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Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11

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Marine mammal species that are captured in New Zealand commercial trawl fisheries include common dolphin (*Delphinus delphis*), New Zealand fur seal (*Arctocephalus forsteri*), and New Zealand sea lion (*Phocarctos hookeri*). These incidental captures are recorded by fisheries observers when they are on-board vessels. For fisheries with sufficient observer coverage, these data, combined with fishing effort data, allow estimations of the total number of incidental captures via the development of statistical models. Here, we present estimates of the capture of common dolphin, New Zealand fur seal and New Zealand sea lion in New Zealand trawl fisheries, including the 2010–11 fishing year.

Common dolphin are frequently captured in the mackerel trawl fishery on the North Island west coast. In 2010–11, seven common dolphin were observed caught in six separate capture events in this fishery. Over the 16-year reporting period between 1995–96 and 2010–11, a total of 119 common dolphin were observed captured. A two-stage Bayesian hurdle model was built to estimate the total number of common dolphin captures and to identify covariates that were related to captures. The estimated total number of common dolphin captures in the most recent fishing year was 64 (95% c.i.: 26 to 116), more than twice the estimate of the previous year, 30 (95% c.i.: 7 to 68). The high capture estimate resulted from the influence of the observed event rate, which increased in the 2010–11 fishing year. Headline depth (distance of the headline below the surface) was confirmed as the covariate that best explained common dolphin captures, and this finding was supported by observer data, with the majority of observed captures occurring on tows with headline depths less than 40 m. The model results suggest that increasing headline depth by 21 m would halve the capture event probability.

Fur seal are captured in trawl fisheries encompassing a range of fishing areas and target species. In 2010–11, inshore fisheries were included in the fur seal bycatch assessment for the first time, following a recent increase in observer effort. In this fishing year, there were a total of 69 fur seal captures observed in trawl fisheries in New Zealand waters. In the 9-year period between 2002–03 and 2010–11, a total of 922 fur seal were recorded as bycatch by fisheries observers. The highest observed capture rate in 2010–11 was in southern blue whiting fisheries (8.33 fur seal captures per 100 tows), followed by ling fisheries (1.96 observed fur seal captures per 100 tows). The total number of estimated captures derived from Bayesian models was 376 (95% c.i.: 221 to 668) in the 2010–11 fishing year. This estimate is a decrease from the total 472 (95% c.i.: 269 to 914) estimated captures in 2009–10. The two covariates distance from shore and day of year were correlated with fur seal captures. The fur seal capture rate decreased with increasing distance from shore. At the same time, there was strong seasonal variation in fur seal captures, with a peak in August, and relatively high captures in July and September.

New Zealand sea lion have historically been frequently caught in the squid trawl fishery around Auckland Islands, and most observed sea lion captures between 1995–96 and 2010–11 have been in this fishery; however, in 2010–11, there were no observed captures in this fishery. In contrast, six male sea lion were observed captured in the Campbell Island southern blue whiting fishery, with one released alive and two caught in one net. Capture estimates for this fishing year revealed a total of 29 (95% c.i.: 17 to 43) sea lion captures in all trawl fisheries. This estimate is a decrease from 46 (95% c.i.: 32 to 66) captures in 2009–10.

Owing to the high number of incidental sea lion captures in the Auckland Islands squid fishery, this fishery uses sea lion exclusion devices (SLEDs) that are fitted to the trawl nets to allow sea lion to

escape the net. On tows using SLEDs, the number and fate of sea lion that may have escaped the net are unknown. To account for this uncertainty, the Auckland Islands squid fishery model includes an estimate of the retention probability of sea lion on tows with SLEDs. The retention probability is then used to estimate the number of interactions, that is, the number of sea lion that would have been caught had no SLEDs been used. As the SLED design changed during the reporting period, estimates of the retention probability were derived by combining two models that included either a single or a split SLED retention probability.

The resulting number of estimated interactions in 2010–11 was 56 (95% c.i.: 4 to 233), with a corresponding strike rate of 3.5 (95% c.i.: 0.4 to 14.9) sea lion interactions per 100 tows. Both estimates were lower than those in 2009–10, but the large variation around the mean values highlights the uncertainty associated with these estimates. In addition to the dataset becoming more biased toward tows that used SLEDs, the decrease in observed captures in recent years makes it increasingly difficult to estimate the number of interactions and strike rate in the Auckland Islands squid fishery.

1. INTRODUCTION

Interactions between commercial fishing operations and non-target species frequently result in the capture and mortality of marine animals, involving a variety of fisheries worldwide (Hall et al. 2000, Lewison et al. 2004). When this fishing-related mortality involves protected species in New Zealand waters, the Fisheries Act (1996) requires the Crown to take measures to "avoid, remedy, or mitigate any adverse effects of fishing". An integral part of these measures is the accurate assessment of the number of protected species inadvertently caught in commercial fisheries. The present report provides information on the incidental capture and mortality of marine mammals in relation to commercial fishing in New Zealand. It is part of project PRO2010/01A, which has the objective of "estimating the nature and extent of incidental captures of seabirds, marine mammals, and turtles in New Zealand commercial fisheries". This report provides data on total marine mammal captures in trawl fisheries where there has been sufficient observer coverage. Incidental captures of seabirds and turtles will be reported elsewhere.

Management strategies to assess and mitigate protected species bycatch include the systematic collection of at-sea mortality data by on-board observers, and statistical modelling to derive capture estimates for different species and fisheries (Babcock et al. 2003, Sims et al. 2008, Laneri et al. 2010). In New Zealand, government fisheries observers report any captures of marine mammals that occur while they are on-board fishing vessels. This independently collected information provides a basis for estimating total captures across all fishing effort. As observer effort varies depending on the fishing method and target fishery, however, total captures can only be reliably estimated for fisheries that have sufficient observer data. As a consequence, low numbers of observed captures do not necessarily imply low numbers of total captures. Trawl fisheries targeting inshore species in particular are characterised by high fishing effort with typically poor observer coverage, preventing reliable estimates of the total capture of marine mammals in these fisheries. Annual observer coverage in inshore trawl fisheries has been 0.8% or less before 2008–09, when it increased to 3.5%; in 2010–11, it was 1.3% (of a total of 34 935 tows).

In the 9-year period between 2002–03 and 2010–11, observed marine mammal bycatch in New Zealand commercial fisheries included a variety of species (see summary in Table 1). Incidental captures involved different pinnipeds such as New Zealand fur seal (*Arctocephalus forsteri*), New Zealand sea lion (*Phocarctos hookeri*), leopard seal (*Hydrurga leptonyx*), and southern elephant seal (*Mirounga leonina*), and also different cetacean species, such as common dolphin (*Delphinus delphis*), pilot whale (*Globicephala melas*), Hector's dolphin (*Cephalorhynchus hectori*), bottlenose dolphin (*Tursiops truncatus*), and dusky dolphin (*Lagenorhynchus obscurus*). There were also several observer records of unidentified species of seal, dolphin, and whale bycatch. The fisheries involved in these captures were trawl, surface and bottom longline, and set-net fisheries.

There were few observed captures of pilot whale, Hector's, bottlenose, and dusky dolphins between 2002–03 and 2010–11. In the recent fishing year, 2010–11, two dusky dolphin were observed caught in set nets off South Island's east coast, targeting moki and school shark, respectively. Hector's dolphin have also been observed caught in set nets in the past, and have also previously been reported as bycatch in trawl fisheries (Baird & Bradford 2000). The incidental captures of endemic Hector's dolphin are of concern, as this species is endangered, with a small population size that is considered to be decreasing (Currey et al. 2012). Hector's dolphin have a coastal distribution, which makes them vulnerable to inshore fisheries, including trawling given the high fishing effort involved. At the same time, low observer coverage in these fisheries precludes reliable estimates of total Hector's dolphin captures.

The most frequently observed marine mammal captures between 2002–03 and 2010–11 were of New Zealand fur seal, New Zealand sea lion, and common dolphin. Most of the observed captures involved trawl fisheries, with all sea lion and common dolphin captures occurring in these fisheries. New Zealand fur seal captures were also observed in surface longlines, with occasional captures in set-net and bottom-longline fisheries. In the recent fishing year, there were nine common dolphin mortalities in trawl fisheries, with seven observed captures in the mackerel trawl fishery on North Island's west coast. Two other common dolphin captures were observed in trawl fisheries targeting gurnard off the east coast of North Island, and targeting barracouta off the east coast of South Island.

Recently observed fur seal captures were in trawl, surface-longline, and set-net fisheries, with a total of 87 observed captures in 2010–11. Sixty-eight of these captures resulted in mortality. The majority of fur seal captures occurred in different trawl fisheries, with the subantarctic southern blue whiting and the Cook Strait hoki fisheries accounting for 36 and 18 captures, respectively. Four fur seal caught in trawls were released alive. One fur seal was observed caught (and killed) in a set net targeting bluenose, with 17 observed fur seal captures in surface longline fisheries targeting southern bluefin tuna in Fiordland, on North Island's east coast, and in Northland waters. Two of the surface-longline captures were mortalities, with 15 fur seal released alive. All six observed sea lion captures in 2010–11 were in the southern blue whiting fishery around Campbell Island, including one sea lion that was released alive.

Incidental captures of common dolphin, New Zealand fur seal, and New Zealand sea lion are observed sufficiently frequent in commercial trawl fisheries to allow estimations of the total number of individuals bycaught in New Zealand waters. These estimates are presented here for each of the three species for the 2010–11 fishing year. The impact of these captures on the respective marine mammal populations was not considered.

Common dolphin have a global distribution in warm-temperate and tropical regions, where they are commonly abundant in coastal and oceanic waters (Perrin 2009). This species often forms large aggregations (up to several hundred individuals), including multi-species associations with other cetaceans, such as pilot whale *Globicephala* sp., bottlenose dolphin *Tursiops truncatus* and striped dolphin *Stenella coeruleoalba* (Frantzis & Herzing 2002, Currey et al. 2008, Stockin et al. 2008).

In New Zealand waters, common dolphin are found around North and South islands (Brager & Schneider 1998) with a number of recent studies focused on northern populations in Bay of Islands and Hauraki Gulf (Neumann et al. 2002, Meynier et al. 2008, Stockin & Orams 2009). Generally considered a mesopelagic species, common dolphin are usually found in deeper waters, with New Zealand populations exhibiting some inshore-offshore movements (Neumann 2001, Meynier et al. 2008). In addition, small groups of common dolphin are present year-round in shallow waters (less than 20 m depth) in Hauraki Gulf (Stockin et al. 2008). The conservation status of common dolphin in New Zealand is "not threatened" (Baker et al. 2010), although regional abundance and distributional data are limited for this region (Brager & Schneider 1998, Stockin et al. 2008).

Common dolphin feed predominantly on meso- and epi-pelagic fishes and squids (Evans 1994, Rossman 2010). In New Zealand waters, the diet of common dolphin largely consists of jack mackerel (*Trachurus* spp.), anchovy (*Engraulis australis*), and arrow squid (*Nototodarus* spp.)(Meynier et al. 2008). Their prey preference makes common dolphin susceptible to trawl fisheries targeting the same species (Morizur et al. 1999). In New Zealand, common dolphin are frequently caught in trawl fisheries targeting mackerel, and total common dolphin captures in these fisheries have been estimated in previous studies (Thompson & Abraham 2009a, Thompson et al. 2010a, 2011). In the 2009–10 fishing year, there were an estimated 30 (95% c.i.: 7 to 68) common dolphin captures in this fishery (Thompson et al. 2011).

Fur seal are widely distributed in New Zealand and southern Australia, where populations have recovered after exploitation close to extinction in the late eighteenth and early nineteenth centuries (Harcourt 2001). In New Zealand, this species inhabits rocky coastlines of North and South islands and subantarctic islands, with breeding colonies extending from mostly southern locations to northern areas (Lalas & Bradshaw 2001). The population trend for fur seal is considered to be increasing, with an overall

Table 1: All marine mammal captures reported by fishery observers in New Zealand waters, during the 9-year period from 2002–03 to 2010–11. For each fishing year, the total number of observed captures is presented for each species and for each fishing method that had observed captures. The captures include animals that were released alive.

Fishing year	Method	New Zealand fur seal	New Zealand sea lion	Elephant seal	Leopard seal	Unidentified seal	Common dolphin	Pilot whale	Hector's dolphin	Bottlenose dolphin	Dusky dolphin	Unidentified dolphin	Unidentified whale
2002–03	Trawl	68	12	1	-	-	21	-	-	-	-	-	-
	Surface longline	56	-	-	-	-	-	-	-	-	-	1	-
	Bottom longline	1	-	-	-	-	-	2	-	-	-	-	-
2003–04	Trawl	84	21	-	-	-	17	-	-	-	-	-	-
	Surface longline	40	-	-	-	-	-	2	-	-	-	-	2
2004–05	Trawl	200	14	-	1	-	22	6	-	-	-	-	-
	Surface longline	20	-	-	-	-	-	-	-	-	-	-	1
2005–06	Trawl	143	15	-	-	-	4	-	-	-	1	-	-
	Surface longline	12	-	-	-	-	-	-	-	-	-	-	-
	Bottom longline	1	-	-	-	-	-	-	-	-	-	-	-
2006–07	Trawl	73	12	-	-	-	11	-	-	-	-	-	-
	Surface longline	10	-	-	-	-	-	-	-	-	-	-	-
2007–08	Trawl	141	11	-	-	-	20	-	-	1	-	-	-
	Surface longline	10	-	-	-	-	-	-	-	-	-	-	1
	Setnet	1	-	-	-	-	-	1	1	-	-	-	-
2008–09	Trawl	72	3	-	-	1	20	2	-	-	-	-	-
	Surface longline	22	-	-	-	-	-	-	-	-	-	-	-
	Setnet	1	-	-	-	-	-	-	1	-	-	-	-
2009–10	Trawl	72	15	-	-	-	4	-	-	-	-	-	-
	Surface longline	19	-	-	-	-	-	-	-	-	-	-	-
	Setnet	5	-	-	-	-	-	-	2	-	2	-	-
2010–11	Trawl	69	6	-	-	-	9	-	-	-	-	-	-
	Surface longline	17	-	-	-	-	-	-	-	-	-	-	-
	Setnet	1	-	-	-	-	-	-	-	-	2	-	-

population estimate of approximately 200 000 individuals in Australia and New Zealand (Goldsworthy & Gales 2008). The size of the New Zealand population is unknown as there has been no recent (within the past 30 years) national census, and current population data are scarce (Baird 2011).

Fur seal feed on a variety of prey species, predominantly cephalopods and fishes, including arrow squids (*Nototodarus* spp.), octopus, a variety of lanternfishes (myctophids), hoki (*Macruronus novaezelandiae*), and jack mackerel (*Trachurus* spp.)(Boren 2010, Harcourt 2001). The diversity of their diet reflects their foraging behaviour, as fur seal feed in inshore, continental shelf and oceanic waters, and at the surface to over 300 m water depth (Goldsworthy et al. 2003). Females stay close to breeding sites during summer following pupping, when their foraging does not greatly extend beyond the continental shelf; in autumn and winter, they forage at a greater distance from breeding colonies and in deeper waters (Harcourt

2001).

Previous reports of fur seal bycatch in New Zealand trawl fisheries included model-based estimates for the period between 1994–95 and 2005–06 (Smith & Baird 2009), and more recently, for the periods between 2002–03 and 2007–08, 2008–09, and 2009–10, respectively (Thompson & Abraham 2010, Thompson et al. 2010b, 2011). Fur seal were predominantly caught by trawlers targeting hoki, and southern blue whiting (*Micromesistius australis*). In the 2009–10 fishing year, there were 72 observed fur seal captures, with an estimated 472 (95% c.i.: 269 to 914) total captures (Thompson et al. 2011).

New Zealand sea lion are the only pinniped endemic to New Zealand, and have a relatively small population size (approximately 11 000 to 13 000 individuals)(Childerhouse & Gales 1998, Gales 2008, Ministry of Agriculture and Forestry 2011). This species' distribution and population size were heavily reduced by commercial sealers in the nineteenth century, and its current distribution is centred on New Zealand's subantarctic islands (Department of Conservation 2009). Apart from a small population that is re-colonising and breeding on Otago Peninsula in South Island, the main sea lion breeding colonies are on Auckland and Campbell islands, with 71 to 87% of pup production occurring on the former island group (McConkey et al. 2002, Lalas & Bradshaw 2003, Ministry of Agriculture and Forestry 2011, Robertson & Chilvers 2011). In recent years, there has been concern about the continued decline in pup production on Auckland Islands (40% since 1998), which has been attributed to high (pup) mortality caused by bacterial disease outbreaks, and the failure of philopatric females to return to breeding areas (Robertson & Chilvers 2011). Although quantitative data are lacking, the failure of females to return to breeding grounds has been attributed to direct fishing mortality or indirect effects of fishing (Robertson & Chilvers 2011). The indirect effects of squid fishing on the Auckland Islands sea lion population were examined in a subsequent literature review (Bowen 2012). This review found no evidence to suggest that competition for food with the squid fishery in that area adversely impacts sea lion, and the reasons for the declining population at Auckland Islands remain unclear. Based on the declining population, New Zealand sea lion are assessed as "nationally critical", and are classified as "vulnerable" by the International Union for Conservation of Nature (Gales 2008, Baker et al. 2010).

Sea lion are considered generalist predators and predominantly benthic feeders, with their diet consisting of a variety of benthic and pelagic species, including vertebrates and invertebrates, such as hoki, opalfish, rattails, and octopus and squids (Gales 2008, Meynier et al. 2010).

The distribution of sea lion overlaps with that of trawl fisheries around the subantarctic islands, which has led to the incidental capture of sea lion by commercial trawlers, in particular in the squid fishery near Auckland Islands and the southern blue whiting fishery near Campbell Island (Thompson & Abraham 2011, Thompson et al. 2011). The majority of observed sea lion captures have been in the Auckland Islands squid fishery (within management area SQU6T), prompting a number of management strategies aimed at reducing the impact of incidental sea lion captures in this fishery. These management measures include the modification of trawl nets to allow sea lion to escape from the net, the sea lion exclusion device (SLED)(Figure 1). The SLED is a mid-section of netting fitted to the trawl net that includes a metal grid with an opening (escape hole) above it. The grid guides sea lion to the escape hole, enabling them to exit the net. A forward-facing hood above the escape hole, held open by floats and a strip of material known as kite, is designed so that only actively swimming sea lion escape the net. The SLED can be closed by fitting a cover net over the escape hole.

SLEDs were first introduced in 2001, and since 2004–05, the majority of tows in this fishery have involved SLEDs that are audited and approved by the Ministry for Primary Industries. Although SLEDs are designed to allow the escape of sea lion, some animals may still get captured. The number and fate of animals that escape the net via SLEDs are unknown.

Another management measure used in the Auckland Islands squid fishery is the setting of tow limits based on the number of sea lion that may be killed without compromising the population (the Fishing Related Mortality Limit or FRML) and a strike rate (a measure of the number of sea lion killed per tow).

This report presents the most recent data on marine mammal bycatch in commercial trawl fisheries in New Zealand, including the 2010–11 fishing year. It updates existing information regarding the bycatch of common dolphin (Thompson & Abraham 2009a, Thompson et al. 2010a, 2011), fur seal (Thompson & Abraham 2010, Thompson et al. 2010b, 2011), and New Zealand sea lion (Thompson & Abraham 2009b, 2011, Thompson et al. 2010c, 2011), including model-based statistical estimates derived from observer data.

As the development of these statistical models is dependent on sufficient observer data, this report focuses on trawl fisheries targeting pelagic, middle-depth and deepwater species, which have had sufficient observer coverage. Owing to the recent increase in observer coverage, trawl fisheries targeting inshore species (excluding flatfish) were also included for the first time.

Fur seal captures were estimated over the period 2002–03 to 2010–11, whereas sea lion and common dolphin captures were estimated over a longer period, 1995–96 to 2010–11. This longer period allowed the model to better reflect changes in the fisheries that have affected the capture rates. The period covered in this report included the periods previously used for estimations (Thompson & Abraham 2010, 2011, Thompson et al. 2010a, 2011). As data have been updated and all models were re-run, the previous reports are superseded. Any comparison across fishing years should be made using the current report.

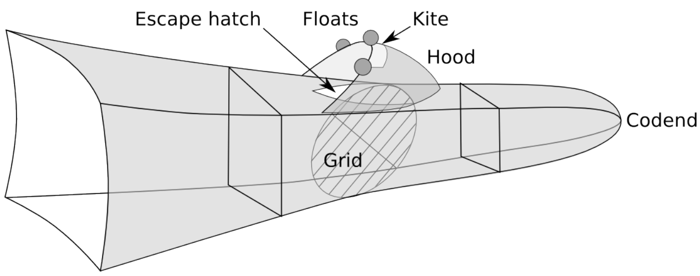


Figure 1: Schematic diagram of a sea lion exclusion device (SLED) used in the Auckland Islands squid fishery. The SLED consists of a mid-section of netting with a metal grid and an opening (escape hole) above it. The grid directs sea lion to the escape hole, enabling them to exit the net. The forward-facing hood above the escape hole is designed so that only actively swimming sea lion escape the net. The hood is held open by floats, and a strip of material known as a kite. A cover net may be fitted over the escape hole to close the SLED.

2. METHODS

2.1 Data sources

This reports presents estimates of incidental captures of marine mammals in commercial trawl fisheries within the outer boundary of New Zealand's Exclusive Economic Zone (EEZ). Estimates were derived for common dolphin, fur seal, and New Zealand sea lion captures using statistical models based on fishing effort and observer data. Fishing data were obtained from records of trawler activity reported by commercial fishers on Trawl Catch Effort Processing Return (TCEPR), Trawl Catch Effort Return (TCER), or Catch Effort Landing Return (CELR) forms. Information recorded on these forms includes the date and time of trawl effort, the position of the start and end of each tow, the target species, catch weight, and details of the fishing gear used. These data were assumed to include a complete record of the trawl effort, and were used as the authoritative source for tow time and location information required for modelling.

Incidental captures of protected species are recorded by New Zealand's Ministry for Primary Industries and Department of Conservation observers on-board commercial fishing vessels. Observer data include the identity of the species captured, and the time and location of the captures and of every observed tow. These data are entered into a database administered by National Institute of Water and Atmospheric Research (NIWA) on behalf of Ministry for Primary Industries. Observer data used for building the models encompassed a 9-year period for fur seal, and a 16-year period for common dolphin and sea lion (see summary of model data sets in Figure 2).

Both fishing effort and observer records were groomed and linked, correcting for errors in date, time, and position fields. The observer data were groomed by NIWA, and did not require further grooming. The existing grooming rules were applied (Abraham & Thompson 2011), but did not result in any updates. The preparation of fisher-reported data was updated from that used previously (Thompson & Abraham 2010, 2011, Thompson et al. 2010a, 2011, Abraham & Thompson 2011), with the most important change concerning the handling of missing values. On some forms, the fisher had entered some data for the first row, only entering data on subsequent rows when the data changed. In these cases, the missing fields were imputed by considering the data in the first row. This imputation primarily affected the statistical area code, but also data describing fishing effort, such as the height of trawl nets used in the common dolphin capture model. Over the reporting period, less than 6% of all trawl records (excluding those targeting flatfish) were affected in each year since 1998–99, with 1.7% of records in 2010–11 having missing values imputed.

Missing or improbable values for target species, effort number, and primary fishing method were imputed by comparing records in the same area, around the same time, and by the same vessel, or vessels in the same size class. A total of 0.072% of trawl records had the target species imputed, and 0.121% of records in the 2010–11 fishing year. Similarly, 0.004% of records had an imputed effort number, and 0.001% of records had an imputed primary fishing method.

Observer records were linked to the fisher-reported effort data by comparing the start and end times, location, and target species for each vessel. There were a number of inconsistencies associated with fishing effort data reported on electronic devices, which were introduced in 2008–09 for observing inshore fisheries. As the observer data are only used to link captures to the fisher-reported effort, only the capture information was used from these electronic records.

For the linking of observer records to the fisher-reported effort data, improvements were made to the linking algorithm, so that more of the observed fur seal captures were included in the modelling. The main improvement concerned the linking of observed tows on trips reported on the older CELR forms, in particular in the 2005–06 fishing year. The improvements resulted in the linking of 99% of all observed trawl effort since the 2000–01 fishing year, with over 99% of the observed trawl records in 2010–11 being linked. Observer effort that was not linked was not included in the capture models. None of the marine mammal captures were excluded because they were on unlinked tows.

Position information was discarded if it reported fishing events on land, or at improbably far distances. Fishing effort recorded on older CELR form did not report latitude and longitude, and these forms were phased out from 2007–08. Trawl effort data with missing latitude and longitude were updated by imputing information from linked observer records, or by sampling from similar effort by the same vessel, in the same statistical area, targeting the same species, in the same year. The rules for imputing the data were successively relaxed to allow all the trawl events to be located. Approximately 12% of all records had imputed position information in this way, which included only a small proportion, approximately 0.1%, since the 2007–08 fishing year. Covariates used in the models were derived from the fisher-reported data in the linked records. Using fisher-reported data ensured consistency between data used for building the models, and those used for making the estimations.

Trawl fishing events were assigned to fisheries on a tow-by-tow basis using the target species code reported by the fisher (following Abraham & Thompson 2011). Single species fisheries included trawls targeting squid, hoki, hake, ling, southern blue whiting, and scampi (a small number of tows targeting prawn killer were included with the scampi fishery). Deepwater trawling was defined as fishing targeting orange roughy, oreos, cardinal fish, or Patagonian toothfish. Mackerel trawling included tows targeting jack or blue mackerel. Middle-depth trawling was defined as tows targeting barracouta, ribaldo, rubyfish, alfonsino, bluenose, frostfish, ghost shark, gemfish, spiny dogfish, sea perch, or warehou. Inshore trawling encompassed all tows targeting inshore fish species (excepting flatfish), including tarakihi, snapper, gurnard, red cod, trevally, John dory, giant stargazer, elephantfish, leatherjacket, school shark, blue moki, blue cod, rig, and hapuku.

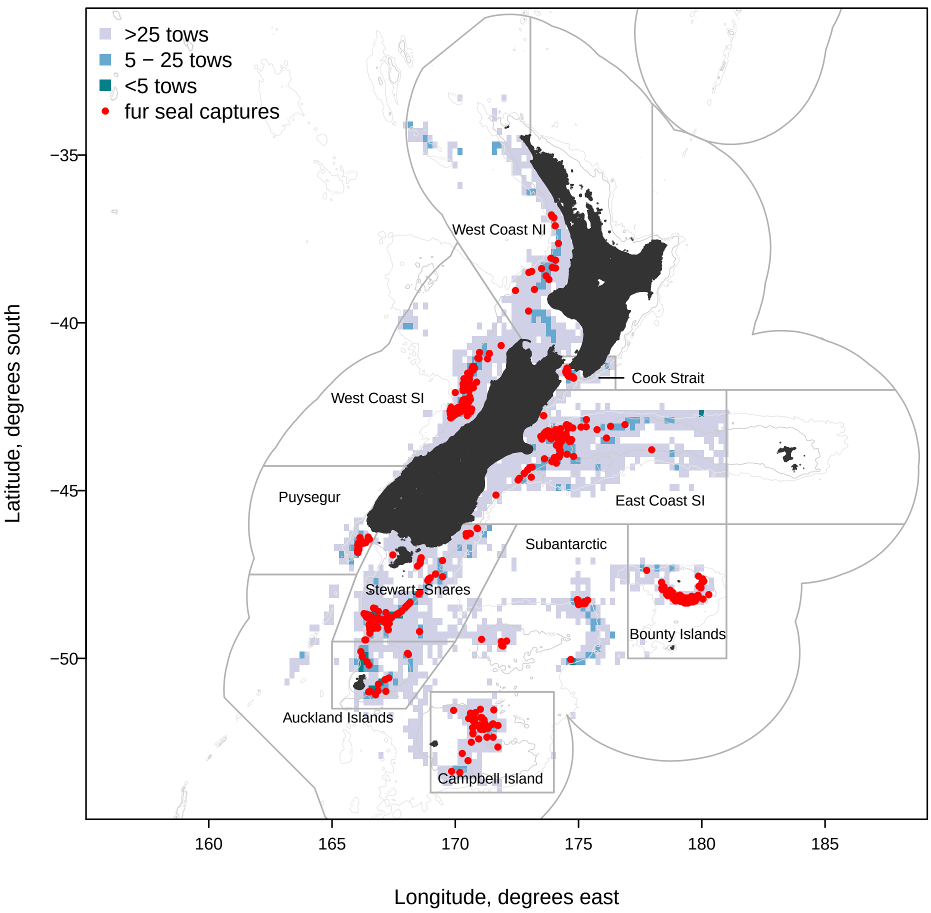
Fishing effort targeting unusual species (targeted on fewer than 100 tows) was assigned a fishery based either on the closest defined fishery targeted by the same vessel, or else was imputed from other fishing within the same area.

Methods and results are presented in separate sub-sections for common dolphin, fur seal, and New Zealand sea lion. As the fishing year in New Zealand runs from 1 October to 30 September, data analysis and presentation follow this format, with the most recent data encompassing the 2010–11 fishing year. The only exception is the subantarctic southern blue whiting fishery, east of Campbell Island. As this fishery extends past the end of the standard fishing year with most trawl effort occurring between August and November, data from this fishery are presented by calendar year. Estimates of fur seal captures included the period from 2002–03 to 2010–11, while estimates of common dolphin and sea lion captures covered the period between 1995–96 and 2010–11.

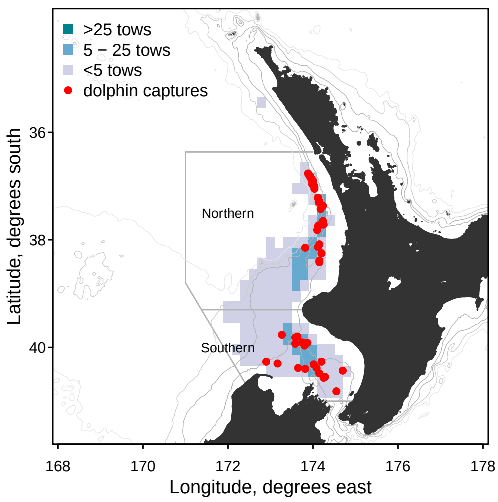
2.2 Marine mammal capture models

The statistical models developed to estimate total captures of each marine mammal species were Bayesian models, with ratio estimates used to estimate sea lion captures for some of the trawl fisheries. The models were coded in the BUGS language (Spiegelhalter et al. 2003), a domain-specific language for describing Bayesian models. Each model was fitted with the software package JAGS (Plummer 2005), using Monte Carlo Markov chains (MCMCs). To ensure that the models had converged, an initial burn-in of 10 000 iterations was conducted for common dolphin and fur seal models, with 50 000 iterations for the sea lion model. Subsequently, each model was run for another 40 000 iterations with every twentieth iteration retained. Two chains were fitted to each model, and the output included 2000 samples of the

(a) Observed fur seal captures



(b) Observed dolphin captures



(c) Observed sea lion captures

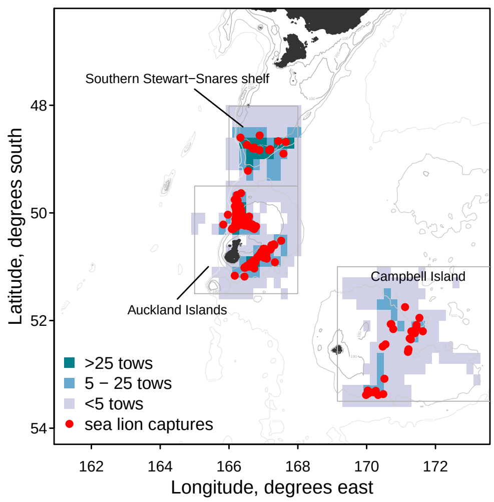


Figure 2: Maps of model data sets, including the areas used for defining the models. The model data sets encompassed nine fishing years for fur seal, from 2002–03 to 2010–11, and 16 fishing years for common dolphin and sea lion, from 1995–96 to 2010–11. Observed captures are indicated with red dots. The average annual observed fishing effort within 0.2° square cells is indicated with blue shades.

posterior distribution from each chain. Model convergence was assessed with diagnostics provided by the CODA package for the R statistical system (Plummer et al. 2006) including the criteria of Heidelberger & Welch (1983) and Geweke (1992).

2.3 Common dolphin capture model

The statistical model built to estimate the total number of common dolphin captures was a two-stage Bayesian model that separately predicted the probability of capture events occurring and the number of captures on each capture event. Models of this kind are called hurdle models (Mullahy 1986, Ridout et al. 1998), and are appropriate when different processes are influencing the occurrence of captures and the number of animals caught on each capture event. In the first stage, a logistic generalised linear model estimated the probability of capturing common dolphin on a given tow as a linear function of a number of covariates. Given that there was a capture event, the number of captures was then estimated in the second stage by sampling from a zero-truncated Poisson distribution. In addition to estimating total captures, the model explored which covariates are related to dolphin captures in the examined fishery. This modelling approach was previously applied to the jack mackerel fishery on North Island's west coast between 1995–96 and 2009–10, as common dolphin captures were observed sufficiently frequent in this fishery to allow development of the model (Thompson & Abraham 2009a, Thompson et al. 2010a, 2011). Here, the model was updated to include data from the mackerel fishery from the 2010–11 fishing year, encompassing the 16-year period between 1 October 1995 and 30 September 2011.

Data for modelling and analysis were from an area on the North Island west coast that included the region where common dolphin captures have been observed in the mackerel fishery. This area was enclosed by a line extending north along longitude 173°2.8′ E, a line across Cook Strait at latitude 41° S, boundary at 171° E, and the boundary of New Zealand's EEZ (Figure 2(b)). For higher spatial resolution, the area was divided into northern and southern sub-areas by a line at latitude 39°18′ S.

The statistical model estimated the probability, π_i, of capturing dolphins on a tow, i. A year effect, λ_j was estimated for each year, j, allowing for annual variation in the capture event rates that was unrelated to the covariates, x_{ic}. The contribution of each covariate, indexed by c, was governed by a regression coefficient, β_c, that was estimated by the model. The logit transform of the capture event probability was defined as the sum of the year effect, $\lambda_{j[i]}$, and the covariates:

$$\operatorname{logit}(\pi_i) = \lambda_{j[i]} + \sum_c \beta_c x_{ic}. \tag{1}$$

Diffuse normal priors were given to the regression coefficients, β_c, and to the mean of the year effects, λ_j. A half-Cauchy prior, with a scale of 25, was given to the variance of the year effects.

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

$$\Pr(y_i = y) = \begin{cases} (1-\pi_i) & \text{if} \quad y = 0 \\ \pi_i \frac{e^{-\mu}\mu^y}{(1-e^{-\mu})y!} & \text{if} \quad y > 0. \end{cases}$$

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

Estimates were prepared for groups of trawls, grouped by fishing year, y, and vessel, v. The estimated total number of dolphins captured in a group, D^t_{yv}, was calculated as the sum of actual reported captures on observed tows, d^o_{yv}, and estimated captures on the unobserved tows, D^e_{yv},

$$D^t_{yv} = d^o_{yv} + D^e_{yv}. \tag{2}$$

Total captures in a year were obtained by summing the captures over all vessels fishing in that year, $D^t_y = \sum_v D^t_{yv}$.

The model structure allowed for the dolphin capture event probability to depend on covariates. The same covariates used in previous common dolphin reports (Thompson & Abraham 2009a, Thompson et al. 2010a) were used in this report, and included trawl duration, headline depth, sub-area, and light condition (see definitions in Table 2).

2.4 Fur seal capture model

A Bayesian capture model was developed to predict fur seal captures in commercial trawl fisheries. The same modelling approach was previously used to estimate annual fur seal bycatch for fishing periods from 2002–03 to 2007–08, 2008–09, and 2009–10, respectively (Thompson & Abraham 2010, Thompson et al. 2010b, 2011). In this report, parameters from the fitted model were used to update fur seal capture estimates across commercial trawl effort, including vessels targeting inshore fish species (excluding flatfish), for the 9-year period from 1 October 2002 to 30 September 2011.

As the number of observed tows greatly exceeded the number of tows that could be easily fitted by the model, trawl events were aggregated to reduce the computational load. The grouping was similar to methods used by Manly et al. (2002). Tow groups were defined as trawls by the same vessel, in the same statistical area, fishing for species in the same target fishery, observed or unobserved, and in the same calendar month. The aggregation of trawl events into groups reduced the accuracy of representation of some covariates, but allowed the simultaneous fitting of all trawl data from New Zealand's EEZ between 2002–03 and 2010–11 by the model using Bayesian methods.

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

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

where n_i is the number of tows in a trawl group. The shape parameter, θ, allows for extra dispersion in the number of captures, relative to a Poisson distribution. The 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 capture 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,

$$\begin{aligned} \mu_i &= \lambda_{y_i} \nu_{v_i y_i} \exp\left(\sum_c \beta_c x^c_i\right), && (4) \\ \log(\lambda_{y_i}) &\sim \text{Normal}(\mu = \mu_\lambda,\ \sigma = \sigma_\lambda), && (5) \\ \nu_{v_i y_i} &\sim \text{Gamma}(\text{shape} = \theta_\nu,\ \text{rate} = \theta_\nu). && (6) \end{aligned}$$

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

Table 2: Covariates included in the common dolphin capture model.

Covariate	Description
Trawl duration	Duration of trawls in hours from start and end times recorded on TCEPR forms.
Headline depth	Depth in metres of the top of the net, derived by subtracting the headline height from the ground line depth (both recorded on TCEPR forms). Indicates the depth of the top of the net.
Sub-area	The west coast North Island region, divided into two sub-areas (north and south of 39°18′ S) that were included as a factor variable.
Light condition	Three-level factor characterising the time of the haul and the phase of the moon: light (net hauled between dawn and dusk, or between dusk and midnight on a moonlit night), dark (net hauled between dusk and midnight on a dark night, or between midnight and dawn on a moonlit night), and black (net hauled between midnight and dawn on a dark night). The illumination of the moon and time of dawn and dusk were calculated using algorithms from Meeus (1991). Night was classified as moonlit if more than 17% of the moon's disc was illuminated. Dawn and dusk were defined as when the centre of the sun's disk was 6° below the horizon (civil dawn and dusk).

shape and rate θ_v. 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:

$$\log(\mu_\lambda) \sim \text{Mean}(\mu = \bar{y}_i, \sigma = 100), \tag{7}$$

$$\sigma_\lambda \sim \text{Half-Cauchy}(25), \tag{8}$$

$$\theta \sim \text{Uniform-shrinkage}(\bar{y}_i), \tag{9}$$

$$\theta_v \sim \text{Uniform-shrinkage}(\bar{y_{v_i}}), \tag{10}$$

$$\beta_c \sim \text{Normal}(\mu = 0, \sigma = 100). \tag{11}$$

The same covariates selected in previous modelling of fur seal captures (Thompson & Abraham 2010, Thompson et al. 2010b, 2011) were used in the current report, and included fishing area, target fishery, day of year, and distance from shore (see definitions in Table 3). Fishing area was used to provide higher spatial resolution within New Zealand's entire EEZ. The latter was divided into 13 fishing areas, using the same areas as those defined by Thompson & Abraham (2010). Fur seal captures were observed in ten of the fishing areas, which were included in the analysis (see Figure 2(a)). Tows in the three fishing areas in which no fur seal captures were observed, north and east of North Island, and around Chatham Islands were excluded from the model, based on the assumption that there were no captures by the unobserved effort in these fishing areas.

The definition of target fishery was the same as those applied previously (Thompson & Abraham 2010, Thompson et al. 2011), with tows targeting hoki, hake, and ling combined into one group during the modelling (estimated captures are reported separately for each of these target species). Included for the first time in the modelling were tows targeting inshore species, excluding flatfish targets. Low observer effort in the past prevented the inclusion of inshore target fisheries in previous bycatch assessments. An increase in observer effort in recent years allowed for the inshore trawl fisheries (excluding flatfish targets) to be included in the present estimation.

The covariate distance from shore was correlated with fur seal captures in some areas in previous analyses Mormede et al. (2008), Smith & Baird (2009), and was included in the present model. The New Zealand coastline was obtained from the GSHHS database (Wessel & Smith 1996), and distance from shore was calculated using functions from PostGIS (http://postgis.refractions.net/). Islands with an area of less than 0.25 km^2 were excluded from the calculations of distance from shore. To account for seasonal variation, day of year was included as a covariate in the model.

A single area–target interaction term was included in the model, following Thompson & Abraham (2010), for the subantarctic area and the deepwater target group. The inclusion of this single interaction term allowed the model to accurately fit the observed captures within each area and by each target fishery.

2.5 Sea lion capture models and ratio estimates

New Zealand sea lion captures in trawl fisheries around the subantarctic islands were estimated using Bayesian generalised linear models and ratio estimation, closely following methods applied previously to estimate sea lion captures in the 1995–96 to 2007–08, 2008–09, and 2009–10 fishing years, respectively (Thompson & Abraham 2011, Thompson et al. 2010c, 2011). Here, the present estimates were updated by including data from the 2010–11 fishing year, presenting capture estimates over the 16-year period between 1 October 1995 and 30 September 2011.

Data from the subantarctic trawl fisheries were organised into five separate strata: the squid fishery near Auckland Islands, the southern blue whiting fishery near Campbell Island, the scampi fishery near Auckland Islands, other (non-squid) fisheries near Auckland Islands, and all trawl fisheries on the southern end of the Stewart-Snares shelf (Figure 2(c)). This data organisation was necessitated by differences in observer coverage and number of observed captures, which demanded independent estimation methods for each stratum (Table 4).

For the Auckland Islands squid fishery, observer and capture data supported the development of a generalised linear Bayesian model, with a simpler model applied to data from the Campbell Island southern blue whiting fishery. The other three strata involved fisheries with lower observer coverage and sporadic records of sea lion captures, so that capture estimates for the non-squid Auckland Islands fisheries (scampi, other non-squid targets) and the Stewart-Snares shelf fishery were derived using ratio estimation. The latter estimation method was based on the assumptions that observer effort was representative and that strata were homogeneous. A single total estimate was calculated by combining the output from all strata.

2.6 Terminology for the Auckland Islands squid fishery

Owing to the number of sea lion incidentally taken by trawlers targeting squid near Auckland Islands, management of this fishery has included usage of SLEDs as a bycatch mitigation method, and the application of a FRML (Breen et al. 2003). As a consequence, sea lion capture estimates for this fishery involve terms that do not apply to other subantarctic trawl fisheries (see full terminology in Table 5, Figure 3).

SLEDs were first introduced in 2001, and since 2004–05, the majority of tows in the Auckland Islands squid fishery have involved SLEDs that have been audited and approved by Ministry for Primary Industries. Since their introduction, the design of SLEDs has undergone some modifications, including

Table 3: Covariates included in the step analysis of the fur seal capture model.

Fishing area	New Zealand's EEZ was divided into 13 fishing areas. Ten areas in which fur seal captures had been observed were included in the model data set (as in previous analysis, Thompson & Abraham (2010), Thompson et al. (2011)).
Target fishery	Defined by individual target species and species groups: hoki, hake, ling; southern blue whiting; squid; jack (and blue) mackerel; scampi; middle-depth species (barracouta, ribaldo, rubyfish, alfonsino, bluenose, frostfish, ghost shark, gemfish, spiny dogfish, sea perch, and warehou); deepwater species (orange roughy, oreos, and cardinalfish); inshore species (tarakihi, snapper, gurnard, red cod, trevally, John dory, giant stargazer, elephantfish, leatherjacket, school shark, blue moki, blue cod, rig, hapuku).
Day of year	Calculated from the mean day of the year of the tows in a group, and used to account for any seasonal variation. Harmonic functions were used to ensure that the seasonal effects were truly periodic.
Distance from shore	Four level factor calculated using the distance from shore: coastal ($\leq$ 25 km), near (between 25 km and 90 km), far (between 90 km and 180 km), and ocean ($>$ 180 km)(see map in Thompson & Abraham (2010)).

Table 4: Strata used for estimating sea lion captures.

Stratum		Estimation method
Area	Fisheries	
Auckland Islands	Squid trawl	Bayesian model
Campbell Island	Southern blue whiting trawl	Bayesian model
Auckland Islands	Scampi trawl	Ratio estimate
Auckland Islands	Other (non-squid) trawl	Ratio estimate
Stewart Snares shelf	Squid trawl	Ratio estimate

the narrowing of the bar spacing on the angled grid that guides sea lion to the exit (in 2005–06), and standardisation of the kite material used to hold the SLED hood above the exit open. A detailed audit of SLEDs before the start of the 2006–07 fishing year included alterations to SLEDs that deviated from the standard specifications, ensuring consistency across the squid trawl fishery (Clement & Associates 2007).

On tows using SLEDs, the exact number of sea lion killed (or injured) is unknown, as some sea lion may escape from the net. Because of this uncertainty, the number of sea lion that would have been caught without SLEDs, on both observed and non-observed tows was estimated as the number of interactions. This term denotes the maximum direct fishing-related mortality. Another estimate, exclusions, accounts for sea lion that interact with the net on tows using SLEDs, but are not brought on-board the vessel. Exclusions are calculated as the number of sea lion captures (the sum of observed and estimated captures) subtracted from the number of interactions. To account for sea lion captures in relation to fishing effort, interactions are converted to a strike rate, the number of interactions per 100 tows. This conversion also allows comparisons between fishing years and fisheries.

Another management tool specifically applied to the Auckland Islands squid fishery is the FRML, a maximum number of permitted sea lion mortalities. The FRML is converted into a permitted number of tows by dividing it by an assumed strike rate. The fishery is closed once this number of tows is exceeded (or the season is finished). The setting of the FRML involves the fixing of a discount rate, a percentage reduction in the assumed strike rate for tows made using approved SLEDs (see Figure 3). For the 2010–11 fishing year, the strike rate was set at 5.65%, based on the assumption that 5.65 sea lions are killed per 100 tows that did not use SLEDs. The discount rate for the same fishing year was set at 35%, so that for every 100 tows using SLEDs, the strike rate was reduced to 3.67%, so that 3.67 sea lion mortalities were counted against the FRML. To incorporate vessels that operate with SLEDs not audited and approved by Ministry for Primary Industries, the metric "attributed mortality" is calculated as the sum of interactions on tows with unapproved SLEDs and a percentage (100% less the discount rate) of interactions on tows with approved SLEDs.

2.7 Sea lion capture model for the Auckland Islands squid fishery

The current modelling approach was similar to that used to estimate captures in the Auckland Islands squid fishery during the 2009–10 fishing year (Thompson et al. 2011), but involved only one model with a split SLED retention probability, in addition to a single SLED retention model.

In the previous modelling, a sequence of models with two SLED retention probabilities was fitted, in addition to the single SLED retention model. The split-retention models allowed the SLED retention probability to vary before and after a cut-off date, based on the prior knowledge that the SLED design had changed sometime in the three years 2004–05, 2005–06, and 2006–07. To allow for this change in SLED design, the cut-off date was set at the end of these three fishing years, 2004–05, 2005–06, or 2006–07, with "early" and "late" sled retention probabilities for the periods up to and including the cut-off year and subsequently.

Modelling for the 2010–11 fishing year followed this previous approach, but differed in that one split-retention model was fitted. This split-retention model chose the cut-off date from the three fishing years, 2004–05, 2005–06, and 2006–07. A model with a single SLED retention probability was also run, and the results from both models were combined with equal weight.

The basic unit of effort used in the models was a single trawl event. Observers recorded the number of sea lion caught per tow, and the objective of the estimation was to predict the expected number of captured sea lion on the unobserved tows. Tows in fishing year y were indexed by vessel key, j, and number, k, and the number of sea lion captured on tow jk in year y was denoted c^y_{jk}. The captures, c^y_{jk}, were assumed to follow a negative-binomial distribution with a mean, μ^y_{jk}, that varied from tow to tow, and with an over-dispersion, θ, that was the same for all tows. The negative-binomial distribution was implemented using a Poisson distribution with a gamma distributed mean, which was achieved by multiplying the mean strike rate by a value randomly sampled from a gamma distribution with shape θ and unit mean. As $1/\theta$ decreases the model becomes less dispersed, with the limiting case, when $1/\theta = 0$, being a Poisson model. The model parameter θ was given the uniform shrinkage prior (Natarajan & Kass 2000, Gelman 2006) with mean equal to the mean number of sea lion captures per tow, μ_θ:

$$\begin{aligned} c^y_{jk} &\sim \text{Poisson}(\mu^y_{jk} g_\theta), & (12)\\ g_\theta &\sim \text{Gamma}(\theta, \theta), & (13)\\ \theta &\sim \text{Uniform-shrinkage}(\mu_\theta). & (14) \end{aligned}$$

The mean strike rate μ^y_{jk} was composed of three components multiplied together: a random year effect λ_i, a random vessel-year effect ν^y_j, and a linear regression component that depended on the value of covariates x^{yb}_{jk} and the regression coefficients β_b,

$$\mu^y_{jk} = \lambda^y \nu^y_j \exp\left(\sum_b x^{yb}_{jk} \beta_b\right) \quad . \tag{15}$$

The random year effects, λ^y, carried the mean strike rate for each year, and were drawn from a single log-normal distribution with mean μ_λ and standard deviation σ_λ. These hyper-parameters were given

Table 5: Terminology used in this report for sea lion captures in the Auckland Islands squid fishery (following the definitions used by Thompson & Abraham (2009b)).

Term	Definition
Auckland Islands squid fishery	Trawlers targeting squid in the Auckland Islands part of the SQU6T fishing area
SLED	Sea lion exclusion device, a mitigation method used in the Auckland Islands squid fishery. SLEDs are a fitted mid-section in the trawl net that allow sea lion inside the net to escape. A cover net can be tied down over the exit when the SLED is not being used.
Approved SLED	A SLED that has been audited and approved by Ministry for Primary Industries as meeting specifications.
Closed net	A trawl net that either does not have a SLED fitted, or that has a SLED fitted with the SLED exit covered so that sea lion are unable to escape.
Open net	A trawl net that has a SLED fitted with the SLED's exit being open.
Observed captures	The number of sea lion brought on deck both dead and alive, during observed tows (Figure 3(a)). Decomposed animals and any sea lion that climb on board the vessel, are excluded.
Captures	An estimate of the total number of sea lion captures, calculated as the sum of observed captures and the estimated captures that would have been recorded on unobserved tows, had observers been present (Figure 3(b)).
Interactions	An estimate of the number of sea lion that would have been caught if no SLEDs were used (Figure 3(f)).
Strike rate	Sea lion interactions per 100 tows.
Exclusions	An estimate of the number of sea lion interacting with a net but not being brought on board the vessel (Figure 3(c)). This number is calculated as sea lion captures subtracted from interactions.
FRML (Fishing Related Mortality Limit)	The maximum number of sea lion mortalities permitted in the Auckland Islands Squid Fishery. This number is converted into a permitted number of tows by dividing by an assumed strike rate.
Discount rate	The discount rate is an incentive to vessel operators to use SLEDs. It is a percentage reduction in the assumed strike rate for tows that use approved SLEDs, used when determining the amount of fishing effort permitted in the Auckland Islands squid fishery under the FRML. In the 2010–11 fishing year a discount rate of 35% was applied to tows that used approved SLEDs.
Attributed mortality	The attributed mortality is the sum of interactions on tows with unapproved SLEDs, and a percentage (100% less the discount rate) of interactions on tows with approved SLEDs (Figure 3(d, e)). If the discount rate was 0%, the attributed mortalities would be the same as the interactions. Attributed mortality also includes any sea lion released alive.

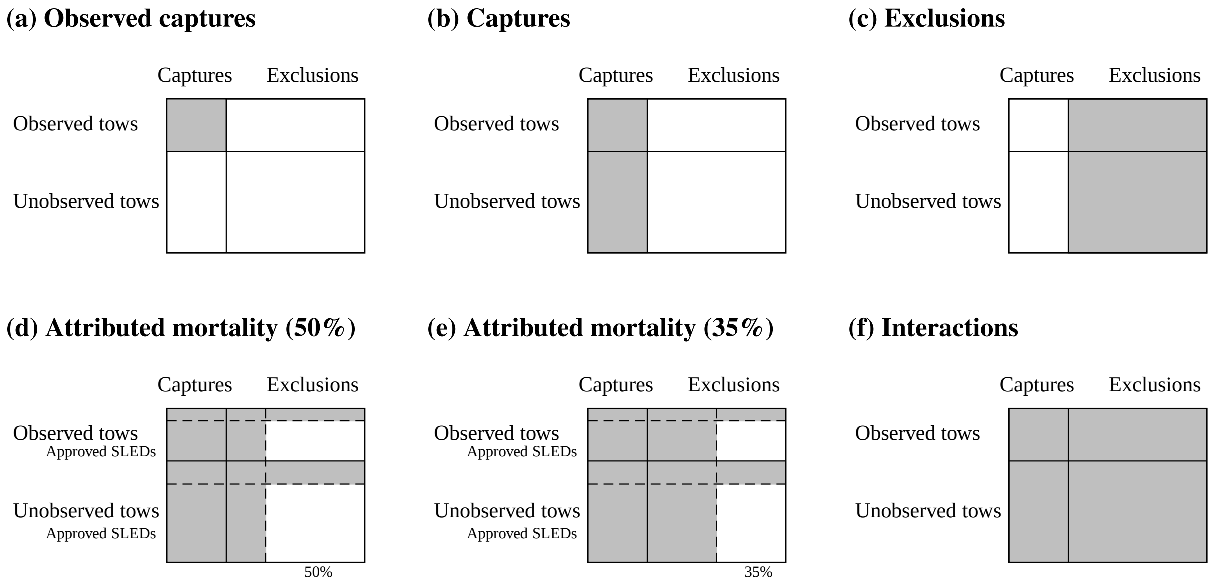


Figure 3: Quantities estimated for tows that used SLEDs. The box represents the total captures that would have occurred if no SLEDs were used, with the shading indicating the portion of the total that was included in each quantity. Tows are either observed or unobserved, and sea lions are either captured or are excluded (escaped through the SLED and would have been captured had a SLED not been used). The shaded grey areas are (a) Observed captures; (b) Captures, the sum of observed captures and estimated captures on unobserved tows; (c) Exclusions, sea lions that escaped being captured because SLEDs were used; (d) attributed mortality at a 50% discount rate; (e) attributed mortality at a 35% discount rate; (f) Interactions. In (d) and (e) the horizontal line is used to indicate that not all SLEDs were approved, and the vertical line indicates the portion of interactions that were ignored because of the discount factor.

fixed prior distributions:

$$\log \lambda^y \sim \text{Normal}(\mu_\lambda, \sigma_\lambda), \tag{16}$$
$$\mu_\lambda \sim \text{Normal}(-4, 100), \tag{17}$$
$$\sigma_\lambda \sim \text{Half-Cauchy}(0, 25). \tag{18}$$

For each vessel and year combination there was a vessel-year random effect, v_j^y, that was drawn from a gamma distribution with mean one. This selection allowed the strike rate for each vessel in each year to have a mean different from the year effect λ^y. The shape of the gamma distribution was defined by the hyper-parameter, θ_v. The shape parameter was given the uniform shrinkage prior, with mean equal to the mean number of sea lion caught per vessel, μ_{vs}. For vessels that were not observed in a given year, a value of the random effect v_j^y was drawn from the gamma distribution:

$$v_j^y \sim \text{Gamma}(\theta_v, \theta_v), \tag{19}$$
$$\theta_v \sim \text{Uniform-shrinkage}(\mu_{vs}). \tag{20}$$

The model was also used to investigate factors that may have contributed to sea lion captures, including distance to colony, tow duration, sub-area and open-net (see definitions in Table 6). The covariates included in the model were those selected previously by Smith & Baird (2007), based on earlier research specifically aimed at identifying the factors associated with sea lion captures (Smith & Baird 2005). To improve model convergence, the covariates were normalised before model fitting by subtracting the mean value and dividing by the standard deviation. This normalisation was removed before presenting results from the model. The regression coefficients, β_b, were assumed to be the same for all years. The priors for the regression coefficients of the three covariates distance to colony, tow duration, and sub-area were non-informative normal distributions,

$$\beta_b \sim \text{Normal}(0, 100). \tag{21}$$

The presence or absence of a SLED with the cover off (open-net) was treated as a covariate. The regression coefficients were $\beta_{open\text{-}net_{1,2}}$, where the index 1 or 2 refers to the two periods (up to and including the cut-off year, and after the cut-off year). These coefficients were transformed into the SLED retention probabilities, $\pi_{1,2} = \exp\left(\beta_{open\text{-}net_{1,2}}\right)$, and were given uniform priors,

$$\pi_{1,2} \sim \text{Uniform}(0, 1). \tag{22}$$

2.7.1 Model selection

The choice to allow the SLED retention probability to vary before and after a cut-off date was made to reflect the known changes that have been made to the SLED design. Two models were fitted, including a model with a single SLED retention probability in addition to a split-retention model.

A problem in this case was that the model dataset was unbalanced, with few observed captures in recent years. This imbalance meant recent changes in SLED retention were unable to greatly improve the overall fit of the model, while adding to model complexity.

2.7.2 Model estimates of interactions, captures, and strike rate

From the fitted model, posterior distributions were calculated for the captures, interactions, strike rate, attributed mortalities, and exclusions (see definitions in Table 5 and Figure 3). For each sample from the MCMC, the estimated number of sea lion interactions i_{jk} was calculated for each tow (here, and in the following, the year index y is assumed). The mean interaction rate was given by the linear predictor, μ_{jk} (Equation 15), but with the net assumed to be closed, irrespective of whether or not a SLED was used. This approach was enforced by setting the open-net covariate to the value corresponding to a closed net. The number of interactions on a tow can be interpreted as the number of sea lion that would have been caught if a SLED had not been used. They were obtained from the mean interaction rate by sampling

Table 6: Covariates used in the sea lion capture model of the Auckland Islands squid fishery.

Covariate	Definition
Distance to colony	A continuous variable, the logarithm of distance to nearest sea lion breeding colony.
Tow duration	A continuous variable, the logarithm of tow duration.
Sub-area	A two-level factor variable, indicating in which sub-area the start of the tow was located. The Auckland Islands part of squid fishing area SQU 6T was divided into two sub-areas, NW (north of 50.45° S and west of 166.95° E), and S&E (South and East: the remainder of the Auckland Islands part of SQU6T).
Open-net	A factor variable, indicating that the net had a SLED attached and that the cover net was open. In models with a split SLED retention probability, the open-net factor depended on whether or not the tow was after the cut-off fishing-year of either 2004–05, 2005–06, or 2006–07.

from a negative-binomial distribution (following Equations 12, 13, and 14). From the interactions, the captures were then calculated by sampling from a binomial distribution with probability given by the SLED retention probability and size given by the number of interactions,

$$c_{jk} \sim \begin{cases} \text{Binomial}(\pi_{1,2}, i_{jk}) & \text{(open net)}, \\ i_{jk} & \text{(closed net)}. \end{cases} \tag{23}$$

This procedure simulated the independent random capture of interacting sea lion, with probability $\pi_{1,2}$. It ensured that, on any tow, the number of captures was less than or equal to the number of interactions. The number of sea lion exclusions on a tow was calculated as the difference between the interactions and the captures, $e_{jk} = i_{jk} - c_{jk}$.

Tow level attributed captures, a_{jk}, were calculated from the interactions in a similar way, by sampling from a binomial distribution,

$$a_{jk} \sim \begin{cases} \text{Binomial}((1 - DR/100) - \pi_{1,2}, i_{jk}) & \text{(open net, approved SLED)}, \\ \text{Binomial}(1 - \pi_{1,2}, i_{jk}) & \text{(open net, unapproved SLED)}, \\ 0 & \text{(closed net)}, \end{cases} \tag{24}$$

where *DR* is the percentage discount rate. With this definition, the attributed captures on a tow are always less than the number of interactions. The SLED retention probability is subtracted from the probability in Equation 24, so that the captures are not included in a_{jk}.

The estimated quantities were calculated as follows:

$$\begin{aligned} \text{Captures} \quad C &= \sum_u c_{jk} + C_o, && (25) \\ \text{Interactions} \quad I &= \sum_u i_{jk} + \sum_o e_{jk} + C_o, && (26) \\ \text{Strike rate} \quad \mu &= I/n, && (27) \\ \text{Exclusions} \quad E &= I - C, && (28) \\ \text{Attributed captures} \quad A &= C + \sum_a a_{jk}, && (29) \end{aligned}$$

where C_o is the number of observed captures in the fishery, $\sum_u$ denotes a sum over unobserved tows, $\sum_o$ denotes a sum over observed tows, $\sum_a$ denotes a sum over all tows, and the total number of tows in the fishery is denoted by n. The attributed captures were calculated for discount rates of 20%, 35%, 50%, and 82%.

Posterior distributions of these quantities were obtained by calculating them for every sample from the MCMC. The posterior distributions were summarised by the median, mean, and 95% confidence interval (calculated from the 2.5% and 97.5% quantiles).

2.8 The Campbell Island southern blue whiting fishery

A simple Bayesian model was used to estimate sea lion captures in the southern blue whiting fishery east of Campbell Island. Data for this fishery were organised by calendar rather than fishing year as this fishery extends beyond the end of the standard fishing year (30 September). This fishery was focused in a short part of the year, with all fishing effort between August and November.

In total, there were 32 observed sea lion captures in the data set, necessitating a considerably simpler model than that developed for the Auckland Islands squid fishery. Sea lion captures occurred throughout the weeks the fishery was operating, with the possible exception of fishing before the beginning of September. This trawl fishery has had observer coverage since 1996, with the first observed sea lion capture in 2002.

The southern blue whiting fishery operates on Pukaki Rise, and to the east of Campbell Island, while all sea lion captures have been observed on the shelf to the east and south of Campbell Island. As a consequence, the data set was restricted to fishing effort near Campbell Island (see Figure A-15).

The southern blue whiting model was a variation of the squid model described above. Simplifications were necessary, mostly because of the small number of observed captures. The inclusion of vessel-year random effects was not feasible due to the small number of vessels that had observed captures. The model used a Poisson error model, and included only random year effects. The year effects allowed for a varying strike rate, without assuming any trend over the years. The same model was used by Thompson et al. (2011), with the exception that the date range has been extended to include all data from 1996 to 2011.

2.9 Other strata

Ratio estimates of sea lion captures were calculated for the three remaining strata: the Auckland Islands scampi fishery, the Auckland Islands other non-squid trawl fishery, and all trawl fisheries at the south end of the Stewart-Snares shelf. The non-squid Auckland Islands trawl fisheries were distinguished as those targeting scampi and all other trawl fisheries not targeting squid in the Auckland Islands part of the SQU6T fishing area. The area for the Stewart-Snares trawl fishery was defined as the southern end of the Stewart-Snares shelf, south of 48.02°, north of 49.5°, west of 168°, and east of 166°.

All of these strata had few observed captures, due in part to low observer coverage. A general linear model was used to test if there was a significant trend in the observed strike rate across years. As no trend was found, ratio estimates were calculated using data from the fishing years 1995–96 to 2010–11, by assuming a constant capture rate over these years.

The estimated number of captures in a year, y, was

$$C^y = C_o^y + C_u^y, \tag{30}$$

where C_o^y were the observed captures and C_u^y were the estimated captures during unobserved fishing. The unobserved captures were estimated by calculating an average rate from the observed data, and applying that to the unobserved effort. If the number of observed tows in a year was o^y, then the average sea lion capture rate was

$$r = \sum_y C_o^y / \sum_y o^y, \tag{31}$$

where the sum was over all the fishing years that were included in the estimate. The unobserved captures in each year were then estimated as

$$C_u^y = r(n^y - o^y), \tag{32}$$

where n^y was the total number of tows in year y. The uncertainty in the captures, C^y, was estimated using bootstrap resampling (e.g., Davison & Hinkley 1997). Data from the observed tows were resampled 5 000 times, and the total bycatch was recalculated for each sample from Equations 30, 31, and 32. The 95% confidence interval in the estimate was calculated from the 2.5% and 97.5% quantiles of the distribution of resampled captures.

2.10 Total estimates

Estimates from the five strata were combined to provide an estimate of total sea lion captures in each year. The posterior distribution of estimated captures in each of the five strata was described by a set of 4000 samples, from the MCMC in the relevant Bayesian models, and from the bootstrap resampling for the strata with ratio estimates. The samples were added to obtain 4000 samples from the combined posterior distribution of total estimated captures in each year. Annual interactions were calculated as the sum of estimated interactions in the Auckland Islands squid fishery and estimated captures in the other four strata. The mean and 95% confidence intervals were calculated for each year from the samples.

3. RESULTS

3.1 Common dolphin captures

In the 2010–11 fishing year, there were nine observed common dolphin captures in trawl fisheries in New Zealand waters. The majority of observed captures involved trawlers targeting mackerel on North Island's west coast, with seven common dolphin captures recorded in this fishery. The other two observed captures occurred on two separate tows; one targeted barracouta on the South Island east coast, while the other tow was by an inshore vessel targeting gurnard on the North Island east coast. All observed common dolphin captures were recorded as mortalities.

Considering the entire 16-year reporting period from 1995–96 to 2010–11, the majority of observed common dolphin captures (119 of a total 135 observed captures) were in the mackerel fishery operating on North Island's west coast. Over this period, there was a total of 119 common dolphin captures recorded in this trawl fishery (see Appendix A.1) All of these captures involved vessels that were longer than 90 m, with the majority of captures occurring on vessels longer than 100 m. Observer data from these large vessels (i.e., over 90 m length) that targeted jack mackerel or blue mackerel on at least one tow per fishing trip were used to derive estimates of common dolphin captures (see Table A-1, Figure A-1).

Trawl effort in the large-vessel mackerel fishery was initially low, but increased substantially between 1999–00 and 2002–03 (Table A-1). Since then, fishing effort has generally been around 2000 tows per year, with a decrease in trawl effort in 2010–11, when 1551 tows were fished. Between 1995–96 and 2010–11, observer coverage fluctuated between 7 and 70%, with at least 20% of all tows observed in most fishing years. In the four most recent fishing years, observer coverage in this fishery was 30% or above; it was 30% in 2010–11.

The large-vessel mackerel fishery was spatially distributed along the North Island west coast, with observer coverage showing a similar spatial distribution throughout both sub-areas (Figure A-1). Observed common dolphin captures in 2010–11 occurred in the northern and southern sub-areas, with a larger number of observed common dolphin captures in the northern sub-area. Considering fishing effort throughout the fishing year, there were distinct peaks in trawl effort in October and December, when approximately 20% and 30% of tows were conducted. There was also some trawl effort in June and July, with approximately 20% of tows fished over these two months. In other months, fishing effort was low, at about 10% or less of overall effort, with no fishing in February and between June and August. Observer coverage reflected the temporal pattern of fishing effort throughout the year, corresponding closely with fluctuations in trawl effort. The number of observed common dolphin captures was highest in December, coinciding with the peak in trawl effort during that month. In addition, there were small peaks in common dolphin captures in April and May, which coincided with low fishing effort in those two months.

Over the entire reporting period, incidental captures of common dolphin occurred on 50 observed tows. Most capture events involved more than one dolphin, with two or three dolphins frequently caught at the same time (Figure 4). These multiple captures involved a maximum of nine common dolphin in a single incident. In 2010–11, seven common dolphin were observed caught in six capture events, with one incident involving the capture of two dolphins. The seven observed captures corresponded with an observed capture rate of 1.51 common dolphin per 100 tows. On average, there were 0.88 capture events per 100 tows, with an average capture rate of 2.1 common dolphin per 100 tows across the entire study period.

Common dolphin captures were observed sufficiently frequent in the large-vessel mackerel fishery to allow the development of a statistical model. A two-stage Bayesian model was fitted using observer and effort data to obtain estimates of total common dolphin captures (Table A-1, Figure A-1). In the 2010–11 fishing year, there were 64 (95% c.i.: 26 to 116) total estimated common dolphin captures in this fishery. This estimate is substantially higher than estimated common dolphin captures in recent years (e.g., 30 (95% c.i.: 7 to 65) estimated captures in 2009–10), and the highest value since the 2004–05 fishing year. It is particularly high considering the concomitant drop in fishing effort in 2010–11 to 1551 tows. Trawl effort in this fishing year was low compared with previous years, and similar to trawl effort in 2001–02, when the fishery was first expanding.

Over the expansion period between 1999–00 and 2002-03, there was a marked increase in annual fishing effort following initial low levels, and the substantial increase in trawl effort was accompanied by high numbers of estimated common dolphin captures. The number of estimated common dolphin captures peaked at 141 (95% c.i.: 56 to 276) in 2002–03, when fishing effort reached its first peak within the reporting period following the expansion of the fishery. Since then, the number of trawls has generally remained high with over 2000 trawls per year, whereas estimated common dolphin captures have gradually decreased over time, excepting the most recent fishing year. In the preceding two fishing years, 2008–09 and 2009–10, there were 28 (95% c.i.: 13 to 52) and 30 (95% c.i.: 7 to 68) estimated common dolphin captures, respectively, with a corresponding annual trawl effort of 1820 and 2189 tows. The high estimate of common dolphin captures in 2010–11 was reflected in the estimated capture rate of 4.13 (95% c.i.: 1.68 to 7.48) common dolphin per 100 tows. This estimated capture rate was considerably higher than estimated capture rates in the previous six fishing years, and one of the highest estimated capture rates over the entire reporting period.

In addition to predicting the probability of capture events, the two-stage Bayesian model also predicted the number of common dolphin caught per capture event over the 16-year period. This second stage was important, as most capture events involved multiple captures, most frequently two or three common dolphin, with groups of up to nine individuals observed caught at the same time (Figure 4). The posterior distribution of the size of the zero-truncated Poisson distribution, μ, had an approximately normal distribution, with a median value of 2.1 (95% c.i.: 1.7 to 2.6) common dolphin per capture event (Appendix B, Table B-19). Comparing observer data and model estimates of the number of common dolphin caught per capture event showed that observer data were well represented by the zero-truncated Poisson distribution. All observations were within the 95% confidence intervals of the model estimates, except for the single incident involving the capture of nine dolphins, which was less likely to occur in the model. The 2010–11 fishing year was unusual in that most observed capture events involved individual common dolphin, with only one incident involving the simultaneous capture of two dolphins.

Also included in the modelling were potential factors that may explain common dolphin captures, with the selection of these covariates following previous assessments (Thompson et al. 2010a, 2011). Among the covariates included in the analysis, headline depth, trawl duration, light condition, and sub-area were confirmed as important explanatory factors for common dolphin captures (Table B-19). Headline depth and trawl duration (in this order) were the most important factors regarding common dolphin captures,

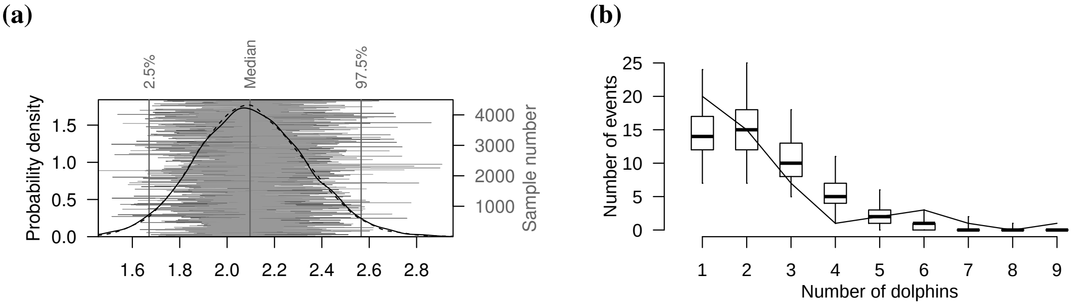


Figure 4: Number of common dolphin caught per capture event in the large mackerel trawl fishery between 1995–96 and 2010–11. (a) Posterior distribution of the size of the zero-truncated Poisson distribution, μ, showing the probability density and trace of the two chains. (b) Comparison of the predicted distribution of the number of common dolphin caught per capture event between the observed captures (shown by the line) and samples from the model posterior (shown by boxplots that indicate the median, quartiles, and 95% confidence interval of the distributions).

followed by light condition and sub-area, both of which had markedly less explanatory power. Light condition was included as a three-level factor and, dependent on the time of the haul and the phase of the moon, defined as light, dark, and black light conditions.

Comparison of the observed and modelled data sets showed that the distributions of the selected covariates were representative of overall fishing effort (Figure 5). Observed common dolphin captures were closely associated with the four covariates. For headline depth, the highest number of observed captures was associated with headline depths between 10 and 40 m, with 83 (70%) of the total 119 observed captures involving tows at headline depths of less than 40 m. There were no observed common dolphin captures at headline depths exceeding 110 m. In relation to trawl duration, the majority of observed captures (88 captures, 73%) occurred on tows that were between 2 and 6 h in duration. Light condition also influenced common dolphin captures, with dark and black light conditions associated with 95 (80%) observed captures. For the spatial distribution, there was a prevalence of common dolphin captures in the northern sub-area, with 74 (62%) observed captures occurring in this sub-area (Figure 5).

The associated regression coefficients from the model fit were used to quantify the influence of the covariates on the probability of common dolphin captures (Table B-19). Headline depth had a negative correlation with a mean coefficient of -0.033 m^{-1}, indicating that increasing the headline depth by 21 metres would halve the probability of a common dolphin capture event. Trawl duration was positively correlated with captures, indicating that a decrease in trawl duration would decrease the probability of a capture event. Light conditions also influenced the capture event probability, with tows hauled in the light having a mean capture event probability of 0.177 relative to tows hauled in the dark. Tows hauled in black light conditions (i.e., between midnight and dawn on a dark night) had a mean capture event probability that indicated it was 1.078 times more likely for those tows to capture common dolphins than for tows hauled in the dark. Comparing the two sub-areas, tows in the southern sub-area had about half the capture event probability to those in the northern sub-area, indicated by the mean coefficient of 0.539.

Considering the seven vessels that were associated with most of the trawl effort between 1995–96 and 2010–11, the North Island west coast mackerel fishery was generally conducted in a coherent fleet, with main fishing characteristics shared across vessels (Figure 6). There was no evidence to suggest that particular vessels were better or worse in avoiding the incidental capture of common dolphin.

Both trawl effort and trawl duration showed an overall increase over the reporting period, with some fluctuations in recent years. Trawl effort declined in 2010–11, following a marked increase the previous year. The decrease in fishing effort in 2010–11 was partly caused by one vessel not participating in

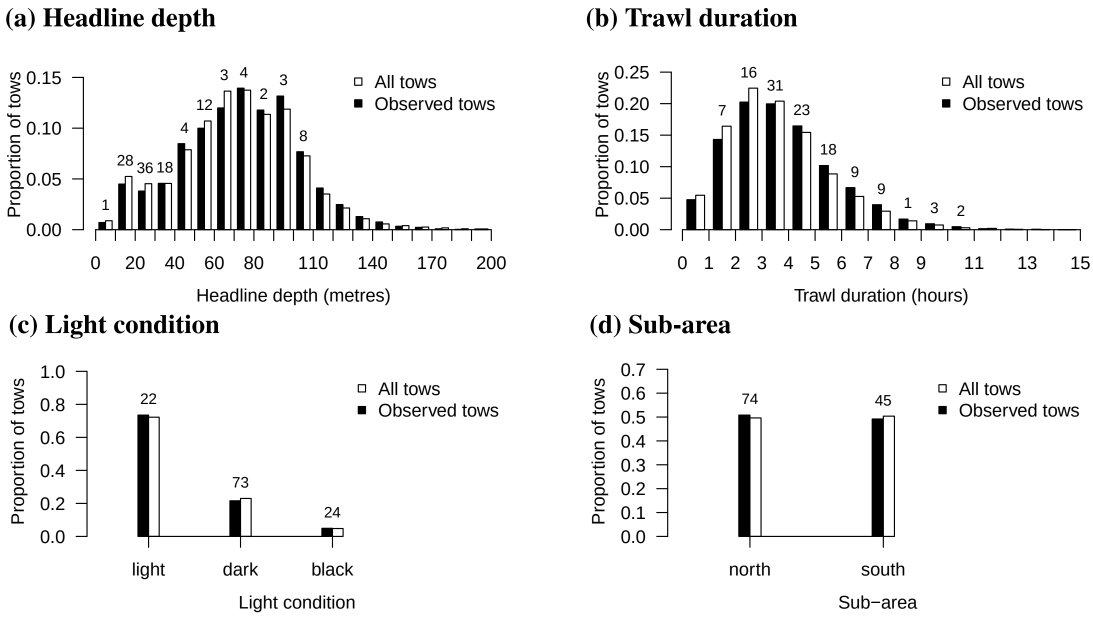


Figure 5: Distribution of the four selected covariates for observed and all trawl effort by large mackerel vessels off the west coast of North Island, between 1 October 1995 and 30 September 2011. Total observed common dolphin captures are indicated above the bars.

this fishery, and also by the remaining vessels fishing less this year. Headline depth showed relatively little variation throughout the study period, and median values have remained below 50 m depth since 2001–02. The spatial distribution of trawl effort has been relatively even between the northern and southern sub-areas since 2007–08, with a slight bias towards the northern sub-area in the current fishing year. All vessels involved in this fishery moved at the same time from one sub-area to another.

Regarding trawl effort in relation to light conditions, the proportions of tows conducted in dark and in black light conditions were also uniform across vessels. Approximately 20% of tows were conducted in dark light conditions, when the net was being hauled between dusk and midnight on a dark night, or between midnight and dawn on a moonlit night. This proportion has remained constant since 2001–02. In comparison, approximately 5% of tows were hauled in black light conditions, with the net being hauled between midnight and dawn on a dark night.

3.2 Fur seal captures

3.2.1 Observed fur seal captures

Observed fur seal captures in 2010–11 occurred across a number of different target fisheries in New Zealand waters, with 69 fur seal observed caught, and a corresponding capture rate of 0.93 fur seal per 100 tows (see Appendix A.2, Table A-2, and detailed summary of captures by fishery and area in Appendix A.3 to A.12, and Appendix D). Four of the captured fur seal were released alive, with 65 observed captures resulting in mortality. Inshore trawl fisheries (excluding flatfish targets) were included in the bycatch assessment for the first time, facilitated by the recent increases in observer data. In this fishing year, fishing effort was over 85 000 tows across all trawl fisheries, with inshore trawling contributing a significant proportion to overall effort (34 935 tows).

Over the entire 9-year reporting period, there were 922 observed fur seal captures. Fishing effort showed an overall decrease over time, with a distinct drop in the number of tows in the 2007–08 fishing

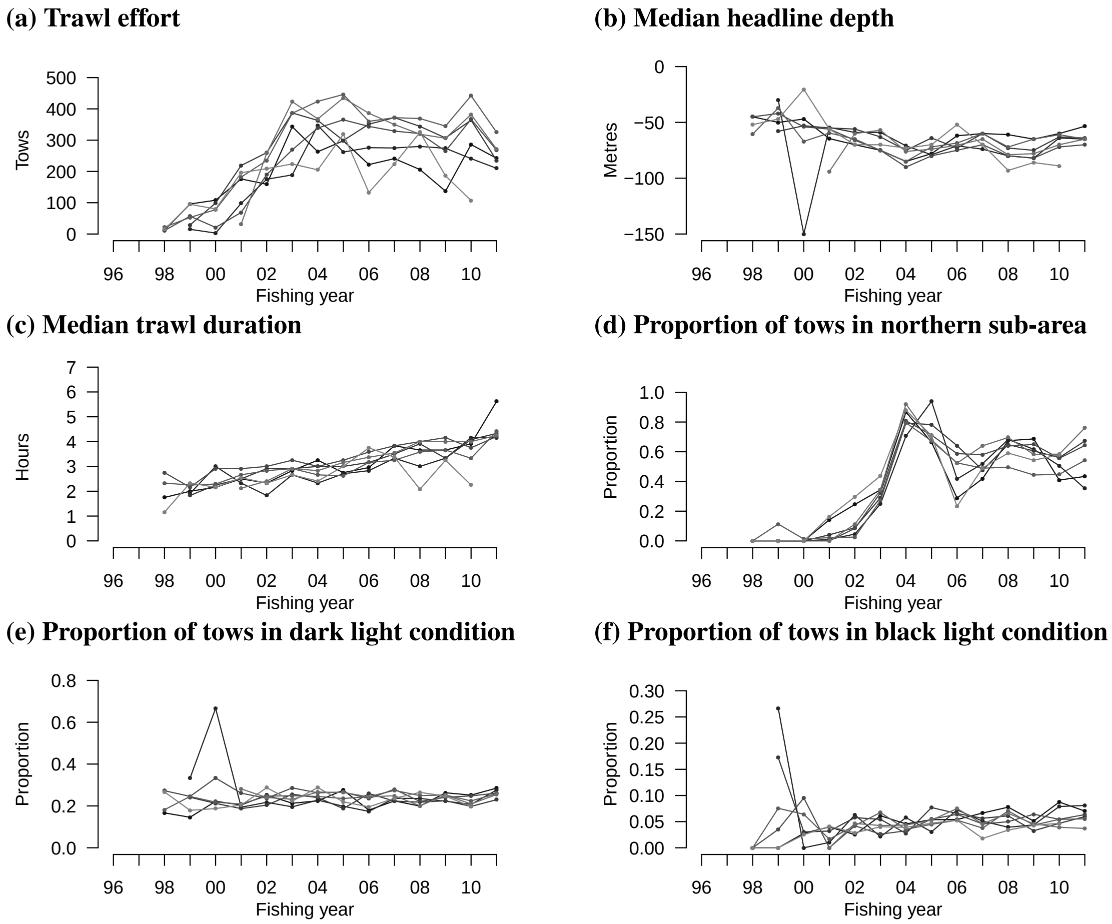


Figure 6: Annual trends of (a) trawl effort, (b) median headline depth, (c) trawl duration, (d) proportion of tows in the north, (e) proportion of tows in dark light conditions, and (f) proportion of tows in black light conditions, for each of the seven vessels responsible for most of the mackerel trawl effort in recent years.

year. Since then, the number of tows has remained relatively constant with approximately 90 000 tows conducted annually. In 2010–11, there was a slight decrease in effort with 85 971 tows conducted. Throughout the reporting period, observer coverage was generally low, but increased from approximately 5% initially to about 10% in 2007–08 and 2008–09. In the most recent fishing year, observer effort was low, with 8.6% of all tows observed.

Observed fur seal captures varied considerably throughout the reporting period, with a maximum of 200 fur seal observed caught in 2004–05, corresponding with an observed capture rate of 2.61 fur seal per 100 tows. In the three most recent fishing years, the number of observed fur seal captures was comparatively low with 69 fur seal observed caught in 2010–11, and an observed capture rate of 0.93 fur seal per 100 tows.

The spatial distribution of trawl effort extended throughout most of New Zealand's EEZ. As previously, there were no documented fur seal captures on the North Island's north and east sides, or in the Chatham Islands area. The monthly distribution of observer effort closely matched fishing effort across months, with fishing effort distributed evenly throughout the fishing year. In contrast, there was a distinct temporal pattern in observed fur seal captures, with a marked increase in the proportion of fur seal captures in July to a maximum of over 40% of captures occurring in August. The following month, the proportion of fur seal captures decreased to about 15%, before further declining and remaining low between October and June.

New Zealand's EEZ was divided into 13 fishing areas to provide higher spatial resolution in the statistical models. Used in the models were the 10 areas where fur seal were observed caught, including the North Island and South Island west coasts, Cook Strait, South Island's east coast, and southern South Island and subantarctic fishing areas (Figure 2a, Table 7). Considering fishing effort, observer coverage, and fur seal captures, there was considerable variation across fishing areas in the reporting period. Fishing effort was highest on the east coast of South Island, with over 150 000 tows, followed by 87 727 and 79 989 tows in the fishing areas on the North Island and South Island west coasts. Trawl effort was also comparatively high at 73 121 tows in the Stewart-Snares fishing area. In other fishing areas, trawl effort ranged from 3833 tows around Bounty Islands to 47 052 tows in Cook Strait. Observer coverage also varied across fishing areas, with relatively high observer effort around Bounty Islands and in sub-antarctic fishing areas, ranging between 22% in waters around Auckland Islands and 34% around Campbell Island. In other fishing areas, observer coverage was considerably lower, between 4% and 12%.

Observed fur seal captures also depended on the fishing area involved, with a minimum of 15 observed captures around Auckland Islands, compared with a maximum of 246 fur seal observed caught on South Island's west coast. The highest observed capture rate was in the Bounty Islands fishing area with 13.73 fur seal per 100 tows; the second highest capture rate was 8.96 fur seal per 100 tows in Cook Strait. Observed capture rates in other fishing areas were considerably lower, ranging between 0.21 and 3.37 fur seal per 100 tows (Table 7).

Another factor considered in the modelling was target fishery, based on individual species and species groups (see Appendix A.3 to A.12, Table 8). Inshore fisheries (targeting a range of different species but exluding flatfish) had the highest fishing effort with 162 145 tows, followed by the hoki target fishery that had a fishing effort of 119 722 tows. The squid and middle-depth fisheries conducted a similar number of tows, around 58 000 tows each, whereas fishing effort in other fisheries was markedly lower, ranging from 7792 tows for southern blue whiting to 31 643 tows targeting deepwater species. Coinciding with high fishing effort in inshore fisheries was low observer coverage of 1.1%. Conversely, the highest observer coverage of 35.2% was in the southern blue whiting fishery, which had the lowest trawl effort. Observer coverage in other target fisheries varied between 9.4 and 26.7%.

Observed fur seal captures in hoki fisheries exceeded those in all other target fisheries combined, with 453 observed fur seal captures. The number of fur seal captures was also high in southern blue whiting fisheries, where 212 fur seal were observed caught. In other target fisheries, observed fur seal captures were markedly lower, ranging from 73 in squid fisheries to one observed capture in inshore fisheries. Corresponding with the high number of captures (and comparatively low trawl effort) in southern blue whiting fisheries was the highest observed capture rate of 7.73 fur seal per 100 tows. The second highest observed capture rate was 3.50 fur seal per 100 tows in ling target fisheries, which was followed by similar capture rates in the hoki and hake target fisheries of 2.59 and 2.55 fur seal per 100 tows, respectively. All other fisheries had low observed capture rates of approximately one or less fur seal per 100 tows, with the lowest observed capture rate in inshore fisheries. It is worth noting that the lowest number of observed captures and the lowest capture rate in these fisheries coincided with low observer coverage (and high fishing effort, Table 8).

3.2.2 Estimated fur seal captures

In the 2010–11 fishing year, the number of estimated fur seal captures across all trawl fisheries included in the model was 376 (95% c.i.: 221 to 668), with an estimated capture rate of 0.44 (95% c.i.: 0.26 to 0.78) fur seal per 100 tows (Table A-2). Both the number of captures and the capture rates were the lowest estimates in the 9-year reporting period, and consistent with low estimates in preceding years. Since the 2005–06 fishing year, estimated captures and capture rates have decreased from previously

Table 7: Summary of the model dataset by fishing area for the period between 1 October 2002 and 30 September 2011. Included are total and observed trawl effort, observer coverage (%), observed fur seal captures, and observed fur seal capture rate (number of captures per 100 tows). Data are sorted in decreasing order of the number of captures.

		Observed tows		Fur seals	
	Tows	Tows	Coverage %	Captures	Rate
West Coast South Island	79 989	9 804	12.3	246	2.51
Bounty Islands	3 833	1 224	31.9	168	13.73
Cook Strait	47 052	1 753	3.7	157	8.96
Stewart-Snares	73 121	12 992	17.8	110	0.85
East Coast South Island	154 280	11 278	7.3	110	0.98
Campbell Island	6 156	2 070	33.6	48	2.32
Puysegur	7 658	919	12.0	31	3.37
Subantarctic islands	14 400	4 215	29.3	19	0.45
West Coast North Island	87 727	6 768	7.7	18	0.27
Auckland Islands	32 534	7 204	22.1	15	0.21

Table 8: Summary of the model dataset by target fishery for the period between 1 October 2002 and 30 September 2011. Included are total and observed trawl effort, observer coverage (%), observed fur seal captures and fur seal capture rate (number of captures per 100 tows). Data are sorted in decreasing order of the number of captures.

		Observed tows		Fur seals	
	Tows	Tows	Coverage %	Captures	Rate
Hoki	119 722	17 492	14.6	453	2.59
Southern blue whiting	7 792	2 742	35.2	212	7.73
Squid	57 747	13 265	23.0	73	0.55
Hake	11 297	2 275	20.1	58	2.55
Middle depth species	58 873	3 341	5.7	36	1.08
Ling	9 733	1 030	10.6	36	3.50
Jack mackerel	22 533	5 544	24.6	33	0.60
Deepwater species	31 643	8 449	26.7	14	0.17
Scampi	25 265	2 377	9.4	6	0.25
Inshore (excluding flatfish)	162 145	1 712	1.1	1	0.06

high levels, following a general decline in fishing effort over time.

Compared with other target fisheries (excepting inshore trawling), hoki fisheries had a consistently high fishing effort, with 10 395 tows conducted in 2010–11 (Appendix A.3, Table A-3). There were 23 observed fur seal captures in this fishing year, equating to a capture rate of 1.34 fur seal per 100 tows targeting hoki. The number of estimated captures was 159 (95% c.i.: 76 to 323), with a corresponding capture rate of 1.53 (95% c.i.: 0.73 to 3.11) fur seal per 100 tows. This target fishery was predominately in southern waters, including Cook Strait, West and East coasts South Island, Stewart-Snares shelf and north of Auckland Islands. Observed fur seal captures were documented from three of these fishing areas, Cook Strait, and West and East coasts South Island. Throughout the year, the main fishing effort occurred in July and August, with low effort in remaining months. Observer coverage closely matched the monthly distribution of fishing effort, indicating that observer coverage was representative of fishing effort throughout the fishing year. High fishing effort in July and August was accompanied by a peak in the proportion of observed fur seal captures in the latter month, with relatively high captures also in July and September. There were few observed captures in other months.

Over the 9 years of data, fishing effort in hoki fisheries decreased over time, but has remained relatively constant at 8000 to 10 000 tows since 2007–08. At the same time, observer coverage has increased and has remained comparatively high in recent fishing years, with a slight decrease to 16.5% in 2010–11. Concomitant with the decrease in fishing effort has been a reduction in estimated fur seal captures over time, with recent estimates of less than 200 fur seal captures and estimated capture rates below two fur seal per 100 tows in the last two fishing years (see Appendix A.3, Table A-3).

Although considerably smaller than the hoki fisheries, trawl effort in southern blue whiting fisheries increased over time (Appendix A.4, Table A-4). In 2010–11, there were 1171 tows conducted in these fisheries, similar to fishing effort in the preceding two years. There were 36 fur seal observed caught in this fishing year, over twice the number of fur seal captures observed the previous year, and the highest number of observed captures since 2005–06. Similarly, the observed capture rate was high, with over eight fur seal per 100 tows. Estimated captures were 70 (95% c.i.: 37 to 214) fur seal and the estimated capture rate was 5.94 (95% c.i.: 3.16 to 18.28) fur seal per 100 tows. These trawl fisheries occurred exclusively around Bounty Islands, Campbell Island and in the subantarctic fishing area, with a restricted spatial range in each of these areas. All fishing for southern blue whiting occurred in August and September, with a peak in effort in the latter month. Observed fur seal captures were recorded in both months the fisheries were active, but over 80% of the observed captures occurred in August. Observer coverage was representative of fishing effort throughout the year, and relatively high with over 35% of all tows observed. Throughout the reporting period, observer coverage in the southern blue whiting fisheries was above 30% in most years, with over 40% of tows observed in two years, 2002–03 and 2007–08. Model estimates for the number of captures and capture rates have remained high in recent years, although were lower in 2010–11 than in the preceding three years.

Other target fisheries with more than 70 estimated fur seal captures in 2010–11 were the middle-depth trawl fisheries (Appendix A.5, Table A-5). In this fishing year, 7248 tows were fished, with two observed fur seal captures and a corresponding capture rate of 0.32 fur seal per 100 tows. The model estimates were 76 (95% c.i.: 26 to 180) captures and a capture rate of 1.05 (95% c.i.: 0.36 to 2.48) fur seal per 100 tows. Most of the fishing effort for middle-depth species occurred in Cook Strait, on the west coasts of North Island and South Island, east coast of South Island and in the Stewart-Snares fishing area. Both observed captures in 2010–11 occurred on the Stewart-Snares shelf. Fishing effort was evenly distributed across months, and observer effort corresponded with fishing effort throughout the year. Fur seal captures were documented for most months, with a drastic increase in observed captures in July and August, and a subsequent decrease in September. The middle-depth fisheries have been relatively constant in their fishing effort throughout the 9-year study period, accompanied by a gradual, overall increase in observer effort. At the same time, estimated captures and capture rates have been comparatively high, with estimated captures generally exceeding 100 fur seal per 100 tows. Model estimates have decreased to some extent in the two most recent fishing years, in particular in 2010–11.

3.2.3 Fur seal model covariates

The capture rate covariates included in the fur seal model revealed marked differences regarding the fishing area and target fishery (Appendix C). The highest area covariate was that of the Bounty Islands fishing area (20 times the rate of the Stewart-Snares shelf), followed by that of the subantarctic area (5 times the rate of the Stewart-Snares shelf). When considering the fishing area covariates in the context of target fishery, however, the southern blue whiting fishery that is associated with the Bounty Islands area had a capture rate that was 0.5 times the capture rate of the hoki-hake-ling target fisheries. These findings indicate that the high capture rate in the Bounty Islands area was related to the area, rather than the target fishery.

Another factor that influenced fur seal captures was distance from shore, which was included as a four-level factor in the model and correlated with captures. The distance from shore covariates decreased with increasing distance from shore, with coastal waters (less than 25 km) having the highest covariate for this factor. Trawling within this distance had 1.6 times the capture rate of that associated with tows conducted between 25 and 90 km from shore. Tows conducted at distances of over 180 km from shore had an associated capture rate of 0.2 times compared with that of tows fished at distances between 25 and 90 km from shore.

Also correlated with fur seal captures was the covariate day of the year, which was included to account for seasonal variation. There were strong day of the year effects in the fitted model, with a peak in August and September (Figure 7). This peak coincided with the strong seasonal peak in observed captures (see Appendix A-2, Figure A-2).

3.3 New Zealand sea lion captures

3.3.1 Auckland Islands squid fishery

In 2010–11, there were no observed sea lion captures in the Auckland Island squid fishery, the first time in the 16-year reporting period (see Appendix A.14, Table A-14). In this fishing year, trawl effort increased from the previous year, with 1586 tows being conducted. The highest effort in this fishery was in the 3-year period between 2003–04 and 2005–06, when over 2400 tows were fished annually, and there has been an overall decrease in the number of tows fished since then. Observer coverage has also fluctuated over time, with 99% of tows observed in 2000–01, and considerably lower observer coverage before and after this fishing year. Since 2001–02, observer coverage has varied between 25 and 46%. In 2010–11, 34% of tows were observed, an increase from the 25% observer effort the previous year.

For the estimation, two different models were fitted, based on single and split SLED retention probabilities (see Appendix E). The results from both models were combined with equal weight. The split-retention model accounted for the change in SLED retention probability, associated with the change in SLED design occurring at the end of the 2004–05, 2005–06, or 2006–07 fishing years. The time of the split was chosen by the model, with a clear preference for the cut-off date at the end of the 2006–07 fishing year. Approximately 50% of samples were split in this fishing year, with approximately 25% in each of the two earlier fishing years. Both model runs resulted in a similar distribution of splits across the three fishing years, confirming convergence of the MCMCs.

In the split model, the SLED retention probability was higher before the split than after, but there was considerable uncertainty in the late SLED retention probability (Table 9). This finding corresponds with a decrease in observed capture rates in recent fishing years, and scarcity of data in the period following the change in SLED design, in particular concerning the number and fate of sea lion exiting through SLEDs. The high uncertainty associated with the late SLED retention probability in the split-retention model also resulted in high uncertainty in the estimated interactions and, to some extent, in the strike rate.

Estimates of sea lion interactions were derived from the model by calculating the captures that would have occurred had no SLEDs been used. The interactions were calculated assuming a strike rate for each tow that did not have the SLED retention probability applied. In the split-retention model, estimated sea lion interactions markedly increased in the period following the split at the end of the 2006–07 fishing year, compared with the single retention probability model (Figure 8). At the same time, the uncertainty of estimated interactions in the split retention model increased considerably after the cut-off data, in the 2007–08 to 2010–11 fishing years. These increases were substantial, even though uncertainties around

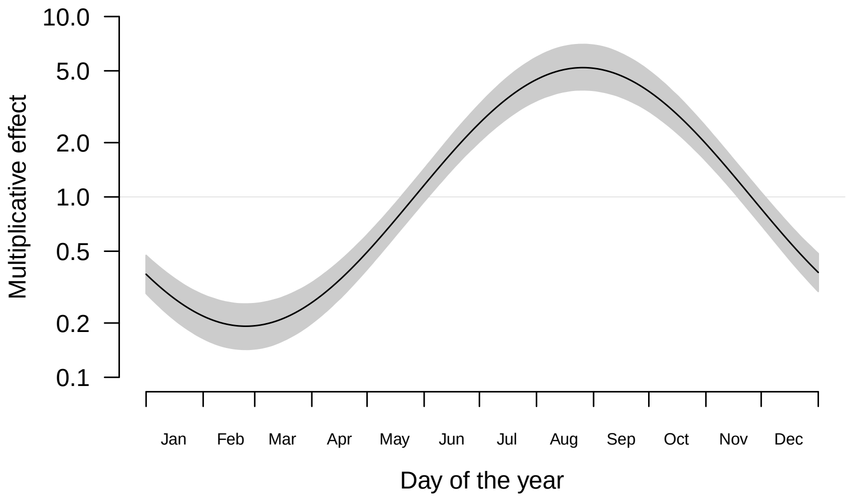


Figure 7: The multiplicative effect of the covariate day of the year included in the fur seal capture model for the period between 2002–03 and 2010–11 (the shading indicates the 90% confidence interval).

Table 9: Estimated SLED retention probabilities for the Auckland Islands squid fishery sea lion capture models.

	Early SLED retention, π_1			Late SLED retention, π_2		
	Mean	Median	95% c.i	Mean	Median	95% c.i.
Single SLED retention	0.17	0.17	0.10 – 0.28			
Split SLED retention	0.19	0.18	0.10 - 0.33	0.17	0.12	0.02 - 0.67

the mean values of estimated interactions were already relatively high in fishing years from 2003–04 onwards. Combining the two models resulted in 56 (95% c.i.: 4 to 233) estimated sea lion interactions in 2010–11 (Table A-14).

The estimated strike rate in 2010–11 was 3.5 sea lion per 100 tows (95% c.i.: 0.4 to 14.9), a decrease from estimates in previous years. It was one of the lowest estimated strike rates in the reporting period, although the upper confident limit was within the confidence intervals of previous years. The decrease in the mean strike rate was related to the drop in the observed capture rate in the most recent fishing year, when there were no observed sea lion captures. The mean estimate of captures in 2010–11 was 4 sea lion (95% c.i.: 0 to 11).

3.3.2 Campbell Island southern blue whiting fishery

The southern blue whiting fishery around Campbell Island is conducted between August and November each year, so that the fishing season extends beyond the end of a standard fishing year at the end of September. As a consequence, data for this fishery were organised by calendar year. In 2011, there were six observed sea lion captures in the southern blue whiting fishery near Campbell Island (Appendix A.15, Table A-15). All observed captures involved male sea lion, including one male that was released alive, and two that were caught on the same tow. Overall, sea lion captures in this fishery have been

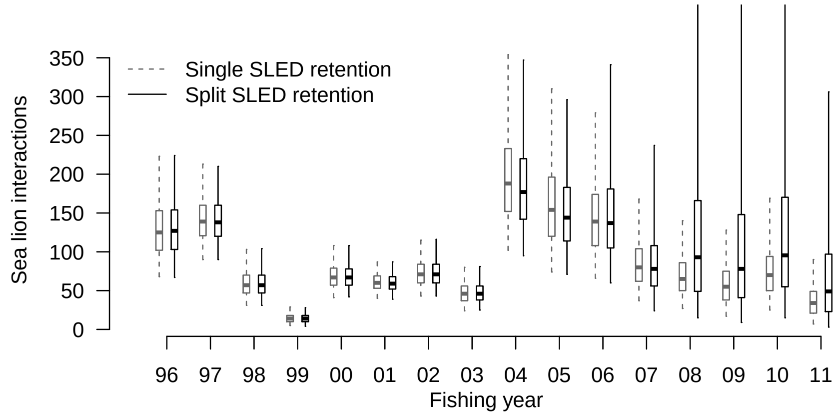


Figure 8: Mean estimated sea lion interactions for the single SLED retention and split SLED retention Auckland Islands squid fishery sea lion capture models. The boxes indicate the 50% confidence interval, while the whiskers indicate the 95% confidence interval. The final results were obtained by drawing samples from both these models.

male-biased, with only one female sea lion observed caught since 1996. One other female sea lion was captured in the southern blue whiting trawl fishery before the start of this study, in 1995, but this capture was not in the Campbell Island southern blue whiting fishery, but occurred in an area northwest of Campbell Island.

Trawl effort in this fishery has been consistently lower than that in the Auckland Islands squid trawl fishery, with between 447 and 980 tows per year since 1996. In 2011, 815 tows were conducted, with 40% of all tows observed. Observer effort on southern blue whiting trawl vessels has varied between 20 and 60% across years. There were no recorded sea lion captures during the period between 1996 and 2001. Since then, sea lion have been observed caught in most years.

Owing to the limited number of observed captures, a simple Bayesian model was used to estimate sea lion captures in the southern blue whiting fishery. This model included a single random year effect, as observer data did not support the inclusion of vessel-year random effects. In 2011, the mean number of estimated captures in the Campbell Island southern blue whiting fishery was 15 sea lion (95% c.i.: 8 to 25), and the estimated mean strike rate was 1.8 sea lion per hundred tows (95% c.i.: 0.7 to 3.4)(Table A-15). Both estimates decreased between 2010 and 2011, but remained comparatively high considering the entire study period.

3.3.3 Other trawl fisheries

Other trawl fisheries that overlap in their distribution with that of sea lion are scampi and other non-squid trawl fisheries around Auckland Islands and on the Stewart-Snares shelf.

There were no observed sea lion captures in the scampi trawl fishery in 2010–11 (Appendix A.16). This fishery is concentrated east of Auckland Islands, with some trawl effort in the south. The annual fishing effort for scampi is generally about 1300 to 1400 tows, with an unusually low effort in 2009–10 of 940 tows. In 2010–11, 1401 tows were fished. Observer coverage has increased in recent years, with 10 and 15% observer effort in 2009–10 and 2010–11, respectively. Observer effort varied across months, with the highest proportion of tows observed in November. There have been few observed sea lion captures in this fishery, with a total of 12 observed captures since 1995–96.

Other non-squid trawl fisheries in the Auckland Islands area had no observed sea lion captures in 2010–11 (Appendix A.17). There have only been three observed captures in these fisheries overall, with no observed captures since the 1999–00 fishing year. Estimated captures and strike rates were correspondingly low. Both trawl and observer effort have been variable since the start of the reporting period, ranging between 38 and 750 tows and between 4 and 66% observer effort. In 2010–11, there were 131 tows conducted, almost double the fishing effort in the previous year. At the same time, observer coverage was 37%, reduced from 66% the year before.

Trawl fisheries on the Stewart-Snares shelf had no observed sea lion captures in 2010–11 (Appendix A.18). Fishing effort was 2256 tows in this fishing year, similar to that in the previous two years. This trawl effort is a reduction from previous high levels, with 3249 to 7582 tows per year annually before the 2008–09 fishing year. Observer coverage in recent years has been above 30%, and was 36% in 2010–11. Throughout the fishing year, observer effort matched fishing effort, and most captures were observed in February and March. The mean estimate of sea lion captures in this area was one sea lion (95% c.i.: 0 to 4), with a mean estimated strike rate of 0.1 (95% c.i.: 0.0 to 0.2) sea lion per 100 tows.

3.3.4 Estimated sea lion captures and interactions in all trawl fisheries

The five fishing strata were combined to obtain total estimates for all trawl fisheries, resulting in a mean of 29 (95% c.i.: 17 to 43) estimated sea lion captures in the 2010–11 fishing year (Appendix A.13, Table 10). The Campbell Island southern blue whiting trawl fishery contributed almost half of the total estimated captures, similar to the previous year. Except for the Auckland Islands scampi fishery, the most recent estimates for all fisheries were lower than those in 2009–10, resulting in lower total estimates.

The number of interactions is a metric specific to the Auckland Islands squid fishery, as it estimates the number of sea lion that would have been caught in nets if no SLEDs had been used (on observed and non-observed tows). As SLEDs are only used in this trawl fishery, the estimate of sea lion interactions is equivalent to the estimate of sea lion captures in all other trawl fisheries. In the 2010–11 fishing year, there were a total of 81 (95% c.i.: 26 to 259) sea lion interactions across all trawl fisheries. Because of the high uncertainty in the estimated interactions in the Auckland Islands squid fishery, no trend in the total number of interactions could be inferred.

Table 10: Estimated sea lion captures and interactions, in 2009–10 and 2010–11, in the five trawl fishing strata used in the estimation. (See Appendix A for a longer time series of estimates.)

	Est. captures		Est. interactions	
	Mean	95% c.i.	Mean	95% c.i.
2009–10				
Auckland Islands squid trawl	13	5 - 27	107	18 - 402
Campbell Island southern blue whiting trawl	24	15 - 36	24	15 - 36
Auckland Islands scampi trawl	6	1 - 13	6	1 - 13
Stewart Snares shelf trawl	3	1 - 6	3	1 - 6
Other Auckland Islands trawl	0	0 - 1	0	0 - 1
All trawl	46	32 - 66	141	51 - 439
2010–11				
Auckland Islands squid trawl	4	0 - 11	56	4 - 233
Campbell Island southern blue whiting trawl	15	8 - 25	15	8 - 25
Auckland Islands scampi trawl	9	2 - 17	9	2 - 17
Stewart Snares shelf trawl	1	0 - 4	1	0 - 4
Other Auckland Islands trawl	0	0 - 2	0	0 - 2
All trawl	29	17 - 43	81	26 - 259

4. DISCUSSION

4.1 Common dolphin captures

Between 1995–96 and 2010–11, a total of 119 common dolphin captures were observed in the large-vessel mackerel fishery on the North Island west coast. In the 2010–11 fishing year, there were seven observed common dolphin captures, involving six separate capture events in both sub-areas. Trawl effort was relatively low in this fishing year, with 1551 tows being conducted, and observer coverage was 30%. Inclusion of data from this fishing year confirmed previous assessments of common dolphin captures in the mackerel fishery (Thompson & Abraham 2009a, Thompson et al. 2010a, 2011), including the suitability of the two-stage Bayesian model. The model fit the data well, which was evident in the close agreement between observed and modelled data sets.

Capture estimates in 2010–11 increased markedly from the previous fishing year, with 64 (95% c.i.: 26 to 116) estimated common dolphin mortalities, and an estimated capture rate of 4.13 (95% c.i.: 1.68 to 7.48) common dolphin per 100 tows. Both estimates were relatively high, in particular given the decrease in tow effort the same year. This increase in estimated captures is related to the random year effect that was included in the model to account for unexplained variation across fishing years. The year effect is sensitive to the observed event rate, that is, the number of capture events per observed tow. In 2010–11, the observed event rate increased from low values (less than 1 per 100 tows since 2004–05) to 1.30 events per 100 tows. This value reflects the highest event rate since the 2004–05 fishing year, when it was 1.78 events per 100 tows. The increase in the observed event rate resulted in the doubling of the year effect in 2010–11 (from 0.12 to 0.22), leading to the concomitant increase in capture estimates.

Bycatch of common dolphin in the large-vessel mackerel fishery has frequently involved multiple captures per capture event, most often two or three common dolphin. In the 2010–11 fishing year, there was only one multiple capture with two common dolphin observed caught in a single incident, whereas all other observed capture events involved individual dolphins. As a consequence, inclusion of the 2010–11 data slightly decreased the mean number of dolphins captured per event to 2.1 (95% c.i.: 1.7 to 2.6) over the 16-year reporting period.

Part of the modelling was the assessment of potential factors that influence common dolphin captures in this fishery. As in previous analyses, headline depth was highlighted as an important covariate that contributed to common dolphin captures, with the majority of observed captures occurring on tows with headline depths less than 30 m below the surface. Model results based on these data indicate that increasing the headline depth by 21 m would halve the capture event probability. Headline depth has remained relatively constant in recent fishing years, and a key recommendation from this assessment continues to be the increase in headline depth for efforts to reduce common dolphin bycatch in the large-vessel mackerel fishery.

4.2 New Zealand fur seal captures

In 2010–11, the total number of observed New Zealand fur seal captures across all trawl fisheries (excluding flatfish targets) was 69, with a corresponding capture rate of 0.93 fur seal per 100 tows. Tow effort in this fishing year was lower than in previous years, and observer coverage was 8.6%. The estimated number of fur seal captures was 376 (95% c.i.: 221 to 668), with an estimated capture rate of 0.44 (95% c.i.: 0.26 to 0.78) fur seal per 100 tows. Corresponding with the reduction in observed captures, both estimated captures and the capture rate were lower in 2010–11 than in the previous year, reflecting the lowest estimates in the 9-year reporting period. This trends follows the overall decrease in fishing effort across the trawl fisheries included in the modelling (see detailed summary of fur seal captures by area and fishery in Appendix D).

Inshore fisheries were included in the estimation for the first time, following increases in observer effort. These fisheries consistently contributed a significant proportion to the overall trawl effort, fishing over 34 000 tows annually. Although observer coverage has increased recently, it remains low with less than 1.5% of all tows observed in the two most recent fishing years. There has only been one observed capture in inshore trawl fisheries (by a vessel targeting Giant Stargazer (*Kathetostoma* spp.) in 2009), and there were 15 (95% c.i.: 0 to 74) estimated fur seal captures in the 2010–11 fishing year.

Among the different target fisheries, hoki trawl fisheries have been characterised by consistently high numbers of observed captures and high capture estimates (see Appendix A.3). In 2010–11, a third (23 of 69) of the observed fur seal captures occurred in hoki fisheries, with the largest proportion of the total estimated captures (159 (95% c.i.: 76 to 323) of 376 (95% c.i.: 221 to 668) captures) in these fisheries. Although observed fur seal captures have remained relatively high in the hoki fisheries, they have decreased in recent years despite an increase in fishing effort; in 2010–11 the observed capture rate was 1.34 fur seal per 100 tows, the lowest capture rate for the entire 9-year reporting period. Capture estimates for the 2010–11 fishing year remained well within the 95% confidence interval of previous estimates, but also continued to decrease, with a capture rate of 1.53 (95% c.i.: 0.73 to 3.11) fur seal per 100 tows. This rate was the lowest mean capture rate of any of the nine years for which estimates were made.

An exception to the overall trend of decreasing captures in hoki fisheries was the Cook Strait fishery (Figure 9). This fishery showed an increase in the observed capture rate in 2010–11 (to 20 fur seal per 100 tows). Consequently, capture estimates remained high, with 88 (95% c.i.: 33 to 219) estimated captures and an estimated capture rate of 5.55 (95% c.i.: 2.07 to 13.76) fur seal per 100 tows in 2010–11 (see Table D-3).

Southern blue whiting fisheries also had high numbers of observed and estimated captures, with the number of observed captures increasing to 36 fur seal in 2010–11, more than twice the 16 observed captures the previous year (see Appendix A.4). Thirty-one of the observed captures occurred in the Bounty Islands area, and the corresponding capture rate for this area-target fishery was 50.82 fur seal per

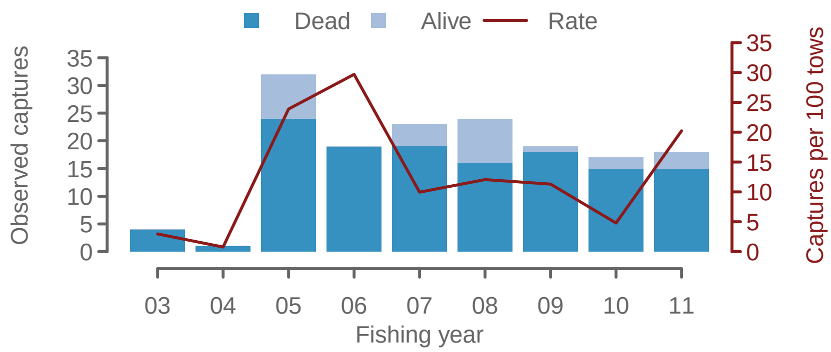


Figure 9: Annual time series of observed fur seal captures and capture rate, in the hoki trawl fishery operating in Cook Strait between 2002–03 and 2010–11.

100 tows (Table D-3) with an estimated capture rate of 32.40 (95% c.i.: 17.71 to 114.86) fur seal per 100 tows in the 2010–11 fishing year.

4.3 New Zealand sea lion captures and interactions

The majority of observed sea lion captures in the 16 years of data have been in the Auckland Islands squid fishery. In the 2010–11 fishing year, however, there were no observed sea lion captures in this fishery. Management of the Auckland Islands squid fishery has included specific mitigation measures designed to reduce the impact of incidental captures on sea lion populations. Mitigation measures include the use of SLEDs that were introduced in 2000–01 and enable sea lion to exit the trawl nets. The use of SLEDs means that the total number of sea lion that may have been captured in trawl nets but were able to escape is unknown. To account for this lack of data, the sea lion capture model used to estimate total captures and interactions includes an estimate of the SLED retention probability, π, which is a measure of the effectiveness of the SLEDs.

Following their introduction, SLEDs underwent several improvements and audits to increase their efficacy (Clement & Associates 2007). For this reason, sea lion capture estimates for the Auckland Islands squid fishery were derived using two models, including a modified model with a split SLED retention probability, in addition to a single SLED retention model. The split in SLED retention probability was associated with a cut-off date in the 3-year period between 2004–05 and 2006–07. The split-retention model chose the cut-off date at the end of the 2006–07 fishing year, reflecting the best fit to the data. In this model, the late SLED retention probability was slightly lower than the early one, while its uncertainty increased markedly, with a mean late retention probability of 0.17 and a 95% confidence interval of 0.02 to 0.67 (see Table 9).

Providing reliable estimates of sea lion interactions has become increasingly difficult. The capture rate depends on both the SLED retention probability and the strike rate, and the data are unable to distinguish between changes in either of these quantities. A similar capture rate could be the result of a low strike rate and a high retention probability, or a low retention probability and a high strike rate. By allowing the SLED retention probability to change, uncertainty is introduced into the estimation of the strike rate, and the number of interactions. In the 2010–11 fishing year, the 95% confidence interval of the estimated number of interactions in the Auckland Islands squid fishery was 4 to 233 sea lion. Similarly, the 95% confidence interval of the strike rate was 0.4 to 14.9 sea lion per 100 tows. This range includes the mean value of the estimated strike rate for all the years from 1995–96 to 2010–11, and so it is not possible to determine whether the strike rate has changed relative to previous years. An additional problem is that

Table 11: Predicted total interactions, attributed interactions at discount rates (DR) of 20%, 35%, 50%, and 82%, captures, exclusions, and strike rate for the 2009–10 and 2010–11 fishing years in the Auckland Islands squid fishery. Presented are the mean and selected percentiles of the posterior distribution.

	Mean	2.5%	50%	97.5%
2009–10				
Interactions	107.2	18	77	402
Attributed mortalities, 20% DR	95.3	21	72	333
Attributed mortalities, 35% DR	79.3	19	60	272
Attributed mortalities, 50% DR	63.5	16	49	214
Attributed mortalities, 82% DR	30.4	9	24	92
Captures	13.1	5	12	27
Exclusions	94.1	9	64	384
2010–11				
Strike rate, %	9.02	1.70	6.53	33.58
Interactions	56.1	4	38	233
Attributed mortalities, 20% DR	49.3	5	34	194
Attributed mortalities, 35% DR	40.5	5	29	159
Attributed mortalities, 50% DR	31.9	4	23	124
Attributed mortalities, 82% DR	13.4	1	10	47
Captures	4.2	0	4	11
Exclusions	51.9	3	33	230
Strike rate, %	3.54	0.36	2.37	14.86

the model assumes that fishing effort before the introduction of SLEDs is comparable with more recent fishing effort, from the point of view of sea lion interactions. As the period before the introduction of SLEDs becomes more distant in time, this assumption becomes less and less tenable. In the future, it will be difficult to use the strike rate and interactions as suitable measures for monitoring the performance of the fishery. Other metrics such as the attributed mortalities (Table 11), that also depend on the strike rate, show a similar high uncertainty.

Estimation of the number of captures is not affected by these issues, and the estimated captures in 2010–11 of 4 (95% c.i.: 0 to 11) sea lion were the lowest of all the years in the series. This low estimate reflects that 2010–11 was the first year in which there were no observed sea lion captures in the Auckland Islands squid fishery, with 34% of the effort in the fishery being observed. The squid fishery, primarily through the use of SLEDs, has been effective at reducing the number of sea lion captures. All six observed sea lion captures in 2011 were in the southern blue whiting fishery around Campbell Island. Previously, there were six observed captures in this fishery in 2007, and 11 observed captures in 2010; otherwise, the highest number of observed captures in any year in the southern blue whiting fishery was less than three. As in 2009–10, over half of the total estimated sea lion captures in 2010–11 were in the southern blue whiting fishery.

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APPENDIX A: Mammal capture estimates

APPENDIX A.1: Common dolphin captures in the west coast NI mackerel trawl fishery

Table A-1: Annual trawl effort, observer coverage, observed number of common dolphin captures, observed capture rate (dolphin per 100 tows), estimated common dolphin captures, and the estimated capture rate (with 95% confidence intervals), in the west coast North Island mackerel trawl fishery.

			Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Events	Rate	Mean	95% c.i.	Mean	95% c.i.
1995–96	406	29.6	2	1	1.67	5	2 – 16	1.20	0.49 – 3.94
1996–97	230	70.4	0	0	0.00	0	0 – 4	0.15	0.00 – 1.74
1997–98	560	38.9	0	0	0.00	2	0 – 9	0.30	0.00 – 1.61
1998–99	350	24.0	0	0	0.00	3	0 – 15	1.00	0.00 – 4.29
1999–00	412	17.2	1	1	1.41	8	1 – 27	1.83	0.24 – 6.55
2000–01	974	12.2	1	1	0.84	12	1 – 40	1.28	0.10 – 4.11
2001–02	1 577	7.0	1	1	0.90	31	3 – 90	1.97	0.19 – 5.71
2002–03	2 249	9.9	21	6	9.42	141	56 – 276	6.27	2.49 – 12.27
2003–04	2 309	7.1	17	7	10.37	108	47 – 204	4.67	2.03 – 8.83
2004–05	2 424	23.1	21	10	3.74	82	45 – 132	3.38	1.86 – 5.45
2005–06	2 117	30.6	2	1	0.31	13	2 – 34	0.60	0.09 – 1.61
2006–07	2 167	28.7	11	5	1.77	55	23 – 103	2.53	1.06 – 4.75
2007–08	2 164	34.0	20	5	2.72	44	25 – 74	2.04	1.16 – 3.42
2008–09	1 820	38.1	11	4	1.59	28	13 – 52	1.55	0.71 – 2.86
2009–10	2 189	30.1	4	2	0.61	30	7 – 68	1.36	0.32 – 3.11
2010–11	1 551	29.9	7	6	1.51	64	26 – 116	4.13	1.68 – 7.48

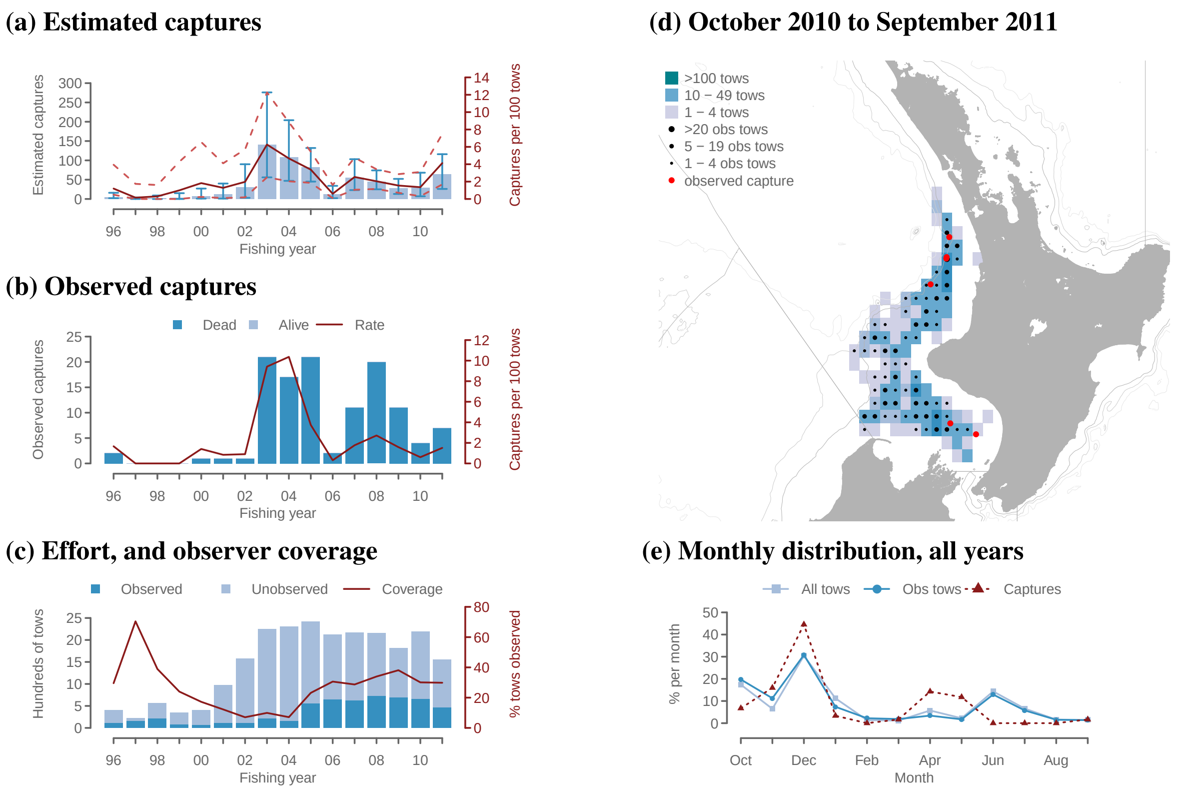


Figure A-1: Annual time series of (a) estimated common dolphin captures, (b) observed common dolphin captures and the capture rate, and (c) trawl effort and observer coverage, in the west coast North Island jack mackerel fishery from 1995–96 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.2: Fur seal captures in all trawl fisheries (excluding flatfish targets).

Table A-2: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in all trawl fisheries, excluding flatfish targets.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	129 773	5.2	68	1.00	841	503 – 1380	0.65	0.39 – 1.06
2003–04	120 785	5.4	84	1.29	1052	635 – 1728	0.87	0.53 – 1.43
2004–05	120 136	6.4	200	2.61	1471	914 – 2392	1.22	0.76 – 1.99
2005–06	109 913	6.2	143	2.10	917	577 – 1479	0.83	0.52 – 1.35
2006–07	103 280	7.6	73	0.93	533	324 – 871	0.52	0.31 – 0.84
2007–08	89 428	10.1	141	1.57	765	476 – 1348	0.86	0.53 – 1.51
2008–09	87 490	11.1	72	0.74	546	308 – 961	0.62	0.35 – 1.10
2009–10	92 800	9.6	72	0.81	472	269 – 914	0.51	0.29 – 0.98
2010–11	85 971	8.6	69	0.93	376	221 – 668	0.44	0.26 – 0.78

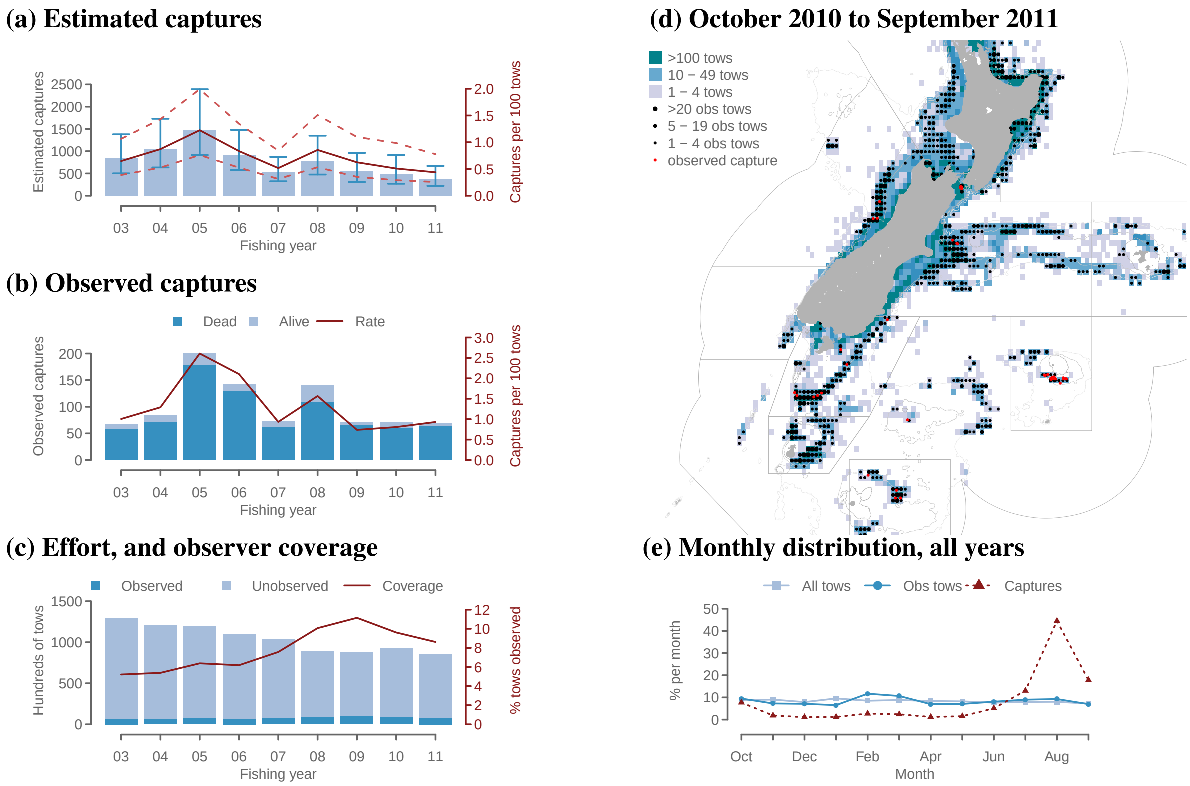


Figure A-2: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in all trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.3: Fur seal captures in hoki trawl fisheries

Table A-3: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in hoki trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	27 748	9.3	45	1.74	595	330 – 1045	2.14	1.19 – 3.77
2003–04	22 498	10.4	49	2.10	719	395 – 1288	3.19	1.76 – 5.73
2004–05	14 522	14.6	120	5.65	782	427 – 1447	5.38	2.94 – 9.96
2005–06	11 585	15.4	62	3.47	430	216 – 841	3.71	1.86 – 7.26
2006–07	10 603	16.5	29	1.65	257	123 – 517	2.43	1.16 – 4.88
2007–08	8 768	21.3	58	3.11	316	161 – 653	3.61	1.84 – 7.45
2008–09	8 171	20.3	37	2.24	207	100 – 434	2.53	1.22 – 5.31
2009–10	9 952	20.7	30	1.46	176	90 – 358	1.77	0.90 – 3.60
2010–11	10 395	16.5	23	1.34	159	76 – 323	1.53	0.73 – 3.11

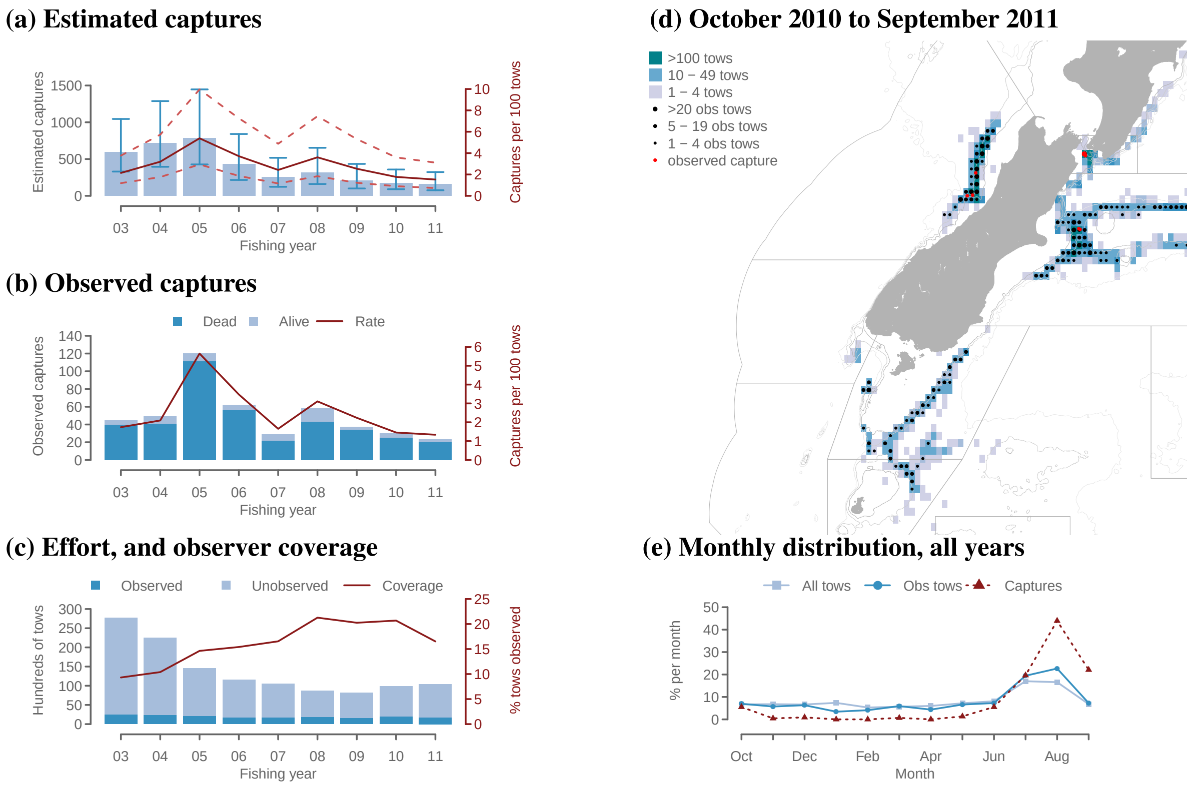


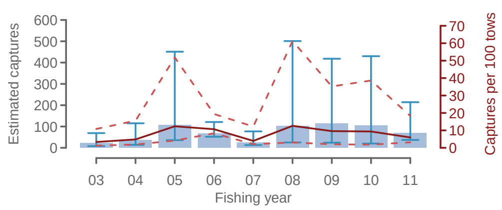
Figure A-3: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in hoki trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.4: Fur seal captures in southern blue whiting trawl fisheries

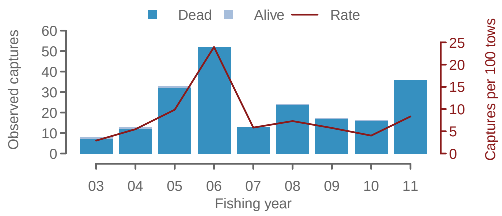
Table A-4: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in southern blue whiting trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	638	43.1	8	2.91	21	8 – 69	3.33	1.25 – 10.82
2003–04	740	32.2	13	5.46	36	14 – 115	4.81	1.89 – 15.54
2004–05	870	38.5	33	9.85	107	36 – 451	12.35	4.14 – 51.84
2005–06	624	34.8	52	23.96	67	52 – 121	10.67	8.33 – 19.39
2006–07	630	35.4	13	5.83	25	13 – 77	3.95	2.06 – 12.22
2007–08	818	40.2	24	7.29	103	25 – 501	12.61	3.06 – 61.25
2008–09	1 187	24.9	17	5.74	114	24 – 418	9.59	2.02 – 35.21
2009–10	1 114	35.6	16	4.03	104	20 – 430	9.37	1.80 – 38.60
2010–11	1 171	36.9	36	8.33	70	37 – 214	5.94	3.16 – 18.28

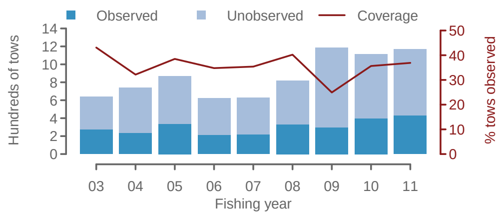
(a) Estimated captures



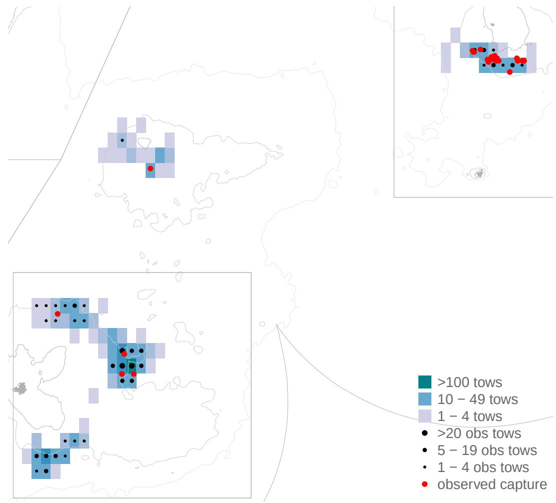
(b) Observed captures



(c) Effort, and observer coverage



(d) October 2010 to September 2011



(e) Monthly distribution, all years

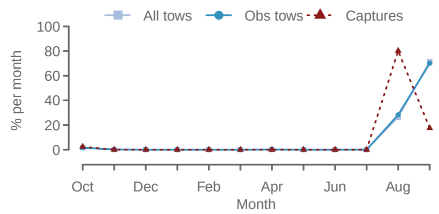


Figure A-4: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in southern blue whiting trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.5: Fur seal captures in middle depths trawl fisheries

Table A-5: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in middle depths trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	11 164	3.1	1	0.29	101	32 – 248	0.91	0.29 – 2.22
2003–04	9 204	2.1	0	0.00	125	40 – 301	1.36	0.43 – 3.27
2004–05	9 184	2.4	10	4.50	216	88 – 454	2.35	0.96 – 4.94
2005–06	8 386	6.2	4	0.76	163	60 – 383	1.94	0.72 – 4.57
2006–07	8 167	4.5	3	0.81	105	40 – 227	1.28	0.49 – 2.78
2007–08	7 412	6.1	9	2.00	144	63 – 291	1.94	0.85 – 3.93
2008–09	7 231	10.1	2	0.27	115	38 – 288	1.59	0.53 – 3.98
2009–10	7 210	11.8	5	0.59	90	31 – 236	1.25	0.43 – 3.27
2010–11	7 248	8.5	2	0.32	76	26 – 180	1.05	0.36 – 2.48

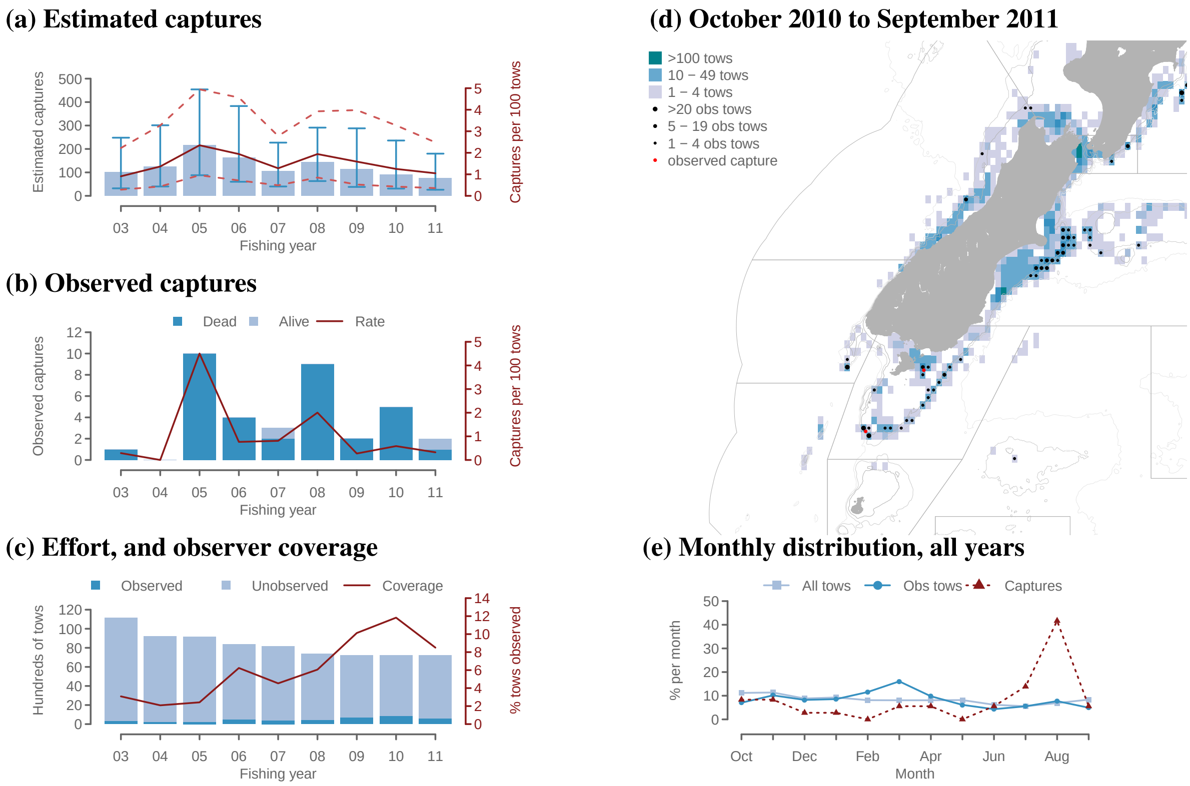


Figure A-5: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in middle depths trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.6: Fur seal captures in squid trawl fisheries

Table A-6: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in squid trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 410	15.5	8	0.61	55	26 – 103	0.65	0.31 – 1.22
2003–04	8 336	21.1	17	0.96	88	47 – 157	1.05	0.56 – 1.88
2004–05	10 489	23.9	16	0.64	157	81 – 291	1.49	0.77 – 2.77
2005–06	8 574	15.7	4	0.30	98	44 – 195	1.15	0.51 – 2.27
2006–07	5 905	21.8	8	0.62	41	20 – 79	0.70	0.34 – 1.34
2007–08	4 236	34.3	6	0.41	33	14 – 69	0.78	0.33 – 1.63
2008–09	3 868	33.5	1	0.08	19	6 – 46	0.50	0.16 – 1.19
2009–10	3 788	28.1	8	0.75	33	15 – 66	0.87	0.40 – 1.74
2010–11	4 212	29.8	5	0.40	18	8 – 37	0.43	0.19 – 0.88

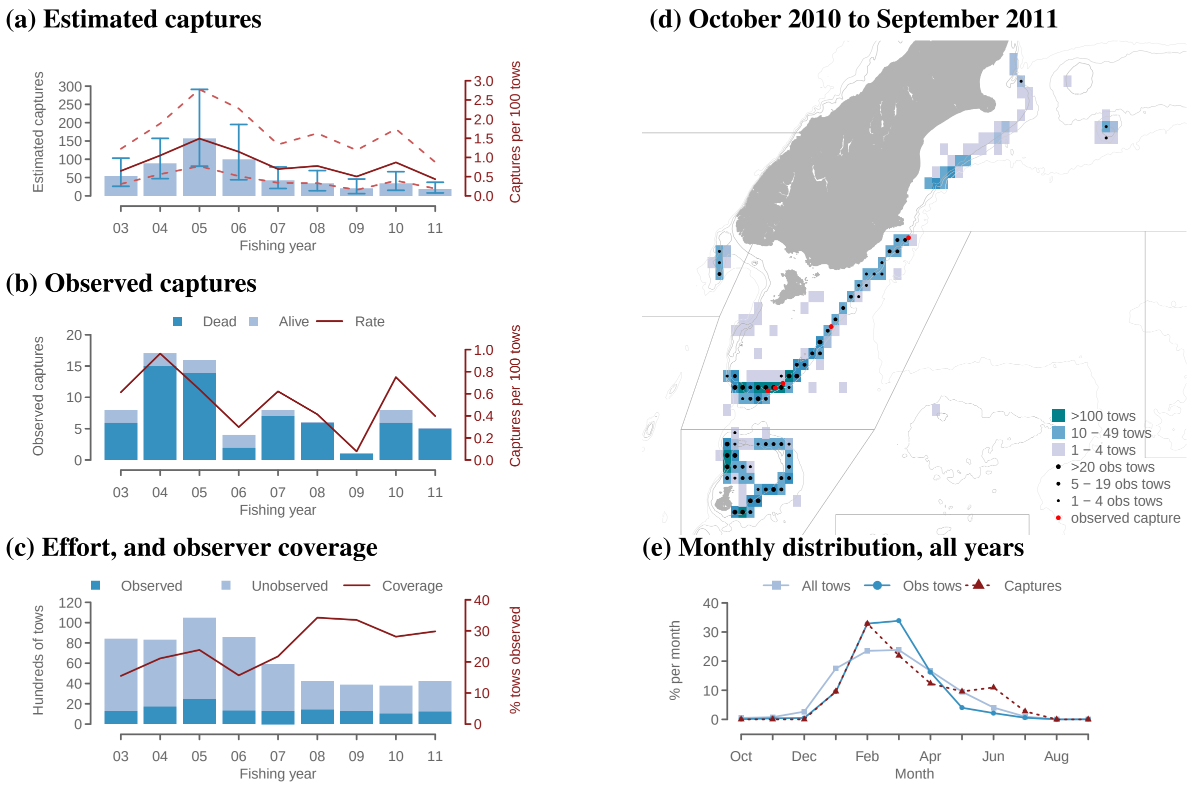


Figure A-6: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in squid trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.7: Fur seal captures in ling trawl fisheries

Table A-7: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in ling trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	625	2.6	0	0.00	10	0 – 43	1.61	0.00 – 6.88
2003–04	549	4.0	0	0.00	16	0 – 83	2.96	0.00 – 15.12
2004–05	987	7.7	10	13.16	59	17 – 177	5.95	1.72 – 17.93
2005–06	1 391	8.1	2	1.77	46	11 – 132	3.29	0.79 – 9.49
2006–07	1 658	9.5	12	7.64	44	19 – 109	2.68	1.15 – 6.58
2007–08	2 231	10.8	4	1.66	43	14 – 112	1.95	0.63 – 5.02
2008–09	1 410	10.3	0	0.00	27	6 – 75	1.94	0.43 – 5.32
2009–10	1 197	16.6	6	3.02	26	9 – 83	2.17	0.75 – 6.94
2010–11	1 106	9.3	2	1.94	19	4 – 60	1.75	0.36 – 5.42

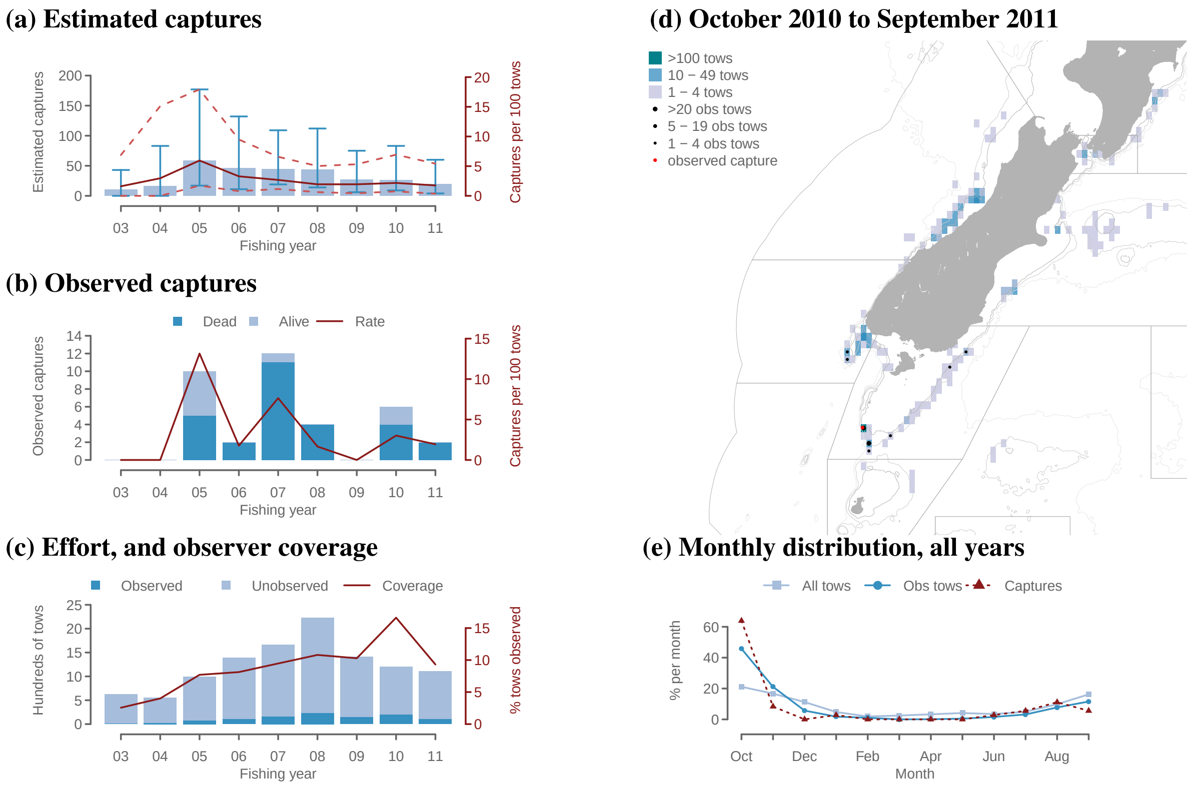


Figure A-7: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in ling trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.8: Fur seal captures in hake trawl fisheries

Table A-8: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in hake trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	937	5.2	3	6.12	11	3 – 31	1.22	0.32 – 3.31
2003–04	1 641	8.5	0	0.00	14	2 – 41	0.84	0.12 – 2.50
2004–05	1 550	6.1	2	2.11	33	8 – 85	2.13	0.52 – 5.48
2005–06	1 359	30.8	11	2.63	35	15 – 84	2.60	1.10 – 6.18
2006–07	1 604	18.4	4	1.36	19	6 – 46	1.17	0.37 – 2.87
2007–08	1 545	25.5	28	7.11	50	32 – 95	3.25	2.07 – 6.15
2008–09	1 764	19.9	5	1.42	21	7 – 53	1.18	0.40 – 3.00
2009–10	821	40.1	4	1.22	12	4 – 33	1.41	0.49 – 4.02
2010–11	866	26.2	1	0.44	10	1 – 34	1.18	0.12 – 3.93

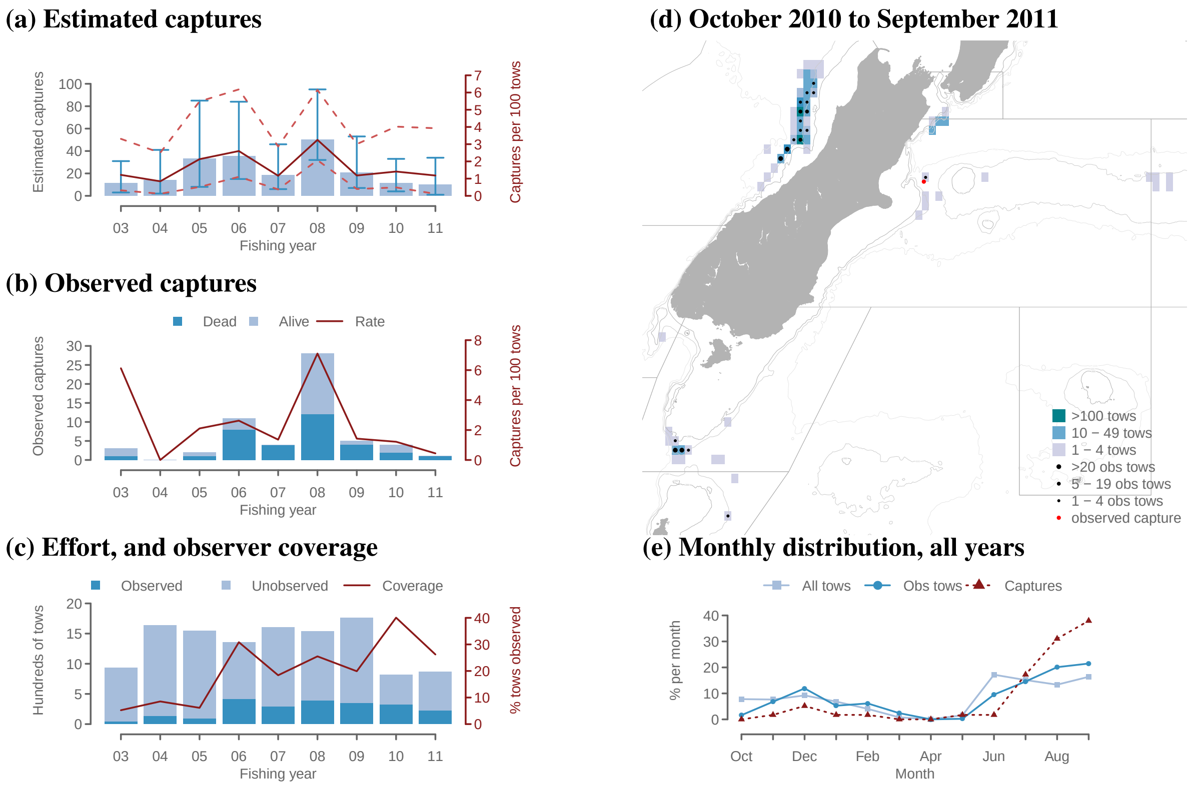


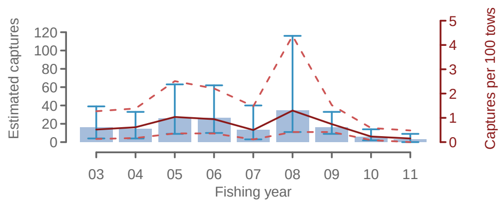
Figure A-8: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in hake trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.9: Fur seal captures in mackerel trawl fisheries

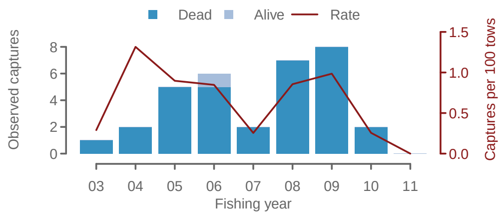
Table A-9: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in mackerel trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	3 067	11.2	1	0.29	16	4 – 39	0.52	0.13 – 1.27
2003–04	2 383	6.4	2	1.32	15	4 – 33	0.61	0.17 – 1.38
2004–05	2 509	22.2	5	0.90	26	9 – 63	1.03	0.36 – 2.51
2005–06	2 807	25.2	6	0.85	26	10 – 62	0.94	0.36 – 2.21
2006–07	2 711	29.0	2	0.25	14	3 – 40	0.50	0.11 – 1.48
2007–08	2 651	30.9	7	0.86	34	11 – 116	1.30	0.41 – 4.38
2008–09	2 169	37.4	8	0.99	16	9 – 33	0.74	0.41 – 1.52
2009–10	2 406	32.5	2	0.26	6	2 – 14	0.23	0.08 – 0.58
2010–11	1 879	31.6	0	0.00	3	0 – 9	0.15	0.00 – 0.48

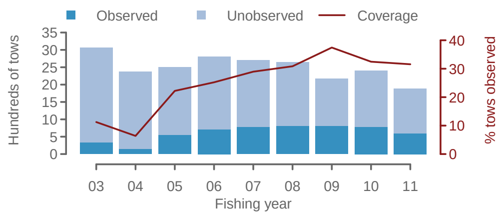
(a) Estimated captures



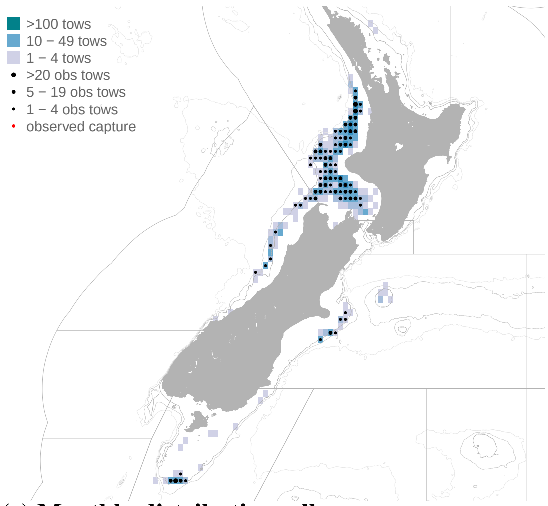
(b) Observed captures



(c) Effort, and observer coverage



(d) October 2010 to September 2011



(e) Monthly distribution, all years

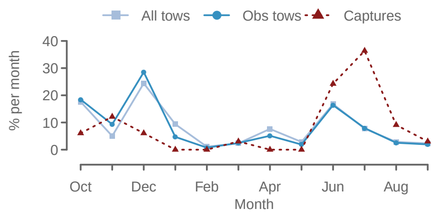


Figure A-9: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in mackerel trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.10: Fur seal captures in scampi trawl fisheries

Table A-10: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in scampi trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	5 115	10.0	2	0.39	7	2 – 21	0.14	0.04 – 0.41
2003–04	3 750	11.0	1	0.24	5	1 – 18	0.14	0.03 – 0.48
2004–05	4 622	3.1	0	0.00	21	1 – 95	0.46	0.02 – 2.06
2005–06	4 846	6.7	0	0.00	7	0 – 25	0.14	0.00 – 0.52
2006–07	5 119	7.5	0	0.00	6	0 – 23	0.12	0.00 – 0.45
2007–08	4 802	10.8	1	0.19	9	1 – 32	0.19	0.02 – 0.67
2008–09	3 972	9.8	1	0.26	6	1 – 19	0.14	0.03 – 0.48
2009–10	4 240	8.2	1	0.29	5	1 – 17	0.12	0.02 – 0.40
2010–11	4 445	11.9	0	0.00	4	0 – 16	0.08	0.00 – 0.36

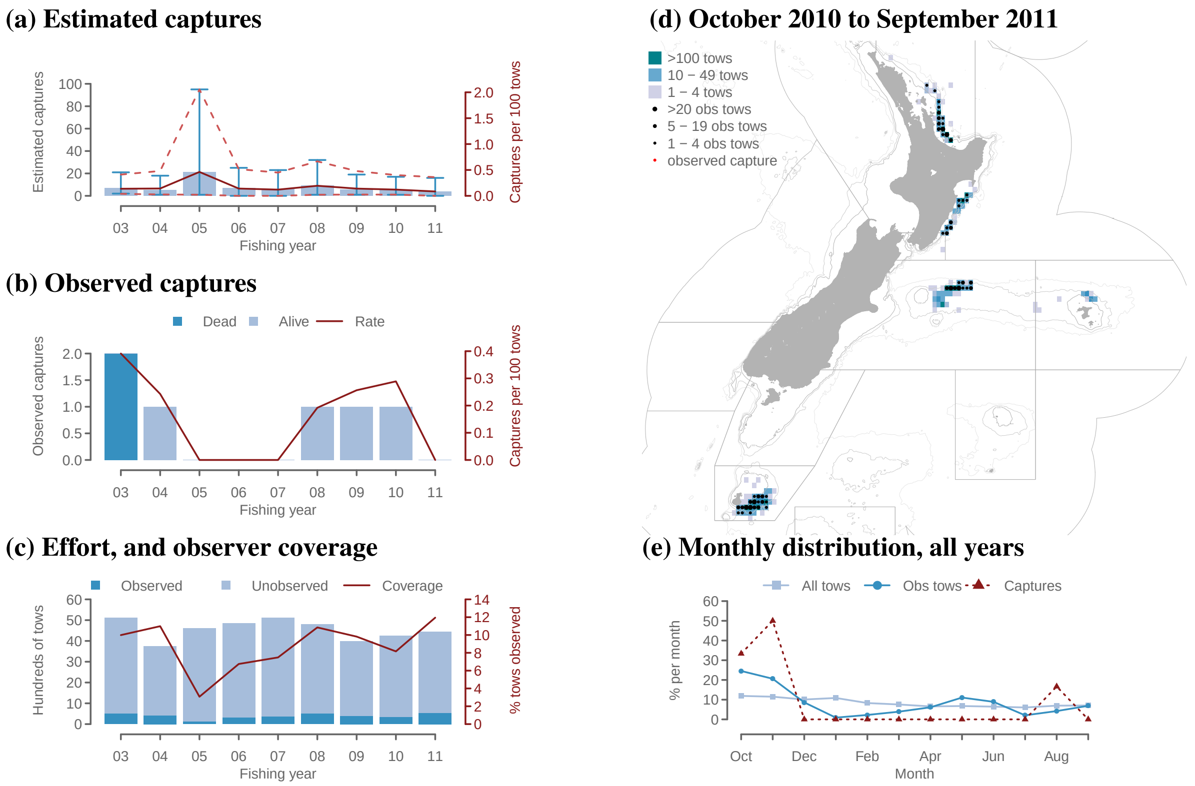


Figure A-10: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in scampi trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.11: Fur seal captures in deepwater trawl fisheries

Table A-11: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in deepwater trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	8 859	15.0	0	0.00	4	0 – 16	0.04	0.00 – 0.18
2003–04	7 994	15.5	2	0.16	7	2 – 21	0.09	0.03 – 0.26
2004–05	8 405	19.0	4	0.25	17	4 – 79	0.21	0.05 – 0.94
2005–06	8 284	15.2	2	0.16	9	2 – 32	0.11	0.02 – 0.39
2006–07	7 353	30.9	2	0.09	3	2 – 7	0.04	0.03 – 0.10
2007–08	6 728	41.6	4	0.14	7	4 – 17	0.10	0.06 – 0.25
2008–09	6 130	38.3	0	0.00	3	0 – 14	0.04	0.00 – 0.23
2009–10	6 013	35.4	0	0.00	2	0 – 10	0.04	0.00 – 0.17
2010–11	4 172	28.6	0	0.00	2	0 – 13	0.06	0.00 – 0.31

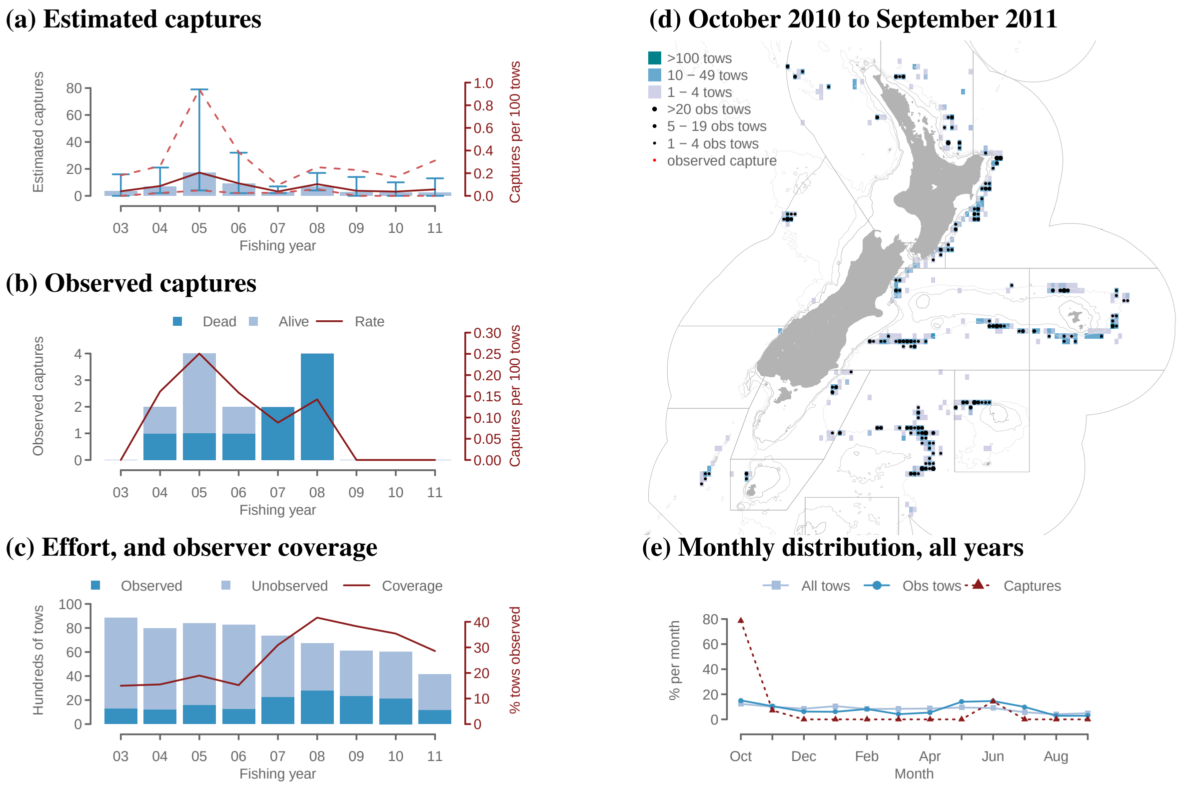


Figure A-11: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in deepwater trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.12: Fur seal captures in inshore trawl fisheries

Table A-12: Annual trawl effort, observer coverage, observed number of fur seal captures, observed capture rate (fur seal per 100 tows), estimated fur seal captures, and the estimated capture rate (with 95% confidence intervals), in inshore trawl fisheries.

		Observed			Est. captures		Est. capture rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	36 459	0.0	0	0.00	22	0 – 110	0.06	0.00 – 0.30
2003–04	37 569	0.0	0	0.00	28	0 – 136	0.07	0.00 – 0.36
2004–05	40 749	0.0	0	0.00	53	0 – 245	0.13	0.00 – 0.60
2005–06	39 183	0.3	0	0.00	35	0 – 168	0.09	0.00 – 0.43
2006–07	35 782	0.8	0	0.00	20	0 – 95	0.05	0.00 – 0.27
2007–08	31 373	0.4	0	0.00	24	0 – 117	0.08	0.00 – 0.37
2008–09	33 058	3.5	1	0.09	19	1 – 82	0.06	0.00 – 0.25
2009–10	35 922	1.4	0	0.00	18	0 – 82	0.05	0.00 – 0.23
2010–11	34 935	1.3	0	0.00	15	0 – 74	0.04	0.00 – 0.21

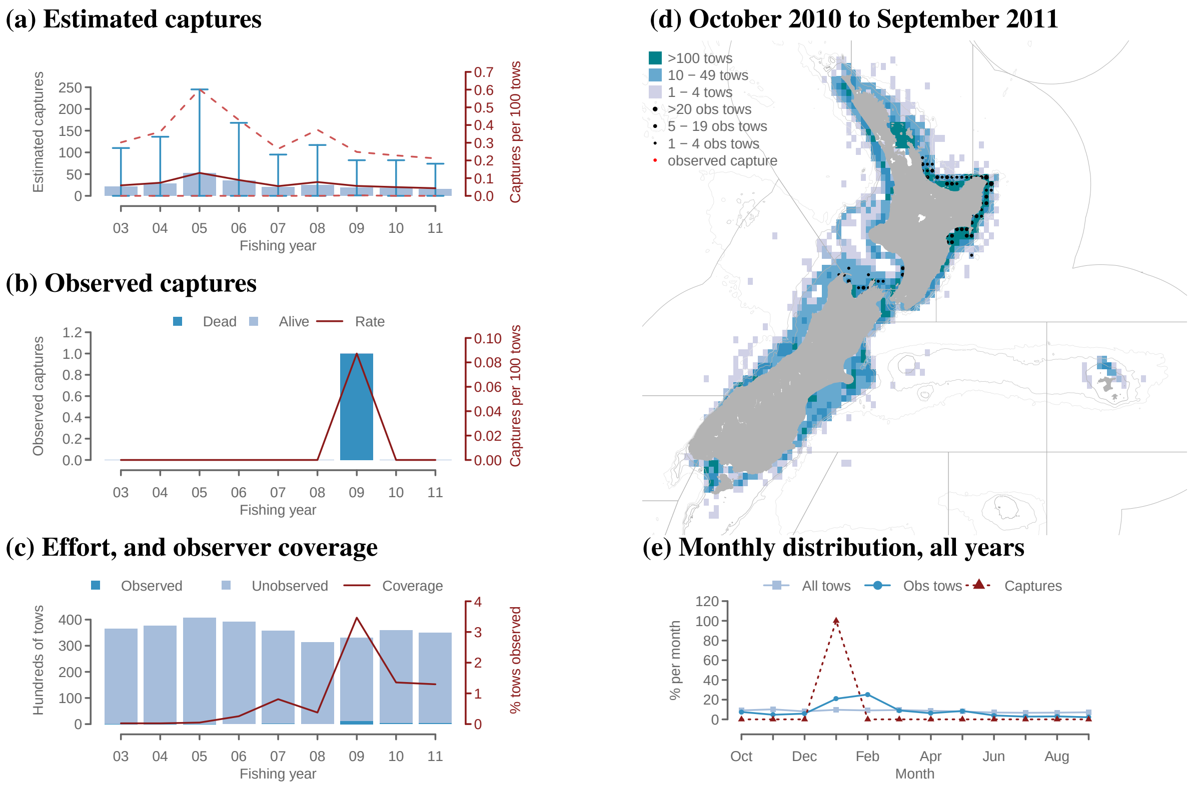


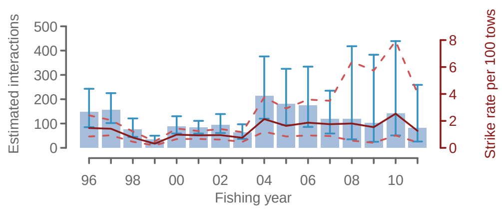
Figure A-12: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in inshore trawl fisheries from 2002–03 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.13: Sea lion captures in all trawl fisheries

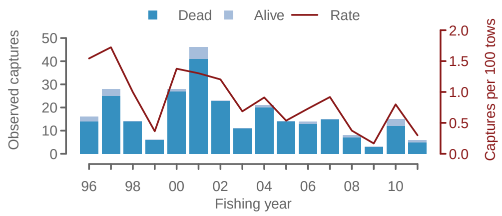
Table A-13: Annual trawl effort, observer coverage, observed number of sea lion captures, observed capture rate (sea lion per 100 tows), estimated sea lion captures, interactions, and the estimated strike rate (with 95% confidence intervals), from all trawl fisheries, in the four estimated strata.

		Observed			Est. captures		Est. interactions		Est. strike rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995–96	10 081	10	16	1.5	148	85 – 242	148	85 – 243	1.5	0.8 – 2.4
1996–97	10 941	15	28	1.7	155	104 – 221	155	102 – 225	1.4	0.9 – 2.1
1997–98	9 964	14	14	1.0	76	47 – 119	76	45 – 121	0.8	0.5 – 1.2
1998–99	10 551	16	6	0.4	33	20 – 49	33	19 – 50	0.3	0.2 – 0.5
1999–00	9 043	22	28	1.4	88	63 – 129	89	59 – 130	1.0	0.7 – 1.4
2000–01	8 910	40	46	1.3	61	52 – 72	83	59 – 111	0.9	0.7 – 1.2
2001–02	9 945	19	23	1.2	64	46 – 88	94	61 – 139	0.9	0.6 – 1.4
2002–03	8 308	19	11	0.7	34	22 – 48	62	37 – 97	0.7	0.4 – 1.2
2003–04	10 033	23	21	0.9	61	43 – 85	214	120 – 376	2.1	1.2 – 3.7
2004–05	11 109	23	14	0.5	53	36 – 77	181	94 – 325	1.6	0.8 – 2.9
2005–06	9 316	21	14	0.7	52	35 – 75	174	86 – 334	1.9	0.9 – 3.6
2006–07	6 728	24	15	0.9	47	32 – 66	118	59 – 235	1.8	0.9 – 3.5
2007–08	6 545	33	8	0.4	29	18 – 42	118	35 – 418	1.8	0.5 – 6.4
2008–09	6 677	27	3	0.2	22	12 – 36	103	25 – 383	1.5	0.4 – 5.7
2009–10	5 541	34	15	0.8	46	32 – 66	141	51 – 439	2.5	0.9 – 7.9
2010–11	6 389	31	6	0.3	29	17 – 43	81	26 – 259	1.3	0.4 – 4.1

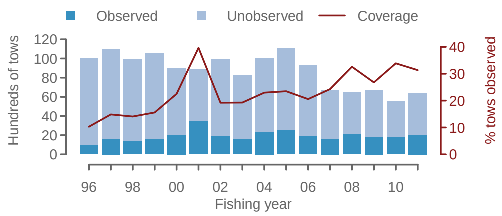
(a) Estimated interactions



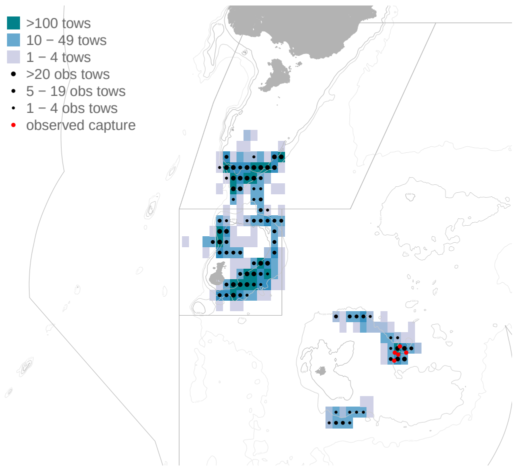
(b) Observed captures



(c) Effort, and observer coverage



(d) October 2010 to September 2011



(e) Monthly distribution, all years

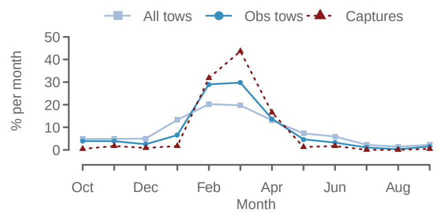


Figure A-13: Annual time series of (a) estimated sea lion interactions, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in all trawl fisheries from 1995–96 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.14: Sea lion captures in the Auckland Islands squid fishery

Table A-14: Annual trawl effort, observer coverage, observed number of sea lion captures, observed capture rate (sea lions per 100 trawls), estimated sea lion captures, interactions, and the estimated strike rate (with 95% confidence intervals), in the Auckland Islands squid fishery.

		Observed			Est. captures		Est. interactions		Est. strike rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995–96	4 467	12	13	2.4	131	69 – 226	131	67 – 224	2.9	1.6 – 5.0
1996–97	3 716	19	28	3.9	142	91 – 208	142	89 – 210	3.8	2.6 – 5.5
1997–98	1 441	22	13	4.2	60	33 – 102	60	31 – 104	4.2	2.5 – 6.9
1998–99	402	38	5	3.2	14	7 – 27	15	5 – 29	3.6	2.1 – 5.9
1999–00	1 206	36	25	5.7	69	45 – 107	69	42 – 108	5.8	4.0 – 8.6
2000–01	583	99	39	6.7	39	39 – 40	61	39 – 87	10.4	8.6 – 13.1
2001–02	1 648	34	21	3.7	43	30 – 64	73	43 – 116	4.4	3.0 – 6.6
2002–03	1 470	29	11	2.6	19	13 – 29	48	24 – 81	3.2	2.0 – 5.1
2003–04	2 594	30	16	2.0	41	26 – 62	194	100 – 356	7.5	4.0 – 13.5
2004–05	2 706	30	9	1.1	31	17 – 51	159	73 – 303	5.9	2.7 – 11.1
2005–06	2 462	28	9	1.3	28	15 – 45	149	62 – 308	6.0	2.7 – 12.5
2006–07	1 320	41	7	1.3	16	9 – 27	87	29 – 201	6.6	2.3 – 14.8
2007–08	1 265	46	5	0.9	12	6 – 21	101	19 – 396	8.0	1.6 – 30.9
2008–09	1 925	40	2	0.3	8	3 – 17	89	12 – 365	4.6	0.7 – 18.4
2009–10	1 190	25	3	1.0	13	5 – 27	107	18 – 402	9.0	1.7 – 33.6
2010–11	1 586	34	0	-	4	0 – 11	56	4 – 233	3.5	0.4 – 14.9

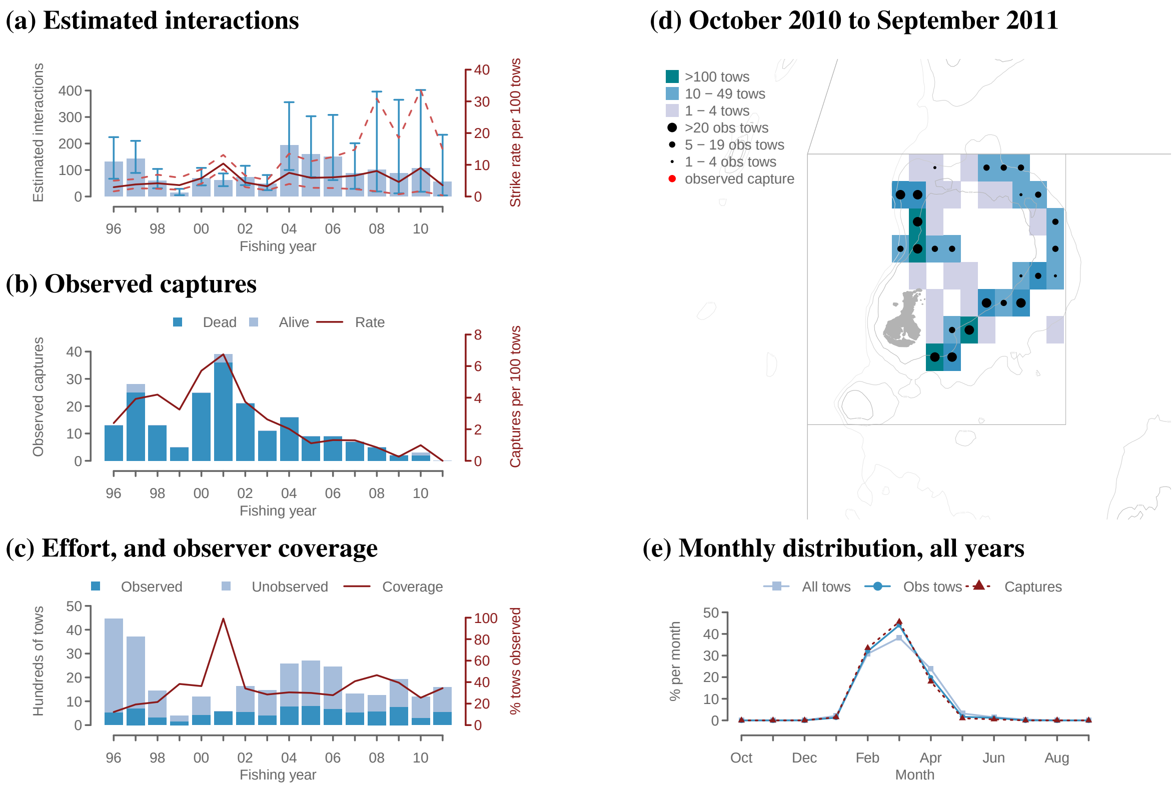


Figure A-14: Annual time series of (a) estimated sea lion interactions, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in the Auckland Islands squid fishery from 1995–96 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.15: Sea lion captures in the Campbell Island southern blue whiting fishery

Table A-15: Annual trawl effort, observer coverage, observed number of sea lion captures, observed capture rate (sea lion per 100 tows), estimated sea lion captures, and the estimated strike rate (with 95% confidence intervals), in the Campbell Island southern blue whiting fishery.

		Observed			Est. captures		Est. strike rate	
	Effort	% obs.	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
1996	474	27	0	-	0	0 – 4	0.2	0.0 – 1.1
1997	641	34	0	-	1	0 – 3	0.2	0.0 – 0.7
1998	963	28	0	-	1	0 – 5	0.1	0.0 – 0.6
1999	788	28	0	-	1	0 – 5	0.1	0.0 – 0.7
2000	447	52	0	-	0	0 – 3	0.1	0.0 – 0.7
2001	672	60	0	-	0	0 – 2	0.1	0.0 – 0.5
2002	980	28	1	0.4	4	1 – 11	0.4	0.0 – 1.2
2003	599	43	0	-	1	0 – 3	0.2	0.0 – 0.7
2004	690	34	1	0.4	3	1 – 9	0.4	0.0 – 1.4
2005	726	37	2	0.7	5	2 – 12	0.7	0.1 – 1.9
2006	521	28	3	2.1	10	3 – 21	1.8	0.4 – 4.4
2007	544	32	6	3.5	15	6 – 29	3.1	1.1 – 6.0
2008	557	41	2	0.9	8	5 – 14	0.8	0.1 – 2.2
2009	627	20	0	-	1	0 – 7	0.2	0.0 – 1.2
2010	550	43	11	4.7	24	15 – 36	4.3	2.1 – 7.2
2011	815	40	6	1.8	15	8 – 25	1.8	0.7 – 3.4

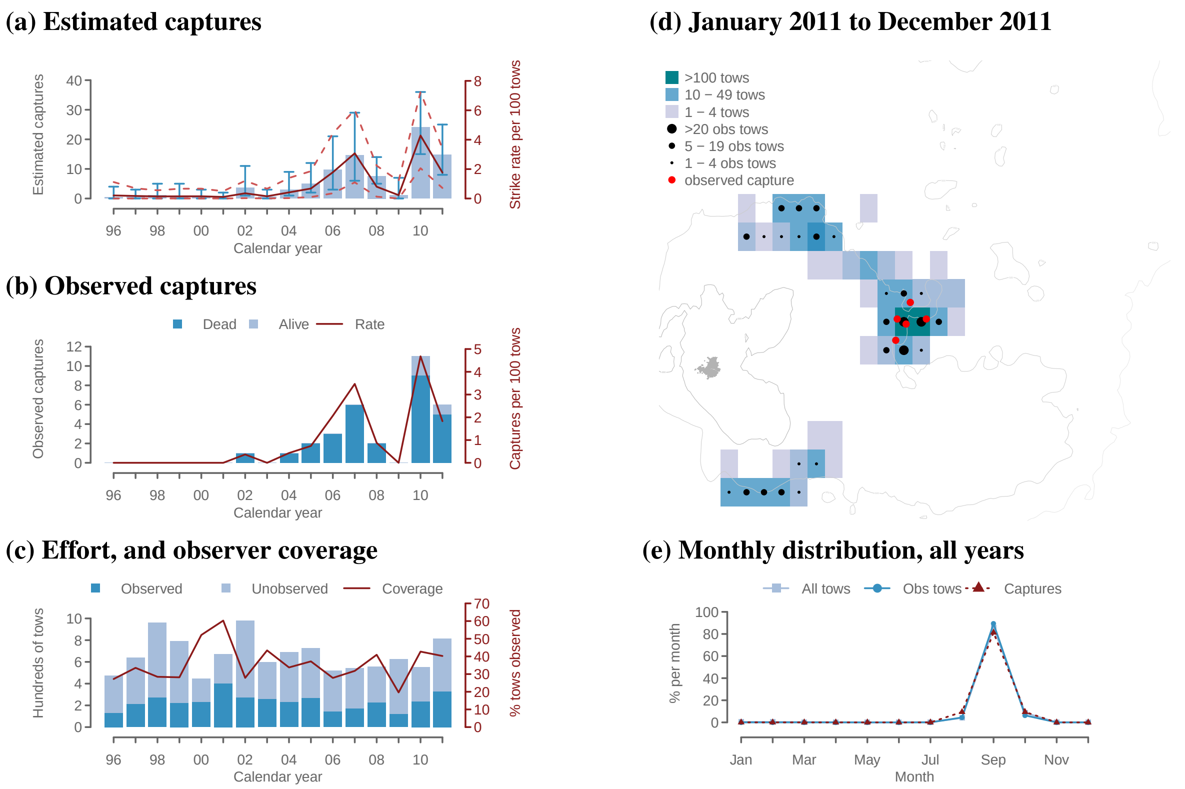


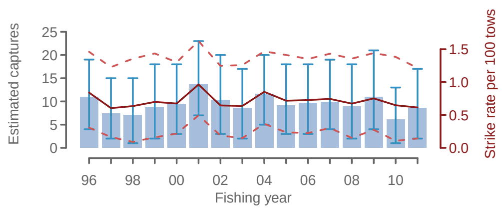
Figure A-15: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in the Campbell Island southern blue whiting fishery from 2000 to 2011. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.16: Sea lion captures in the Auckland Islands scampi fishery

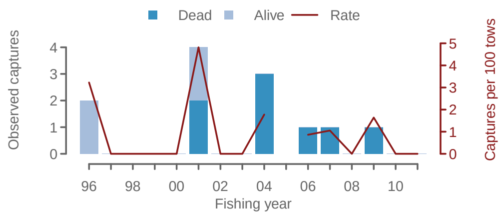
Table A-16: Annual trawl effort, observer coverage, observed number of sea lion captures, observed capture rate (sea lion per 100 tows), estimated sea lion captures, and the estimated strike rate (with 95% confidence intervals), in the trawl fisheries near the Auckland Islands targeting scampi.

		Observed			Est. captures		Est. strike rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995–96	1 303	5	2	3.2	11	4 – 19	0.8	0.3 – 1.5
1996–97	1 222	15	0	-	7	2 – 15	0.6	0.2 – 1.2
1997–98	1 107	11	0	-	7	1 – 15	0.6	0.1 – 1.4
1998–99	1 254	2	0	-	9	2 – 18	0.7	0.2 – 1.4
1999–00	1 383	5	0	-	9	3 – 18	0.7	0.2 – 1.3
2000–01	1 417	6	4	4.8	14	7 – 23	1.0	0.5 – 1.6
2001–02	1 604	9	0	-	10	3 – 20	0.6	0.2 – 1.2
2002–03	1 351	11	0	-	9	2 – 17	0.6	0.1 – 1.3
2003–04	1 363	12	3	1.8	12	5 – 20	0.9	0.4 – 1.5
2004–05	1 275	0			9	3 – 18	0.7	0.2 – 1.4
2005–06	1 331	9	1	0.9	10	3 – 18	0.7	0.2 – 1.4
2006–07	1 328	7	1	1.1	10	4 – 19	0.7	0.3 – 1.4
2007–08	1 327	7	0	-	9	2 – 18	0.7	0.2 – 1.4
2008–09	1 457	4	1	1.6	11	4 – 21	0.8	0.3 – 1.4
2009–10	940	10	0	-	6	1 – 13	0.6	0.1 – 1.4
2010–11	1 401	15	0	-	9	2 – 17	0.6	0.1 – 1.2

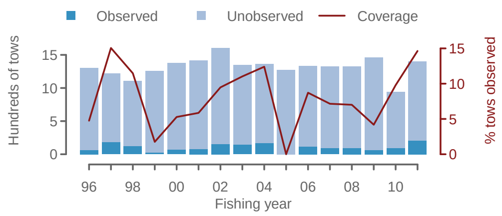
(a) Estimated captures



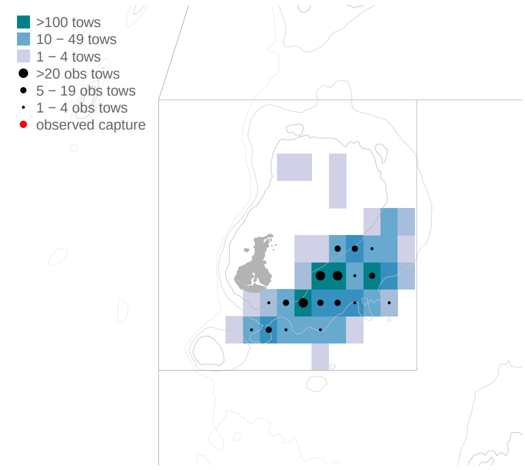
(b) Observed captures



(c) Effort, and observer coverage



(d) October 2010 to September 2011



(e) Monthly distribution, all years

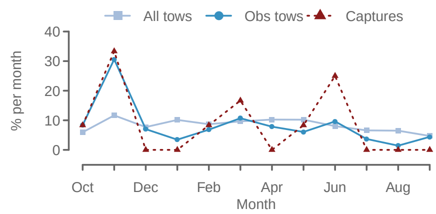


Figure A-16: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in the Auckland Islands scampi fishery from 1995–96 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.17: Sea lion captures in the other Auckland Islands trawl fisheries

Table A-17: Annual trawl effort, observer coverage, observed number of sea lion captures, observed capture rate (sea lion per 100 tows), estimated sea lion captures, and the estimated strike rate (with 95% confidence intervals), in the trawl fisheries near the Auckland Islands not targeting squid or scampi.

		Observed			Est. captures		Est. strike rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995–96	405	6	1	4.0	3	1 – 6	0.6	0.2 – 1.5
1996–97	296	4	0	-	1	0 – 4	0.4	0.0 – 1.4
1997–98	684	17	1	0.9	3	1 – 8	0.5	0.1 – 1.2
1998–99	525	10	1	1.8	3	1 – 7	0.6	0.2 – 1.3
1999–00	750	13	0	-	3	0 – 8	0.4	0.0 – 1.1
2000–01	577	7	0	-	2	0 – 7	0.4	0.0 – 1.2
2001–02	589	4	0	-	2	0 – 7	0.4	0.0 – 1.2
2002–03	543	13	0	-	2	0 – 7	0.4	0.0 – 1.3
2003–04	289	17	0	-	1	0 – 4	0.3	0.0 – 1.4
2004–05	170	7	0	-	1	0 – 3	0.4	0.0 – 1.8
2005–06	39	15	0	-	0	0 – 1	0.4	0.0 – 2.6
2006–07	38	5	0	-	0	0 – 1	0.4	0.0 – 2.6
2007–08	147	45	0	-	0	0 – 2	0.2	0.0 – 1.4
2008–09	121	50	0	-	0	0 – 2	0.2	0.0 – 1.7
2009–10	77	66	0	-	0	0 – 1	0.2	0.0 – 1.3
2010–11	131	37	0	-	0	0 – 2	0.3	0.0 – 1.5

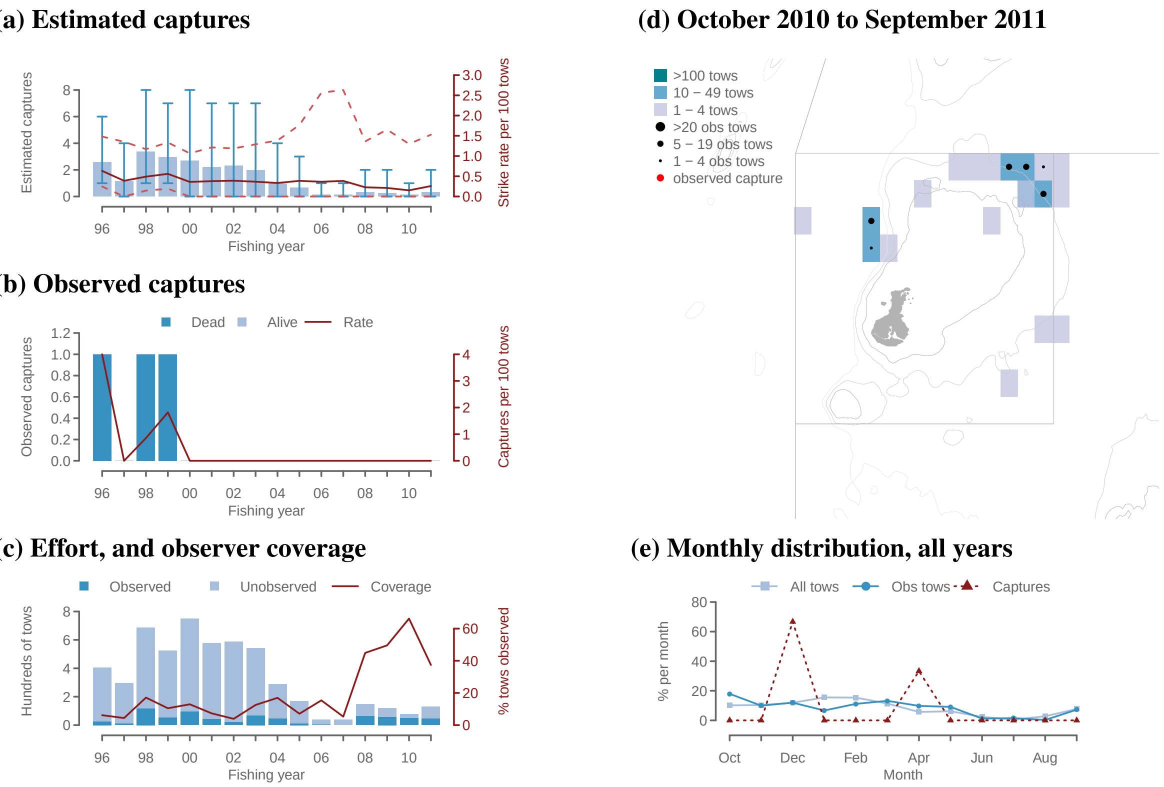


Figure A-17: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in Auckland Islands trawl fisheries not targeting squid or scampi from 1995–96 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX A.18: Sea lion captures in all trawl fisheries on the Stewart-Snares shelf

Table A-18: Annual trawl effort, observer coverage, observed number of sea lion captured, observed capture rate (sea lion per 100 tows), estimated sea lion captures, and the estimated strike rate (with 95% confidence intervals), in all trawl fisheries on the Stewart-Snares shelf.

		Observed			Est. captures		Est. strike rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995–96	3 432	8	0	-	3	0 – 7	0.1	0.0 – 0.2
1996–97	5 066	10	0	-	4	0 – 9	0.1	0.0 – 0.2
1997–98	5 769	10	0	-	5	1 – 10	0.1	0.0 – 0.2
1998–99	7 582	16	0	-	6	1 – 13	0.1	0.0 – 0.2
1999–00	5 257	23	3	0.3	7	3 – 12	0.1	0.1 – 0.2
2000–01	5 661	43	3	0.1	6	3 – 10	0.1	0.1 – 0.2
2001–02	5 124	18	1	0.1	5	1 – 10	0.1	0.0 – 0.2
2002–03	4 345	16	0	-	3	0 – 8	0.1	0.0 – 0.2
2003–04	5 097	21	1	0.1	5	1 – 10	0.1	0.0 – 0.2
2004–05	6 232	24	3	0.2	7	4 – 13	0.1	0.1 – 0.2
2005–06	4 963	19	1	0.1	5	1 – 10	0.1	0.0 – 0.2
2006–07	3 498	24	1	0.1	4	1 – 7	0.1	0.0 – 0.2
2007–08	3 249	36	1	0.1	3	1 – 7	0.1	0.0 – 0.2
2008–09	2 547	31	0	-	2	0 – 5	0.1	0.0 – 0.2
2009–10	2 784	43	1	0.1	3	1 – 6	0.1	0.0 – 0.2
2010–11	2 456	36	0	-	1	0 – 4	0.1	0.0 – 0.2

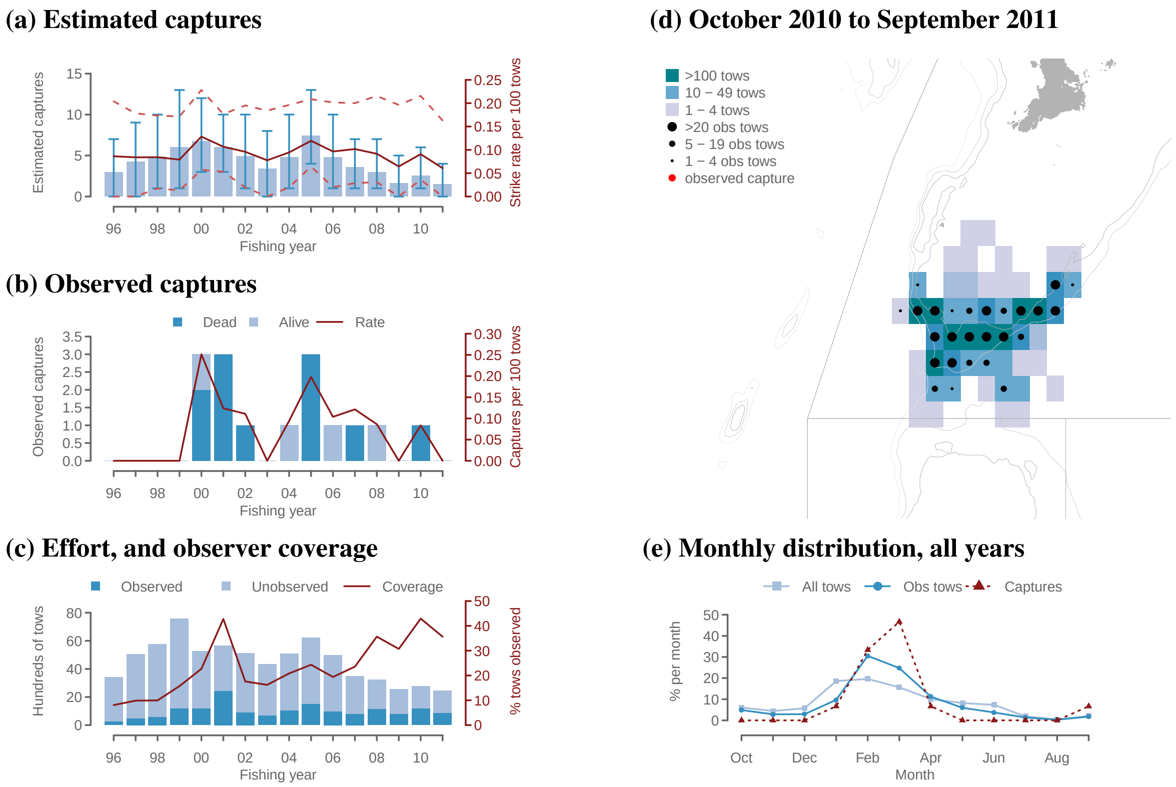


Figure A-18: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in all trawl fisheries on the Stewart-Snares shelf from 1995–96 to 2010–11. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

APPENDIX B: Common dolphin capture model parameters

Table B-19: Mean, median, and 95% confidence intervals for final model parameters. Calculated from samples of the corresponding posterior distributions.

Parameter	Mean	Median	95% c.i.	
Mean number of dolphins per capture event	2.103	2.097	1.671	2.566
Mean event rate, (events per 100 tows)	0.246	0.238	0.114	0.431
1995–96 base rate (events per 100 tows)	0.476	0.345	0.055	1.721
1996–97 base rate (events per 100 tows)	0.288	0.200	0.019	1.084
1997–98 base rate (events per 100 tows)	0.252	0.182	0.018	0.917
1998–99 base rate (events per 100 tows)	0.236	0.173	0.017	0.829
1999–00 base rate (events per 100 tows)	0.498	0.351	0.064	1.780
2000–01 base rate (events per 100 tows)	0.392	0.300	0.054	1.284
2001–02 base rate (events per 100 tows)	0.332	0.260	0.045	1.027
2002–03 base rate (events per 100 tows)	1.151	1.014	0.313	2.841
2003–04 base rate (events per 100 tows)	0.691	0.614	0.211	1.635
2004–05 base rate (events per 100 tows)	0.456	0.422	0.176	0.925
2005–06 base rate (events per 100 tows)	0.107	0.090	0.017	0.281
2006–07 base rate (events per 100 tows)	0.219	0.198	0.070	0.478
2007–08 base rate (events per 100 tows)	0.177	0.161	0.053	0.400
2008–09 base rate (events per 100 tows)	0.165	0.149	0.046	0.375
2009–10 base rate (events per 100 tows)	0.116	0.101	0.024	0.292
2010–11 base rate (events per 100 tows)	0.226	0.203	0.068	0.519
Headline depth, $\beta_{headline}$	-0.033	-0.033	-0.045	-0.022
Log trawl duration, $\beta_{duration}$	1.470	1.462	0.700	2.285
Light condition, relative to dark				
Light, $\exp(\beta_{light})$	0.177	0.166	0.075	0.346
Black, $\exp(\beta_{black})$	1.078	1.000	0.421	2.139
Sub-area, relative to north				
South, $\exp(\beta_{south})$	0.539	0.510	0.246	0.996

APPENDIX C: Fur seal capture model parameters

Table C-20: Mean, median, and 95% confidence intervals for final model parameters. Calculated from samples of the corresponding posterior distributions.

Parameter	Mean	Median	95% c.i.	
Extra dispersion, $1/\theta$	14.085	13.844	10.175	19.384
Mean rate, μ (captures per 100 tows)	0.389	0.389	0.267	0.498
Vessel/year effect standard deviation	0.692	0.690	0.522	0.854
2002–03 base rate (captures per 100 tows)	0.300	0.296	0.179	0.455
2003–04 base rate (captures per 100 tows)	0.386	0.379	0.230	0.582
2004–05 base rate (captures per 100 tows)	0.655	0.642	0.400	0.968
2005–06 base rate (captures per 100 tows)	0.476	0.470	0.290	0.701
2006–07 base rate (captures per 100 tows)	0.324	0.318	0.194	0.481
2007–08 base rate (captures per 100 tows)	0.505	0.495	0.322	0.735
2008–09 base rate (captures per 100 tows)	0.318	0.313	0.195	0.471
2009–10 base rate (captures per 100 tows)	0.285	0.277	0.173	0.424
2010–11 base rate (captures per 100 tows)	0.258	0.253	0.154	0.397
Sine(doy) coefficient	-1.337	-1.333	-1.612	-1.088
Cosine(doy) coefficient	-0.956	-0.955	-1.178	-0.726
Area coefficients relative to Stewart-Snares shelf				
East Coast SI	1.029	1.011	0.645	1.549
West Coast SI	0.513	0.500	0.300	0.802
Auckland Islands	0.243	0.236	0.121	0.428
West Coast NI	0.158	0.143	0.065	0.329
Subantarctic	4.987	4.201	1.105	13.708
Campbell Island	1.513	1.132	0.339	4.748
Cook Strait	1.615	1.533	0.791	2.863
Puysegur	1.209	1.141	0.609	2.236
Bounty Islands	20.207	14.589	4.000	71.023
Target coefficients relative to Hoki/Hake/Ling				
Squid	2.247	2.162	1.308	3.564
Deepwater	0.004	0.003	0.000	0.018
Middle depth	0.838	0.812	0.497	1.313
Jack mackerel	1.379	1.301	0.693	2.491
Southern blue whiting	0.505	0.417	0.103	1.401
Scampi	0.373	0.335	0.113	0.824
Inshore	0.100	0.066	0.002	0.408
Distance coefficients relative to Near (between 25 km and 90 km)				
Coastal (< 25 km)	1.653	1.620	0.973	2.504
Far (between 90 km and 180 km)	0.866	0.856	0.602	1.178
Ocean (> 180 km)	0.223	0.209	0.097	0.434
Interaction term				
Deepwater/Subantarctic	0.793	0.684	0.242	1.862

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

Table D-1: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seal in trawl fisheries, organised by target group, for five fishing years from 2006–07 to 2010–11.

		Observed				Est. captures		Est. capture rate	
	Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2006–07									
Hoki	10 158	1 592	15.7	29	1.82	257	123 - 517	16.15	7.72 - 32.47
Hake	1 469	287	19.5	4	1.39	19	6 - 46	6.52	2.09 - 16.03
SBW	630	223	35.4	13	5.83	25	13 - 77	11.17	5.83 - 34.53
Middle depth	6 569	303	4.6	3	0.99	105	40 - 227	34.51	13.20 - 74.92
Squid	5 892	1 282	21.8	8	0.62	41	20 - 79	3.21	1.56 - 6.16
Ling	1 446	157	10.9	12	7.64	44	19 - 109	28.34	12.10 - 69.44
Jack mackerel	2 710	785	29.0	2	0.25	14	3 - 40	1.72	0.38 - 5.10
Scampi	3 396	219	6.4	0	0.00	6	0 - 23	2.81	0.00 - 10.50
Deepwater	3 021	1 469	48.6	2	0.14	3	2 - 7	0.19	0.14 - 0.48
Inshore	17 282	168	1.0	0	0.00	20	0 - 95	11.68	0.00 - 56.55
2007–08									
Hoki	8 356	1 812	21.7	58	3.20	316	161 - 653	17.46	8.89 - 36.04
Hake	1 499	382	25.5	28	7.33	50	32 - 95	13.15	8.38 - 24.87
SBW	816	329	40.3	24	7.29	103	25 - 501	31.36	7.60 - 152.29
Middle depth	5 911	347	5.9	9	2.59	144	63 - 291	41.44	18.16 - 83.86
Squid	4 234	1 451	34.3	6	0.41	33	14 - 69	2.27	0.96 - 4.76
Ling	1 790	221	12.3	4	1.81	43	14 - 112	19.64	6.33 - 50.68
Jack mackerel	2 643	810	30.6	7	0.86	34	11 - 116	4.25	1.36 - 14.32
Scampi	3 284	298	9.1	1	0.34	9	1 - 32	3.13	0.34 - 10.74
Deepwater	3 415	1 405	41.1	4	0.28	7	4 - 17	0.49	0.28 - 1.21
Inshore	14 849	74	0.5	0	0.00	24	0 - 117	33.07	0.00 - 158.14
2008–09									
Hoki	7 953	1 653	20.8	37	2.24	207	100 - 434	12.53	6.05 - 26.26
Hake	1 748	349	20.0	5	1.43	21	7 - 53	5.97	2.01 - 15.19
SBW	1 189	298	25.1	17	5.70	114	24 - 418	38.18	8.05 - 140.27
Middle depth	5 812	648	11.1	2	0.31	115	38 - 288	17.74	5.86 - 44.44
Squid	3 860	1 296	33.6	1	0.08	19	6 - 46	1.50	0.46 - 3.55
Ling	1 249	143	11.4	0	0.00	27	6 - 75	19.17	4.20 - 52.45
Jack mackerel	2 155	812	37.7	8	0.99	16	9 - 33	1.98	1.11 - 4.06
Scampi	2 793	267	9.6	1	0.37	6	1 - 19	2.08	0.37 - 7.12
Deepwater	2 849	1 050	36.9	0	0.00	3	0 - 14	0.26	0.00 - 1.33
Inshore	15 880	867	5.5	1	0.12	19	1 - 82	2.13	0.12 - 9.46
2009–10									
Hoki	9 407	2 055	21.8	30	1.46	176	90 - 358	8.58	4.38 - 17.42
Hake	817	327	40.0	4	1.22	12	4 - 33	3.54	1.22 - 10.09
SBW	1 114	397	35.6	16	4.03	104	20 - 430	26.29	5.04 - 108.32
Middle depth	5 640	669	11.9	5	0.75	90	31 - 236	13.46	4.63 - 35.28
Squid	3 788	1 066	28.1	8	0.75	33	15 - 66	3.09	1.41 - 6.19
Ling	1 017	180	17.7	6	3.33	26	9 - 83	14.45	5.00 - 46.13
Jack mackerel	2 404	781	32.5	2	0.26	6	2 - 14	0.71	0.26 - 1.79
Scampi	2 460	203	8.3	1	0.49	5	1 - 17	2.52	0.49 - 8.37
Deepwater	3 183	1 116	35.1	0	0.00	2	0 - 10	0.20	0.00 - 0.90
Inshore	18 048	414	2.3	0	0.00	18	0 - 82	4.26	0.00 - 19.81
2010–11									
Hoki	9 914	1 694	17.1	23	1.36	159	76 - 323	9.37	4.49 - 19.07
Hake	861	227	26.4	0	0.00	10	1 - 34	4.50	0.44 - 14.98
SBW	1 171	432	36.9	36	8.33	70	37 - 214	16.11	8.56 - 49.55
Middle depth	5 696	402	7.1	2	0.50	76	26 - 180	18.89	6.47 - 44.78
Squid	4 211	1 257	29.9	5	0.40	18	8 - 37	1.46	0.64 - 2.94
Ling	1 007	102	10.1	2	1.96	19	4 - 60	19.03	3.92 - 58.82
Jack mackerel	1 879	593	31.6	0	0.00	3	0 - 9	0.47	0.00 - 1.52
Scampi	2 623	322	12.3	0	0.00	4	0 - 16	1.17	0.00 - 4.97
Deepwater	2 443	804	32.9	0	0.00	2	0 - 13	0.29	0.00 - 1.62
Inshore	17 968	78	0.4	0	0.00	15	0 - 74	19.26	0.00 - 94.87

Table D-2: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seal in trawl fisheries, organised by area, for five fishing years from 2006–07 to 2010–11.

		Observed				Est. captures		Est. capture rate	
	Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2006–07									
Cook Strait	4 423	249	5.6	23	9.24	184	66 - 433	73.75	26.51 - 173.92
West coast South Island	8 550	942	11.0	5	0.53	94	41 - 184	10.02	4.35 - 19.54
East coast South Island	17 071	1 041	6.1	7	0.67	117	53 - 238	11.20	5.09 - 22.87
Stewart-Snares	8 178	1 359	16.6	21	1.55	84	47 - 150	6.19	3.46 - 11.04
Bounty Islands	273	155	56.8	8	5.16	12	8 - 52	7.96	5.16 - 33.56
Campbell Island	565	181	32.0	5	2.76	13	5 - 40	7.07	2.76 - 22.10
West coast North Island	8 827	1 036	11.7	1	0.10	9	2 - 23	0.84	0.19 - 2.22
Subantarctic islands	1 424	831	58.4	2	0.24	5	2 - 17	0.63	0.24 - 2.05
Auckland Islands	2 853	648	22.7	0	0.00	5	0 - 16	0.72	0.00 - 2.47
Puysegur	409	43	10.5	1	2.33	11	1 - 50	25.00	2.33 - 116.34
2007–08									
Cook Strait	3 756	247	6.6	24	9.72	236	89 - 565	95.61	36.03 - 228.78
West coast South Island	6 951	942	13.6	57	6.05	150	95 - 258	15.96	10.08 - 27.39
East coast South Island	13 998	1 352	9.7	15	1.11	160	75 - 330	11.86	5.55 - 24.41
Stewart-Snares	6 516	1 529	23.5	13	0.85	70	35 - 137	4.60	2.29 - 8.96
Bounty Islands	298	156	52.3	17	10.90	85	17 - 480	54.42	10.90 - 307.71
Campbell Island	559	230	41.1	7	3.04	17	7 - 60	7.29	3.04 - 26.09
West coast North Island	9 485	922	9.7	1	0.11	16	4 - 40	1.76	0.43 - 4.34
Subantarctic islands	1 825	878	48.1	5	0.57	12	5 - 37	1.33	0.57 - 4.21
Auckland Islands	3 030	860	28.4	2	0.23	10	2 - 31	1.21	0.23 - 3.60
Puysegur	379	13	3.4	0	0.00	8	0 - 35	61.19	0.00 - 269.23
2008–09									
Cook Strait	4 221	177	4.2	19	10.73	201	75 - 470	113.40	42.37 - 265.54
West coast South Island	6 516	1 187	18.2	18	1.52	73	38 - 141	6.16	3.20 - 11.88
East coast South Island	13 260	1 617	12.2	8	0.49	90	39 - 181	5.55	2.41 - 11.19
Stewart-Snares	6 032	1 427	23.7	5	0.35	38	16 - 80	2.70	1.12 - 5.61
Bounty Islands	646	215	33.3	17	7.91	103	19 - 403	47.75	8.84 - 187.48
Campbell Island	620	124	20.0	0	0.00	9	0 - 37	7.40	0.00 - 29.84
West coast North Island	8 745	1 117	12.8	4	0.36	12	5 - 27	1.07	0.45 - 2.42
Subantarctic islands	1 493	480	32.2	0	0.00	5	0 - 22	1.07	0.00 - 4.58
Auckland Islands	3 679	997	27.1	1	0.10	8	1 - 24	0.81	0.10 - 2.41
Puysegur	276	42	15.2	0	0.00	7	0 - 42	17.72	0.00 - 100.00
2009–10									
Cook Strait	4 474	434	9.7	17	3.92	145	54 - 361	33.38	12.44 - 83.18
West coast South Island	7 242	1 088	15.0	7	0.64	56	25 - 113	5.12	2.30 - 10.39
East coast South Island	14 750	1 388	9.4	12	0.86	87	41 - 175	6.23	2.95 - 12.61
Stewart-Snares	6 755	1 902	28.2	18	0.95	58	32 - 109	3.05	1.68 - 5.73
Bounty Islands	679	163	24.0	10	6.13	93	11 - 417	56.81	6.75 - 255.83
Campbell Island	537	226	42.1	2	0.88	7	2 - 24	2.90	0.88 - 10.62
West coast North Island	9 165	851	9.3	2	0.24	7	2 - 18	0.82	0.24 - 2.12
Subantarctic islands	1 624	660	40.6	4	0.61	8	4 - 22	1.28	0.61 - 3.33
Auckland Islands	2 271	443	19.5	0	0.00	5	0 - 18	1.18	0.00 - 4.06
Puysegur	381	53	13.9	0	0.00	7	0 - 39	13.23	0.00 - 73.58
2010–11									
Cook Strait	4 626	148	3.2	18	12.16	123	50 - 277	83.35	33.78 - 187.16
West coast South Island	8 292	804	9.7	3	0.37	66	25 - 147	8.27	3.11 - 18.28
East coast South Island	13 877	1 302	9.4	2	0.15	59	22 - 134	4.54	1.69 - 10.29
Stewart-Snares	6 096	1 323	21.7	9	0.68	33	17 - 63	2.53	1.28 - 4.76
Bounty Islands	420	155	36.9	31	20.00	57	31 - 201	36.71	20.00 - 129.68
Campbell Island	968	364	37.6	4	1.10	11	4 - 31	3.06	1.10 - 8.52
West coast North Island	8 710	605	6.9	0	0.00	4	0 - 15	0.71	0.00 - 2.48
Subantarctic islands	886	306	34.5	1	0.33	5	1 - 20	1.67	0.33 - 6.54
Auckland Islands	3 302	848	25.7	0	0.00	5	0 - 15	0.53	0.00 - 1.77
Puysegur	596	56	9.4	0	0.00	12	0 - 49	20.80	0.00 - 87.50

Table D-3: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seal in trawl fisheries, organised by area and target, for nine fishing years from 2002–03 to 2010–11. Area/target combinations are included in the table if, across all years, more than one fur seal capture was estimated, or if the total fishing effort exceeded 1000 tows. The area/target combinations are ordered by decreasing number of estimated captures.

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03										
Hoki	Cook Strait	4 122	135	3.3	4	2.96	261	89 - 629	6.33	2.16 - 15.26
Hoki	West coast SI.	7 862	923	11.7	18	1.95	162	74 - 318	2.06	0.94 - 4.05
Hoki	East coast SI.	9 927	863	8.7	13	1.51	103	47 - 205	1.04	0.47 - 2.07
SBW	Bounty Islands	24	-	-	-	-	7	0 - 50	30.36	0.00 - 208.33
Middle depth	East coast SI.	2 816	29	1.0	0	0.00	28	5 - 89	0.99	0.18 - 3.16
Middle depth	Cook Strait	1 083	1	0.1	0	0.00	26	3 - 87	2.41	0.28 - 8.03
Squid	Stewart-Snares	3 279	503	15.3	7	1.39	23	11 - 45	0.72	0.34 - 1.37
Middle depth	West coast SI.	1 824	-	-	-	-	21	3 - 68	1.15	0.16 - 3.73
Hake	West coast SI.	516	36	7.0	3	8.33	9	3 - 27	1.72	0.58 - 5.23
Middle depth	Stewart-Snares	978	138	14.1	1	0.72	14	2 - 44	1.41	0.20 - 4.50
Squid	East coast SI.	1 744	50	2.9	0	0.00	17	3 - 48	0.96	0.17 - 2.75
Hoki	Stewart-Snares	2 414	433	17.9	3	0.69	20	6 - 53	0.84	0.25 - 2.20
SBW	Campbell Island	606	269	44.4	8	2.97	14	8 - 34	2.30	1.32 - 5.61
Inshore	East coast SI.	7 565	1	0.0	0	0.00	10	0 - 53	0.14	0.00 - 0.70
Ling	Stewart-Snares	149	-	-	-	-	2	0 - 12	1.34	0.00 - 8.05
Ling	Puysegur	63	-	-	-	-	4	0 - 30	6.68	0.00 - 47.62
Jack mackerel	West coast NI.	2 293	218	9.5	0	0.00	6	0 - 20	0.27	0.00 - 0.87
Hoki	Puysegur	494	55	11.1	6	10.91	26	7 - 87	5.20	1.42 - 17.61
Deepwater	Subantarctic	1 157	139	12.0	0	0.00	3	0 - 16	0.28	0.00 - 1.38
Ling	East coast SI.	37	-	-	-	-	1	0 - 4	1.80	0.00 - 10.81
Jack mackerel	West coast SI.	386	53	13.7	0	0.00	7	0 - 23	1.80	0.00 - 5.96
Inshore	Cook Strait	1 972	-	-	-	-	5	0 - 29	0.25	0.00 - 1.47
Middle depth	West coast NI.	1 790	75	4.2	0	0.00	7	0 - 24	0.38	0.00 - 1.34
Squid	Puysegur	1 420	311	21.9	1	0.32	10	1 - 36	0.73	0.07 - 2.54
Squid	Auckland Islands	1 466	416	28.4	0	0.00	2	0 - 7	0.11	0.00 - 0.48
Inshore	Stewart-Snares	1 479	-	-	-	-	3	0 - 19	0.21	0.00 - 1.28
Ling	West coast SI.	27	-	-	-	-	1	0 - 5	2.41	0.00 - 18.52
Middle depth	Subantarctic	37	5	13.5	0	0.00	4	0 - 39	12.09	0.00 - 105.41
Scampi	Auckland Islands	1 399	149	10.7	0	0.00	1	0 - 6	0.08	0.00 - 0.43
Scampi	East coast SI.	909	257	28.3	2	0.78	5	2 - 16	0.54	0.22 - 1.76
Inshore	West coast SI.	1 672	-	-	-	-	1	0 - 8	0.08	0.00 - 0.48
Jack mackerel	East coast SI.	175	32	18.3	1	3.12	2	1 - 6	1.05	0.57 - 3.43
Hake	East coast SI.	96	8	8.3	0	0.00	1	0 - 5	0.83	0.00 - 5.21
Inshore	West coast NI.	6 654	-	-	-	-	2	0 - 9	0.02	0.00 - 0.14
Squid	Subantarctic	236	19	8.1	0	0.00	1	0 - 8	0.63	0.00 - 3.39
Scampi	Cook Strait	247	7	2.8	0	0.00	1	0 - 4	0.25	0.00 - 1.62
Hake	Stewart-Snares	149	-	-	-	-	2	0 - 10	1.09	0.00 - 6.71
Middle depth	Puysegur	136	7	5.1	0	0.00	1	0 - 9	0.97	0.00 - 6.62
Ling	Subantarctic	180	16	8.9	0	0.00	1	0 - 5	0.46	0.00 - 2.78
Hoki	Auckland Islands	1 140	63	5.5	0	0.00	1	0 - 6	0.11	0.00 - 0.53
Jack mackerel	Stewart-Snares	202	42	20.8	0	0.00	1	0 - 5	0.42	0.00 - 2.48
Deepwater	Bounty Islands	280	40	14.3	0	0.00	0	0 - 3	0.09	0.00 - 1.07
Ling	Auckland Islands	27	-	-	-	-	0	0 - 0	0.09	0.00 - 0.00
Ling	West coast NI.	16	-	-	-	-	0	0 - 1	0.79	0.00 - 6.25
Inshore	Puysegur	94	-	-	-	-	0	0 - 2	0.27	0.00 - 2.13
Deepwater	East coast SI.	1 556	214	13.8	0	0.00	0	0 - 1	0.00	0.00 - 0.06
Deepwater	Cook Strait	168	-	-	-	-	0	0 - 0	0.01	0.00 - 0.00
Deepwater	Stewart-Snares	627	34	5.4	0	0.00	0	0 - 1	0.01	0.00 - 0.16
Deepwater	West coast NI.	289	123	42.6	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table D-3: (*continued*)

		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
			Observed				Est. captures		Est. capture rate	
2003–04										
Hoki	Cook Strait	4 273	130	3.0	1	0.77	366	130 - 850	8.57	3.04 - 19.89
Hoki	West coast SI.	6 845	1 336	19.5	27	2.02	195	92 - 381	2.85	1.34 - 5.57
Hoki	East coast SI.	7 094	547	7.7	17	3.11	122	53 - 269	1.71	0.75 - 3.79
SBW	Bounty Islands	34	9	26.5	9	100.00	20	9 - 88	59.57	26.47 - 258.90
Middle depth	East coast SI.	1 702	11	0.6	0	0.00	27	5 - 84	1.56	0.29 - 4.94
Middle depth	Cook Strait	1 327	-	-	-	-	39	5 - 137	2.97	0.38 - 10.32
Squid	Stewart-Snares	4 533	950	21.0	10	1.05	52	25 - 100	1.14	0.55 - 2.21
Middle depth	West coast SI.	1 521	3	0.2	0	0.00	27	5 - 84	1.78	0.33 - 5.52
Hake	West coast SI.	608	53	8.7	0	0.00	9	0 - 34	1.55	0.00 - 5.59
Middle depth	Stewart-Snares	622	29	4.7	0	0.00	15	1 - 57	2.41	0.16 - 9.16
Squid	East coast SI.	581	3	0.5	0	0.00	11	1 - 36	1.82	0.17 - 6.20
Hoki	Stewart-Snares	1 912	96	5.0	0	0.00	18	4 - 52	0.96	0.21 - 2.72
SBW	Campbell Island	706	229	32.4	4	1.75	15	4 - 60	2.18	0.57 - 8.50
Inshore	East coast SI.	6 979	7	0.1	0	0.00	11	0 - 56	0.16	0.00 - 0.80
Ling	Stewart-Snares	158	8	5.1	0	0.00	5	0 - 30	3.07	0.00 - 18.99
Ling	Puysegur	134	-	-	-	-	9	0 - 65	6.56	0.00 - 48.51
Jack mackerel	West coast NI.	2 247	140	6.2	0	0.00	10	1 - 26	0.43	0.04 - 1.16
Hoki	Puysegur	145	32	22.1	3	9.38	9	3 - 33	5.87	2.07 - 22.76
Deepwater	Subantarctic	1 064	201	18.9	2	1.00	6	2 - 20	0.59	0.19 - 1.88
Ling	East coast SI.	15	-	-	-	-	0	0 - 2	1.32	0.00 - 13.33
Jack mackerel	West coast SI.	87	9	10.3	2	22.22	5	2 - 14	5.33	2.30 - 16.12
Inshore	Cook Strait	1 862	-	-	-	-	8	0 - 46	0.41	0.00 - 2.47
Middle depth	West coast NI.	1 786	53	3.0	0	0.00	8	0 - 28	0.45	0.00 - 1.57
Squid	Puysegur	251	-	-	-	-	7	0 - 26	2.59	0.00 - 10.36
Squid	Auckland Islands	2 595	792	30.5	7	0.88	12	7 - 22	0.45	0.27 - 0.85
Inshore	Stewart-Snares	2 021	-	-	-	-	5	0 - 27	0.23	0.00 - 1.34
Ling	West coast SI.	44	-	-	-	-	1	0 - 7	2.33	0.00 - 15.91
Middle depth	Subantarctic	66	8	12.1	0	0.00	8	0 - 63	12.87	0.00 - 95.49
Scampi	Auckland Islands	1 450	169	11.7	1	0.59	3	1 - 8	0.17	0.07 - 0.55
Scampi	East coast SI.	623	205	32.9	0	0.00	3	0 - 13	0.41	0.00 - 2.09
Inshore	West coast SI.	1 957	-	-	-	-	2	0 - 11	0.10	0.00 - 0.56
Jack mackerel	East coast SI.	11	-	-	-	-	0	0 - 1	0.73	0.00 - 9.09
Hake	East coast SI.	766	34	4.4	0	0.00	3	0 - 12	0.39	0.00 - 1.57
Inshore	West coast NI.	7 095	-	-	-	-	2	0 - 12	0.03	0.00 - 0.17
Squid	Subantarctic	332	17	5.1	0	0.00	6	0 - 29	1.79	0.00 - 8.73
Scampi	Cook Strait	45	-	-	-	-	0	0 - 2	0.33	0.00 - 4.44
Hake	Stewart-Snares	166	53	31.9	0	0.00	1	0 - 11	0.85	0.00 - 6.63
Middle depth	Puysegur	122	27	22.1	0	0.00	1	0 - 5	0.60	0.00 - 4.10
Ling	Subantarctic	97	11	11.3	0	0.00	1	0 - 4	0.61	0.00 - 4.12
Hoki	Auckland Islands	711	137	19.3	1	0.73	2	1 - 5	0.23	0.14 - 0.70
Jack mackerel	Stewart-Snares	38	3	7.9	0	0.00	0	0 - 2	0.53	0.00 - 5.26
Deepwater	Bounty Islands	295	26	8.8	0	0.00	1	0 - 4	0.19	0.00 - 1.36
Ling	Auckland Islands	21	-	-	-	-	0	0 - 0	0.05	0.00 - 0.00
Ling	West coast NI.	12	-	-	-	-	0	0 - 1	0.60	0.00 - 8.33
Inshore	Puysegur	20	-	-	-	-	0	0 - 0	0.16	0.00 - 0.00
Deepwater	East coast SI.	1 456	96	6.6	0	0.00	0	0 - 1	0.00	0.00 - 0.07
Deepwater	Cook Strait	99	-	-	-	-	0	0 - 0	0.01	0.00 - 0.00
Deepwater	Stewart-Snares	374	84	22.5	0	0.00	0	0 - 1	0.01	0.00 - 0.27
Deepwater	West coast NI.	350	152	43.4	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table D-3: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2004–05										
Hoki	Cook Strait	3 082	133	4.3	32	24.06	399	129 - 1001	12.96	4.19 - 32.48
Hoki	West coast SI.	3 939	1 013	25.7	63	6.22	206	109 - 413	5.22	2.77 - 10.49
Hoki	East coast SI.	5 121	714	13.9	14	1.96	109	46 - 255	2.13	0.90 - 4.98
SBW	Bounty Islands	100	52	52.0	24	46.15	74	24 - 410	73.51	24.00 - 410.00
Middle depth	East coast SI.	1 689	7	0.4	0	0.00	46	9 - 136	2.71	0.53 - 8.05
Middle depth	Cook Strait	1 052	1	0.1	0	0.00	63	11 - 197	5.99	1.05 - 18.73
Squid	Stewart-Snares	5 858	1 573	26.9	8	0.51	80	37 - 160	1.37	0.63 - 2.73
Middle depth	West coast SI.	1 552	75	4.8	9	12.00	49	17 - 119	3.18	1.10 - 7.67
Hake	West coast SI.	782	85	10.9	2	2.35	21	4 - 60	2.71	0.51 - 7.67
Middle depth	Stewart-Snares	1 004	46	4.6	0	0.00	36	6 - 113	3.58	0.60 - 11.26
Squid	East coast SI.	1 515	61	4.0	3	4.92	45	12 - 122	2.98	0.79 - 8.05
Hoki	Stewart-Snares	994	113	11.4	2	1.77	29	6 - 92	2.88	0.60 - 9.26
SBW	Campbell Island	758	280	36.9	9	3.21	34	10 - 117	4.46	1.32 - 15.44
Inshore	East coast SI.	7 047	2	0.0	0	0.00	26	0 - 130	0.36	0.00 - 1.85
Ling	Stewart-Snares	399	67	16.8	3	4.48	15	3 - 51	3.78	0.75 - 12.78
Ling	Puysegur	233	4	1.7	0	0.00	21	0 - 109	9.16	0.00 - 46.78
Jack mackerel	West coast NI.	2 378	528	22.2	5	0.95	23	8 - 56	0.95	0.34 - 2.36
Hoki	Puysegur	292	58	19.9	9	15.52	31	9 - 117	10.70	3.08 - 40.08
Deepwater	Subantarctic	1 156	323	27.9	4	1.24	16	4 - 77	1.42	0.35 - 6.66
Ling	East coast SI.	51	-	-	-	-	5	0 - 35	9.84	0.00 - 68.68
Jack mackerel	West coast SI.	68	17	25.0	0	0.00	2	0 - 12	3.18	0.00 - 17.65
Inshore	Cook Strait	1 503	11	0.7	0	0.00	8	0 - 46	0.56	0.00 - 3.06
Middle depth	West coast NI.	1 721	48	2.8	1	2.08	12	2 - 38	0.70	0.12 - 2.21
Squid	Puysegur	296	63	21.3	4	6.35	16	4 - 59	5.25	1.35 - 19.93
Squid	Auckland Islands	2 693	805	29.9	1	0.12	7	1 - 21	0.28	0.04 - 0.78
Inshore	Stewart-Snares	2 321	-	-	-	-	9	0 - 48	0.38	0.00 - 2.07
Ling	West coast SI.	128	-	-	-	-	7	0 - 43	5.58	0.00 - 33.59
Middle depth	Subantarctic	60	5	8.3	0	0.00	6	0 - 49	10.14	0.00 - 81.67
Scampi	Auckland Islands	1 275	-	-	-	-	5	0 - 27	0.42	0.00 - 2.12
Scampi	East coast SI.	1 248	63	5.0	0	0.00	4	0 - 20	0.35	0.00 - 1.60
Inshore	West coast SI.	2 565	-	-	-	-	5	0 - 26	0.20	0.00 - 1.01
Jack mackerel	East coast SI.	9	4	44.4	0	0.00	0	0 - 2	2.58	0.00 - 22.22
Hake	East coast SI.	311	9	2.9	0	0.00	7	0 - 36	2.21	0.00 - 11.58
Inshore	West coast NI.	6 682	-	-	-	-	4	0 - 23	0.07	0.00 - 0.34
Squid	Subantarctic	67	1	1.5	0	0.00	5	0 - 29	7.57	0.00 - 43.28
Scampi	Cook Strait	186	-	-	-	-	11	0 - 73	5.77	0.00 - 39.26
Hake	Stewart-Snares	143	-	-	-	-	4	0 - 25	3.11	0.00 - 17.48
Middle depth	Puysegur	129	-	-	-	-	3	0 - 18	2.45	0.00 - 13.95
Ling	Subantarctic	51	2	3.9	0	0.00	2	0 - 13	4.07	0.00 - 25.49
Hoki	Auckland Islands	320	2	0.6	0	0.00	1	0 - 8	0.37	0.00 - 2.50
Jack mackerel	Stewart-Snares	53	8	15.1	0	0.00	1	0 - 6	1.90	0.00 - 11.32
Deepwater	Bounty Islands	398	86	21.6	0	0.00	1	0 - 4	0.15	0.00 - 1.01
Ling	Auckland Islands	77	-	-	-	-	1	0 - 6	1.08	0.00 - 7.82
Ling	West coast NI.	9	-	-	-	-	0	0 - 2	1.84	0.00 - 22.22
Inshore	Puysegur	22	-	-	-	-	0	0 - 1	0.46	0.00 - 4.55
Deepwater	East coast SI.	1 363	121	8.9	0	0.00	0	0 - 1	0.01	0.00 - 0.07
Deepwater	Cook Strait	108	-	-	-	-	0	0 - 0	0.02	0.00 - 0.00
Deepwater	Stewart-Snares	243	66	27.2	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	West coast NI.	323	67	20.7	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table D-3: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2005–06										
Hoki	Cook Strait	1 969	64	3.3	19	29.69	233	70 - 616	11.86	3.56 - 31.28
Hoki	West coast SI.	3 546	802	22.6	23	2.87	109	48 - 232	3.07	1.35 - 6.54
Hoki	East coast SI.	4 902	724	14.8	12	1.66	64	27 - 142	1.31	0.55 - 2.90
SBW	Bounty Islands	94	82	87.2	51	62.20	56	51 - 89	59.31	54.26 - 94.71
Middle depth	East coast SI.	2 121	57	2.7	1	1.75	66	14 - 206	3.11	0.66 - 9.71
Middle depth	Cook Strait	682	-	-	-	-	25	2 - 90	3.62	0.29 - 13.20
Squid	Stewart-Snares	4 477	644	14.4	2	0.31	57	21 - 120	1.27	0.47 - 2.68
Middle depth	West coast SI.	1 167	28	2.4	0	0.00	27	4 - 89	2.28	0.34 - 7.63
Hake	West coast SI.	1 145	331	28.9	8	2.42	31	11 - 79	2.71	0.96 - 6.90
Middle depth	Stewart-Snares	1 214	303	25.0	2	0.66	28	6 - 89	2.29	0.49 - 7.33
Squid	East coast SI.	1 361	9	0.7	0	0.00	26	5 - 78	1.94	0.37 - 5.73
Hoki	Stewart-Snares	776	136	17.5	1	0.74	13	2 - 45	1.61	0.26 - 5.80
SBW	Campbell Island	510	135	26.5	1	0.74	10	1 - 48	2.04	0.20 - 9.41
Inshore	East coast SI.	6 783	-	-	-	-	16	0 - 77	0.23	0.00 - 1.14
Ling	Stewart-Snares	608	97	16.0	2	2.06	18	3 - 59	2.90	0.49 - 9.70
Ling	Puysegur	235	15	6.4	0	0.00	16	0 - 85	6.92	0.00 - 36.18
Jack mackerel	West coast NI.	2 067	641	31.0	4	0.62	14	5 - 34	0.66	0.24 - 1.64
Hoki	Puysegur	108	34	31.5	7	20.59	11	7 - 32	9.87	6.48 - 29.63
Deepwater	Subantarctic	987	134	13.6	1	0.75	7	1 - 28	0.73	0.10 - 2.84
Ling	East coast SI.	96	-	-	-	-	5	0 - 27	5.25	0.00 - 28.12
Jack mackerel	West coast SI.	208	6	2.9	0	0.00	6	0 - 29	2.72	0.00 - 13.94
Inshore	Cook Strait	1 818	7	0.4	0	0.00	7	0 - 45	0.41	0.00 - 2.48
Middle depth	West coast NI.	804	12	1.5	1	8.33	5	1 - 17	0.63	0.12 - 2.11
Squid	Puysegur	203	6	3.0	0	0.00	6	0 - 35	3.20	0.00 - 17.24
Squid	Auckland Islands	2 462	685	27.8	2	0.29	6	2 - 14	0.22	0.08 - 0.57
Inshore	Stewart-Snares	1 983	-	-	-	-	5	0 - 28	0.26	0.00 - 1.41
Ling	West coast SI.	148	-	-	-	-	5	0 - 23	3.14	0.00 - 15.54
Middle depth	Subantarctic	22	2	9.1	0	0.00	7	0 - 58	31.28	0.00 - 263.75
Scampi	Auckland Islands	1 332	116	8.7	0	0.00	3	0 - 14	0.22	0.00 - 1.05
Scampi	East coast SI.	1 511	96	6.4	0	0.00	3	0 - 12	0.17	0.00 - 0.79
Inshore	West coast SI.	2 605	10	0.4	0	0.00	4	0 - 20	0.15	0.00 - 0.77
Jack mackerel	East coast SI.	436	58	13.3	2	3.45	6	2 - 20	1.34	0.46 - 4.59
Hake	East coast SI.	15	1	6.7	0	0.00	0	0 - 2	0.98	0.00 - 13.33
Inshore	West coast NI.	5 547	74	1.3	0	0.00	2	0 - 13	0.04	0.00 - 0.23
Squid	Subantarctic	41	-	-	-	-	3	0 - 21	6.99	0.00 - 51.22
Scampi	Cook Strait	71	-	-	-	-	1	0 - 9	1.91	0.00 - 12.68
Hake	Stewart-Snares	174	87	50.0	3	3.45	4	3 - 9	2.19	1.72 - 5.17
Middle depth	Puysegur	157	2	1.3	0	0.00	6	0 - 36	3.68	0.00 - 22.93
Ling	Subantarctic	16	-	-	-	-	0	0 - 3	1.93	0.00 - 18.75
Hoki	Auckland Islands	18	3	16.7	0	0.00	0	0 - 1	0.39	0.00 - 5.56
Jack mackerel	Stewart-Snares	86	3	3.5	0	0.00	1	0 - 7	1.43	0.00 - 8.14
Deepwater	Bounty Islands	365	99	27.1	1	1.01	2	1 - 8	0.50	0.27 - 2.19
Ling	Auckland Islands	76	1	1.3	0	0.00	0	0 - 3	0.64	0.00 - 3.95
Ling	West coast NI.	46	-	-	-	-	1	0 - 4	1.28	0.00 - 8.70
Inshore	Puysegur	109	-	-	-	-	0	0 - 1	0.13	0.00 - 0.92
Deepwater	East coast SI.	1 338	224	16.7	0	0.00	0	0 - 1	0.01	0.00 - 0.07
Deepwater	Cook Strait	158	4	2.5	0	0.00	0	0 - 1	0.02	0.00 - 0.63
Deepwater	Stewart-Snares	275	7	2.5	0	0.00	0	0 - 0	0.01	0.00 - 0.00
Deepwater	West coast NI.	331	113	34.1	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table D-3: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2006–07										
Hoki	Cook Strait	2 078	225	10.8	23	10.22	157	53 - 404	7.58	2.55 - 19.45
Hoki	West coast SI.	2 117	515	24.3	0	0.00	34	8 - 93	1.61	0.38 - 4.39
Hoki	East coast SI.	4 724	639	13.5	4	0.63	47	15 - 129	0.99	0.32 - 2.73
SBW	Bounty Islands	51	38	74.5	8	21.05	12	8 - 52	24.03	15.69 - 102.01
Middle depth	East coast SI.	1 969	51	2.6	1	1.96	34	7 - 100	1.70	0.36 - 5.08
Middle depth	Cook Strait	738	2	0.3	0	0.00	21	2 - 74	2.79	0.27 - 10.03
Squid	Stewart-Snares	2 925	705	24.1	6	0.85	22	10 - 44	0.76	0.34 - 1.50
Middle depth	West coast SI.	1 709	24	1.4	0	0.00	33	7 - 91	1.91	0.41 - 5.32
Hake	West coast SI.	1 069	160	15.0	4	2.50	17	6 - 43	1.58	0.56 - 4.02
Middle depth	Stewart-Snares	1 316	142	10.8	2	1.41	15	4 - 38	1.12	0.30 - 2.89
Squid	East coast SI.	1 490	37	2.5	2	5.41	16	4 - 43	1.09	0.27 - 2.89
Hoki	Stewart-Snares	1 198	205	17.1	2	0.98	18	4 - 52	1.52	0.33 - 4.34
SBW	Campbell Island	559	181	32.4	5	2.76	12	5 - 40	2.21	0.89 - 7.16
Inshore	East coast SI.	5 582	26	0.5	0	0.00	9	0 - 46	0.17	0.00 - 0.82
Ling	Stewart-Snares	639	122	19.1	11	9.02	25	12 - 61	3.86	1.88 - 9.55
Ling	Puysegur	208	18	8.7	1	5.56	9	1 - 48	4.22	0.48 - 23.08
Jack mackerel	West coast NI.	2 136	585	27.4	1	0.17	5	1 - 14	0.24	0.05 - 0.66
Hoki	Puysegur	24	3	12.5	0	0.00	1	0 - 6	2.74	0.00 - 25.00
Deepwater	Subantarctic	1 218	817	67.1	2	0.24	3	2 - 6	0.22	0.16 - 0.49
Ling	East coast SI.	230	-	-	-	-	5	0 - 26	2.04	0.00 - 11.30
Jack mackerel	West coast SI.	432	183	42.4	1	0.55	6	1 - 22	1.31	0.23 - 5.09
Inshore	Cook Strait	1 336	1	0.1	0	0.00	3	0 - 18	0.22	0.00 - 1.35
Middle depth	West coast NI.	721	54	7.5	0	0.00	2	0 - 9	0.28	0.00 - 1.25
Squid	Puysegur	19	2	10.5	0	0.00	0	0 - 3	1.56	0.00 - 15.79
Squid	Auckland Islands	1 318	537	40.7	0	0.00	1	0 - 5	0.09	0.00 - 0.38
Inshore	Stewart-Snares	1 745	-	-	-	-	3	0 - 19	0.19	0.00 - 1.09
Ling	West coast SI.	80	-	-	-	-	2	0 - 11	2.74	0.00 - 13.75
Middle depth	Subantarctic	18	10	55.6	0	0.00	0	0 - 2	0.93	0.00 - 11.11
Scampi	Auckland Islands	1 329	95	7.1	0	0.00	3	0 - 12	0.19	0.00 - 0.90
Scampi	East coast SI.	1 989	107	5.4	0	0.00	3	0 - 14	0.16	0.00 - 0.70
Inshore	West coast SI.	2 945	60	2.0	0	0.00	2	0 - 12	0.08	0.00 - 0.41
Jack mackerel	East coast SI.	110	17	15.5	0	0.00	2	0 - 18	2.00	0.00 - 16.36
Hake	East coast SI.	229	72	31.4	0	0.00	1	0 - 4	0.25	0.00 - 1.75
Inshore	West coast NI.	5 627	81	1.4	0	0.00	2	0 - 9	0.03	0.00 - 0.16
Squid	Subantarctic	109	-	-	-	-	1	0 - 4	0.67	0.00 - 3.67
Scampi	Cook Strait	78	17	21.8	0	0.00	0	0 - 3	0.44	0.00 - 3.85
Hake	Stewart-Snares	166	55	33.1	0	0.00	1	0 - 5	0.49	0.00 - 3.01
Middle depth	Puysegur	97	20	20.6	0	0.00	1	0 - 5	0.90	0.00 - 5.15
Ling	Subantarctic	51	-	-	-	-	1	0 - 11	2.61	0.00 - 21.57
Hoki	Auckland Islands	11	5	45.5	0	0.00	0	0 - 0	0.24	0.00 - 0.00
Jack mackerel	Stewart-Snares	22	-	-	-	-	0	0 - 3	1.55	0.00 - 13.64
Deepwater	Bounty Islands	222	117	52.7	0	0.00	0	0 - 1	0.04	0.00 - 0.45
Ling	Auckland Islands	189	11	5.8	0	0.00	1	0 - 5	0.42	0.00 - 2.65
Ling	West coast NI.	26	6	23.1	0	0.00	0	0 - 1	0.35	0.00 - 3.85
Inshore	Puysegur	45	-	-	-	-	0	0 - 1	0.22	0.00 - 2.22
Deepwater	East coast SI.	748	92	12.3	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	Cook Strait	160	4	2.5	0	0.00	0	0 - 0	0.01	0.00 - 0.00
Deepwater	Stewart-Snares	167	130	77.8	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	West coast NI.	313	309	98.7	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table D-3: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2007–08										
Hoki	Cook Strait	1 845	198	10.7	24	12.12	199	70 - 509	10.80	3.79 - 27.59
Hoki	West coast SI.	1 386	462	33.3	23	4.98	45	26 - 95	3.24	1.88 - 6.86
Hoki	East coast SI.	4 157	696	16.7	7	1.01	62	20 - 161	1.49	0.48 - 3.87
SBW	Bounty Islands	200	98	49.0	17	17.35	84	17 - 477	41.93	8.50 - 238.54
Middle depth	East coast SI.	1 884	154	8.2	6	3.90	47	16 - 118	2.47	0.85 - 6.26
Middle depth	Cook Strait	599	7	1.2	0	0.00	32	4 - 113	5.28	0.67 - 18.86
Squid	Stewart-Snares	2 412	861	35.7	6	0.70	21	9 - 48	0.88	0.37 - 1.99
Middle depth	West coast SI.	1 346	72	5.3	3	4.17	37	9 - 108	2.76	0.67 - 8.02
Hake	West coast SI.	1 071	319	29.8	25	7.84	46	29 - 90	4.29	2.71 - 8.41
Middle depth	Stewart-Snares	1 013	81	8.0	0	0.00	21	3 - 70	2.11	0.30 - 6.91
Squid	East coast SI.	539	-	-	-	-	9	0 - 32	1.70	0.00 - 5.94
Hoki	Stewart-Snares	758	332	43.8	3	0.90	7	3 - 21	0.98	0.40 - 2.77
SBW	Campbell Island	559	230	41.1	7	3.04	17	7 - 60	3.00	1.25 - 10.73
Inshore	East coast SI.	3 777	8	0.2	0	0.00	10	0 - 50	0.26	0.00 - 1.32
Ling	Stewart-Snares	691	134	19.4	3	2.24	14	4 - 42	2.00	0.58 - 6.08
Ling	Puysegur	217	13	6.0	0	0.00	6	0 - 28	2.54	0.00 - 12.90
Jack mackerel	West coast NI.	2 191	716	32.7	1	0.14	8	2 - 22	0.38	0.09 - 1.00
Hoki	Puysegur	10	-	-	-	-	0	0 - 3	2.30	0.00 - 30.00
Deepwater	Subantarctic	1 684	831	49.3	4	0.48	7	4 - 17	0.41	0.24 - 1.01
Ling	East coast SI.	250	3	1.2	0	0.00	14	0 - 67	5.69	0.00 - 26.81
Jack mackerel	West coast SI.	265	77	29.1	6	7.79	13	6 - 39	4.94	2.26 - 14.72
Inshore	Cook Strait	1 108	-	-	-	-	4	0 - 21	0.35	0.00 - 1.90
Middle depth	West coast NI.	968	22	2.3	0	0.00	4	0 - 16	0.46	0.00 - 1.65
Squid	Puysegur	15	-	-	-	-	0	0 - 2	1.13	0.00 - 13.33
Squid	Auckland Islands	1 265	588	46.5	0	0.00	2	0 - 10	0.19	0.00 - 0.79
Inshore	Stewart-Snares	1 322	-	-	-	-	5	0 - 28	0.36	0.00 - 2.12
Ling	West coast SI.	317	-	-	-	-	6	0 - 24	1.79	0.00 - 7.58
Middle depth	Subantarctic	21	11	52.4	0	0.00	1	0 - 7	3.33	0.00 - 33.33
Scampi	Auckland Islands	1 327	93	7.0	1	1.08	6	1 - 23	0.43	0.08 - 1.73
Scampi	East coast SI.	1 891	182	9.6	0	0.00	3	0 - 14	0.17	0.00 - 0.74
Inshore	West coast SI.	2 566	12	0.5	0	0.00	4	0 - 18	0.14	0.00 - 0.70
Jack mackerel	East coast SI.	168	14	8.3	0	0.00	13	0 - 89	7.58	0.00 - 52.99
Hake	East coast SI.	271	14	5.2	2	14.29	3	2 - 5	0.98	0.74 - 1.85
Inshore	West coast NI.	6 025	53	0.9	0	0.00	2	0 - 14	0.04	0.00 - 0.23
Squid	Subantarctic	2	2	100.0	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Scampi	Cook Strait	65	23	35.4	0	0.00	0	0 - 3	0.62	0.00 - 4.62
Hake	Stewart-Snares	157	49	31.2	1	2.04	2	1 - 5	1.02	0.64 - 3.18
Middle depth	Puysegur	80	-	-	-	-	2	0 - 14	2.40	0.00 - 17.50
Ling	Subantarctic	56	33	58.9	1	3.03	2	1 - 6	2.73	1.79 - 10.71
Hoki	Auckland Islands	191	124	64.9	1	0.81	1	1 - 4	0.71	0.52 - 2.09
Jack mackerel	Stewart-Snares	14	3	21.4	0	0.00	0	0 - 1	0.44	0.00 - 7.14
Deepwater	Bounty Islands	97	58	59.8	0	0.00	0	0 - 0	0.01	0.00 - 0.00
Ling	Auckland Islands	188	38	20.2	0	0.00	1	0 - 6	0.48	0.00 - 3.19
Ling	West coast NI.	64	-	-	-	-	1	0 - 6	1.60	0.00 - 9.38
Inshore	Puysegur	50	-	-	-	-	0	0 - 1	0.22	0.00 - 2.00
Deepwater	East coast SI.	1 061	281	26.5	0	0.00	0	0 - 1	0.00	0.00 - 0.09
Deepwater	Cook Strait	127	19	15.0	0	0.00	0	0 - 0	0.01	0.00 - 0.00
Deepwater	Stewart-Snares	148	69	46.6	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	West coast NI.	233	131	56.2	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table D-3: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2008–09										
Hoki	Cook Strait	1 944	168	8.6	19	11.31	144	49 - 362	7.39	2.52 - 18.62
Hoki	West coast SI.	1 171	500	42.7	11	2.20	24	12 - 53	2.03	1.02 - 4.53
Hoki	East coast SI.	3 860	570	14.8	4	0.70	29	9 - 81	0.76	0.23 - 2.10
SBW	Bounty Islands	403	120	29.8	17	14.17	103	19 - 403	25.45	4.71 - 100.02
Middle depth	East coast SI.	2 080	236	11.3	2	0.85	38	11 - 98	1.81	0.53 - 4.71
Middle depth	Cook Strait	841	4	0.5	0	0.00	48	3 - 198	5.69	0.36 - 23.54
Squid	Stewart-Snares	1 807	531	29.4	1	0.19	12	3 - 29	0.65	0.17 - 1.60
Middle depth	West coast SI.	994	38	3.8	0	0.00	19	2 - 63	1.86	0.20 - 6.34
Hake	West coast SI.	1 004	210	20.9	3	1.43	16	4 - 44	1.60	0.40 - 4.38
Middle depth	Stewart-Snares	1 004	251	25.0	0	0.00	9	1 - 30	0.87	0.10 - 2.99
Squid	East coast SI.	121	3	2.5	0	0.00	4	0 - 18	3.00	0.00 - 14.88
Hoki	Stewart-Snares	808	299	37.0	3	1.00	9	3 - 26	1.16	0.37 - 3.22
SBW	Campbell Island	620	124	20.0	0	0.00	9	0 - 37	1.48	0.00 - 5.97
Inshore	East coast SI.	4 421	308	7.0	0	0.00	7	0 - 36	0.16	0.00 - 0.81
Ling	Stewart-Snares	376	73	19.4	0	0.00	5	0 - 23	1.21	0.00 - 6.12
Ling	Puysegur	166	-	-	-	-	7	0 - 41	3.98	0.00 - 24.70
Jack mackerel	West coast NI.	1 817	696	38.3	4	0.57	8	4 - 17	0.44	0.22 - 0.94
Hoki	Puysegur	8	-	-	-	-	0	0 - 5	5.67	0.00 - 62.50
Deepwater	Subantarctic	1 219	417	34.2	0	0.00	3	0 - 14	0.21	0.00 - 1.15
Ling	East coast SI.	206	16	7.8	0	0.00	6	0 - 24	2.74	0.00 - 11.65
Jack mackerel	West coast SI.	204	81	39.7	4	4.94	8	4 - 22	3.68	1.96 - 10.78
Inshore	Cook Strait	1 241	-	-	-	-	4	0 - 20	0.31	0.00 - 1.61
Middle depth	West coast NI.	767	70	9.1	0	0.00	2	0 - 7	0.25	0.00 - 0.91
Squid	Puysegur	4	1	25.0	0	0.00	0	0 - 2	3.76	0.00 - 50.00
Squid	Auckland Islands	1 925	761	39.5	0	0.00	4	0 - 15	0.20	0.00 - 0.78
Inshore	Stewart-Snares	1 532	84	5.5	1	1.19	4	1 - 15	0.23	0.07 - 0.98
Ling	West coast SI.	265	-	-	-	-	5	0 - 18	1.75	0.00 - 6.79
Middle depth	Subantarctic	65	6	9.2	0	0.00	0	0 - 2	0.35	0.00 - 3.08
Scampi	Auckland Islands	1 457	61	4.2	1	1.64	4	1 - 15	0.26	0.07 - 1.03
Scampi	East coast SI.	1 306	204	15.6	0	0.00	2	0 - 8	0.12	0.00 - 0.61
Inshore	West coast SI.	2 808	292	10.4	0	0.00	2	0 - 13	0.09	0.00 - 0.46
Jack mackerel	East coast SI.	52	1	1.9	0	0.00	0	0 - 3	0.76	0.00 - 5.77
Hake	East coast SI.	470	61	13.0	2	3.28	4	2 - 18	0.92	0.43 - 3.83
Inshore	West coast NI.	5 866	183	3.1	0	0.00	2	0 - 9	0.03	0.00 - 0.15
Squid	Subantarctic	1	-	-	-	-	0	0 - 0	0.40	0.00 - 0.00
Scampi	Cook Strait	29	2	6.9	0	0.00	0	0 - 1	0.46	0.00 - 3.45
Hake	Stewart-Snares	274	78	28.5	0	0.00	0	0 - 3	0.15	0.00 - 1.09
Middle depth	Puysegur	59	41	69.5	0	0.00	0	0 - 2	0.33	0.00 - 3.39
Ling	Subantarctic	43	7	16.3	0	0.00	0	0 - 2	0.59	0.00 - 4.65
Hoki	Auckland Islands	155	114	73.5	0	0.00	0	0 - 2	0.14	0.00 - 1.29
Jack mackerel	Stewart-Snares	82	34	41.5	0	0.00	0	0 - 1	0.20	0.00 - 1.22
Deepwater	Bounty Islands	243	95	39.1	0	0.00	0	0 - 1	0.05	0.00 - 0.41
Ling	Auckland Islands	89	46	51.7	0	0.00	0	0 - 1	0.04	0.00 - 1.12
Ling	West coast NI.	56	1	1.8	0	0.00	1	0 - 4	0.93	0.00 - 7.14
Inshore	Puysegur	11	-	-	-	-	0	0 - 0	0.25	0.00 - 0.00
Deepwater	East coast SI.	744	218	29.3	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	Cook Strait	118	3	2.5	0	0.00	0	0 - 0	0.02	0.00 - 0.00
Deepwater	Stewart-Snares	148	77	52.0	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	West coast NI.	236	166	70.3	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table D-3: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2009–10										
Hoki	Cook Strait	1 631	341	20.9	17	4.99	104	36 - 272	6.35	2.21 - 16.68
Hoki	West coast SI.	2 098	658	31.4	4	0.61	29	10 - 69	1.37	0.48 - 3.29
Hoki	East coast SI.	4 369	617	14.1	7	1.13	30	13 - 66	0.70	0.30 - 1.51
SBW	Bounty Islands	394	89	22.6	10	11.24	92	11 - 417	23.44	2.79 - 105.84
Middle depth	East coast SI.	2 262	212	9.4	1	0.47	31	7 - 86	1.36	0.31 - 3.80
Middle depth	Cook Strait	1 020	76	7.5	0	0.00	35	3 - 152	3.46	0.29 - 14.90
Squid	Stewart-Snares	2 257	760	33.7	8	1.05	23	11 - 50	1.03	0.49 - 2.22
Middle depth	West coast SI.	855	82	9.6	0	0.00	11	1 - 38	1.25	0.12 - 4.44
Hake	West coast SI.	546	135	24.7	3	2.22	10	3 - 31	1.87	0.55 - 5.68
Middle depth	Stewart-Snares	887	241	27.2	4	1.66	12	4 - 34	1.32	0.45 - 3.83
Squid	East coast SI.	299	2	0.7	0	0.00	5	0 - 19	1.72	0.00 - 6.35
Hoki	Stewart-Snares	1 237	433	35.0	2	0.46	12	3 - 39	0.98	0.24 - 3.15
SBW	Campbell Island	535	226	42.2	2	0.88	6	2 - 24	1.21	0.37 - 4.49
Inshore	East coast SI.	5 079	203	4.0	0	0.00	7	0 - 35	0.14	0.00 - 0.69
Ling	Stewart-Snares	295	128	43.4	3	2.34	7	3 - 23	2.30	1.02 - 7.80
Ling	Puysegur	124	6	4.8	0	0.00	5	0 - 35	4.14	0.00 - 28.23
Jack mackerel	West coast NI.	2 213	710	32.1	2	0.28	4	2 - 9	0.19	0.09 - 0.41
Hoki	Puysegur	5	2	40.0	0	0.00	0	0 - 3	4.32	0.00 - 60.00
Deepwater	Subantarctic	1 383	568	41.1	0	0.00	2	0 - 10	0.14	0.00 - 0.72
Ling	East coast SI.	225	37	16.4	3	8.11	10	3 - 44	4.34	1.33 - 19.56
Jack mackerel	West coast SI.	63	26	41.3	0	0.00	1	0 - 5	1.32	0.00 - 7.94
Inshore	Cook Strait	1 585	-	-	-	-	3	0 - 19	0.21	0.00 - 1.20
Middle depth	West coast NI.	478	5	1.0	0	0.00	1	0 - 5	0.23	0.00 - 1.05
Squid	Puysegur	34	1	2.9	0	0.00	1	0 - 8	2.76	0.00 - 23.60
Squid	Auckland Islands	1 189	303	25.5	0	0.00	4	0 - 15	0.30	0.00 - 1.26
Inshore	Stewart-Snares	1 687	68	4.0	0	0.00	3	0 - 16	0.17	0.00 - 0.95
Ling	West coast SI.	286	9	3.1	0	0.00	3	0 - 10	0.90	0.00 - 3.50
Middle depth	Subantarctic	42	10	23.8	0	0.00	0	0 - 2	0.44	0.00 - 4.76
Scampi	Auckland Islands	941	92	9.8	0	0.00	1	0 - 7	0.12	0.00 - 0.74
Scampi	East coast SI.	1 446	106	7.3	1	0.94	3	1 - 11	0.20	0.07 - 0.76
Inshore	West coast SI.	3 308	99	3.0	0	0.00	3	0 - 13	0.08	0.00 - 0.39
Jack mackerel	East coast SI.	51	16	31.4	0	0.00	0	0 - 4	0.90	0.00 - 7.84
Hake	East coast SI.	33	5	15.2	0	0.00	0	0 - 1	0.42	0.00 - 3.03
Inshore	West coast NI.	6 296	44	0.7	0	0.00	2	0 - 9	0.03	0.00 - 0.14
Squid	Subantarctic	4	-	-	-	-	0	0 - 1	2.44	0.00 - 25.00
Scampi	Cook Strait	73	5	6.8	0	0.00	1	0 - 7	1.40	0.00 - 9.59
Hake	Stewart-Snares	226	187	82.7	1	0.53	1	1 - 3	0.51	0.44 - 1.33
Middle depth	Puysegur	96	43	44.8	0	0.00	0	0 - 3	0.38	0.00 - 3.12
Ling	Subantarctic	17	-	-	-	-	0	0 - 2	0.76	0.00 - 11.76
Hoki	Auckland Islands	63	3	4.8	0	0.00	0	0 - 4	0.70	0.00 - 6.35
Jack mackerel	Stewart-Snares	75	28	37.3	0	0.00	0	0 - 1	0.17	0.00 - 1.33
Deepwater	Bounty Islands	285	74	26.0	0	0.00	0	0 - 3	0.09	0.00 - 1.05
Ling	Auckland Islands	16	-	-	-	-	0	0 - 1	0.28	0.00 - 6.25
Ling	West coast NI.	15	-	-	-	-	0	0 - 1	0.68	0.00 - 6.67
Inshore	Puysegur	90	-	-	-	-	0	0 - 2	0.30	0.00 - 2.22
Deepwater	East coast SI.	985	189	19.2	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	Cook Strait	125	12	9.6	0	0.00	0	0 - 0	0.01	0.00 - 0.00
Deepwater	Stewart-Snares	91	57	62.6	0	0.00	0	0 - 0	0.01	0.00 - 0.00
Deepwater	West coast NI.	161	91	56.5	0	0.00	0	0 - 0	0.00	0.00 - 0.00

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Table D-3: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2010–11										
Hoki	Cook Strait	1 592	90	5.7	18	20.00	88	33 - 219	5.55	2.07 - 13.76
Hoki	West coast SI.	2 808	552	19.7	3	0.54	41	11 - 109	1.45	0.39 - 3.88
Hoki	East coast SI.	4 132	737	17.8	2	0.27	23	6 - 62	0.55	0.15 - 1.50
SBW	Bounty Islands	175	61	34.9	31	50.82	57	31 - 201	32.40	17.71 - 114.86
Middle depth	East coast SI.	2 324	177	7.6	0	0.00	24	4 - 70	1.01	0.17 - 3.01
Middle depth	Cook Strait	1 106	26	2.4	0	0.00	29	3 - 101	2.58	0.27 - 9.13
Squid	Stewart-Snares	2 173	683	31.4	5	0.73	13	6 - 26	0.60	0.28 - 1.20
Middle depth	West coast SI.	883	17	1.9	0	0.00	11	1 - 35	1.27	0.11 - 3.97
Hake	West coast SI.	683	127	18.6	0	0.00	9	0 - 28	1.25	0.00 - 4.10
Middle depth	Stewart-Snares	773	147	19.0	2	1.36	9	2 - 28	1.23	0.26 - 3.62
Squid	East coast SI.	394	15	3.8	0	0.00	3	0 - 13	0.73	0.00 - 3.30
Hoki	Stewart-Snares	992	232	23.4	0	0.00	5	0 - 20	0.55	0.00 - 2.02
SBW	Campbell Island	928	364	39.2	4	1.10	11	4 - 31	1.20	0.43 - 3.34
Inshore	East coast SI.	4 693	-	-	-	-	5	0 - 26	0.11	0.00 - 0.55
Ling	Stewart-Snares	266	92	34.6	2	2.17	3	2 - 11	1.31	0.75 - 4.14
Ling	Puysegur	231	7	3.0	0	0.00	9	0 - 46	4.07	0.00 - 19.91
Jack mackerel	West coast NI.	1 570	474	30.2	0	0.00	1	0 - 5	0.08	0.00 - 0.32
Hoki	Puysegur	76	1	1.3	0	0.00	1	0 - 8	1.05	0.00 - 10.53
Deepwater	Subantarctic	767	293	38.2	0	0.00	2	0 - 12	0.28	0.00 - 1.56
Ling	East coast SI.	96	-	-	-	-	2	0 - 14	2.47	0.00 - 14.58
Jack mackerel	West coast SI.	118	32	27.1	0	0.00	1	0 - 6	0.91	0.00 - 5.08
Inshore	Cook Strait	1 736	-	-	-	-	3	0 - 19	0.19	0.00 - 1.09
Middle depth	West coast NI.	513	-	-	-	-	1	0 - 6	0.26	0.00 - 1.17
Squid	Puysegur	57	16	28.1	0	0.00	0	0 - 3	0.67	0.00 - 5.26
Squid	Auckland Islands	1 585	543	34.3	0	0.00	2	0 - 8	0.12	0.00 - 0.50
Inshore	Stewart-Snares	1 606	-	-	-	-	2	0 - 11	0.11	0.00 - 0.68
Ling	West coast SI.	340	-	-	-	-	2	0 - 9	0.66	0.00 - 2.65
Middle depth	Subantarctic	32	3	9.4	0	0.00	1	0 - 8	2.96	0.00 - 25.00
Scampi	Auckland Islands	1 401	205	14.6	0	0.00	2	0 - 10	0.15	0.00 - 0.71
Scampi	East coast SI.	1 195	115	9.6	0	0.00	1	0 - 6	0.09	0.00 - 0.50
Inshore	West coast SI.	3 346	4	0.1	0	0.00	3	0 - 15	0.08	0.00 - 0.45
Jack mackerel	East coast SI.	72	28	38.9	0	0.00	0	0 - 2	0.35	0.00 - 2.78
Hake	East coast SI.	57	6	10.5	0	0.00	1	0 - 11	1.94	0.00 - 19.30
Inshore	West coast NI.	6 437	74	1.1	0	0.00	2	0 - 9	0.02	0.00 - 0.14
Squid	Subantarctic	2	-	-	-	-	0	0 - 0	2.06	0.00 - 1.25
Scampi	Cook Strait	27	2	7.4	0	0.00	1	0 - 6	2.46	0.00 - 22.22
Hake	Stewart-Snares	94	90	95.7	0	0.00	0	0 - 0	0.01	0.00 - 0.00
Middle depth	Puysegur	63	31	49.2	0	0.00	1	0 - 6	1.40	0.00 - 9.52
Ling	Subantarctic	3	3	100.0	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Hoki	Auckland Islands	262	82	31.3	0	0.00	1	0 - 4	0.20	0.00 - 1.53
Jack mackerel	Stewart-Snares	119	59	49.6	0	0.00	0	0 - 2	0.16	0.00 - 1.68
Deepwater	Bounty Islands	245	94	38.4	0	0.00	0	0 - 2	0.08	0.00 - 0.82
Ling	Auckland Islands	4	-	-	-	-	0	0 - 0	0.10	0.00 - 0.00
Ling	West coast NI.	19	-	-	-	-	0	0 - 1	0.70	0.00 - 5.26
Inshore	Puysegur	146	-	-	-	-	0	0 - 2	0.13	0.00 - 1.37
Deepwater	East coast SI.	914	224	24.5	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	Cook Strait	94	30	31.9	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	Stewart-Snares	73	20	27.4	0	0.00	0	0 - 0	0.00	0.00 - 0.00
Deepwater	West coast NI.	169	57	33.7	0	0.00	0	0 - 0	0.00	0.00 - 0.00

APPENDIX E: Auckland Islands squid fishery sea lion capture model parameters

Table E-4: Mean, median, and 95% confidence intervals for final model parameters. Calculated from samples of the corresponding posterior distributions.

Parameter	Mean	Median	95% c.i.	
Single SLED retention probability				
Extra dispersion, $1/\theta$	2.784	2.746	1.339	4.730
Vessel/year effect standard deviation	0.534	0.536	0.195	0.877
1995–96 base rate (captures per 100 tows)	1.046	0.990	0.504	1.900
1996–97 base rate (captures per 100 tows)	1.714	1.657	0.975	2.807
1997–98 base rate (captures per 100 tows)	1.482	1.403	0.708	2.709
1998–99 base rate (captures per 100 tows)	1.386	1.298	0.556	2.747
1999–00 base rate (captures per 100 tows)	2.484	2.347	1.295	4.476
2000–01 base rate (captures per 100 tows)	3.689	3.555	2.000	6.168
2001–02 base rate (captures per 100 tows)	1.600	1.526	0.850	2.786
2002–03 base rate (captures per 100 tows)	1.136	1.089	0.542	2.048
2003–04 base rate (captures per 100 tows)	2.337	2.237	1.277	3.949
2004–05 base rate (captures per 100 tows)	1.851	1.756	0.917	3.333
2005–06 base rate (captures per 100 tows)	1.471	1.405	0.724	2.624
2006–07 base rate (captures per 100 tows)	1.527	1.457	0.693	2.810
2007–08 base rate (captures per 100 tows)	1.307	1.248	0.518	2.418
2008–09 base rate (captures per 100 tows)	0.802	0.746	0.261	1.626
2009–10 base rate (captures per 100 tows)	1.475	1.373	0.536	2.959
2010–11 base rate (captures per 100 tows)	0.814	0.757	0.187	1.789
Tow duration	0.609	0.605	0.293	0.938
Distance to colony	-0.626	-0.623	-1.074	-0.189
Subarea, relative to north and east area	0.450	0.441	0.307	0.641
SLED retention probability	0.173	0.168	0.100	0.282
Split SLED retention probabilities				
Extra dispersion, $1/\theta$	2.734	2.643	1.326	4.851
Vessel/year effect standard deviation	0.541	0.542	0.200	0.870
1995–96 base rate (captures per 100 tows)	1.135	1.077	0.518	2.093
1996–97 base rate (captures per 100 tows)	1.816	1.750	0.994	3.004
1997–98 base rate (captures per 100 tows)	1.579	1.504	0.729	2.909
1998–99 base rate (captures per 100 tows)	1.473	1.379	0.550	2.931
1999–00 base rate (captures per 100 tows)	2.615	2.469	1.366	4.680
2000–01 base rate (captures per 100 tows)	3.757	3.622	2.040	6.254
2001–02 base rate (captures per 100 tows)	1.687	1.620	0.874	2.875
2002–03 base rate (captures per 100 tows)	1.226	1.171	0.550	2.202
2003–04 base rate (captures per 100 tows)	2.319	2.229	1.280	3.865
2004–05 base rate (captures per 100 tows)	1.851	1.777	0.921	3.256
2005–06 base rate (captures per 100 tows)	1.510	1.456	0.717	2.638
2006–07 base rate (captures per 100 tows)	1.548	1.483	0.662	2.826
2007–08 base rate (captures per 100 tows)	1.446	1.355	0.510	2.922
2008–09 base rate (captures per 100 tows)	0.921	0.842	0.237	2.011
2009–10 base rate (captures per 100 tows)	1.618	1.491	0.518	3.515
2010–11 base rate (captures per 100 tows)	0.931	0.843	0.173	2.159
Tow duration	0.608	0.604	0.285	0.945
Distance to colony	-0.622	-0.619	-1.071	-0.182
Subarea, relative to north and east area	0.453	0.445	0.304	0.642
Late SLED retention probability	0.168	0.115	0.017	0.671
Early SLED retention probability	0.193	0.185	0.101	0.329
SLED change, at end of this year	2006	2007	2005	2007