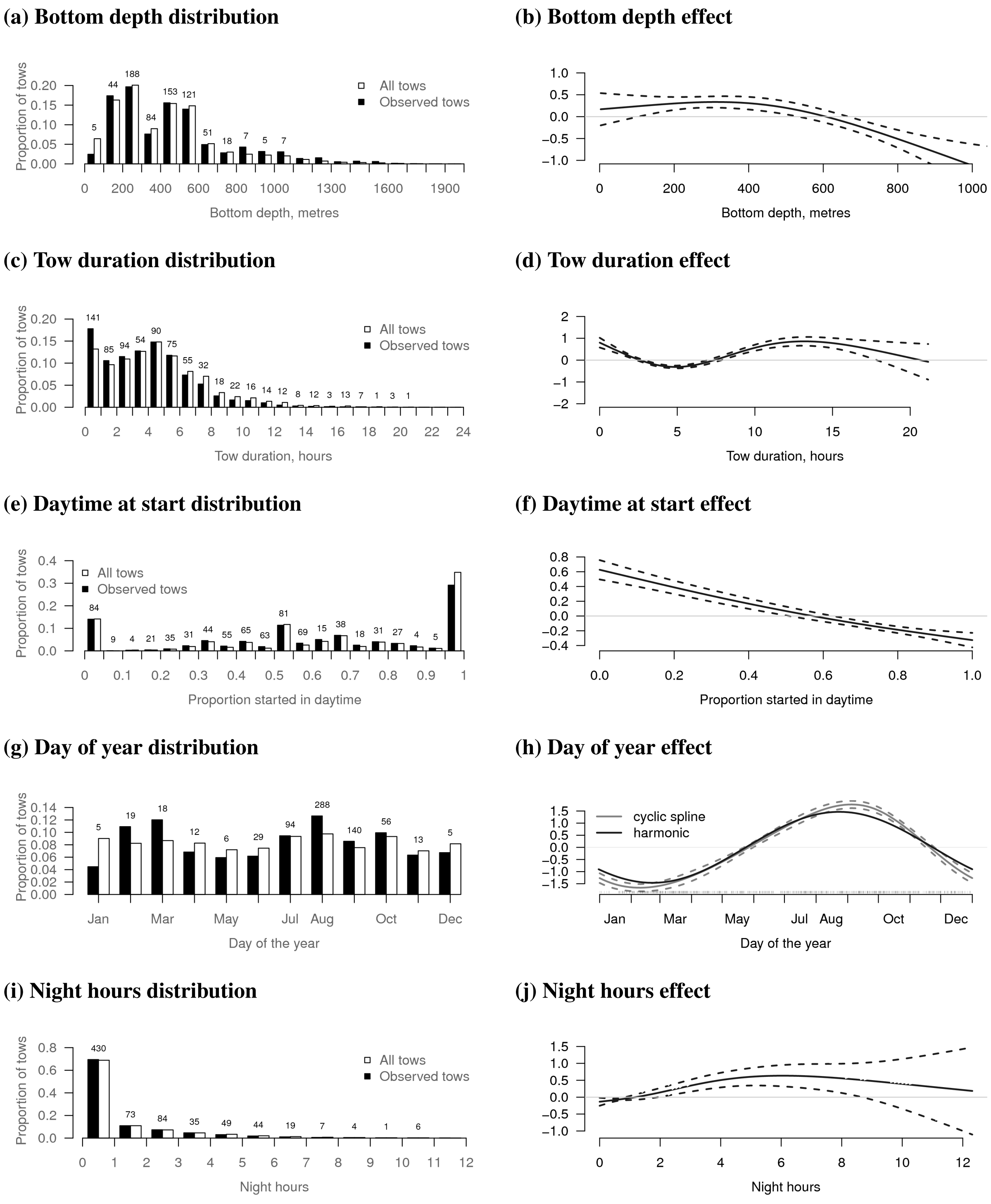


Figure 5: Detailed plots of various continuous covariates. On the left are distributions comparing observer and fisher reported effort. The number of observed captures in each level on the distribution plots is displayed above the bars. On the right are plots of the effect of covariates on the fur seal capture rate, derived from fitting GAMs. Note that target and area effects were included in the GAM structures. The dashed lines in these figures indicate the 90% confidence interval of the covariate effect, from the GAM fit.

Table 5: Analysis of deviance returned from the model selection algorithm. The columns are respectively the degrees of freedom, deviance, residual degrees of freedom, residual deviance, percentage of deviance explained by the addition of each term, and the AIC.

	Df	Dev.	Resid. Df	Resid. Dev.	% dev.	AIC
Intercept			6965	2575.20		3917.19
Area	9	647.85	6956	1927.35	25.2	3530.28
Target	7	146.39	6949	1780.96	7.6	3436.99
Sine of day of the year	1	96.03	6948	1684.93	5.4	3356.51
Cosine of day of the year	1	78.01	6947	1606.92	4.6	3286.61
Fishing year	6	49.41	6941	1557.50	3.1	3253.90
Distance to shore factor	3	33.37	6938	1524.14	2.1	3227.23
Processor type	2	15.13	6936	1509.01	1.0	3216.12
Log of night hours	1	6.74	6935	1502.27	0.4	3211.53
Vessel flag	5	14.00	6930	1488.27	0.9	3207.74
Vessel size	3	13.48	6927	1474.79	0.9	3200.29
Phase of the moon	1	3.29	6926	1471.50	0.2	3199.01

residual deviance, while the target species factor accounted for a further 7% of the deviance. The strength of the area and target factors identified with the step analysis justified their inclusion in the final Bayesian models. The sine and cosine of the day of year carried a strong seasonal effect, accounting for 10% of the deviance. When these terms were included in the model, time of day effects were dropped. This was due to a relationship between season and hours of darkness: in the winter a larger proportion of tows start at night than in the summer, when daylight hours are longer. The Bayesian model carried the mean in a random fishing year effect, and so fishing year was included in the final model. The distance to shore factor appeared next, explaining over 2% of deviance, and was included in the two models tested.

The remaining covariates, processor type, log of night hours, vessel flag, vessel size, and the phase of the moon, were selected by the step analysis in a different order, and explained 1% of deviance or less.

The second step analysis tested each of the area–target interactions relative to the base model which included separate area and target effects, sine and cosine of the day of the year, a distance to shore factor, and the fishing year. The deepwater targets in the other subantarctic area was ranked first, explaining 2.1% of deviance (Table 6), while none of remaining area–target interaction terms explained more than 0.5%. For this reason one interaction term was selected for inclusion in the Bayesian model with interaction terms.

Table 6: Analysis of deviance returned from the interaction selection algorithm. The columns are respectively the degrees of freedom, deviance, residual degrees of freedom, residual deviance, percentage of deviance explained by the addition of each area–target interaction term, and the AIC. The base model included area, target, fishing year, sine and cosine of day of the year, and a four level distance to shore factor.

		Df	Dev.	Resid. Df	Resid. Dev.	% dev.	AIC
Base model, no interaction				6938	1536.09		3228.49
Deepwater	Subantarctic	1	32.61	6937	1503.47	2.1	3198.58
Hoki	Puysegur	1	5.87	6936	1497.60	0.4	3194.75
Inshore	Stewart-Snares	1	5.17	6935	1492.43	0.3	3191.59
Hoki	Bounty Islands	1	3.91	6934	1488.52	0.3	3189.71
Scampi	Auckland Islands	1	3.28	6933	1485.23	0.2	3188.42

3.4 Model selection

Two models were tested as candidates for the model used in predictions. Both models included the fishing areas, target species, day of the year, and distance to shore covariates that were identified by Thompson et al. (2010), and used by them as the predictive model. This was included as the base model, without an interaction term. The other model tested had the same covariates and structure as the base model, with the addition of one fishing area–target species interaction term: deepwater targets in the other subantarctic area.

In Table 7 various model diagnostics are presented. The model with the lowest DIC was chosen as the final model. Note that this model also had the lower extra-dispersion ($1/\theta$). Quantile-quantile plots for the two models are presented in Figure 6. These compare the difference between the observed captures and the estimated mean capture rate with the theoretically expected residuals. If the model described the data accurately, the observed distribution of residuals, q_s, would be the same as the distribution predicted by the model q_t, and the difference $q_s - q_t$ would be zero. Both the models tested had very good quantile-quantile plots.

Table 7: Model diagnostics for the two models tested, the mean deviance, $\bar{D}$, the deviance information criteria, DIC, and the extra dispersion, $1/\theta$.

Model	$\bar{D}$	DIC	$1/\theta$	
			Median	95% c.i.
without inteaction	2325	4009	13.01	9.21 - 17.73
with interaction	2323	3949	12.23	8.93 - 16.60

(a) Without interaction **(b) With interaction**

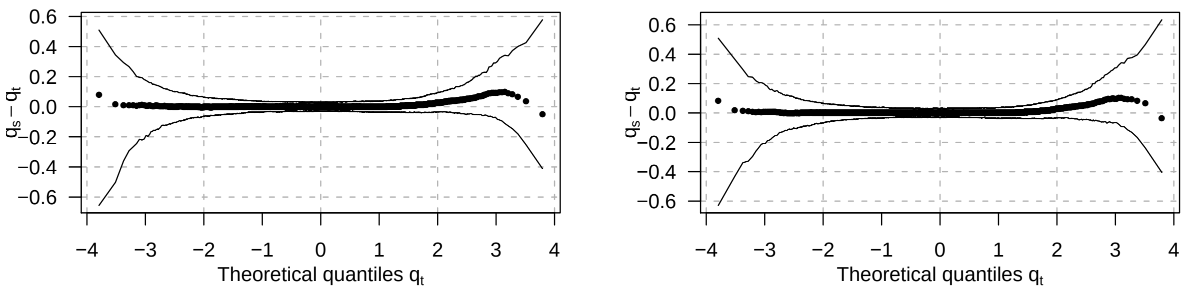


Figure 6: Quantile-quantile plots for the two tested Bayesian models.

3.5 Model diagnostics

The model with the interaction term included was selected as the final model used for estimating fur seal captures. The posterior distributions of the parameters of the negative binomial distribution are presented in Figure 7. The chains converged well, and showed good mixing. Note that $\mu/\theta << 1$, and so the fur seal captures were close to being Poisson distributed.

As a check, the fitted model was used to estimate the captures on the observed tows. The total annual observed captures are compared with estimated annual captures on the observed tows in Figure 8(a). The observed captures all fell within the 50% confidence interval, with the exception of 2005–06, where the observed captures were slightly higher. In Figure 8(b) the observed distribution of the number of captures in each trawl group is compared with the estimated distribution, giving a measure of how successfully the negative-binomial model fitted the data. The distribution of observed captures was consistent with

(a) Mean strike rate μ **(b) Extra dispersion $1/\theta$**

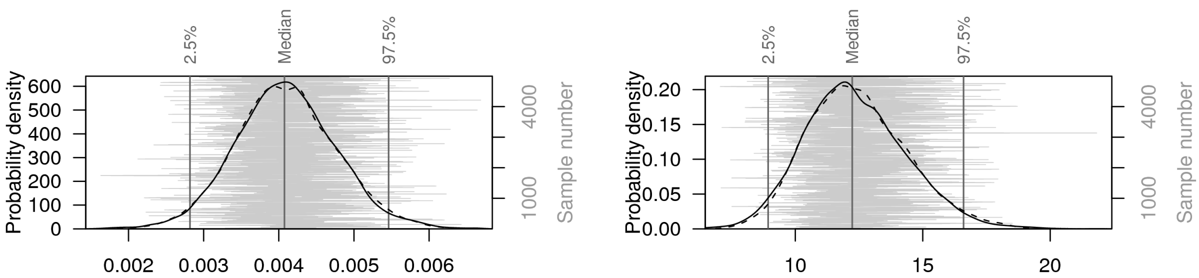


Figure 7: Posterior distributions from the two independent MCMC chains (solid and dashed lines) of (a) the mean strike rate, and (b) the extra dispersion $1/\theta$. Samples from the two chains are displayed in grey in the background. The median and 95% confidence interval are also indicated

(a) Observed trawls **(b) Multiple captures**

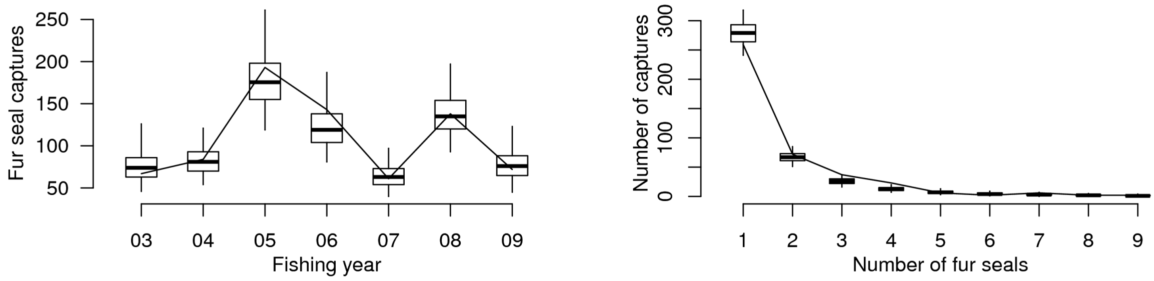


Figure 8: Predicted fur seal captures on observed (line) tows (a) presented as a box plot with 50% confidence interval boxes, and 95% confidence interval whiskers, and (b) comparing the observed (line) and estimated (box and whiskers) distributions of the number of fur seals caught within each trawl group. In (a) the year refers to the second year of the fishing-year, so '09' is the 2008–09 year.

the distribution of estimated captures.

The model was also checked by comparing maps of observed captures (Figure 9a), with maps of simulated captures on observed tows (Figure 9b, c). The simulations were generated using the parameters from two (out of 5000) samples of the MCMCs. For comparison a map is shown with randomly generated capture events, obtained by shuffling the observed captures between the observed trawl groups (Figure 9(d)). The model-simulated captures better represented many of the geographical features of the observed captures than the randomly generated captures. For example, as with the observations, the simulations had few captures further out on the Chatham Rise or in the north west of the North Island. The simulations also had a cluster of captures near the Bounty Islands that was not evident in the randomly generated captures. There were some areas where the maps suggested the model could be improved, in particular, on the west coast South Island the observed captures appeared to be more tightly focused on the Hokitika canyon, towards the south of the observed effort, than was seen in the model simulations.

3.6 Impact of adding the interaction term

The two Bayesian models produced very similar total estimates. Adding an interaction term allowed more flexibility in distributing the captures between the area–target groups. The interaction term selected from the step analysis, the subantarctic–deepwater group, was the only one of the 16 area–target groups

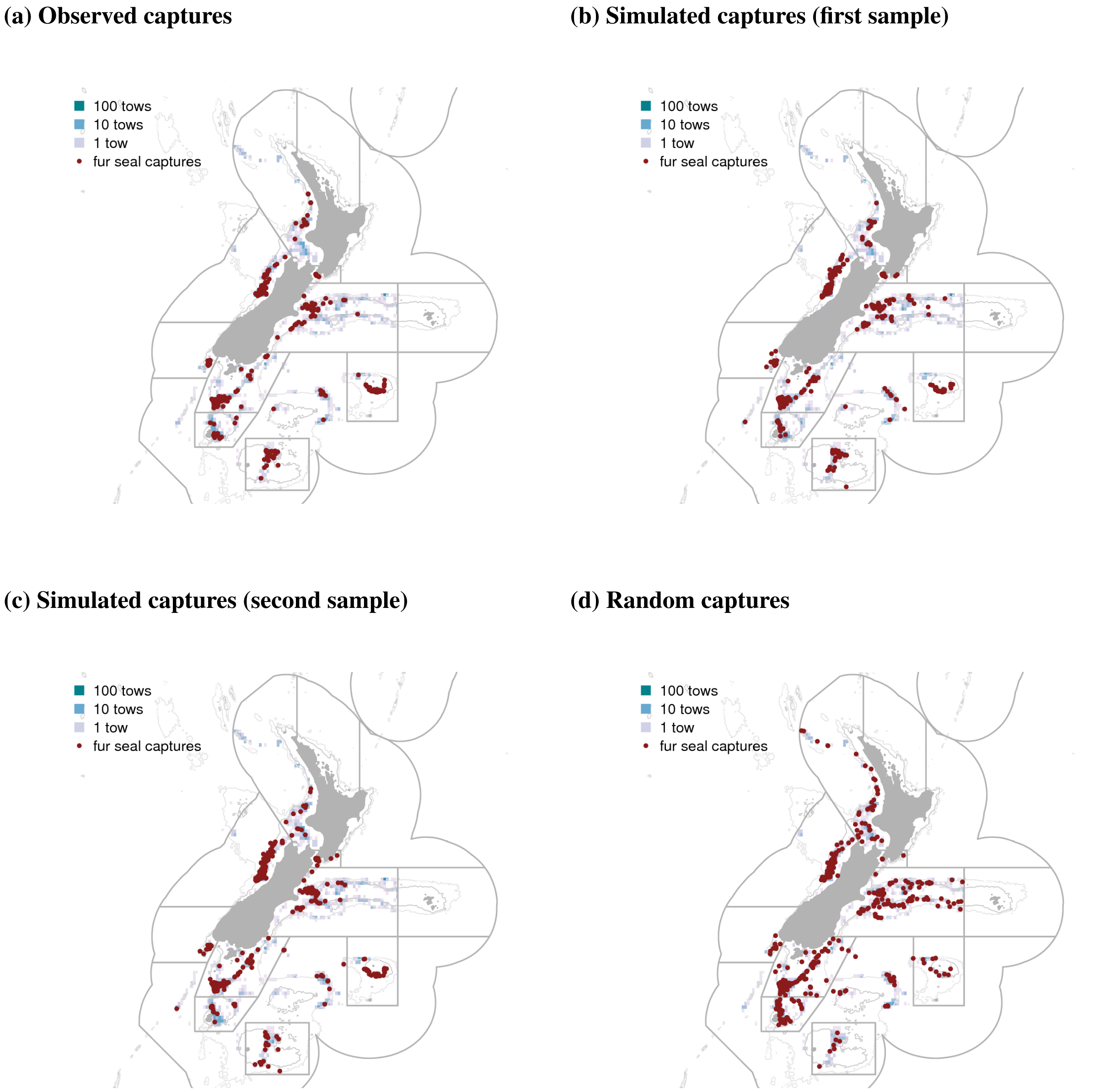


Figure 9: Maps of captures on observed tows from all years, showing (a) all observed captures; (b) randomly assigned captures; and (c, d) captures simulated from 2 of the 5000 samples of the Markov chains. The colours of the heat map indicate the average number of observed tows per year in $0.2^{\circ} \times 0.2^{\circ}$ cells.

including either deepwater targets or in the subantarctic area where more than one fur seal was observed captured. By including the interaction term, it allowed the estimates for the other area–target groups to be much closer to the observed captures, and allowed the estimate for the subantarctic–deepwater group to be centered on the observed captures precisely (Figure 10a, b).

The interaction term also affected the estimates for other area–target groups (Figure 10c, d), even those that were not targeting deepwater species or were in the subantarctic area. The largest effect was on estimates for the southern blue whiting fishery. Estimated fur seal captures for the Bounty Islands southern blue whiting fishery increased from 112 (95% c.i.: 57 to 200) without the interaction term to 129 (95% c.i.: 65 to 226) when the interaction was added. Estimated captures by the southern blue

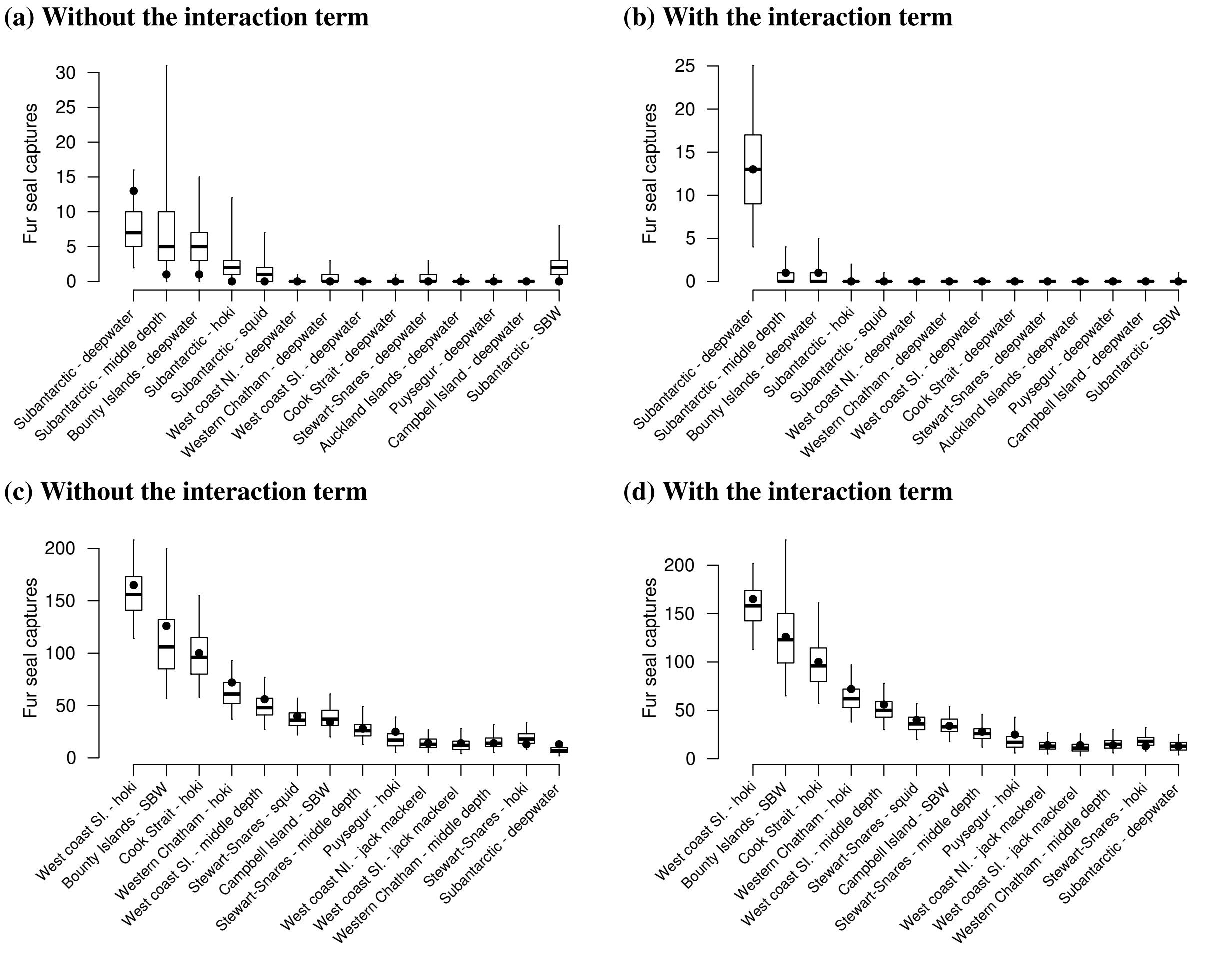


Figure 10: Estimated captures on observed tows from, (a,c) the base model without the interaction term, and (b,d) the model with a subantarctic–deepwater interaction term included, organised by target species and fishing area groups. The groups presented are are limited to (a,b) those that either target deepwater species, or are in the subantarctic area, or (c,d) the fourteen groups with the highest number of observed captures. The actual observed captures are indicated with a black dot.

whiting fishery near Campbell Island decreased from 38 (95% c.i.: 20 to 61) without the interaction term, to 34 (95% c.i.: 18 to 54) when the interaction was added.

3.7 Model parameters

The model estimated the coefficients of the area, target species, distance to shore, and day of year covariates. Random effects parameters were estimated for the fishing year and the vessel-year. A full list of the model parameters is given in Appendix A (Table A-1). The model base rates carried the year effects. The coefficients for each of the area, target, and distance effects were multipliers on the rate relative to the Stewart-Snares area, the hoki target species, and a distance to shore of between 25 km and 90 km. For example, the west coast of the North Island area had a model strike rate of about one-tenth that of the Stewart-Snares area, all other factors remaining equal. Similarly, the squid fishery had a strike rate about 2.5 times that of the hoki fishery. In the raw data the strike rate was higher in the hoki fishery (see Table 4). The difference is due to other effects, such as area effects, that are also influencing the strike rate.

With the interaction term added, the area and target effects were more easily interpreted than the values reported by Thompson et al. (2010). The highest rates were for the Bounty Islands and Campbell Island area parameters, which had rates of 100 and 10 times the rates of the Stewart-Snares shelf area. This reflected the high observed fur seal capture rates in these areas.

The distance to shore factor was defined with four values. The model estimated that trawls in coastal regions ($\leq$ 25 km) had a similar chance of catching fur seals as those in the near region (between 25 km and 90 km). The distance coefficients in the far (between 90 km and 180 km) and ocean ($>$ 180 km) regions were significantly less than 1, indicating a reduction in the capture rate when fishing was more than 90 km from shore. These results were in broad agreement with results from the initial exploration of the data (see Figure 3b).

The day of year effect was modelled as a harmonic function with two parameters. The multiplicative effect of the day of year on fur seal captures is plotted in Figure 11. The confidence interval was small compared to the scale of the effect, indicating that the seasonal variation was significant. The peak in the day of year effect was at the end of August, in the middle of winter, when it was five times higher than the annual average. It then dropped to around a fifth of the average rate in the summer months. The shape of the seasonal pattern may be related to the fur seal breeding season. Pupping occurs at the same time around the whole region, with pups born in December and January (McKenzie 2006). Fur seal mating, pupping, and the first few months of the pups' lives coincide with the period of lowest capture rate.

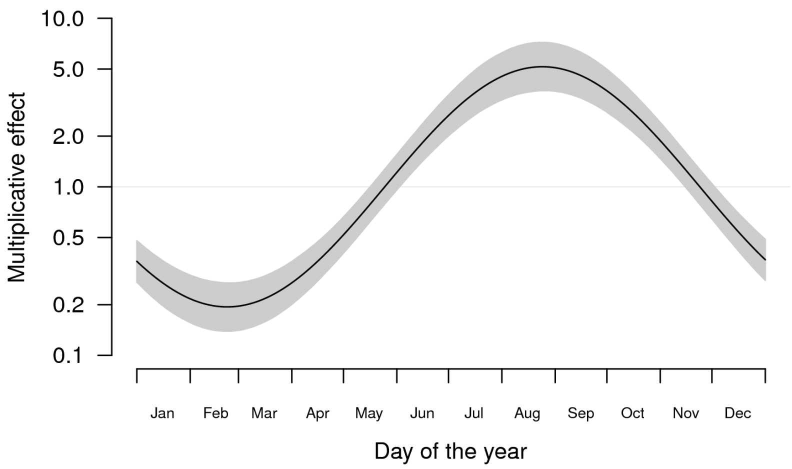


Figure 11: Day of year effect, with 95% confidence interval indicated with the shaded area, plotted with a logarithmic scale on the y-axis.

3.8 Estimated fur seal captures

Estimates of fur seal captures on unobserved trawl effort were made by sampling the model, with parameters obtained by drawing from the posterior distributions. All trawl effort was used, excluding tows targeting inshore species and fishing in areas where fur seal captures were not observed. The estimates and uncertainty are presented in Table 8 and Figure 12 for each of the seven fishing years.

In 2008–09, an estimated 550 (95% c.i.: 338 to 826) fur seals were caught in commercial trawl fisheries in New Zealand's EEZ. The estimate for 2008–09 was in line with estimates in previous years, and the mean value was within the confidence interval of both the estimate for 2007–08 of 710 (95% c.i.: 489 to 996) fur seals, and the estimate for 2006–07 of 501 (95% c.i.: 304 to 764). There was no trend apparent in the estimate. The capture rate in 2008–09 was estimated to be 1.11 (95% c.i.: 0.70 to 1.66), which was within the confidence intervals of estimated rates for all but the 2004–05 fishing year. Trawl effort has been declining over the whole seven year period included in the study, with 29 729 tows reported in study area in 2008–09, only 52.7% of the 2002–03 fishing effort.

Table 8: Estimated captures of New Zealand fur seals in trawl fisheries, excluding inshore targets, for the seven fishing years from 2002–03 to 2008–09. Capture rates are expressed as animals caught per 100 tows. The effort and observations summarise the model dataset.

	Effort	Modelled observations			Estimates			
	Tows	Tows	Captures	Rate	Mean	95% c.i.	Rate	95% c.i.
2002–03	56 371	5 780	67	1.16	807	494 - 1238	1.08	0.67 - 1.69
2003–04	48 356	5 682	84	1.48	971	611 - 1578	1.43	0.89 - 2.29
2004–05	44 352	6 569	193	2.94	1273	829 - 1974	2.02	1.26 - 3.13
2005–06	38 927	5 542	143	2.58	881	591 - 1320	1.61	1.05 - 2.44
2006–07	35 461	6 251	61	0.98	501	304 - 764	0.99	0.63 - 1.50
2007–08	31 947	7 024	138	1.96	710	489 - 996	1.55	1.06 - 2.21
2008–09	29 729	6 446	71	1.10	550	338 - 826	1.11	0.70 - 1.66

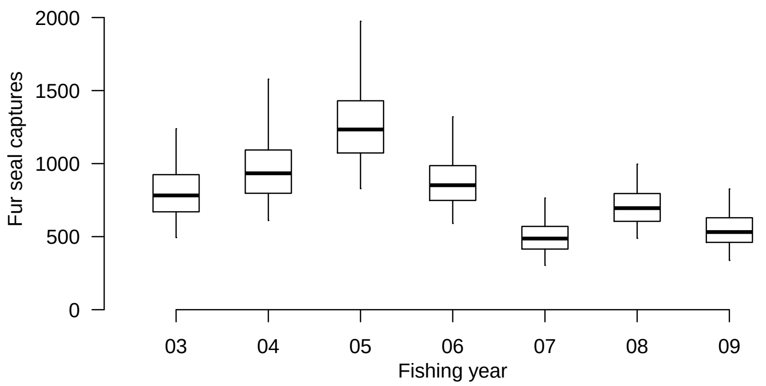


Figure 12: Estimated total fur seal captures by year, in all trawl fisheries other than inshore targets, for the seven fishing years from 2002–03 to 2008–09. The box and whiskers mark the 50% and 95% quantile ranges of the estimates.

A summary of the observations and the model estimates grouped by target species is given in Appendix B (Table B-1). Fur seals were predominantly caught by tows targeting middle depth species such as hoki and barracouta (included in the middle depth group). In 2008–09, an estimated 191 (95% c.i.: 112 to 306) fur seals were caught in the hoki fishery. This was the lowest estimate of fur seal captures in the hoki fishery over the period studied, and a decrease from 290 (95% c.i.: 180 to 463) captures in 2007–08 (although note that the decrease was not significant). An estimated 150 (95% c.i.: 57 to 307) fur seals were caught by vessels targeting middle depth species in 2008–09, despite only 2 observed captures. This was largely due to the low coverage of trawlers targeting middle depth species in the areas where fur seals are caught. The highest reported fur seal capture rates were in the southern blue whiting fishery, especially that operating near the Bounty Islands. In 2008–09 an estimated 106 (95% c.i.: 47 to 207) fur seals were caught in this fishery, the highest estimate over the period studied. The high estimate was largely due to the increased effort, with, for the first time, more than 1000 tows targeting southern blue whiting in a single year. The estimated rate of 7.87 (95% c.i.: 3.95 to 13.76) captures per 100 tows, while higher than the observed rate in 2008–09, was lower than the estimated rate in all other years apart from 2006–07.

The fur seal captures by area are summarised in Appendix B (Table B-2). In 2008–09, an estimated 80 (95% c.i.: 47 to 125) fur seals were caught on the west coast of the South Island, the lowest estimate in this area over the period, which reflects the relatively low number of tows. An estimated 96 (95% c.i.: 40 to 195) fur seals were caught near the Bounty Islands, the highest estimate in that area, and the first year the Bounty Islands estimate was higher than the estimate for the west coast of the South Island. Fishing effort more than doubled around the Bounty Islands to 637 tows in 2008–09. The estimate of fur seal captures in Cook Strait was 195 (95% c.i.: 89 to 366) in 2008–09, lower than the estimate in 2007–08, but higher than the estimate in 2006–07. About 40% of estimated fur seal captures were caught in Cook Strait, continuing the pattern of previous years.

A summary of fur seal captures by fishing area and target species group, ordered by total estimated captures, is presented in Appendix B (Table B-3). Area target species combinations are included in the table if more than 1000 tows were reported by the fishers, or if there was more than one estimated fur seal capture within that stratum.

4. DISCUSSION

4.1 New Zealand fur seal captures

Effort has been stable at about 2000 tows for the four years since 2005–06. Despite fairly low observer coverage, observers on hoki trawlers in Cook Strait have reported high fur seal capture rates, with the exception of 2003–04 when only one fur seal capture was observed, and the rate was 0.79 fur seals per 100 tows.

The model estimated that in each fishing year about one-quarter of all estimated fur seal captures were caught in Cook Strait by trawlers targeting hoki. This pattern continued in 2008–09, 128 fur seal captures (95% c.i.: 63 to 231) were estimated to have been caught, 23% of the total. Although the estimated rate has dropped from 8.39 in 2007–08 (95% c.i.: 4.36 to 14.76) to 6.50 in 2008–09 (95% c.i.: 3.63 to 10.92), this is not a significant change. In fact the mean estimated capture rates in the Cook Strait hoki fishery for all years are within the 95% confidence intervals for all years. The observed capture rate was higher than the model estimated rate for the five years since 2004–05 (Table B-3). Variability in the observed capture rate is expected due to the low observer coverage.

Hoki trawls on the west coast of the South Island, and on the western end of the Chatham Rise, are the area–target groups with the next highest estimated fur seal captures over all seven years. This is presented in the ordering of the area–target groups on Table B-3. In 2008–09, trawls on the west coast of the South Island targeting hoki, hake, and other middle depth species reported similar numbers of tows. The model estimated similar numbers of captures: 23 (95% c.i.: 14 to 37), 22 (95% c.i.: 9 to 44), and 22 (95% c.i.: 6 to 48) fur seals respectively. This continues a trend for the past few years where hake, hoki, and other middle depth species have similar fur seal capture rates. The estimate for all captures on the west coast of the South Island in 2008–09 was 80 fur seals (95% c.i.: 47 to 125), the lowest value for the seven years, reflecting a big drop in fishing effort in that area to 3726 tows, from 9364 in 2003–04.

In 2008–09, the area–target group with the second highest fur seal capture estimate was the Bounty Islands southern blue whiting fishery, with 96 estimated captures (95% c.i.: 40 to 195). Effort in this group doubled from 201 tows in 2007–08 to 403 tows in 2008–09, the highest number of tows reported in this group from all seven years. The high estimated rate reflects high observed capture rates, which peaked at 100 fur seal captures per 100 tows in 2003–04. The estimated coefficient of the Bounty Islands area effect had a high mean value of 109.833 and a wide 95% confidence interval, 12.303 to 458.270, reflecting the small number of observations in that area. In 2008–09, an estimated 96 (95% c.i.: 40 to 195) fur seals were captured in the Bounty Islands area, almost all of which are estimated on southern blue whiting trawls, which is similar to the estimates for the west coast of the South Island and the western Chatham Rise of 80 fur seals (95% c.i.: 47 to 125) and 100 fur seals (95% c.i.: 53 to 179) respectively.

No fur seals were observed captured on the north and eastern sides of the North Island, and in the waters of the Chatham Rise. For this reason we excluded the trawl effort from these areas from our study. Observer coverage on the eastern end of the Chatham Rise is high enough to expect fur seal captures if they were caught at the same rate as in areas closer to the South Island. It is not clear why the Chatham Island fur seal population was not observed caught by trawlers operating nearby. Fur seals were observed captured on the west coast of the North Island in trawl fisheries, and by surface longline vessels targeting southern bluefin tuna in the Bay of Plenty, with nine observed caught in 2008–09 (Abraham et al. 2010). Trawl effort on the east coast of the North Island and in the Bay of Plenty had very low observer coverage, and mostly targets inshore species. The presence of fur seals in the Bay of Plenty indicates that they are potentially at risk from trawlers in those areas as well. More observer coverage would be required to assess the risk.

4.2 Comparison with previous work

In this report the model developed by Thompson et al. (2010) for estimating fur seal captures in commercial trawl fisheries was extended to include the 2008–09 fishing year. The model included data from the region of the New Zealand EEZ where fur seal captures have been observed. To allow a single model to be fitted, trawl events were grouped together, reducing the scale of the computation. Trawls targeting inshore species were not included in the estimates. Inshore trawl effort accounted for over 50% of all effort in each year when measured in numbers of tows (e.g., Abraham et al. 2010).

The estimated number of fur seal captures was similar to those reported by Thompson et al. (2010) in the years that overlap (Table 9). Stratified ratio estimates of fur seal captures were presented by Abraham et al. (2010). Trawl effort was stratified by fishing area, fishing year, and target species group. Bootstrap ratio estimates were made independently in each stratum, provided there were enough observations (more than 1% coverage, and at least 100 observed tows). None of the inshore trawl effort was included in these ratio estimates. The best model estimates in 2002–03, 2004–05, 2006–07, and 2007–08, were within the ratio estimate confidence intervals (Table 9). In the other two years (2003–04 and 2005–06) the model estimated captures were higher. The confidence intervals for the model estimates were wider than confidence intervals around the ratio estimates. Ratio estimation ignores correlation between captures, but assumes that all observations are independent. For this reason, the ratio estimate was likely to overestimate the number of degrees of freedom, and so underestimate the uncertainty.

Manly et al. (2002) estimated fur seal captures in commercial trawl fisheries for the period 1990–91 to 1995–96. The estimates were calculated with a stratified ratio method, similar to the method used by Abraham et al. (2010). The estimated total fur seal captures ranged from 401 in 1990–91 to 2110

Table 9: Comparison of estimated fur seal captures from this report with model estimates made by Thompson et al. (2010), and ratio estimates made by Abraham et al. (2010), also including percentage of non-inshore effort used in ratio estimate.

	This report		Thompson et al. (2010)		Abraham et al. (2010)		
Year	Captures	95% c.i.	Captures	95% c.i.	Captures	95% c.i.	% eff. in est.
2002–03	807	494 - 1238	786	468 - 1321	666	487 - 874	91.4
2003–04	971	611 - 1578	935	553 - 1594	617	487 - 764	91.5
2004–05	1273	829 - 1974	1314	839 - 2098	1325	1039 - 1656	90.4
2005–06	881	591 - 1320	869	552 - 1378	560	461 - 675	89.1
2006–07	501	304 - 764	488	288 - 826	513	412 - 626	92.6
2007–08	710	489 - 996	714	465 - 1130	622	522 - 730	91.4
2008–09	550	338 - 826					

in 1995–96. Although there was no overlap in the years, these numbers were broadly similar in range to those reported in Table 8. In addition, Manly et al. (2002) looked at factors influencing the capture rate. They grouped data together to allow the inclusion of the whole data set in a step analysis, and used generalised linear models to estimate a strike rate, using a Poisson error model. The first four factors identified in the step analysis (area, target, year, and season), were the same as those identified in this report (see Table 5). The seasonal effect was included as a four parameter factor and was included after the fishing year covariate, while we fitted the seasonal effect as a two parameter harmonic function which was included before the fishing year. Manly et al. (2002) did not consider distance to shore as a potential covariate.

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APPENDIX A: Model parameters

Table A-1: Mean, median, and 95% confidence intervals for final model parameters. Calculated from 5000 samples of the corresponding posterior distributions.

Parameter	Mean	Median	95% c.i.	
Extra dispersion, $1/\theta$	12.391	12.231	8.933	16.599
Mean rate, μ (captures per 100 tows)	0.409	0.408	0.282	0.546
Vessel/year effect standard deviation	0.733	0.730	0.566	0.916
2002–03 base rate (captures per 100 tows)	0.299	0.292	0.177	0.457
2003–04 base rate (captures per 100 tows)	0.393	0.384	0.237	0.602
2004–05 base rate (captures per 100 tows)	0.605	0.595	0.366	0.916
2005–06 base rate (captures per 100 tows)	0.461	0.452	0.283	0.699
2006–07 base rate (captures per 100 tows)	0.305	0.299	0.177	0.467
2007–08 base rate (captures per 100 tows)	0.484	0.474	0.301	0.724
2008–09 base rate (captures per 100 tows)	0.318	0.310	0.187	0.493
Sine(doy) coefficient	-1.303	-1.302	-1.596	-1.012
Cosine(doy) coefficient	-0.996	-0.995	-1.277	-0.717
Area coefficients relative to Stewart-Snares shelf				
Western Chatham Rise	1.109	1.076	0.660	1.750
West Coast SI	0.557	0.536	0.308	0.940
Auckland Islands	0.309	0.295	0.146	0.561
West Coast NI	0.153	0.139	0.057	0.333
Other subantarctic	0.937	0.561	0.016	4.120
Campbell Island	11.528	7.456	1.487	45.235
Cook Strait	1.969	1.808	0.828	4.086
Puysegur	1.368	1.289	0.626	2.543
Bounty Islands	109.833	68.698	12.303	458.270
Target coefficients relative to Hoki				
Squid	2.539	2.419	1.305	4.476
Deepwater	0.001	0.001	0.000	0.008
Middle depth	1.320	1.300	0.919	1.832
Jack mackerel	1.717	1.622	0.851	3.116
Southern blue whiting	0.120	0.085	0.014	0.430
Scampi	0.393	0.346	0.105	0.953
Distance coefficients relative to Near (between 25 km and 90 km)				
Coastal (< 25 km)	1.227	1.188	0.719	1.957
Far (between 90 km and 180 km)	0.656	0.646	0.448	0.929
Ocean (> 180 km)	0.193	0.180	0.077	0.383
Interaction term				
Deepwater/Subantarctic	1.032	0.897	0.314	2.537

APPENDIX B: Estimate of New Zealand fur seal captures in trawl fisheries

Table B-1: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by target group, for six fishing years from 2003–04 to 2008–09.

		Observed				Estimated			
	Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2008–09									
Hoki	7 950	1 650	20.8	38	2.30	191	112 - 306	2.22	1.42 - 3.41
Hake	1 724	293	17.0	4	1.37	28	12 - 51	1.61	0.96 - 2.54
SBW	1 187	296	24.9	17	5.74	106	47 - 207	7.87	3.95 - 13.76
Middle depth	5 898	650	11.0	2	0.31	150	57 - 307	2.04	0.92 - 3.88
Squid	3 856	1 291	33.5	1	0.08	20	8 - 43	0.87	0.42 - 1.69
Ling	1 277	143	11.2	0	0.00	29	10 - 61	2.24	1.09 - 4.10
Jack mackerel	2 161	813	37.6	8	0.98	18	10 - 33	0.96	0.66 - 1.50
Scampi	2 795	267	9.6	1	0.37	6	1 - 16	0.21	0.07 - 0.51
Deepwater	2 881	1 043	36.2	0	0.00	4	0 - 12	0.07	0.01 - 0.20
2007–08									
Hoki	8 396	1 796	21.4	55	3.06	290	180 - 463	2.96	1.85 - 4.57
Hake	1 497	387	25.9	28	7.24	53	38 - 74	2.81	2.09 - 3.84
SBW	817	329	40.3	24	7.29	76	37 - 164	13.27	9.22 - 20.36
Middle depth	5 931	327	5.5	9	2.75	173	89 - 312	2.74	1.43 - 5.07
Squid	4 235	1 447	34.2	6	0.41	28	15 - 49	0.96	0.56 - 1.54
Ling	1 788	221	12.4	4	1.81	45	22 - 78	2.38	1.40 - 3.86
Jack mackerel	2 639	809	30.7	7	0.87	29	13 - 56	2.15	1.58 - 3.16
Scampi	3 276	297	9.1	1	0.34	10	2 - 26	0.31	0.09 - 0.79
Deepwater	3 368	1 411	41.9	4	0.28	8	4 - 18	0.15	0.06 - 0.39
2006–07									
Hoki	10 195	1 546	15.2	17	1.10	216	118 - 370	1.80	1.03 - 2.91
Hake	1 485	284	19.1	4	1.41	24	12 - 46	1.56	0.86 - 2.62
SBW	630	223	35.4	13	5.83	22	14 - 36	5.60	5.02 - 6.64
Middle depth	6 615	296	4.5	3	1.01	131	57 - 261	1.84	0.92 - 3.50
Squid	5 903	1 280	21.7	8	0.62	40	21 - 67	0.84	0.49 - 1.38
Ling	1 438	157	10.9	12	7.64	44	25 - 78	2.76	1.70 - 4.57
Jack mackerel	2 711	783	28.9	2	0.26	15	5 - 29	0.69	0.33 - 1.25
Scampi	3 415	219	6.4	0	0.00	6	0 - 19	0.21	0.05 - 0.61
Deepwater	3 069	1 463	47.7	2	0.14	3	2 - 6	0.07	0.05 - 0.11
2005–06									
Hoki	11 328	1 754	15.5	62	3.53	390	244 - 627	2.86	1.77 - 4.71
Hake	1 344	419	31.2	11	2.63	41	24 - 70	2.98	1.87 - 4.69
SBW	624	215	34.5	52	24.19	67	55 - 88	17.73	15.70 - 21.72
Middle depth	6 220	365	5.9	4	1.10	193	89 - 371	3.02	1.49 - 5.75
Squid	8 568	1 097	12.8	4	0.36	96	47 - 176	1.48	0.77 - 2.56
Ling	1 242	113	9.1	2	1.77	50	20 - 102	3.52	1.75 - 6.38
Jack mackerel	2 805	703	25.1	6	0.85	28	13 - 53	1.23	0.72 - 2.15
Scampi	2 951	214	7.3	0	0.00	8	1 - 20	0.44	0.10 - 1.14
Deepwater	3 845	662	17.2	2	0.30	9	2 - 24	0.16	0.06 - 0.42
2004–05									
Hoki	13 995	2 014	14.4	113	5.61	658	417 - 1020	3.81	2.39 - 5.98
Hake	1 239	94	7.6	2	2.13	36	16 - 70	2.37	1.26 - 4.37
SBW	869	335	38.6	33	9.85	75	43 - 149	10.31	7.28 - 15.93
Middle depth	7 244	182	2.5	10	5.49	246	107 - 532	3.60	1.61 - 7.88
Squid	10 488	2 503	23.9	16	0.64	145	82 - 247	2.01	1.12 - 3.47
Ling	959	76	7.9	10	13.16	55	24 - 113	4.99	2.93 - 8.69
Jack mackerel	2 509	557	22.2	5	0.90	22	9 - 42	1.11	0.56 - 2.06
Scampi	2 820	64	2.3	0	0.00	19	3 - 56	0.86	0.19 - 2.45
Deepwater	4 229	744	17.6	4	0.54	18	6 - 48	0.26	0.09 - 0.63
2003–04									
Hoki	21 484	2 288	10.6	49	2.14	637	392 - 1043	2.58	1.54 - 4.25
Hake	1 529	140	9.2	0	0.00	18	7 - 36	1.16	0.60 - 2.04
SBW	740	238	32.2	13	5.46	33	18 - 70	7.96	6.20 - 11.37
Middle depth	7 130	133	1.9	0	0.00	149	55 - 350	2.24	0.90 - 5.17
Squid	8 335	1 762	21.1	17	0.96	83	50 - 135	1.26	0.72 - 2.13
Ling	522	22	4.2	0	0.00	23	5 - 72	3.14	1.11 - 7.64
Jack mackerel	2 379	152	6.4	2	1.32	15	5 - 30	0.93	0.52 - 1.63
Scampi	2 178	374	17.2	1	0.27	5	1 - 13	0.21	0.07 - 0.53
Deepwater	4 059	573	14.1	2	0.35	7	2 - 17	0.12	0.04 - 0.29

Table B-2: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area, for six fishing years from 2003–04 to 2008–09.

		Observed				Estimated			
	Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2008–09									
Cook Strait	2 960	176	5.9	20	11.36	195	89 - 366	3.25	1.57 - 6.03
West coast South Island	3 726	851	22.8	18	2.12	80	47 - 125	1.41	0.93 - 2.13
Western Chatham Rise	8 950	1 305	14.6	8	0.61	100	53 - 179	0.86	0.47 - 1.43
Stewart-Snares	4 509	1 331	29.5	4	0.30	38	19 - 66	0.71	0.38 - 1.24
Bounty Islands	637	214	33.6	17	7.94	96	40 - 195	16.16	8.06 - 28.74
Campbell Island	619	124	20.0	0	0.00	9	2 - 21	1.50	0.70 - 2.85
West coast North Island	2 873	918	32.0	3	0.33	10	4 - 20	0.13	0.07 - 0.25
Other subantarctic islands	1 508	487	32.3	0	0.00	4	0 - 12	0.21	0.05 - 0.59
Auckland Islands	3 684	998	27.1	1	0.10	10	3 - 22	0.30	0.13 - 0.58
Puysegur	263	42	16.0	0	0.00	8	1 - 25	2.31	0.77 - 5.60
2007–08									
Cook Strait	2 645	221	8.4	21	9.50	212	101 - 384	4.36	2.11 - 7.79
West coast South Island	4 390	915	20.8	57	6.23	158	108 - 228	2.36	1.69 - 3.32
Western Chatham Rise	10 212	1 361	13.3	15	1.10	152	88 - 251	1.17	0.71 - 1.88
Stewart-Snares	5 168	1 528	29.6	13	0.85	64	37 - 103	1.07	0.65 - 1.64
Bounty Islands	300	158	52.7	17	10.76	60	25 - 143	22.45	12.84 - 39.63
Campbell Island	559	230	41.1	7	3.04	16	9 - 28	6.74	5.98 - 7.95
West coast North Island	3 465	866	25.0	1	0.12	15	4 - 34	0.21	0.09 - 0.42
Other subantarctic islands	1 840	884	48.0	5	0.57	9	5 - 19	0.59	0.32 - 1.27
Auckland Islands	3 040	848	27.9	2	0.24	11	4 - 25	0.32	0.15 - 0.65
Puysegur	328	13	4.0	0	0.00	12	2 - 33	2.82	1.15 - 5.96
2006–07									
Cook Strait	3 113	202	6.5	11	5.45	159	69 - 311	2.78	1.26 - 5.30
West coast South Island	5 689	875	15.4	5	0.57	103	53 - 199	1.29	0.70 - 2.20
Western Chatham Rise	11 502	1 010	8.8	7	0.69	109	54 - 184	0.70	0.40 - 1.12
Stewart-Snares	6 402	1 350	21.1	21	1.56	78	48 - 128	1.06	0.65 - 1.64
Bounty Islands	260	145	55.8	8	5.52	10	8 - 21	5.06	4.56 - 6.31
Campbell Island	565	181	32.0	5	2.76	13	6 - 28	5.30	3.82 - 9.61
West coast North Island	3 246	945	29.1	1	0.11	8	2 - 17	0.11	0.04 - 0.22
Other subantarctic islands	1 448	854	59.0	2	0.23	3	2 - 7	0.23	0.14 - 0.50
Auckland Islands	2 870	646	22.5	0	0.00	6	0 - 16	0.22	0.08 - 0.51
Puysegur	366	43	11.7	1	2.33	11	3 - 28	2.18	0.84 - 4.61
2005–06									
Cook Strait	2 964	68	2.3	19	27.94	240	114 - 452	4.07	1.94 - 7.98
West coast South Island	6 530	1 168	17.9	31	2.65	189	117 - 287	2.01	1.23 - 3.16
Western Chatham Rise	11 777	1 162	9.9	15	1.29	175	100 - 306	1.01	0.58 - 1.77
Stewart-Snares	7 630	1 124	14.7	10	0.89	119	67 - 205	1.53	0.82 - 2.62
Bounty Islands	447	175	39.1	52	29.71	58	52 - 75	26.03	23.57 - 31.16
Campbell Island	519	137	26.4	1	0.73	12	3 - 30	3.80	1.29 - 10.47
West coast North Island	3 270	763	23.3	5	0.66	19	8 - 37	0.34	0.22 - 0.59
Other subantarctic islands	1 107	144	13.0	1	0.69	9	2 - 23	0.74	0.22 - 1.95
Auckland Islands	3 899	671	17.2	2	0.30	11	4 - 23	0.32	0.16 - 0.58
Puysegur	784	130	16.6	7	5.38	48	18 - 111	4.91	2.28 - 10.02
2004–05									
Cook Strait	4 482	108	2.4	24	22.22	409	185 - 776	5.92	2.78 - 11.81
West coast South Island	7 039	1 247	17.7	74	5.93	282	189 - 436	2.69	1.74 - 4.44
Western Chatham Rise	11 410	987	8.7	18	1.82	211	121 - 358	1.32	0.77 - 2.15
Stewart-Snares	8 624	1 863	21.6	13	0.70	142	80 - 236	1.80	0.98 - 3.05
Bounty Islands	449	135	30.1	24	17.78	50	26 - 119	12.89	8.91 - 21.28
Campbell Island	774	283	36.6	16	5.65	33	20 - 52	5.93	4.74 - 7.63
West coast North Island	4 381	637	14.5	6	0.94	30	13 - 65	0.28	0.13 - 0.65
Other subantarctic islands	1 578	343	21.7	4	1.17	21	6 - 57	0.96	0.31 - 2.43
Auckland Islands	4 450	824	18.5	1	0.12	15	5 - 34	0.41	0.18 - 0.83
Puysegur	1 165	142	12.2	13	9.15	80	36 - 158	5.83	3.16 - 10.21
2003–04									
Cook Strait	5 708	126	2.2	1	0.79	389	167 - 805	4.67	1.98 - 9.53
West coast South Island	9 364	1 400	15.0	29	2.07	229	144 - 363	1.93	1.21 - 3.06
Western Chatham Rise	12 300	886	7.2	17	1.92	148	84 - 243	0.81	0.46 - 1.35
Stewart-Snares	7 824	1 226	15.7	10	0.82	86	48 - 138	1.00	0.57 - 1.64
Bounty Islands	328	35	10.7	9	25.71	20	9 - 52	14.96	11.84 - 21.78
Campbell Island	797	232	29.1	4	1.72	24	9 - 70	3.03	1.09 - 8.88
West coast North Island	4 401	339	7.7	0	0.00	18	4 - 40	0.17	0.06 - 0.37
Other subantarctic islands	1 965	273	13.9	2	0.73	10	3 - 29	0.48	0.13 - 1.39
Auckland Islands	4 872	1 106	22.7	9	0.81	19	11 - 30	0.33	0.22 - 0.51
Puysegur	797	59	7.4	3	5.08	29	10 - 72	2.97	1.42 - 5.72

Table B-3: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area and target, for seven fishing years from 2002–03 to 2008–09. 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				Estimated			
		Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2008–09										
Hoki	Cook Strait	1 916	168	8.8	20	11.90	128	63 - 231	6.50	3.63 - 10.92
Hoki	West coast SI.	1 159	496	42.8	11	2.22	23	14 - 37	3.07	2.43 - 4.00
Hoki	Western Chatham	3 893	571	14.7	4	0.70	31	13 - 59	0.72	0.40 - 1.22
Middle depth	Western Chatham	2 123	235	11.1	2	0.85	51	21 - 100	2.23	1.10 - 4.07
Middle depth	Cook Strait	843	4	0.5	0	0.00	61	7 - 180	5.22	0.98 - 14.33
SBW	Bounty Islands	403	120	29.8	17	14.17	96	40 - 195	23.43	11.64 - 41.72
Middle depth	West coast SI.	1 005	40	4.0	0	0.00	22	6 - 48	1.87	0.79 - 3.69
Squid	Stewart-Snares	1 804	528	29.3	1	0.19	11	3 - 24	0.85	0.38 - 1.81
Hake	West coast SI.	1 003	154	15.4	2	1.30	22	9 - 44	2.58	1.55 - 4.05
Middle depth	Stewart-Snares	1 019	252	24.7	0	0.00	13	3 - 31	1.17	0.51 - 2.31
Squid	Western Chatham	120	3	2.5	0	0.00	4	0 - 12	2.91	1.02 - 6.89
SBW	Campbell Island	619	124	20.0	0	0.00	9	2 - 21	1.50	0.70 - 2.85
Hoki	Stewart-Snares	804	300	37.3	3	1.00	8	3 - 18	0.79	0.39 - 1.56
Ling	Puysegur	163	-	-	-	-	7	0 - 23	4.89	1.39 - 13.16
Hoki	Puysegur	8	-	-	-	-	0	0 - 3	3.74	0.28 - 12.07
Ling	Stewart-Snares	380	68	17.9	0	0.00	5	0 - 14	1.26	0.51 - 2.54
Jack mackerel	West coast NI.	1 803	680	37.7	3	0.44	7	3 - 15	0.41	0.23 - 0.75
Squid	Puysegur	4	1	25.0	0	0.00	0	0 - 2	4.39	0.61 - 13.61
Jack mackerel	West coast SI.	221	97	43.9	5	5.15	9	5 - 19	3.76	2.80 - 5.75
Deepwater	Subantarctic	1 233	423	34.3	0	0.00	3	0 - 12	0.25	0.05 - 0.74
Middle depth	West coast NI.	777	70	9.0	0	0.00	2	0 - 7	0.33	0.10 - 0.80
Squid	Auckland Islands	1 925	759	39.4	0	0.00	6	1 - 14	0.39	0.14 - 0.88
Ling	Western Chatham	222	16	7.2	0	0.00	7	1 - 20	2.88	1.15 - 6.15
Scampi	Auckland Islands	1 457	61	4.2	1	1.64	4	1 - 12	0.26	0.09 - 0.67
Ling	West coast SI.	270	-	-	-	-	4	0 - 13	1.41	0.45 - 3.11
Scampi	Western Chatham	1 306	204	15.6	0	0.00	2	0 - 6	0.12	0.02 - 0.34
Middle depth	Puysegur	60	41	68.3	0	0.00	0	0 - 3	1.07	0.22 - 3.05
Hake	Western Chatham	447	61	13.6	2	3.28	5	2 - 10	0.68	0.36 - 1.21
Ling	Campbell Island	-	-	-	-	-	-	-	-	-
Jack mackerel	Western Chatham	54	1	1.9	0	0.00	1	0 - 5	1.68	0.48 - 4.00
Hake	Stewart-Snares	274	78	28.5	0	0.00	0	0 - 2	0.24	0.09 - 0.49
Scampi	Cook Strait	31	2	6.5	0	0.00	0	0 - 1	0.61	0.06 - 2.07
Hoki	Campbell Island	-	-	-	-	-	-	-	-	-
Ling	Cook Strait	55	-	-	-	-	6	0 - 20	11.43	2.99 - 25.54
Hoki	Auckland Islands	157	112	71.3	0	0.00	0	0 - 1	0.13	0.01 - 0.46
Squid	West coast SI.	2	-	-	-	-	0	0 - 1	2.17	0.17 - 7.09
Middle depth	Subantarctic	69	6	8.7	0	0.00	0	0 - 1	0.15	0.00 - 0.80
Hoki	Subantarctic	5	2	40.0	0	0.00	0	0 - 0	0.06	0.00 - 0.36
Ling	Bounty Islands	-	-	-	-	-	-	-	-	-
Ling	Auckland Islands	93	51	54.8	0	0.00	0	0 - 1	0.08	0.02 - 0.21
Jack mackerel	Stewart-Snares	83	35	42.2	0	0.00	0	0 - 2	0.28	0.08 - 0.68
Deepwater	Bounty Islands	234	94	40.2	0	0.00	0	0 - 2	0.09	0.00 - 0.49
Squid	Subantarctic	1	-	-	-	-	0	0 - 0	0.08	0.00 - 0.44
Ling	West coast NI.	55	1	1.8	0	0.00	0	0 - 3	0.74	0.16 - 2.08
Ling	Subantarctic	39	7	17.9	0	0.00	0	0 - 1	0.19	0.00 - 0.99
Hoki	Bounty Islands	-	-	-	-	-	-	-	-	-
Hake	Campbell Island	-	-	-	-	-	-	-	-	-
Deepwater	Western Chatham	785	214	27.3	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	Stewart-Snares	143	70	49.0	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	West coast SI.	66	64	97.0	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	West coast NI.	230	166	72.2	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table B-3: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area and target, for seven fishing years from 2002–03 to 2008–09. 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				Estimated			
		Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2007–08										
Hoki	Cook Strait	1 854	179	9.7	21	11.73	170	79 - 324	8.39	4.36 - 14.76
Hoki	West coast SI.	1 388	462	33.3	23	4.98	47	31 - 70	3.00	2.13 - 4.31
Hoki	Western Chatham	4 187	699	16.7	7	1.00	61	29 - 114	1.24	0.72 - 2.10
Middle depth	Western Chatham	1 897	154	8.1	6	3.90	56	27 - 106	2.74	1.51 - 4.72
Middle depth	Cook Strait	607	4	0.7	0	0.00	41	9 - 110	6.67	1.94 - 17.85
SBW	Bounty Islands	201	98	48.8	17	17.35	60	25 - 143	33.17	18.98 - 58.58
Middle depth	West coast SI.	1 343	54	4.0	3	5.56	45	19 - 91	3.05	1.54 - 5.79
Squid	Stewart-Snares	2 412	857	35.5	6	0.70	16	9 - 27	0.87	0.58 - 1.28
Hake	West coast SI.	1 084	320	29.5	25	7.81	48	34 - 70	3.88	2.85 - 5.36
Middle depth	Stewart-Snares	1 017	81	8.0	0	0.00	23	7 - 47	1.92	0.90 - 3.48
Squid	Western Chatham	540	-	-	-	-	9	1 - 24	2.17	0.80 - 4.50
SBW	Campbell Island	559	230	41.1	7	3.04	16	9 - 28	6.74	5.98 - 7.95
Hoki	Stewart-Snares	744	341	45.8	3	0.88	9	3 - 20	1.13	0.59 - 2.08
Ling	Puysegur	216	13	6.0	0	0.00	8	1 - 23	3.93	1.46 - 9.00
Hoki	Puysegur	10	-	-	-	-	1	0 - 5	6.56	0.65 - 22.42
Ling	Stewart-Snares	692	136	19.7	3	2.21	15	6 - 30	2.07	1.14 - 3.39
Jack mackerel	West coast NI.	2 196	713	32.5	1	0.14	10	2 - 23	0.56	0.26 - 1.07
Squid	Puysegur	15	-	-	-	-	0	0 - 2	1.34	0.39 - 3.06
Jack mackerel	West coast SI.	255	79	31.0	6	7.59	12	6 - 22	9.05	7.42 - 12.23
Deepwater	Subantarctic	1 699	837	49.3	4	0.48	8	4 - 18	0.47	0.18 - 1.23
Middle depth	West coast NI.	966	23	2.4	0	0.00	5	0 - 14	0.55	0.15 - 1.49
Squid	Auckland Islands	1 265	588	46.5	0	0.00	2	0 - 7	0.17	0.08 - 0.33
Ling	Western Chatham	249	3	1.2	0	0.00	12	2 - 33	3.84	1.45 - 8.03
Scampi	Auckland Islands	1 327	93	7.0	1	1.08	6	1 - 18	0.47	0.13 - 1.30
Ling	West coast SI.	320	-	-	-	-	6	0 - 16	1.64	0.58 - 3.51
Scampi	Western Chatham	1 892	182	9.6	0	0.00	3	0 - 10	0.19	0.04 - 0.50
Middle depth	Puysegur	80	-	-	-	-	3	0 - 13	4.06	1.26 - 9.77
Hake	Western Chatham	256	18	7.0	2	11.11	3	2 - 5	0.80	0.56 - 1.17
Ling	Campbell Island	-	-	-	-	-	-	-	-	-
Jack mackerel	Western Chatham	169	14	8.3	0	0.00	7	0 - 22	3.47	1.12 - 8.19
Hake	Stewart-Snares	157	49	31.2	1	2.04	2	1 - 4	0.73	0.34 - 1.54
Scampi	Cook Strait	56	22	39.3	0	0.00	0	0 - 2	0.74	0.12 - 2.26
Hoki	Campbell Island	-	-	-	-	-	-	-	-	-
Ling	Cook Strait	7	-	-	-	-	1	0 - 6	12.11	2.88 - 29.77
Hoki	Auckland Islands	206	115	55.8	1	0.87	2	1 - 4	0.39	0.20 - 0.87
Squid	West coast SI.	-	-	-	-	-	-	-	-	-
Middle depth	Subantarctic	21	11	52.4	0	0.00	0	0 - 2	1.26	0.01 - 6.38
Hoki	Subantarctic	5	-	-	-	-	0	0 - 0	0.18	0.00 - 0.95
Ling	Bounty Islands	-	-	-	-	-	-	-	-	-
Ling	Auckland Islands	184	36	19.6	0	0.00	1	0 - 5	0.55	0.15 - 1.43
Jack mackerel	Stewart-Snares	14	3	21.4	0	0.00	0	0 - 1	0.59	0.14 - 1.53
Deepwater	Bounty Islands	99	60	60.6	0	0.00	0	0 - 0	0.02	0.00 - 0.11
Squid	Subantarctic	2	2	100.0	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Ling	West coast NI.	64	-	-	-	-	1	0 - 4	1.28	0.32 - 3.52
Ling	Subantarctic	56	33	58.9	1	3.03	1	1 - 2	2.39	2.27 - 2.83
Hoki	Bounty Islands	-	-	-	-	-	-	-	-	-
Hake	Campbell Island	-	-	-	-	-	-	-	-	-
Deepwater	Western Chatham	1 022	291	28.5	0	0.00	0	0 - 0	0.00	0.00 - 0.01
Deepwater	Stewart-Snares	131	61	46.6	0	0.00	0	0 - 0	0.00	0.00 - 0.01
Deepwater	West coast SI.	-	-	-	-	-	-	-	-	-
Deepwater	West coast NI.	236	130	55.1	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table B-3: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area and target, for seven fishing years from 2002–03 to 2008–09. 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				Estimated			
		Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2006–07										
Hoki	Cook Strait	2 151	179	8.3	11	6.15	131	55 - 266	5.46	2.53 - 10.36
Hoki	West coast SI.	2 130	514	24.1	0	0.00	33	14 - 60	1.52	0.82 - 2.54
Hoki	Western Chatham	4 675	640	13.7	4	0.62	38	17 - 72	0.70	0.35 - 1.26
Middle depth	Western Chatham	1 984	49	2.5	1	2.04	44	16 - 93	1.93	0.94 - 3.54
Middle depth	Cook Strait	725	2	0.3	0	0.00	26	5 - 72	3.57	0.94 - 9.43
SBW	Bounty Islands	51	38	74.5	8	21.05	10	8 - 21	18.42	16.66 - 23.13
Middle depth	West coast SI.	1 730	20	1.2	0	0.00	40	11 - 97	2.21	0.90 - 5.10
Squid	Stewart-Snares	2 926	704	24.1	6	0.85	21	11 - 38	0.80	0.47 - 1.37
Hake	West coast SI.	1 069	159	14.9	4	2.52	21	10 - 37	1.93	1.10 - 3.16
Middle depth	Stewart-Snares	1 316	142	10.8	2	1.41	17	6 - 35	1.29	0.59 - 2.42
Squid	Western Chatham	1 495	37	2.5	2	5.41	16	6 - 33	1.37	0.73 - 2.43
SBW	Campbell Island	559	181	32.4	5	2.76	12	6 - 22	4.30	3.77 - 5.21
Hoki	Stewart-Snares	1 181	206	17.4	2	0.97	15	5 - 33	1.23	0.68 - 2.25
Ling	Puysegur	213	18	8.5	1	5.56	9	2 - 26	3.75	1.35 - 8.98
Hoki	Puysegur	24	3	12.5	0	0.00	1	0 - 4	2.28	0.27 - 6.85
Ling	Stewart-Snares	632	121	19.1	11	9.09	24	15 - 42	3.33	2.28 - 5.07
Jack mackerel	West coast NI.	2 152	584	27.1	1	0.17	5	1 - 13	0.28	0.12 - 0.57
Squid	Puysegur	19	2	10.5	0	0.00	0	0 - 3	1.92	0.54 - 5.27
Jack mackerel	West coast SI.	417	182	43.6	1	0.55	7	2 - 16	1.79	0.78 - 3.54
Deepwater	Subantarctic	1 243	839	67.5	2	0.24	3	2 - 5	0.23	0.18 - 0.35
Middle depth	West coast NI.	744	53	7.1	0	0.00	2	0 - 8	0.32	0.07 - 0.99
Squid	Auckland Islands	1 317	535	40.6	0	0.00	1	0 - 5	0.10	0.04 - 0.20
Ling	Western Chatham	221	-	-	-	-	5	0 - 16	2.15	0.79 - 4.57
Scampi	Auckland Islands	1 329	95	7.1	0	0.00	3	0 - 13	0.24	0.04 - 0.84
Ling	West coast SI.	80	-	-	-	-	2	0 - 8	2.58	1.08 - 5.43
Scampi	Western Chatham	2 015	107	5.3	0	0.00	3	0 - 10	0.17	0.03 - 0.50
Middle depth	Puysegur	97	20	20.6	0	0.00	1	0 - 6	1.78	0.53 - 4.39
Hake	Western Chatham	246	70	28.5	0	0.00	1	0 - 4	0.62	0.21 - 1.43
Ling	Campbell Island	-	-	-	-	-	-	-	-	-
Jack mackerel	Western Chatham	110	17	15.5	0	0.00	2	0 - 9	1.56	0.41 - 4.03
Hake	Stewart-Snares	166	55	33.1	0	0.00	1	0 - 4	0.65	0.24 - 1.46
Scampi	Cook Strait	71	17	23.9	0	0.00	0	0 - 2	0.50	0.06 - 1.81
Hoki	Campbell Island	-	-	-	-	-	-	-	-	-
Ling	Cook Strait	19	-	-	-	-	2	0 - 8	10.51	2.47 - 26.94
Hoki	Auckland Islands	28	4	14.3	0	0.00	0	0 - 1	0.28	0.08 - 0.71
Squid	West coast SI.	26	-	-	-	-	0	0 - 3	1.82	0.31 - 5.33
Middle depth	Subantarctic	18	10	55.6	0	0.00	0	0 - 1	0.54	0.01 - 3.17
Hoki	Subantarctic	6	-	-	-	-	0	0 - 0	0.08	0.00 - 0.50
Ling	Bounty Islands	-	-	-	-	-	-	-	-	-
Ling	Auckland Islands	191	12	6.3	0	0.00	1	0 - 5	0.62	0.19 - 1.51
Jack mackerel	Stewart-Snares	22	-	-	-	-	0	0 - 2	1.68	0.44 - 4.18
Deepwater	Bounty Islands	209	107	51.2	0	0.00	0	0 - 1	0.05	0.00 - 0.25
Squid	Subantarctic	110	1	0.9	0	0.00	0	0 - 1	0.12	0.00 - 0.58
Ling	West coast NI.	31	6	19.4	0	0.00	0	0 - 1	0.38	0.07 - 1.18
Ling	Subantarctic	51	-	-	-	-	0	0 - 2	0.53	0.01 - 2.54
Hoki	Bounty Islands	-	-	-	-	-	-	-	-	-
Hake	Campbell Island	3	-	-	-	-	1	0 - 9	38.44	1.50 - 195.51
Deepwater	Western Chatham	756	90	11.9	0	0.00	0	0 - 0	0.00	0.00 - 0.01
Deepwater	Stewart-Snares	159	122	76.7	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	West coast SI.	237	-	-	-	-	0	0 - 0	0.00	0.00 - 0.01
Deepwater	West coast NI.	310	301	97.1	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table B-3: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area and target, for seven fishing years from 2002–03 to 2008–09. 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				Estimated			
		Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2005–06										
Hoki	Cook Strait	1 999	64	3.2	19	29.69	202	96 - 382	8.37	4.22 - 15.44
Hoki	West coast SI.	3 547	800	22.6	23	2.88	108	66 - 170	2.78	1.71 - 4.28
Hoki	Western Chatham	4 887	721	14.8	12	1.66	54	29 - 97	0.94	0.53 - 1.64
Middle depth	Western Chatham	2 087	53	2.5	1	1.89	79	31 - 161	3.36	1.60 - 6.89
Middle depth	Cook Strait	729	-	-	-	-	36	8 - 88	5.14	1.57 - 12.79
SBW	Bounty Islands	94	82	87.2	51	62.20	56	51 - 74	112.87	102.24 - 135.30
Middle depth	West coast SI.	1 176	28	2.4	0	0.00	32	7 - 83	2.67	0.86 - 6.16
Squid	Stewart-Snares	4 463	535	12.0	2	0.37	52	24 - 97	1.48	0.77 - 2.71
Hake	West coast SI.	1 146	331	28.9	8	2.42	37	20 - 65	3.11	1.91 - 5.01
Middle depth	Stewart-Snares	1 242	267	21.5	2	0.75	33	12 - 73	2.66	1.22 - 5.32
Squid	Western Chatham	1 394	9	0.6	0	0.00	29	10 - 63	2.57	1.12 - 5.12
SBW	Campbell Island	510	133	26.1	1	0.75	11	3 - 23	1.97	0.93 - 3.73
Hoki	Stewart-Snares	761	131	17.2	1	0.76	12	3 - 29	1.67	0.86 - 3.12
Ling	Puysegur	215	15	7.0	0	0.00	20	4 - 57	7.79	2.85 - 17.81
Hoki	Puysegur	102	34	33.3	7	20.59	13	7 - 30	10.67	6.89 - 18.30
Ling	Stewart-Snares	633	95	15.0	2	2.11	17	6 - 37	2.59	1.33 - 4.84
Jack mackerel	West coast NI.	2 087	638	30.6	4	0.63	13	5 - 27	0.94	0.60 - 1.56
Squid	Puysegur	203	6	3.0	0	0.00	8	1 - 22	4.10	1.41 - 9.42
Jack mackerel	West coast SI.	189	7	3.7	0	0.00	7	1 - 18	3.00	1.07 - 6.89
Deepwater	Subantarctic	1 007	142	14.1	1	0.70	7	1 - 22	0.67	0.19 - 2.00
Middle depth	West coast NI.	800	12	1.5	1	8.33	5	1 - 15	1.15	0.66 - 2.28
Squid	Auckland Islands	2 459	547	22.2	2	0.37	7	3 - 14	0.26	0.15 - 0.47
Ling	Western Chatham	106	-	-	-	-	5	0 - 15	4.22	1.57 - 9.62
Scampi	Auckland Islands	1 331	116	8.7	0	0.00	4	0 - 12	0.29	0.05 - 0.85
Ling	West coast SI.	148	-	-	-	-	5	0 - 17	3.04	1.06 - 6.41
Scampi	Western Chatham	1 558	96	6.2	0	0.00	3	0 - 9	0.37	0.07 - 1.08
Middle depth	Puysegur	159	2	1.3	0	0.00	7	0 - 24	3.99	1.24 - 10.24
Hake	Western Chatham	20	1	5.0	0	0.00	0	0 - 1	1.02	0.31 - 2.35
Ling	Campbell Island	5	-	-	-	-	2	0 - 12	41.22	3.61 - 170.13
Jack mackerel	Western Chatham	436	55	12.6	2	3.64	6	2 - 16	1.37	0.51 - 3.31
Hake	Stewart-Snares	174	87	50.0	3	3.45	4	3 - 6	1.45	0.98 - 2.32
Scampi	Cook Strait	58	-	-	-	-	1	0 - 5	1.92	0.33 - 5.66
Hoki	Campbell Island	-	-	-	-	-	-	-	-	-
Ling	Cook Strait	4	-	-	-	-	0	0 - 5	11.52	2.19 - 31.41
Hoki	Auckland Islands	29	4	13.8	0	0.00	0	0 - 1	0.17	0.03 - 0.51
Squid	West coast SI.	8	-	-	-	-	0	0 - 2	4.35	1.13 - 10.55
Middle depth	Subantarctic	22	2	9.1	0	0.00	1	0 - 5	1.85	0.02 - 8.81
Hoki	Subantarctic	-	-	-	-	-	-	-	-	-
Ling	Bounty Islands	-	-	-	-	-	-	-	-	-
Ling	Auckland Islands	69	3	4.3	0	0.00	1	0 - 3	0.88	0.25 - 2.24
Jack mackerel	Stewart-Snares	92	3	3.3	0	0.00	1	0 - 6	1.16	0.40 - 2.88
Deepwater	Bounty Islands	353	93	26.3	1	1.08	2	1 - 5	0.49	0.33 - 1.06
Squid	Subantarctic	41	-	-	-	-	1	0 - 4	1.20	0.01 - 6.16
Ling	West coast NI.	46	-	-	-	-	1	0 - 3	1.13	0.19 - 3.33
Ling	Subantarctic	16	-	-	-	-	0	0 - 1	0.84	0.01 - 3.71
Hoki	Bounty Islands	-	-	-	-	-	-	-	-	-
Hake	Campbell Island	-	-	-	-	-	-	-	-	-
Deepwater	Western Chatham	1 289	227	17.6	0	0.00	0	0 - 0	0.00	0.00 - 0.01
Deepwater	Stewart-Snares	264	6	2.3	0	0.00	0	0 - 0	0.00	0.00 - 0.01
Deepwater	West coast SI.	314	-	-	-	-	0	0 - 0	0.00	0.00 - 0.01
Deepwater	West coast NI.	334	113	33.8	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table B-3: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area and target, for seven fishing years from 2002–03 to 2008–09. 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				Estimated			
		Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2004–05										
Hoki	Cook Strait	3 088	106	3.4	24	22.64	326	154 - 630	10.15	5.18 - 19.01
Hoki	West coast SI.	3 942	1 012	25.7	63	6.23	184	125 - 269	4.01	2.65 - 6.03
Hoki	Western Chatham	5 164	721	14.0	15	2.08	92	50 - 158	1.62	0.98 - 2.50
Middle depth	Western Chatham	1 699	7	0.4	0	0.00	55	19 - 121	3.40	1.47 - 6.84
Middle depth	Cook Strait	1 090	1	0.1	0	0.00	75	15 - 220	7.50	1.61 - 20.79
SBW	Bounty Islands	100	52	52.0	24	46.15	50	26 - 118	54.22	37.49 - 89.90
Middle depth	West coast SI.	1 564	76	4.9	9	11.84	58	25 - 127	3.79	1.93 - 7.72
Squid	Stewart-Snares	5 865	1 574	26.8	8	0.51	68	36 - 118	1.69	0.89 - 3.04
Hake	West coast SI.	782	85	10.9	2	2.35	26	11 - 52	3.77	2.09 - 6.82
Middle depth	Stewart-Snares	992	46	4.6	0	0.00	40	13 - 88	3.84	1.72 - 7.74
Squid	Western Chatham	1 508	61	4.0	3	4.92	49	20 - 100	3.64	1.73 - 6.90
SBW	Campbell Island	758	280	36.9	9	3.21	25	13 - 44	3.45	2.30 - 5.07
Hoki	Stewart-Snares	957	104	10.9	2	1.92	19	7 - 38	1.83	0.93 - 3.27
Ling	Puysegur	250	4	1.6	0	0.00	24	5 - 66	9.16	3.31 - 20.07
Hoki	Puysegur	286	58	20.3	9	15.52	34	14 - 73	12.34	7.69 - 21.53
Ling	Stewart-Snares	393	67	17.0	3	4.48	12	5 - 25	3.06	1.52 - 5.62
Jack mackerel	West coast NI.	2 351	523	22.2	5	0.96	18	8 - 35	0.81	0.41 - 1.46
Squid	Puysegur	292	62	21.2	4	6.45	16	6 - 39	5.37	2.93 - 9.75
Jack mackerel	West coast SI.	95	22	23.2	0	0.00	3	0 - 11	3.00	0.98 - 6.69
Deepwater	Subantarctic	1 216	328	27.0	4	1.22	17	5 - 47	1.03	0.37 - 2.61
Middle depth	West coast NI.	1 690	47	2.8	1	2.13	12	2 - 38	0.77	0.19 - 2.29
Squid	Auckland Islands	2 697	805	29.8	1	0.12	8	2 - 16	0.32	0.18 - 0.55
Ling	Western Chatham	51	-	-	-	-	3	0 - 12	5.23	1.57 - 11.74
Scampi	Auckland Islands	1 275	-	-	-	-	5	0 - 20	0.42	0.07 - 1.34
Ling	West coast SI.	128	-	-	-	-	6	0 - 22	4.52	0.66 - 14.72
Scampi	Western Chatham	1 340	63	4.7	0	0.00	5	0 - 15	0.60	0.13 - 1.91
Middle depth	Puysegur	145	-	-	-	-	4	0 - 13	2.85	0.80 - 6.81
Hake	Western Chatham	296	9	3.0	0	0.00	6	0 - 17	1.42	0.50 - 3.52
Ling	Campbell Island	3	3	100.0	7	233.33	7	7 - 7	233.33	233.33 - 233.33
Jack mackerel	Western Chatham	9	4	44.4	0	0.00	0	0 - 2	3.23	0.76 - 9.31
Hake	Stewart-Snares	130	-	-	-	-	3	0 - 9	2.26	0.63 - 5.25
Scampi	Cook Strait	176	1	0.6	0	0.00	9	0 - 32	4.07	0.59 - 13.80
Hoki	Campbell Island	13	-	-	-	-	1	0 - 4	6.36	0.27 - 32.73
Ling	Cook Strait	3	-	-	-	-	0	0 - 1	2.12	0.15 - 7.33
Hoki	Auckland Islands	368	8	2.2	0	0.00	1	0 - 5	0.30	0.09 - 0.74
Squid	West coast SI.	59	-	-	-	-	4	0 - 14	5.28	1.51 - 13.00
Middle depth	Subantarctic	64	5	7.8	0	0.00	2	0 - 12	2.31	0.04 - 12.32
Hoki	Subantarctic	172	5	2.9	0	0.00	1	0 - 5	0.49	0.01 - 2.20
Ling	Bounty Islands	-	-	-	-	-	-	-	-	-
Ling	Auckland Islands	73	-	-	-	-	1	0 - 4	1.08	0.22 - 3.28
Jack mackerel	Stewart-Snares	53	8	15.1	0	0.00	1	0 - 4	1.86	0.51 - 4.68
Deepwater	Bounty Islands	349	83	23.8	0	0.00	1	0 - 4	0.17	0.00 - 0.74
Squid	Subantarctic	67	1	1.5	0	0.00	1	0 - 5	1.19	0.02 - 5.55
Ling	West coast NI.	9	-	-	-	-	0	0 - 2	1.55	0.24 - 4.97
Ling	Subantarctic	49	2	4.1	0	0.00	0	0 - 3	0.89	0.01 - 4.42
Hoki	Bounty Islands	-	-	-	-	-	-	-	-	-
Hake	Campbell Island	-	-	-	-	-	-	-	-	-
Deepwater	Western Chatham	1 343	122	9.1	0	0.00	0	0 - 1	0.00	0.00 - 0.01
Deepwater	Stewart-Snares	229	64	27.9	0	0.00	0	0 - 0	0.00	0.00 - 0.01
Deepwater	West coast SI.	460	52	11.3	0	0.00	0	0 - 0	0.00	0.00 - 0.02
Deepwater	West coast NI.	319	67	21.0	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table B-3: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area and target, for seven fishing years from 2002–03 to 2008–09. 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					Estimated			
		Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2003–04										
Hoki	Cook Strait	4 252	126	3.0	1	0.79	334	151 - 658	7.72	3.54 - 14.69
Hoki	West coast SI.	6 825	1 335	19.6	27	2.02	175	110 - 274	2.41	1.55 - 3.68
Hoki	Western Chatham	7 156	537	7.5	17	3.17	95	51 - 162	1.10	0.61 - 1.83
Middle depth	Western Chatham	1 699	11	0.6	0	0.00	34	11 - 74	2.03	0.89 - 4.17
Middle depth	Cook Strait	1 330	-	-	-	-	54	8 - 167	4.41	0.94 - 12.21
SBW	Bounty Islands	34	9	26.5	9	100.00	19	9 - 50	75.87	60.00 - 110.06
Middle depth	West coast SI.	1 538	3	0.2	0	0.00	34	7 - 97	2.24	0.72 - 5.68
Squid	Stewart-Snares	4 536	952	21.0	10	1.05	46	26 - 77	1.23	0.69 - 2.06
Hake	West coast SI.	608	53	8.7	0	0.00	13	4 - 27	2.29	1.23 - 4.12
Middle depth	Stewart-Snares	625	29	4.6	0	0.00	17	4 - 38	2.49	0.99 - 5.02
Squid	Western Chatham	581	3	0.5	0	0.00	13	3 - 33	2.24	0.92 - 4.75
SBW	Campbell Island	706	229	32.4	4	1.75	14	7 - 27	1.56	0.93 - 2.61
Hoki	Stewart-Snares	1 914	107	5.6	0	0.00	18	6 - 39	0.94	0.46 - 1.69
Ling	Puysegur	117	-	-	-	-	11	1 - 38	9.21	2.20 - 25.28
Hoki	Puysegur	146	32	21.9	3	9.38	7	3 - 19	5.53	3.25 - 10.20
Ling	Stewart-Snares	165	8	4.8	0	0.00	3	0 - 10	1.69	0.63 - 3.43
Jack mackerel	West coast NI.	2 252	140	6.2	0	0.00	10	2 - 23	0.51	0.20 - 1.06
Squid	Puysegur	251	-	-	-	-	9	1 - 27	3.56	1.26 - 8.09
Jack mackerel	West coast SI.	78	9	11.5	2	22.22	4	2 - 10	4.85	3.03 - 7.86
Deepwater	Subantarctic	1 092	209	19.1	2	0.96	6	2 - 15	0.63	0.23 - 1.50
Middle depth	West coast NI.	1 750	55	3.1	0	0.00	7	0 - 25	0.43	0.08 - 1.36
Squid	Auckland Islands	2 595	790	30.4	7	0.89	13	8 - 21	0.52	0.36 - 0.78
Ling	Western Chatham	23	-	-	-	-	1	0 - 5	3.72	0.86 - 9.63
Scampi	Auckland Islands	1 450	169	11.7	1	0.59	3	1 - 8	0.16	0.07 - 0.39
Ling	West coast SI.	48	-	-	-	-	1	0 - 6	3.29	0.75 - 8.44
Scampi	Western Chatham	623	205	32.9	0	0.00	2	0 - 7	0.34	0.08 - 0.87
Middle depth	Puysegur	122	27	22.1	0	0.00	1	0 - 6	1.33	0.37 - 3.19
Hake	Western Chatham	755	34	4.5	0	0.00	3	0 - 9	0.54	0.16 - 1.32
Ling	Campbell Island	25	3	12.0	0	0.00	6	0 - 36	21.61	0.78 - 105.51
Jack mackerel	Western Chatham	11	-	-	-	-	0	0 - 1	1.08	0.31 - 2.55
Hake	Stewart-Snares	166	53	31.9	0	0.00	2	0 - 8	1.25	0.31 - 3.12
Scampi	Cook Strait	37	-	-	-	-	0	0 - 1	0.40	0.06 - 1.36
Hoki	Campbell Island	66	-	-	-	-	4	0 - 24	3.84	0.30 - 17.41
Ling	Cook Strait	1	-	-	-	-	0	0 - 1	12.64	1.05 - 42.09
Hoki	Auckland Islands	731	123	16.8	1	0.81	2	1 - 6	0.21	0.08 - 0.50
Squid	West coast SI.	26	-	-	-	-	1	0 - 5	3.55	1.03 - 8.74
Middle depth	Subantarctic	66	8	12.1	0	0.00	1	0 - 8	1.88	0.02 - 9.64
Hoki	Subantarctic	375	28	7.5	0	0.00	1	0 - 9	0.35	0.01 - 1.79
Ling	Bounty Islands	-	-	-	-	-	-	-	-	-
Ling	Auckland Islands	30	-	-	-	-	0	0 - 1	0.27	0.04 - 0.88
Jack mackerel	Stewart-Snares	38	3	7.9	0	0.00	0	0 - 2	0.59	0.13 - 1.59
Deepwater	Bounty Islands	294	26	8.8	0	0.00	1	0 - 4	0.19	0.00 - 0.87
Squid	Subantarctic	334	17	5.1	0	0.00	1	0 - 5	0.29	0.00 - 1.46
Ling	West coast NI.	15	-	-	-	-	0	0 - 1	0.84	0.09 - 2.76
Ling	Subantarctic	98	11	11.2	0	0.00	0	0 - 2	0.28	0.00 - 1.51
Hoki	Bounty Islands	-	-	-	-	-	-	-	-	-
Hake	Campbell Island	-	-	-	-	-	-	-	-	-
Deepwater	Western Chatham	1 452	96	6.6	0	0.00	0	0 - 0	0.00	0.00 - 0.01
Deepwater	Stewart-Snares	336	74	22.0	0	0.00	0	0 - 0	0.00	0.00 - 0.02
Deepwater	West coast SI.	241	-	-	-	-	0	0 - 0	0.00	0.00 - 0.01
Deepwater	West coast NI.	353	144	40.8	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table B-3: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals in trawl fisheries, organised by area and target, for seven fishing years from 2002–03 to 2008–09. 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				Estimated			
		Tows	No. obs	% obs	Capt.	Rate	Est. captures		Est. rate	
2002–03										
Hoki	Cook Strait	4 174	137	3.3	4	2.92	237	104 - 455	5.68	2.65 - 10.71
Hoki	West coast SI.	7 854	922	11.7	18	1.95	156	97 - 247	1.78	1.13 - 2.71
Hoki	Western Chatham	9 886	856	8.7	13	1.52	93	51 - 154	0.81	0.48 - 1.33
Middle depth	Western Chatham	2 836	30	1.1	0	0.00	36	12 - 77	1.39	0.61 - 2.62
Middle depth	Cook Strait	1 131	1	0.1	0	0.00	37	7 - 98	3.73	0.97 - 9.58
SBW	Bounty Islands	24	-	-	-	-	6	0 - 26	26.14	7.60 - 63.68
Middle depth	West coast SI.	1 844	-	-	-	-	26	4 - 77	1.57	0.37 - 4.58
Squid	Stewart-Snares	3 286	505	15.4	7	1.39	24	13 - 41	1.10	0.74 - 1.74
Hake	West coast SI.	516	36	7.0	3	8.33	12	5 - 24	2.47	1.57 - 3.94
Middle depth	Stewart-Snares	985	138	14.0	1	0.72	18	6 - 39	1.64	0.75 - 3.21
Squid	Western Chatham	1 782	50	2.8	0	0.00	21	7 - 46	1.32	0.61 - 2.59
SBW	Campbell Island	606	269	44.4	8	2.97	13	8 - 21	2.14	1.59 - 3.02
Hoki	Stewart-Snares	2 425	423	17.4	2	0.47	14	6 - 30	0.58	0.30 - 1.04
Ling	Puysegur	76	-	-	-	-	3	0 - 15	4.68	0.27 - 14.93
Hoki	Puysegur	492	54	11.0	6	11.11	26	11 - 53	4.82	2.68 - 8.62
Ling	Stewart-Snares	140	-	-	-	-	3	0 - 8	1.52	0.58 - 3.20
Jack mackerel	West coast NI.	2 295	224	9.8	0	0.00	6	1 - 14	0.27	0.10 - 0.58
Squid	Puysegur	1 414	312	22.1	1	0.32	17	5 - 39	1.93	1.14 - 3.43
Jack mackerel	West coast SI.	383	46	12.0	0	0.00	9	1 - 24	2.59	0.93 - 5.91
Deepwater	Subantarctic	1 205	141	11.7	0	0.00	4	0 - 12	0.40	0.08 - 1.24
Middle depth	West coast NI.	1 762	72	4.1	0	0.00	6	0 - 20	0.37	0.06 - 1.16
Squid	Auckland Islands	1 466	416	28.4	0	0.00	2	0 - 5	0.13	0.05 - 0.25
Ling	Western Chatham	43	-	-	-	-	1	0 - 5	2.04	0.73 - 4.34
Scampi	Auckland Islands	1 396	150	10.7	0	0.00	1	0 - 5	0.09	0.02 - 0.28
Ling	West coast SI.	26	-	-	-	-	1	0 - 4	1.65	0.23 - 5.24
Scampi	Western Chatham	919	257	28.0	2	0.78	4	2 - 10	0.43	0.22 - 0.91
Middle depth	Puysegur	136	7	5.1	0	0.00	2	0 - 7	1.50	0.39 - 3.79
Hake	Western Chatham	135	8	5.9	0	0.00	1	0 - 6	0.76	0.26 - 1.75
Ling	Campbell Island	21	-	-	-	-	4	0 - 25	19.66	0.88 - 92.27
Jack mackerel	Western Chatham	159	32	20.1	1	3.12	2	1 - 5	1.22	0.53 - 2.58
Hake	Stewart-Snares	148	-	-	-	-	2	0 - 6	1.03	0.30 - 2.38
Scampi	Cook Strait	247	7	2.8	0	0.00	1	0 - 3	0.27	0.04 - 0.85
Hoki	Campbell Island	189	22	11.6	1	4.55	6	1 - 26	3.90	0.92 - 13.17
Ling	Cook Strait	-	-	-	-	-	-	-	-	-
Hoki	Auckland Islands	1 108	70	6.3	0	0.00	1	0 - 5	0.11	0.04 - 0.28
Squid	West coast SI.	96	-	-	-	-	1	0 - 3	0.99	0.27 - 2.31
Middle depth	Subantarctic	37	5	13.5	0	0.00	1	0 - 6	2.12	0.02 - 12.15
Hoki	Subantarctic	749	61	8.1	0	0.00	2	0 - 12	0.29	0.01 - 1.41
Ling	Bounty Islands	2	-	-	-	-	5	0 - 39	254.31	9.53 - 1221.25
Ling	Auckland Islands	27	-	-	-	-	0	0 - 1	0.15	0.03 - 0.46
Jack mackerel	Stewart-Snares	198	40	20.2	0	0.00	1	0 - 4	0.49	0.14 - 1.23
Deepwater	Bounty Islands	279	39	14.0	0	0.00	0	0 - 2	0.10	0.00 - 0.42
Squid	Subantarctic	237	20	8.4	0	0.00	0	0 - 2	0.15	0.00 - 0.72
Ling	West coast NI.	15	-	-	-	-	0	0 - 1	0.66	0.09 - 2.20
Ling	Subantarctic	180	16	8.9	0	0.00	0	0 - 2	0.14	0.00 - 0.67
Hoki	Bounty Islands	11	7	63.6	0	0.00	1	0 - 10	17.95	0.76 - 75.86
Hake	Campbell Island	-	-	-	-	-	-	-	-	-
Deepwater	Western Chatham	1 528	214	14.0	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	Stewart-Snares	581	30	5.2	0	0.00	0	0 - 0	0.00	0.00 - 0.01
Deepwater	West coast SI.	217	-	-	-	-	0	0 - 0	0.00	0.00 - 0.01
Deepwater	West coast NI.	293	127	43.3	0	0.00	0	0 - 0	0.00	0.00 - 0.00