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Incidental capture of marine mammals in New Zealand trawl fisheries, 1995–96 to 2011–12

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EXECUTIVE SUMMARY

A number of marine mammal species are incidentally captured in New Zealand commercial trawl fisheries each year, including common dolphin (*Delphinus delphis*), New Zealand fur seal (*Arctocephalus forsteri*), and New Zealand sea lion (*Phocarctos hookeri*). To monitor the extent of these incidental captures in New Zealand waters, government fisheries observers are placed on-board commercial fishing vessels to record the number and identity of protected species that are captured. As fisheries observers only cover a proportion of the overall fishing effort, assessments rely on estimation methods to derive the total number of incidental captures of protected species. These estimations include the development of statistical models that incorporate observer and fishing effort data. This report presents the most recent estimates of the total incidental captures of common dolphin, New Zealand fur seal and New Zealand sea lion in New Zealand trawl fisheries, including the 2011–12 fishing year.

Common dolphin is the most frequently captured cetacean species in New Zealand waters, with the majority of captures occurring in the mackerel trawl fishery on the North Island west coast. In the most recent fishing year included in this study, 2011–12, there were five observed common dolphin captures in this fishery, involving four separate capture events. Observer coverage was unusually high in this fishing year, with 79% of all tows being observed. In the 17-year reporting period between 1995–96 and 2011–12, there were 124 observed common dolphin captures.

Estimation of total common dolphin captures in the North Island mackerel trawl fishery involved a two-stage Bayesian hurdle model that also explored potential factors that may have contributed to the captures. Based on this model, the estimated total number of common dolphin captures in 2011–12 was 7 (95% c.i.: 5 to 14), which was a marked reduction from the previous estimate of 60 (95% c.i.: 24 to 113) common dolphin captures in 2010–11. The corresponding capture rates were an estimated 0.43 (95% c.i.: 0.30 to 0.85) common dolphins per 100 tows in 2011–12, compared with an estimated 3.86 (95% c.i.: 1.55 to 7.29) common dolphins per 100 tows in 2010–11. Of the covariates included in the model, headline depth (distance of the headline below the surface) best explained common dolphin captures. Observer data supported this finding, and the majority of observed captures occurred on trawl tows fished at headline depths less than 40 m. The model results suggest that increasing headline depth by 20 m would halve the capture event probability.

New Zealand fur seal are incidentally captured in a number of different trawl fisheries, involving a range of target species and fishing areas. In the 2011–12 fishing year, there were 82 observed fur seal captures in trawl fisheries in New Zealand waters. Over the entire 10-year reporting period from 2002–03 to 2011–12, 1008 incidental fur seal captures were recorded by fisheries observers. These observer data included inshore trawl fisheries (except for flatfish target fisheries) owing to recent increases in observer effort in these fisheries. Across the different trawl fisheries, observer coverage in 2011–12 was 10.8%, similar to that in the previous four years.

Capture estimates for 2011–12 were similar to estimates in the previous fishing year, with 442 (95% c.i.: 256 to 789) estimated fur seal captures and an estimated capture rate of 0.53 (95% c.i.: 0.30 to 0.94) fur seals per 100 tows, compared with 427 (95% c.i.: 246 to 743) fur seals and 0.50 (95% c.i.: 0.29 to 0.86) fur seals per 100 tows in 2010–11. Of the different target fisheries, hoki trawl fisheries contributed the greatest proportion of observed and estimated fur seal captures, with 200 (95% c.i.: 98 to 417) of the total 442 (95% c.i.: 256 to 789) estimated fur seal captures occurring in these fisheries. In addition to fishing areas and target fisheries, two other covariates were correlated with fur seal captures, these were distance from shore and day of year. The fur seal capture rate probability decreased with increasing distance from

shore, whereas for day of year, it varied seasonally, with a distinct peak in August and September.

There was one observed New Zealand sea lion capture in trawl fisheries in the 2011–12 fishing year, on a tow targeting white warehou on the Stewart-Snares shelf. The sea lion was released alive. Observer effort in this fishing year was 42% across all trawl fisheries.

The estimation of incidental sea lion captures across all trawl fisheries in 2011–12 resulted in a total of 13 (95% c.i.: 5 to 22) estimated sea lion captures, reflecting a decrease from the estimated 28 (95% c.i.: 17 to 41) sea lion captures in 2010–11.

The Auckland Islands squid fishery has been characterised by a significant number of New Zealand sea lion captures over time, with most observed captures between 1995–96 and 2011–12 occurring in this fishery. Nevertheless, there were no observed sea lion captures in this fishery in the two most recent fishing years, 2010–11 and 2011–12. Since 2004–05, this fishery has used a sea lion exclusion device (SLED) fitted to trawl nets to allow captured sea lion to exit the net. The use of SLEDs means that the number of sea lions that may have escaped the net and the post-escape survival of escapees are unknown. For this reason, the model used to estimate sea lion captures in the Auckland Islands squid fishery includes an estimate of the retention probability of sea lion on tows with SLEDs. The retention probability is subsequently used to estimate the number of interactions, which is the number of sea lions that would have been caught had no SLEDs been used. As the SLED design changed during the reporting period, the retention probability was estimated by combining two models that included either a single or a split SLED retention probability.

In the 2011–12 fishing year, there were an estimated 43 (95% c.i.: 2 to 206) sea lion interactions, with a corresponding strike rate of 3.3 (95% c.i.: 0.2 to 16.2) sea lion interactions per 100 tows. Both estimates were similar to those in 2010–11. At the same time, the large variation around the mean values highlights the uncertainty associated with these estimates. As the dataset becomes increasingly biased towards tows that used SLEDs and observed captures have decreased in recent years, it is becoming difficult to provide reliable estimate of the number of interactions and strike rate in the Auckland Islands squid fishery.

1. INTRODUCTION

Incidental captures of marine mammals occur across various fisheries worldwide, involving a wide range of pinniped and cetacean species. For some marine mammal species, these incidental captures are a critical source of mortality that have detrimental effects on the population. In New Zealand waters, all marine mammal species are protected under the Fisheries Act 1996, which requires the Crown to "avoid, remedy, or mitigate any adverse effects of fishing on the aquatic environment, including protected species". This responsibility involves management strategies to assess and mitigate incidental captures of protected species in commercial fisheries, including the systematic collection of incidental capture data. These data can then be used to develop statistical models to estimate total captures across all fishing effort for various species and fisheries (Babcock et al. 2003, Sims et al. 2008, Laneri et al. 2010). In New Zealand, data on incidental captures of protected species, including marine mammals, seabirds and turtles are collected by government fisheries observers on-board commercial fishing vessels. Observer records provide independently collected information that forms the basis of assessments of incidental captures that estimate total captures of protected species in New Zealand's Exclusive Economic Zone (EEZ) (e.g., Abraham & Thompson 2011, Abraham et al. 2013).

Estimations of total captures across all fishing effort are dependent on sufficient observer data to inform the statistical models used to derive capture estimates. Observer coverage in New Zealand fisheries varies across fishing methods and target species, and total captures can only be reliably estimated for fisheries with sufficient observer effort. At the same time, low numbers of observed captures do not necessarily imply low numbers of total captures for fisheries with low observer effort. In particular trawl fisheries targeting inshore species are characterised by high fishing effort and poor observer coverage, with less than 1.0% of the total fishing effort observed before the 2008–09 fishing year. Recent increases in observer coverage have allowed the inclusion of inshore trawl fisheries in assessments of incidental captures, even though observer coverage has remained low, at 1.3% (of a total of 34 940 tows) in 2010–11 and 0.4% (of a total of 32 676 tows) in 2011–12.

This report provides an update of previous information on the incidental capture and mortality of marine mammals in commercial fisheries in New Zealand (most recently, Thompson et al. 2011, Thompson et al. 2013a). It is part of project PRO2010/01A, which is aimed at "estimating the nature and extent of incidental captures of seabirds, marine mammals, and turtles in New Zealand commercial fisheries". Presented here are data of total marine mammal captures in trawl fisheries that had sufficient observer coverage, including data from the most recent fishing year, 2011–12. The impact of incidental captures on the respective marine mammal populations was not considered. Incidental captures of seabirds and turtles will be reported elsewhere.

Between 2002–03 and 2011–12, incidental captures documented by fisheries observers in New Zealand's EEZ involved several marine mammal species, including pinnipeds and cetaceans, in trawl, longline and set-net fisheries (see summary in Table 1). These incidental capture records include mortalities and also animals that were released alive. The highest number of incidental captures involved New Zealand fur seal (*Arctocephalus forsteri*), and this species featured prominently in incidental capture records of trawl and also surface-longline fisheries across years. In the most recent fishing year, 2011–12, there were 82 observed fur seal captures in trawl fisheries. The majority of these captures occurred in hoki and in subantarctic southern blue whiting target fisheries, with 33 and 25 recorded incidents, respectively. There were markedly fewer observed fur seal captures in other trawl fisheries, including squid (eight captures), middle-depth (eight captures), jack and blue mackerel (five captures), and hake, ling, and scampi (one capture each) target fisheries. Most of the observed fur seal captures involved mortalities, with eight observed fur seal captures resulting in live releases.

Incidental captures of fur seals were also observed in surface-longline fisheries, with all 40 observed captures occurring in southern bluefin tuna target fisheries. Most observed fur seal captures in southern bluefin tuna fisheries occurred in the Fiordland area (20 observed captures) and on the North Island east coast (17 observed captures). The majority of observed captures involved live releases, with two fur seal mortalities in surface-longline fisheries in 2011–12.

Observed incidental captures of other pinniped species involved New Zealand sea lion (*Phocarctos hookeri*; all in trawl fisheries), with one incidental capture each of southern elephant seal (*Mirounga leonina*) and leopard seal (*Hydrurga leptonyx*) in trawl fisheries. There was also one incidental capture record of an unidentified seal species. The only observed sea lion capture in 2011–12 was in middle-depth trawl fisheries on the Stewart-Snares shelf. The captured sea lion was released alive.

In the 10-year period between 2002–03 and 2011–12, incidental capture records also included several cetacean species, predominantly common dolphin (*Delphinus delphis*). All observed captures of this species occurred in trawl fisheries, including five observed common dolphin captures in 2011–12. Other cetacean species included in observer records were pilot whale (*Globicephala melas*), Hector's dolphin (*Cephalorhynchus hectori*), bottlenose dolphin (*Tursiops truncatus*), and dusky dolphin (*Lagenorhynchus obscurus*). There were no observed captures of these cetacean species in the most recent fishing year, and few observed captures between 2002–03 and 2011–12. The fisheries involved were trawl, surface- and bottom-longline, and set-net fisheries. Incidental captures in surface-longline fisheries also included one observer record of an unidentified species of dolphin, with four incidental captures of unidentified species of whale.

Incidental captures of common dolphins, New Zealand fur seals, and New Zealand sea lions were observed sufficiently frequently in commercial trawl fisheries to allow estimations of the total number of individuals that were incidentally captured in New Zealand waters. This report presents total estimates for each of the three marine mammal species, including data from the most recent fishing year, 2011–12. It updates existing information of incidental captures of common dolphin, New Zealand fur seal, and New Zealand sea lion (most recently, Thompson et al. 2013a).

Presented here are the most recent data on incidental captures of marine mammals in commercial trawl fisheries in New Zealand, including model-based statistical estimates derived from observer data. As development of the statistical models is dependent on sufficient observer effort, the estimations focused on trawl fisheries targeting pelagic, middle-depth and deepwater species, which have had sufficient observer coverage. Owing to recent increases in observer coverage in trawl fisheries targeting inshore species (excluding flatfish), these fisheries were also included in the estimations (for the second time).

Common dolphin are currently recognised as two closely related species worldwide, with short-beaked common dolphin occurring in the New Zealand region (Perrin 2009). This species is widely distributed in tropical and warm-temperate waters of the Atlantic and Pacific oceans, where it is often abundant in coastal and oceanic waters. Common dolphins are gregarious and frequently form large groups (up to several thousand individuals) and multi-species aggregations 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).

Common dolphin abundance data are generally lacking, but population estimates from a number of regions indicate that short-beaked common dolphin is highly abundant (Hammond et al. 2008). Regional estimates include over two million individuals in the eastern tropical Pacific Ocean, and 400 000 individuals off the United States west coast. The global population size of common dolphin has been estimated at over four million individuals, with an unknown population trend.

The New Zealand region is considered to be the southernmost limit of common dolphin, and its presence has been documented along the coastline of both mainland islands, with sighting records also from offshore locations (Bräger & Schneider 1998, Stockin et al. 2013). Observed morphological differences between coastal and oceanic forms have been considered to reflect different species or subspecies of common dolphin, but there has been no confirmed taxonomic differentiation in New Zealand waters (Stockin et al. 2013). Instead, a recent study revealed that the only significant genetic differences were between individuals from Hauraki Gulf and from other New Zealand regions (Stockin et al. 2013).

Common dolphin exhibit distinct shifts in their distribution and abundance in some regions, including inshore-offshore movement that has also been documented in New Zealand waters (Neumann 2001, Meynier et al. 2008, Perrin 2009). These diel, seasonal and/or inter-annual migrations have been attributed to changes in oceanographic conditions, the exploitation of different food sources, and the movement of prey. Research in New Zealand has focused on common dolphin in northern North Island areas, particularly Bay of Islands and Hauraki Gulf (e.g., Neumann et al. 2002, Meynier et al. 2008, Stockin & Orams 2009). In shallow-water habitat (less than 20 m depth) in Hauraki Gulf, a resident subpopulation is present year-round, with groups of 50 individuals or more at times (Stockin et al. 2008). Furthermore, the high number of immature individuals and calves in this area suggests that Hauraki Gulf may be a calving and nursery ground of this species in New Zealand.

The diet of common dolphin consists of a range of meso- and epi-pelagic fish and squid species (Evans 1994, Rossman 2010). In New Zealand waters, common dolphin feed predominantly on jack mackerel (*Trachurus* spp.), anchovy (*Engraulis australis*), and arrow squid (*Nototodarus* spp.)(Meynier et al. 2008). A number of their prey species are also targeted by commercial trawl fisheries, making common dolphin susceptible to incidental capture in these fisheries (Morizur et al. 1999). Incidental common dolphin captures in trawl fisheries have been documented in a number of regions, including the Mediterranean Sea and the Atlantic and Pacific oceans (Waring et al. 1990, Fertl & Leatherwood 1997, Morizur et al. 1999).

Common dolphin are also captured in New Zealand trawl fisheries, i.e., by vessels targeting mackerel on the North Island west coast. Previous incidental capture studies of this fleet have estimated total common dolphin captures for different periods between 1995–96 and 2010–11 (Thompson & Abraham 2009b, Thompson et al. 2010c, Thompson et al. 2011, Thompson et al. 2013a). In the previous fishing year, 2010–11, there were 60 (95% c.i.: 24 to 114) estimated common dolphin captures in this fishery, corresponding with an estimated capture rate of 3.86 (95% c.i.: 1.55 to 7.29) common dolphins per 100 tows (see Appendix A.1).

New Zealand fur seal are native to New Zealand and Australia, where populations are expanding in their distribution and abundance following exploitation and almost extirpation through subsistence hunting and commercial sealing (Harcourt 2001). This species is found in temperate regions in both countries, with rocky coastlines providing preferred habitat for haul-outs and breeding colonies. In New Zealand, breeding colonies are distributed from mostly southern locations to northern areas (e.g., Waikato), and include breeding sites at subantarctic islands, i.e., Bounty Islands (Taylor 1996, Boren 2005, Bouma et al. 2008).

A number of New Zealand studies have focused on the distribution, population biology, foraging behaviour, and diet of fur seal (e.g., Taylor 1996, Lalas & Murphy 1998, Mattlin et al. 1998, Bradshaw et al. 2000, Robertson & Gemmell 2005, Boren 2010). Nevertheless, the total population size of this species is currently unknown, and recent abundance data are only available for some regions such as the South Island west coast and Otago (Lalas 2007, Baker et al. 2010). The most recent estimate of the total population size is 200 000 individuals in New Zealand and Australia, with equal proportions in either country, and an increasing population trend (Goldsworthy & Gales 2008, Baird 2011). Regional population surveys, including pup counts and mark-recapture studies, indicate that the fur seal population in New Zealand is extending into its former range as migrating animals colonise new areas where they establish breeding sites (Bradshaw et al. 2000). New Zealand fur seal exhibit relatively strong site fidelity, and philopatric females return to natal sites to breed.

New Zealand fur seal target a wide range of prey species, primarily cephalopods (octopus and squid, e.g., *Nototodarus* spp.), lanternfishes (myctophids), and jack mackerel (*Trachurus* spp.)(Harcourt 2001, Boren 2010). Their diet and foraging behaviour varies depending on the gender, breeding status, age class, colony location, and environmental conditions. Accordingly, foraging dives are conducted across different water masses and depths, encompassing inshore, continental shelf, and oceanic areas, and surface waters to depths of over 300 m (Goldsworthy et al. 2003).

New Zealand fur seal feature prominently in fisheries observer records of incidental captures involving trawl fisheries, with early model-based estimates encompassing the period between 1994–95 and 2005–06 (Smith & Baird 2009). Since then, assessments of incidental captures and capture estimates have covered different periods between 2002–03 and 2010–11 (Thompson & Abraham 2010, Thompson et al. 2010a, Thompson et al. 2011, Thompson et al. 2013a). These assessments show that observed incidental captures of fur seal occur predominantly in trawl fisheries targeting hoki (*Macruronus novaezelandiae*) and southern blue whiting (*Micromesistius australis*). In 2010–11, there were an estimated 427 (95% c.i.: 246 to 743) total fur seal captures, with an estimated capture rate of 0.50 (95% c.i.: 0.29 to 0.86) fur seals per 100 tows.

New Zealand sea lion are endemic to New Zealand, where subsistence hunting and commercial exploitation have greatly reduced this species' distribution and population size (Childerhouse & Gales 1998, Gales 2008). Although sea lion were widely distributed in New Zealand waters, their main population is now concentrated on New Zealand's subantarctic islands, with the principal breeding colonies at Auckland and Campbell islands (Department of Conservation 2009). About 71–87% of the total pup production is at Auckland Islands (mainly Dundas Island) compared with 13–29% of pup production at Campbell Island (Robertson & Chilvers 2011, Ministry for Primary Industries 2012).

Pups are also occasionally born at The Snares, and births have also been reported at other locations, including Otago Peninsula and Stewart Island (Childerhouse & Gales 1998, McConkey et al. 2002, Lalas & Bradshaw 2003). At Otago Peninsula, a small subpopulation originating from a single matriarchal line has become established since the early 1990s, with 45 pups born between 1994/95 and 2010, and female offspring returning to breed (Augé et al. 2011). In the 2010–11 breeding season, there were five pups born at this location. Pupping also occurs on Stewart Island, where pup numbers appear to be increasing, and 25 sea lion pups were tagged in March 2012 (Childerhouse & Gales 1998, Ministry for Primary Industries 2012).

On Auckland Islands, a long-term population monitoring programme was initiated in 1994–95, with annual pup counts and mark-recapture studies providing estimates of pup production and population size (Childerhouse & Gales 1998). These regular population surveys revealed a marked drop in pup production between 1998 and 2009, with three episodic disease outbreaks causing high levels of early pup mortality (21–53% of the annual pup production) in 1997–98, 2001–02, and 2002–03 (Chilvers et al. 2007). The epizootic in 2001–02, considered to be caused by bacteria (*Klebisella pneumoniae*) also resulted in mortality of adult sea lion, with at least 70 breeding females killed in this mass mortality event. Apart from the immediate impact of these mortalities, long-term repercussions from the declines in pup production include decreases in the number of females that recruit to the population and breed in subsequent years.

Bayesian population modelling for the period between 1995 and 2009 showed that the Auckland Island sea lion population experienced a net decline of 23% (Ministry for Primary Industries 2012). The most recent population estimate of this sea lion population was 12 065 individuals (90% c.i.: 11 160 to 13 061) in 2009.

Sea lion are generalist predators, with individuals targeting benthic and meso-pelagic prey species (Meynier et al. 2009). Their varied diet includes a range of fish and invertebrates, such as hoki (*Macruronus novaezelandiae*), opalfish (*Hemerocoetes monopterygius*), rattails (macrourids), cephalopods (octopus and squid, e.g., *Nototodarus* spp.), and also scampi (*Nephrops norvegicus*)(Gales 2008, Meynier et al. 2010).

The close proximity of the sea lion population to commercial trawl fisheries in subantarctic waters has resulted in a significant number of incidental sea lion captures, in particular in trawl fisheries targeting squid around Auckland Islands and southern blue whiting around Campbell Island (Thompson & Abraham 2011, Thompson et al. 2011). Concern over sea lion captures in the Auckland Islands squid fishery (within management area SQU 6T) has resulted in a number of management measures aimed at mitigating incidental captures of sea lion. These management measures include the implementation of a fishing exclusion zone within 12 nautical miles (22 km) of Auckland Islands in 1982 (this area gained full protection as a marine reserve in 2003)(Duignan & Jones 2007), and mandatory closure of the squid fishery before the end of the season if a set sea lion mortality limit has been reached. This mortality limit (maximum allowable level of fishing related mortality) was initially determined by applying the potential biological removal approach that has been used in United States fisheries (Wade 1998). Since

2003, the fisheries-related mortality limit (FRML) has been based on Bayesian modelling (Breen et al. 2003).

Management of the squid fishery has also involved the use of a sea lion exclusion device (SLED) that was first introduced by the fishing industry in 2001–02, and has been standardised and widely used across the squid fishing fleet since 2004–05. The SLED is fitted to trawl nets to enable sea lion to escape from the net (see illustration in Figure 1). It is placed in the midsection of the net before the codend, and includes a metal grid that guides sea lion to an opening (escape hole) above it. A forward-facing hood above the escape hole is designed to allow actively swimming sea lion to escape the net. The SLED can be closed by fitting a cover net over the escape hole. Although SLEDs are designed to allow the escape of sea lion, some animals may still get captured. Furthermore, the number of animals that escape the net via SLEDs is unknown, as is the injury rate of sea lion interacting with nets and SLEDs, and their post-escape survival.

Since the introduction of SLEDs, it is no longer possible to directly monitor sea lion mortality in the Auckland Islands squid trawl fishery. Instead, incidental captures of sea lions in this fishery are managed by setting tow limits in relation to the number of sea lions that may be killed without compromising the population (the FRML) and a predetermined strike rate (a measure of the number of sea lions killed per tow). This approach means that the number of sea lion interactions with squid trawl fisheries is estimated based on the predetermined strike rate, which is converted to a number of tows. For tows conducted with an approved SLED, the strike rate is reduced by a discount rate, which was 82% in the 2011–12 fishing year. Applying this discount rate to the strike rate of 5.89% results in a discounted strike rate of 1.06%, meaning that 1.06 sea lions are presumed killed for every 100 tows conducted with an approved SLED.

This report presents the most recent data on incidental captures of marine mammals in commercial trawl fisheries in New Zealand, including the 2011–12 fishing year. It updates existing information of incidental captures of common dolphin (Thompson & Abraham 2009b, Thompson et al. 2010c, Thompson et al. 2011, Thompson et al. 2013a, Thompson et al. 2013b, 5), fur seal (Thompson & Abraham 2010, Thompson et al. 2010a, Thompson et al. 2011, Thompson et al. 2013a), and New Zealand sea lion (Thompson & Abraham 2009a, 2011, Thompson et al. 2010b, Thompson et al. 2011, Thompson et al. 2013a), including model-based statistical estimates derived from observer data.

Fur seal captures were estimated over the period 2002–03 to 2011–12, with estimations of common dolphin and sea lion captures covering the periods from 1995–96 to 2011–12. These longer periods allowed the model to better reflect changes in the fisheries that have affected the capture rates. The periods covered in this report include the periods previously used for estimations (Thompson & Abraham 2010, 2011, Thompson et al. 2010c, Thompson et al. 2011, Thompson et al. 2013a). As data were updated and all models were re-run, the previous reports are superseded. Any comparison across fishing years should be made using the current report.

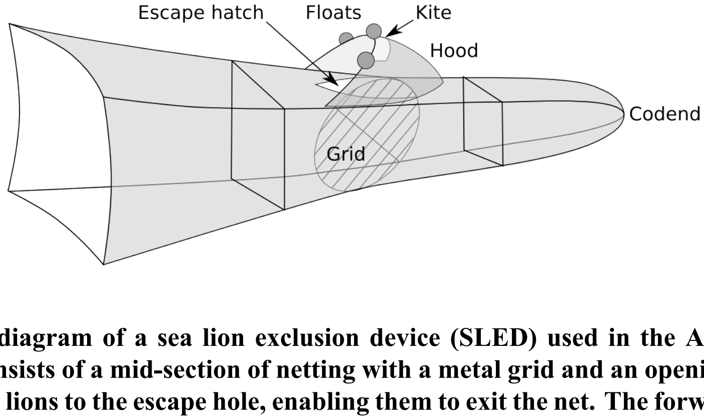


Figure 1: Schematic diagram of a sea lion exclusion device (SLED) used in the Auckland Islands squid fishery. The SLED consists of a mid-section of netting with a metal grid and an opening (escape hole) above it. The grid directs sea lions to the escape hole, enabling them to exit the net. The forward-facing hood above the escape hole is designed so that only actively swimming sea lions 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.

Table 1: All marine mammal captures reported by fishery observers on-board commercial fishing vessels in New Zealand waters between 2002–03 and 2011–12. 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	-	-	-	-	-	-	-	-	-	-	-
	Set net	3	-	-	-	-	-	-	-	-	-	-	-
2006–07	Trawl	73	12	-	-	-	11	-	-	-	-	-	-
	Surface longline	10	-	-	-	-	-	-	-	-	-	-	-
	Set net	-	-	-	-	-	-	-	-	-	1	-	-
2007–08	Trawl	141	11	-	-	-	20	-	-	1	-	-	-
	Surface longline	10	-	-	-	-	-	-	-	-	-	-	1
	Set net	1	-	-	-	-	-	1	1	-	-	-	-
2008–09	Trawl	72	3	-	-	1	20	2	-	-	-	-	-
	Surface longline	22	-	-	-	-	-	-	-	-	-	-	-
	Set net	1	-	-	-	-	-	-	1	-	-	-	-
2009–10	Trawl	72	15	-	-	-	4	-	-	-	-	-	-
	Surface longline	19	-	-	-	-	-	-	-	-	-	-	-
	Set net	5	-	-	-	-	-	-	2	-	2	-	-
2010–11	Trawl	73	6	-	-	-	9	-	-	-	-	-	-
	Surface longline	17	-	-	-	-	-	-	-	-	-	-	-
	Set net	1	-	-	-	-	-	-	-	-	2	-	-
2011–12	Trawl	82	1	-	-	-	5	-	-	-	-	-	-
	Surface longline	40	-	-	-	-	-	-	-	-	-	-	-

2. METHODS

2.1 Data sources

Presented here are estimates of incidental captures of marine mammals in commercial trawl fisheries within the outer boundary of New Zealand's EEZ. These estimates were derived for common dolphin, New Zealand fur seal, and New Zealand sea lion captures using statistical models based on fishing effort and observer data. Fishing data included 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. The information provided 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.

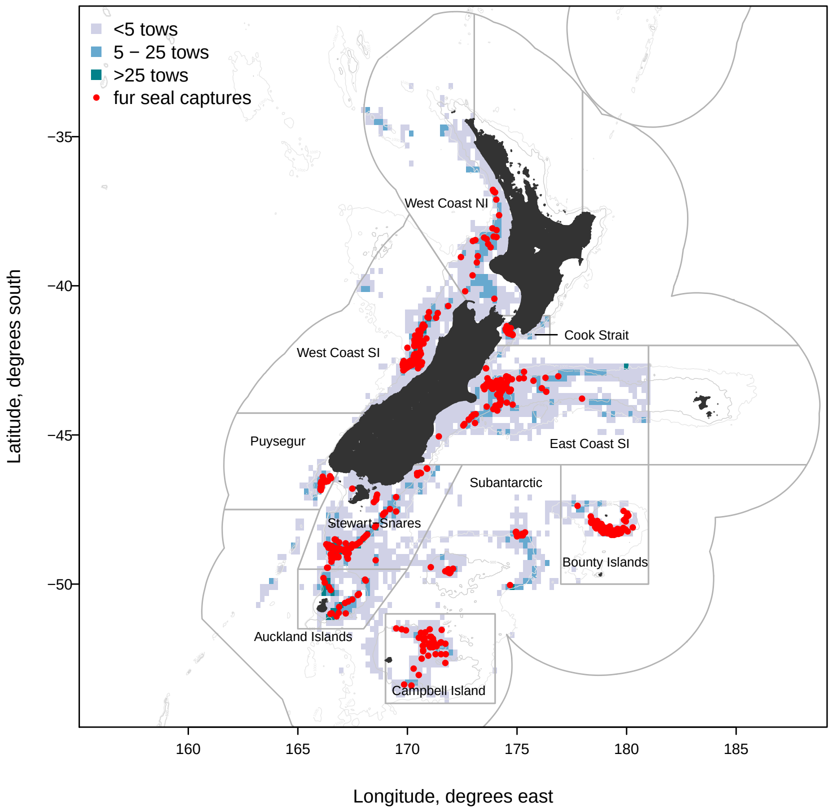
Government fisheries observers (Ministry for Primary Industries and Department of Conservation) on-board commercial fishing vessels document incidental captures of protected species. These observer data include the identity of the species captured, the number of individuals involved, and the time and location of the captures and of every observed tow. The observer records are collated in a database administered by National Institute of Water and Atmospheric Research (NIWA) on behalf of Ministry for Primary Industries. Observer data used here for statistical modelling encompassed a 10-year period for fur seal and a 17-year period for common dolphin and sea lion (see summary of model data sets in Figure 2).

Both fishing effort and observer records were prepared and linked, correcting for errors in date, time, and position fields. The observer data were prepared by NIWA, and did not require further preparation. The existing data preparation 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. 2010c, Abraham & Thompson 2011, Thompson et al. 2011, Thompson et al. 2013a), 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 2% of all trawl records (excluding those targeting flatfish) were affected in each year since 1998–99, with 0.6% of records in 2011–12 having missing values imputed.

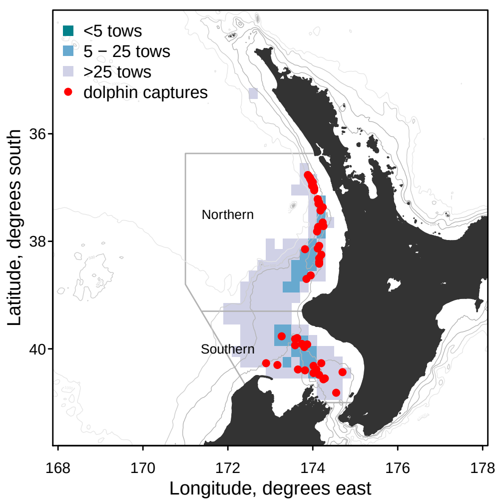
Missing or improbable values for target species, effort number, and primary fishing method were imputed by comparing records in the same area, around the same time, and by the same vessel, or vessels in the same size class. A total of 9 trawls, or 0.013% of trawl records, had the target species imputed in the 2011–12 fishing year. No records required imputed effort numbers or primary method for 2011–12.

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 in-shore 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. The algorithm associates each observed tow with a fisher-reported tow, or confirms that no tow can be found. Those unlinkable records occur when all fisher-reported effort has been accounted for, but the observer recorded extra tows. Over 99% of all observed trawl effort records were linked or found to be unlinkable for each year since 1999–2000, with more than 99.99% since 2009–10. Less that 0.5% of tows were found to be unlinkable in each of the years since 2007–08.

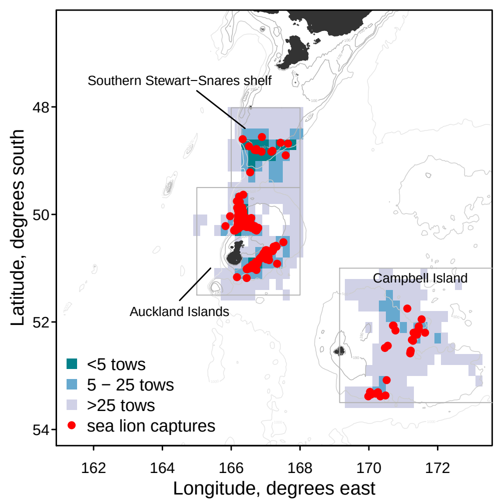
Position information was discarded if it reported fishing events on land, or at improbably far distances. Fishing effort recorded on older CELR forms did not report latitude and longitude, and these forms were phased out from 2007–08. Trawl effort data with missing latitude and longitude were updated 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



(a) Observed fur seal captures



(b) Observed common dolphin captures



(c) Observed sea lion captures

Figure 2: Spatial distribution of observed fishing effort (blue squares) and observed marine mammal captures (red dots) used in statistical models to estimate total captures in New Zealand's Exclusive Economic Zone. Also indicated are the areas used for defining the models. The model data sets encompassed 10 fishing years for fur seals, from 2002–03 to 2011–12, and 17 fishing years for common dolphins and sea lions, from 1995–96 to 2011–12. The average annual observed fishing effort within 0.2° square cells is indicated with blue shades.

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, New Zealand fur seal, and New Zealand sea lion. As the fishing year in New Zealand spans from 1 October to 30 September the following year, data analysis and presentation follow this format, with the most recent data encompassing the 2011–12 fishing year. The only exception is the subantarctic southern blue whiting fishery, east of Campbell Island. This fishery extends past the end of the standard fishing year with most trawl effort occurring between August and November. For this reason, data from this fishery are presented by calendar year. Estimates of fur seal captures included the period from 2002–03 to 2011–12, while estimates of common dolphin and sea lion captures covered the period between 1995–96 and 2011–12.

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 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 (see Appendix B for model parameters). 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 dolphins 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 2010–11, as common dolphin captures were observed sufficiently frequent in this fishery to allow development of the model (Thompson & Abraham 2009b, Thompson et al. 2010c, Thompson et al. 2011, Thompson et al. 2013a). The present study updated the model to include data from the mackerel fishery from the 2011–12 fishing year, encompassing the 17-year period between 1 October 1995 and 30 September 2012.

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:

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

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 previously (see Thompson & Abraham 2009b, Thompson et al. 2010c, Thompson et al. 2011, Thompson et al. 2013a) 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 (see Appendices C and D for model parameters). The same modelling approach was previously used to

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 Trawl Catch Effort Processing Return (TCEPR) forms.
Headline depth	Depth in metres of the top of the net, derived by subtracting the headline height from the ground line depth (both recorded on TCEPR forms). Indicates the depth of the top of the net.
Sub-area	The 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).

estimate the total number of incidental fur seal captures per fishing year for the periods from 2002–03 to 2007–08, 2008–09, 2009–10, and 2010–11, respectively (Thompson & Abraham 2010, Thompson et al. 2010a, Thompson et al. 2011, Thompson et al. 2013a). 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 10-year period from 1 October 2002 to 30 September 2012.

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 2011–12 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,

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

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 shape and rate θ_ν. With this parameterisation, the gamma distribution has unit mean. The coefficient of a covariate c was denoted β_c, while the value of the covariate at tow i was denoted x_i^c.

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

$$\begin{aligned} \log(\mu_\lambda) &\sim \text{Mean}(\mu = \bar{y_i}, \sigma = 100), && (7)\\ \sigma_\lambda &\sim \text{Half-Cauchy}(25), && (8)\\ \theta &\sim \text{Uniform-shrinkage}(\bar{y_i}), && (9)\\ \theta_\nu &\sim \text{Uniform-shrinkage}(\bar{y_{v_i}}), && (10)\\ \beta_c &\sim \text{Normal}(\mu = 0, \sigma = 100). && (11) \end{aligned}$$

The same covariates selected in previous modelling of fur seal captures (Thompson & Abraham 2010, Thompson et al. 2010a, Thompson et al. 2011, Thompson et al. 2013a) 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, Thompson et al. 2013a), 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 second 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 assessments of incidental captures. 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.

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

Fishing area	New Zealand's Exclusive Economic Zone 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 analyses, see Thompson & Abraham 2010, Thompson et al. 2011, Thompson et al. 2013a).
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 (no more than 25 km), near (between 25 and 90 km), far (between 90 and 180 km), and ocean (greater than 180 km)(see map in, Thompson & Abraham 2010).

2.5 Sea lion capture models and ratio estimates

New Zealand sea lion captures in subantarctic trawl fisheries 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, 2009–10, and 2010–11 fishing years, respectively (Thompson et al. 2010b, Thompson & Abraham 2011, Thompson et al. 2011, Thompson et al. 2013a). The previous estimates were updated by including data from the 2011–12 fishing year, presenting capture estimates over the 17-year period between 1 October 1995 and 30 September 2012 (see Appendix E for model parameters).

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 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 required 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 significant number of sea lion that were incidentally taken by trawlers targeting squid near Auckland Islands, management of this fishery has included usage of SLEDs as a mitigation method for incidental captures, 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

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

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 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 lions killed (or injured) is unknown, as some sea lions may escape from the net. Because of this uncertainty, the number of sea lions 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 2011–12 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 82%, so that for every 100 tows using SLEDs, the strike rate was reduced to 1.06%, so that 1.06 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 followed the modelling used to estimate captures in the Auckland Islands squid fishery during the 2010–11 fishing year (Thompson et al. 2013a). Specifically, it involved one model with a split SLED retention probability, in addition to a model with a single SLED retention probability.

The split SLED retention model 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 model chose the cut-off date from these three fishing years, with early and late sled retention probabilities for the periods up to

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

Term	Definition
Auckland Islands squid fishery	Trawlers targeting squid in the Auckland Islands part of the SQU 6T 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.
Approved SLED	A SLED that has been audited and approved by Ministry for Primary Industries as meeting specifications.
Closed SLED	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 lions are unable to escape.
Open SLED	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.

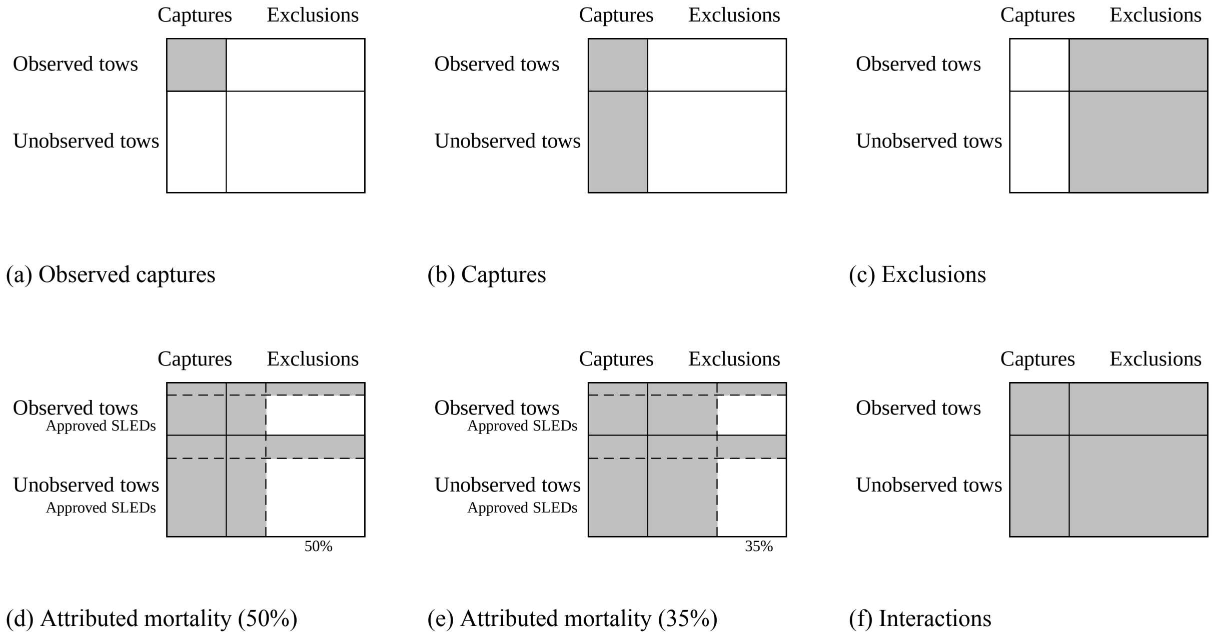


Figure 3: Quantities estimated for tows that used SLEDs. The box represents the total captures that would have occurred if no SLEDs were used, with the shading indicating the portion of the total that was included in each quantity. Tows are either observed or unobserved, and sea lions are either captured 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.

and including the cut-off year (i.e., 2004–05, 2005–06, or 2006–07) and subsequently. Results from the split and the single SLED retention 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,

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

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 fixed prior distributions:

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

For each vessel and year combination, there was a vessel-year random effect, ν^y_j, that was drawn from a gamma distribution with a mean value of one. This selection allowed the strike rate for each vessel in each year to have a mean value different from the year effect λ^y. The shape of the gamma distribution was defined by the hyper-parameter, θ_ν. The shape parameter was given the uniform shrinkage prior, with a mean value 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 ν^y_j was drawn from the gamma distribution:

$$
\begin{aligned}
\nu^y_j &\sim \text{Gamma}(\theta_\nu, \theta_\nu), && (19)\\
\theta_\nu &\sim \text{Uniform-shrinkage}(\mu_{vs}). && (20)
\end{aligned}
$$

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 SLED (i.e., SLED present with its exit open)(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

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 $50.45\,^{\circ}$S and west of $166.95\,^{\circ}$E), and S&E (South and East: the remainder of the Auckland Islands part of SQU 6T).
Open SLED	A factor variable, indicating that the net had a SLED attached and that the SLED exit was open. In the model with a split SLED retention probability, the open-SLED factor depended on whether or not the tow was after the cut-off fishing year of 2004–05, 2005–06, or 2006–07.

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 SLED exit open (open SLED) was treated as a covariate. The regression coefficients were $\beta_{\mathit{open\ net}_{1,2}}$, 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, $\pi_{1,2} = \exp\left(\beta_{\mathit{open\ net}_{1,2}}\right)$, 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 significant limitation to this modelling approach, however, was that the model data set was greatly unbalanced, as there have been few observed captures in recent years. This imbalance means that 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 was 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 with 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 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 the probability given by the

SLED retention probability and the 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 was subtracted from the probability in Equation 24, so that the captures were 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). All fishing effort in the Campbell Island southern blue whiting fishery occurs 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. 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 model used for the southern blue whiting trawl fishery was a variation of the Auckland Islands 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. (2013a), except that the date range has been extended to include all data from 1996 to 2012.

2.9 Other strata

Ratio estimates of sea lion captures were calculated for the three remaining strata: the Auckland Islands scampi fishery, other Auckland Islands non-squid trawl fisheries, and all trawl fisheries at the south end of the Stewart-Snares shelf. In addition to the Auckland Islands trawl fishery targeting scampi, other Auckland Islands non-squid trawl fisheries were distinguished as all other trawl operations not targeting squid in the Auckland Islands part of the SQU 6T fishing area. The area for the Stewart-Snares trawl fishery was defined as the southern end of the Stewart-Snares shelf, south of $48.02\,^{\circ}$S, north of $49.5\,^{\circ}$S, west of $168\,^{\circ}$E, and east of $166\,^{\circ}$E.

The only observed sea lion capture in subantarctic trawl fisheries in 2011–2012 was in the Stewart-Snares fishery, and the captured sea lion was released alive. Over the entire reporting period, all of the other 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 there was no trend, ratio estimates were calculated using data from the fishing years 1995–96 to 2011–12, 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 5000 times, and the total incidental captures were 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 most recent fishing year, 2011–12, there were five observed common dolphin captures in New Zealand trawl fisheries, compared with nine observed captures the previous year. All of the observed captures in 2011–12 occurred on North Island's west coast, and involved trawl vessels targeting mackerel, including jack mackerel (*Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae*) or blue mackerel (*Scomber australasicus*). This target fishery was also involved in the majority of observed common dolphin captures in New Zealand's EEZ in previous fishing years (Table 7). Between 1995–96 and 2011–12, there were 124 of a total 138 observed common dolphin captures in this target fishery along North Island's west coast. There were also two observed incidental captures of common dolphins in surface-longline fisheries in New Zealand waters during that period.

Table 7: Total number of observed common dolphin captures in New Zealand's commercial trawl fisheries between 1995–96 and 2011–12, by main target species. Target species included jack mackerel (JMA), barracouta (BAR), common warehou (WAR), different flatfish (FLA), trevally (TRE), and gurnard (GUR).

	JMA	BAR	WAR	FLA	TRE	GUR	Total
1995–96	2						2
1999–00	1						1
2000–01	1						1
2001–02	1						1
2002–03	21						21
2003–04	17						17
2004–05	21	1					22
2005–06	2				2		4
2006–07	11						11
2007–08	20						20
2008–09	11	3	4	2			20
2009–10	4						4
2010–11	7	1				1	9
2011–12	5						5
Total	124	5	4	2	2	1	138

The mackerel fishing fleet is characterised by large vessels (over 90 m length), and all of the observed common dolphin captures in the 17-year reporting period were on vessels that were longer than 90 m, with most captures on vessels that were over 100 m long. For this reason, the estimation of common dolphin captures was based on observer data from vessels that were over 90 m long and targeted jack mackerel or blue mackerel on at least one tow per fishing trip (see Table A-1, Figure A-1).

Trawl effort in the large-vessel mackerel fishery increased from a relatively low number of tows in the late 1990s to over 2000 tows per year between 2002–03 and 2009–10 (Table A-1). In the two most recent fishing years, trawl effort was slightly lower, with fewer than 1700 tows fished per year. The corresponding observer coverage varied across years, with few tows (less than 10%) observed in the period between 2001–02 and 2003–04, when the fishery first expanded. Subsequently, observer effort has been over 20%, with a substantial increase in the most recent fishing year, 2011–12, when observer coverage reached 79% – the highest observer effort in the entire reporting period.

The spatial distribution of the large-vessel mackerel fishery extended along North Island's west coast, with similar fishing effort in both sub-areas in 2011–12 (Figure A-1(d)). Observer effort showed a similar spatial distribution to fishing effort, extending throughout the northern and southern sub-areas. Observed common dolphin captures in this fishing year were recorded in both sub-areas, with four observed captures in the northern sub-area, and the remaining capture in the southern sub-area.

Considering the monthly distribution of trawl effort across the 17 years of data showed that trawl effort varied throughout the fishing year (Figure A-1(e)). It was highest at the start of the fishing season, in particularly in October and December, when about 20 and 30% of all tows were conducted, respectively. In January, trawl effort dropped to just below 10%, and remained well below this level for the remaining months, except for a small increase (to about 10% of overall effort) in June. Observer effort corresponded closely with trawl effort, showing the same fluctuations as trawl effort throughout the fishing year. The number of observed common dolphin captures was highest in December, and almost 50% of all observed captures occurred during this month, at the time when fishing effort was highest. During other months, observed captures were low, except for small peaks (about 10% of all observed captures each) in April and May, which coincided with low fishing effort in both months.

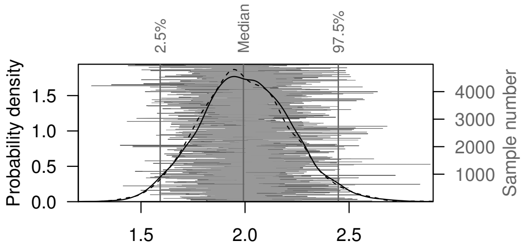
The five observed captures in 2011–12 occurred on four separate tows, with one capture event involving two common dolphins that were caught in the same tow. In most fishing years, there were frequently more than one common dolphin involved in capture events, and the total 124 observed common dolphin captures between 1997–98 and 2011–12 occurred on 53 tows. Since 2002–03, most of the multiple capture events involved two or three common dolphins, up to a maximum of nine individuals that were observed caught in a single incident (Figure 4). The two most recent fishing years were unusual as they each only included one multiple capture event, with two individuals observed caught on a single tow, and the remainder of the observed captures involved single common dolphin. All observed common dolphin captures were mortalities.

The observed captures in 2011–12 corresponded with a capture rate of 0.38 common dolphins per 100 tows. This value was the lowest capture rate since 2005–06 and substantially lower than the observed capture rate in 2010–11, when 1.51 common dolphins were observed captured per 100 tows.

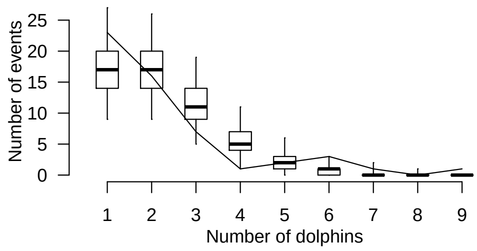
Observer and effort data from the large-vessel mackerel fishery allowed the estimation of total common dolphin captures with a two-stage Bayesian model (Table A-1, Figure A-1). Estimated common dolphin captures in 2011–12 were low, with a total of 7 (95% c.i.: 5 to 14) estimated captures, the lowest estimate since the 1998–99 fishing year. It was considerably lower than the estimate in the previous fishing year of 60 (95% c.i.: 24 to 113) estimated common dolphin captures, even though fishing effort was slightly higher than in 2010–11. The corresponding capture rate was an estimated 0.43 (95% c.i.: 0.30 to 0.85) common dolphins per 100 tows, compared with an estimated 3.86 (95% c.i.: 1.55 to 7.29) common dolphins per 100 tows in 2010–11. Owing to the high observer coverage in 2011–12, the uncertainties associated with the most recent estimates were also markedly lower than in previous years.

Capture estimates showed some fluctuation throughout the reporting period, with relatively low values in the initial three to four years before fishing effort in the mackerel fleet greatly increased. During the expansion period, estimated captures were particularly high, corresponding with high fishing effort, and peaking at 146 (95% c.i.: 61 to 276) estimated captures in 2002–03. In the following years, the number of estimated captures declined to some extent, but varied across years, while fishing effort remained high. In 2010–11, there was a marked increase in the number of estimated captures (60 (95% c.i.: 24 to 113)), even though fishing effort was relatively low (1551 tows); the latter remained at a similar level in 2011–12, concomitant with the low total number of estimated common dolphin captures.

Model predictions also included the number of common dolphin per capture event, as most capture events in the 17-year reporting period involved more than one dolphin (Figure 4). Most frequently, these multiple captures were of two or three common dolphins; the largest group size reported in the observer data was nine common dolphins that were captured in a single tow. The posterior distribution of the size of the zero-truncated Poisson distribution μ, had an approximately normal distribution, and the median number of common dolphins per capture event predicted by the model was 2.0 (95% c.i.: 1.6 to 2.4)(see Appendix B). The model-derived estimates agreed well with the observer data, as the latter were within the 95% confidence intervals of the model estimates. The only exception was the capture event that involved nine common dolphins – a multiple capture of this group size was less likely to occur in the model. The comparison between observer data and model predictions confirmed the suitability of the zero-truncated Poisson distribution for predicting the number of common dolphins involved in capture



(a)



(b)

Figure 4: Number of common dolphins caught per capture event in the large mackerel trawl fishery between 1995–96 and 2011–12. (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 dolphins 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).

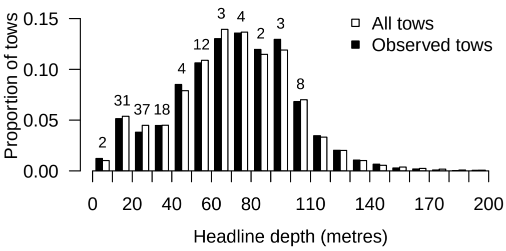
events. The two most recent fishing years were unusual in that they each only included one multiple capture event (involving two individuals), with most captures involving one individual.

Another part of the analysis involved identification of potential factors that may contribute to common dolphin captures, and the model structure allowed for the capture event probability to depend on covariates. The selection of covariates followed previous estimations of common dolphin captures Thompson et al. (2010c), Thompson et al. (2011), Thompson et al. (2013a). The model identified four covariates that had explanatory power for the variation in the capture event probability, including headline depth, trawl duration, light condition, and sub-area. Headline depth was the most important covariate, followed by trawl duration, whereas light condition and sub-area had less explanatory power.

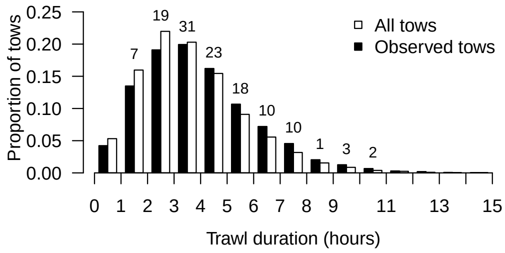
The distributions of the four covariates were representative of overall fishing effort, evident in the close agreement between the observed and modelled data sets (Figure 5). For each of the covariates, there were distinct patterns in the number of observed common dolphin captures. For headline depth, most observed captures (70%) occurred on tows with headline depths between 10 and 40 m. There were few observed captures involving tows at headline depths below 60 m, with no captures at headline depths below 110 m. There was also a clear pattern in common dolphin captures in relation to trawl duration, with 73% of all observed captures involving tows that lasted between 2 and 6 hours. On longer tows, the number of observed captures was still relatively high, but showed a distinct drop when the tow duration exceeded 8 h. Light condition was included as a three-level factor, with light, dark, and black light conditions distinguished by the time of the haul and the phase of the moon. Most observed captures (81%) were in dark and black light conditions. For the two sub-areas, most observed common dolphin captures (63%) were in the northern sub-area (Figure 5).

The regression coefficients of the different covariates allowed quantification of their influence on the probability of common dolphin captures (Table B-19). Headline depth was the covariate with the highest explanatory power of the capture event probability. Its correlation with the latter was negative, with a mean regression coefficient of -0.035 m^{-1} (95% c.i.: -0.047 to -0.024 m^{-1}). The prevalence of observed common dolphin captures supported the model results, as most observed common dolphin captures occurred on tows fished at relatively shallow headline depths (less than 40 m). Based on the model, increasing the headline depth would reduce the capture event probability, with model estimates indicating that a 20 m (95% c.i.: 15 to 29 m) increase in headline depth would halve the probability of a capture event. Trawl duration was positively correlated with captures with a mean regression coefficient of 1.278 (95% c.i.: 0.561 to 2.033), suggesting that a decrease in trawl duration would decrease the probability of a capture event.

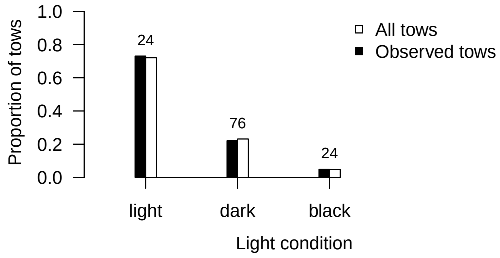
Light condition and the spatial distribution of fishing effort also had some influence on the capture event



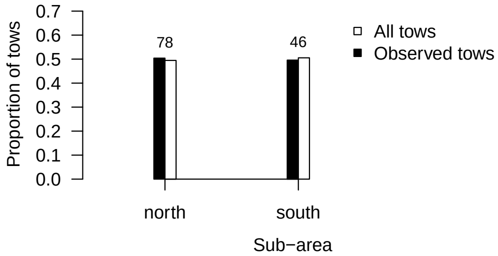
(a) Headline depth



(b) Trawl duration



(c) Light condition



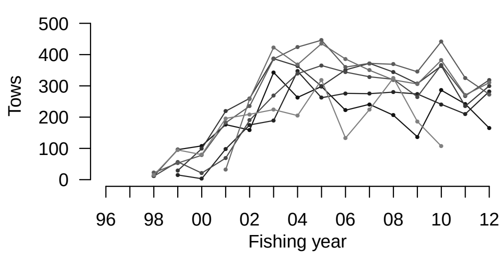
(d) Sub-area

Figure 5: Distribution of the four selected covariates for observed and all trawl effort by large vessels (over 90 m length) targeting mackerel off the west coast of North Island, between 1 October 1995 and 30 September 2012. Numbers above bars indicate the number of observed common dolphin captures.

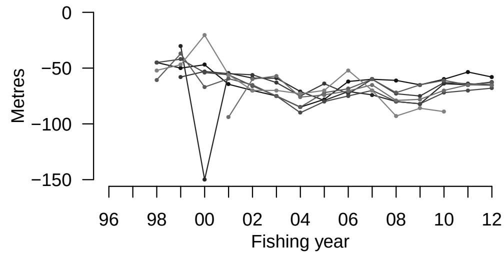
probability. Tows hauled in the light (i.e., between dawn and dusk, or between dusk and midnight on a moonlit night) were less likely to capture dolphins than tows hauled in dark conditions (net hauled between dusk and midnight on a dark night, or between midnight and dawn on a moonlit night), indicated by the mean capture event probability of 0.215 (95% c.i.: 0.099 to 0.392). Tows hauled in black light conditions (i.e., between midnight and dawn on a dark night) were slightly more likely to capture common dolphins than tows hauled in the dark, with a mean capture event probability of 1.034 (95% c.i.: 0.409 to 2.048). For the two sub-areas, tows conducted in the southern sub-area were about half as likely to result in common dolphin captures than in the northern sub-area, indicated by the mean regression coefficient of 0.528 (95% c.i.: 0.249 to 0.974).

Comparing the main fishing characteristics across the different vessels involved in the mackerel target fishery on North Island's west coast showed that this fishery operated in a coherent fleet between 1997–98 and 2011–12 (Figure 6). Over this period, the seven vessels associated with most of the fishing effort were generally consistent in their trawl effort, headline depth, trawl duration, spatial distribution of fishing effort, and the proportion of tows hauled under different light conditions. Changes in the main fishing characteristics were generally uniform across the different vessels. There was no evidence to indicate that any one vessel was better or worse at avoiding the incidental capture of common dolphins.

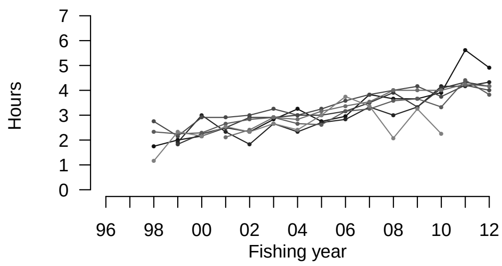
In recent years, there has been a relative decrease in overall trawl effort, with one vessel leaving this fishery in 2010–11, while the remaining vessels fished less, and one vessel fished considerably fewer tows in 2011–12. Headline depth has remained relatively consistent over time, with median depths below 50 m since 2001–02. Trawl duration showed an overall increase across all vessels over time, and was at median values at about 4 hours in the most recent fishing year. Similarly, fishing effort was concentrated in the same sub-area across the different vessels each year, with a similar proportion of fishing effort between the northern and southern sub-areas since 2007–08. The proportion of tows hauled under different light conditions has also remained constant for most of the reporting period. Since 2001–02, about 20% of tows were hauled in dark light conditions (between dusk and midnight on a dark night), compared with about 5% of tows that were hauled in black light conditions (between midnight and dawn on a dark night).



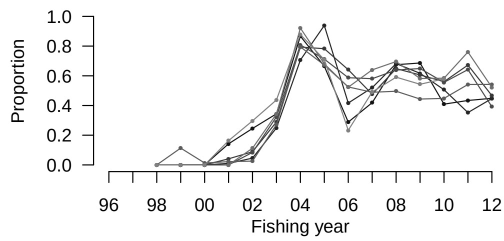
(a) Trawl effort



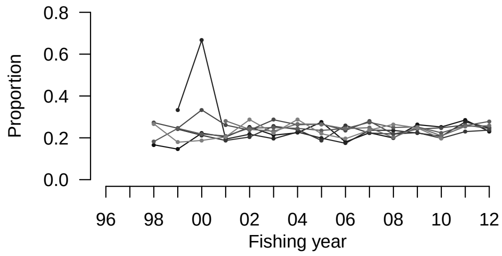
(b) Median headline depth



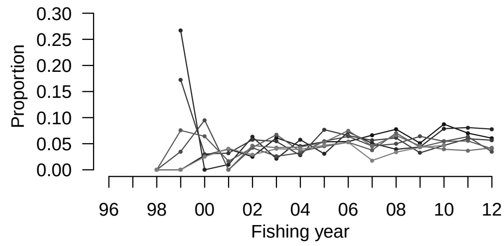
(c) Median trawl duration



(d) Proportion of tows in northern sub-area



(e) Proportion of tows in dark light condition



(f) Proportion of tows in black light condition

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.

3.2 Fur seal captures

3.2.1 Observed fur seal captures

In 2011–12, New Zealand fur seals were captured in a variety of trawl fisheries operating within New Zealand's EEZ, with 82 observed fur seal captures corresponding to an observed capture rate of 0.91 fur seals 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). The total fishing effort across the different trawl fisheries was over 84 000 tows in this fishing year. Included in this overall trawl effort were inshore target fisheries (excluding flatfish targets), as recent increases in observer coverage in inshore fisheries allowed their inclusion in the captures assessment (for the second time). Inshore target fisheries contributed the single largest proportion to the total fishing effort, with 32 676 tows fished in 2011–12.

In the 10-year period between 2002–03 and 2011–12, there was a total of 1008 observed fur seal captures in New Zealand trawl fisheries. Annual fishing effort was comparatively high in the first half of the reporting period (i.e., more than 100 000 tows annually), but decreased to about 89 000 tows in 2007–08, and has remained at about this level since then. The most recent fishing year had a small decrease in fishing effort compared with the previous year, decreasing from 85 982 tows in 2010–11 to 84 179 tows in 2011–12. Observer effort has been low across all fishing years, at less than 12%. In 2011–12, 10.7% of all tows were observed, an increase from the 8.6% observer coverage the previous fishing year.

Observed fur seal captures showed some fluctuations over the reporting period, and were particularly high in 2004–05 and 2005–06, when 200 and 143 fur seal captures were recorded by observers. These observed captures equated to capture rates of 2.61 and 2.10 fur seals per 100 tows, respectively. Following the decrease in fishing effort in 2007–08, the number of observed captures showed a general decrease in the four most recent fishing years, including 2011–12. The 82 observed fur seal captures in 2011–12 and the slightly lower tow effort corresponded with a capture rate of 0.91 fur seals per 100 tows; a slightly lower observed capture rate than in the previous year of 0.98 fur seals per 100 tows in 2010–11.

Trawl effort was widely distributed throughout New Zealand's EEZ, and extended across most areas. As in previous fishing years, there were no observed fur seal captures on the north and east sides of North Island, nor in waters around Chatham Islands. Over the entire 10-year period, fishing effort was evenly distributed across months and closely matched by observer effort. Observed fur seal captures showed a distinct increase in June and July, reaching a peak in August, when over 40% of all observed captures occurred. The number of observed captures was also relatively high in September (about 20% of the total), with few or no observed captures in other months.

To provide higher spatial resolution for modelling purposes, New Zealand's EEZ was divided into 13 fishing areas. As there were no observed captures in three of these areas (north and east sides of North Island, and around Chatham Islands), model estimates were derived for 10 fishing areas, including the North Island and South Island west coasts, Cook Strait, South Island's east coast, and southern South Island and subantarctic islands (Figure 2a, Table 8). There were marked differences in fishing effort, observer coverage and number of observed fur seal captures across the different areas. Fishing effort ranged from a low 4057 tows around Bounty Islands to 167 599 tows on South Island's east coast. It was also high on the west coasts of both North and South islands, with 97 127 and 88 336 tows fished, and on the Stewart-Snares shelf, where 79 473 tows were fished over the reporting period. Observer coverage was highest in the Campbell Island and the Bounty Islands fishing areas (over 30% in each area), while fishing effort in both areas was relatively low. In contrast, the area with the highest fishing effort, South Island's east coast had low observer coverage at 7.6%; this observer effort was the second lowest value of all fishing areas. The lowest observer coverage was in Cook Strait, where 3.8% of 51 633 tows were observed.

Observer records also showed distinct differences in observed captures and observed capture rates across fishing areas. The highest number of observed fur seal captures was on the west coast of South Island, with 267 observed captures, followed by 180 observed captures around Bounty Islands. Observed cap-

		Observed tows		Fur seals	
	Tows	Tows	Coverage %	Captures	Rate
West Coast South Island	88 336	11 275	12.8	267	2.37
Bounty Islands	4 057	1 325	32.7	180	13.58
Cook Strait	51 633	1 984	3.8	173	8.72
Stewart-Snares	79 473	14 648	18.4	121	0.83
East Coast South Island	167 599	12 662	7.6	116	0.92
Campbell Island	6 802	2 528	37.2	52	2.06
Puysegur	8 066	1 009	12.5	31	3.07
Subantarctic islands	15 147	4 548	30.0	28	0.62
West Coast North Island	97 127	8 221	8.5	22	0.27
Auckland Islands	35 184	7 951	22.6	18	0.23

Table 8: Summary of the model dataset by fishing area for the period between 1 October 2002 and 30 September 2012. 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.

tures were also high on the Stewart-Snares shelf, where 173 observed fur seal captures were recorded. The Bounty Islands and Cook Strait fishing areas had the highest observed capture rates with 13.58 and 8.72 observed fur seal captures per 100 tows, respectively. The next highest observed capture rate was 3.07 fur seals per 100 tows in the Puysegur fishing area, while capture rates in the remaining areas ranged between 0.23 and 2.37 observed captures per 100 tows (Table 8).

The different target fisheries, defined by individual species or species groups, were also distinguished in the modelling. They were characterised by differences in fishing effort, observer coverage and the number of observed fur seal captures (see Appendix A.3 to A.12, Table 9). The highest fishing effort was in inshore fisheries targeting a range of different species (excluding flatfish), and had a fishing effort of 179 781 tows over the ten years of data. In comparison, the next highest fishing effort was 130 423 tows in hoki target fisheries, followed by 64 135 and 61 248 tows in middle-depth species and squid target fisheries, respectively. Fishing effort in the other target fisheries varied between 8744 tows in the southern blue whiting trawl fishery and 33 720 tows in trawl fisheries targeting deepwater species.

Coinciding with the highest trawl effort, inshore fisheries had the lowest observer coverage of all target fisheries, with 1.0% of all tows observed. In contrast, the highest observer coverage was 39.0% in the southern blue whiting fishery, which had the lowest fishing effort across all target fisheries. Observer effort in other target fisheries varied from 6.2% in trawl fisheries targeting middle-depth species to 28.9% in the jack mackerel target fishery. Trawlers targeting hoki had the highest number of observed captures, with 487 fur seal captures observed in these fisheries. This value was higher than all observed captures in the other target fisheries combined, and the corresponding observed capture rate was 2.44 fur seals per 100 tows. The second highest number of observed captures was in the southern blue whiting fishery, which had 237 observed captures corresponding with a capture rate of 6.95 fur seals per 100 tows – the highest capture rate across all target fisheries. Observed capture rates were also relatively high in the ling and hake target fisheries (3.17 and 2.36 fur seals per 100 tows, respectively), whereas the number of observed captures and observed capture rates were markedly lower in the other target fisheries, with one or less fur seal per 100 tows.

3.2.2 Estimated fur seal captures

Observer and effort data allowed estimations of the total number of fur seal captures in New Zealand trawl fisheries. In 2011–12, there were 442 (95% c.i.: 256 to 789) estimated fur seal captures in all trawl fisheries (excluding flatfish targets), with an estimated capture rate of 0.53 (95% c.i.: 0.30 to 0.94) fur seals per 100 tows (Table A-2). These estimates were similar to estimated captures and capture

		Observed tows		Fur seals	
	Tows	Tows	Coverage %	Captures	Rate
Hoki	130 423	19 972	15.3	487	2.44
Southern blue whiting	8 744	3 409	39.0	237	6.95
Squid	61 248	14 643	23.9	84	0.57
Hake	11 943	2 501	20.9	59	2.36
Middle depth species	64 135	3 957	6.2	43	1.09
Jack mackerel	24 563	7 088	28.9	38	0.54
Ling	10 599	1 166	11.0	37	3.17
Deepwater species	33 720	9 032	26.8	14	0.16
Scampi	28 268	2 560	9.1	7	0.27
Inshore (excluding flat fish)	179 781	1 823	1.0	2	0.11

Table 9: Summary of the model dataset by target fishery for the period between 1 October 2002 and 30 September 2012. 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.

rates in recent fishing years, and consistent with a general decrease in both parameters since 2004–05. Following high fishing effort and capture estimates in the first few years, the decrease in capture estimates since 2005–06 corresponded with the decrease in fishing effort over the same period. Fishing effort has remained low in recent years, which was reflected in the observed captures and capture estimates.

Considering the different trawl fisheries within New Zealand's EEZ, two different target fisheries, hoki and southern blue whiting, were characterised by high numbers of observed captures, and contributed a substantial proportion to the total estimated fur seal captures. Fishing effort in hoki target fisheries was constant throughout most of the reporting period, even though overall trawl effort decreased in recent years. Both observed and estimated captures were consistently high across years in these fisheries. In 2011–12, there were 11 323 tows targeting hoki, and there were 33 observed fur seal captures, with a capture rate of 1.28 fur seals per 100 tows. Estimated captures showed an increase from the previous two years, and were similar to estimates in 2008–09, with 200 (95% c.i.: 98 to 417) estimated captures and an estimated capture rate of 1.77 (95% c.i.: 0.87 to 3.68) fur seals per 100 tows.

The monthly distribution of fishing effort in hoki fisheries over the 10-year period showed that tow effort was low between October and June, with less than 10% of tows fished per month. Fishing effort increased to about 20% in July and August before dropping back to low levels in September. The monthly distribution of observer effort was representative of the fishing effort throughout the year. Observed captures also corresponded with fishing effort, and were low between October and June, with few or no captures in these months. The highest proportion of observed captures was in August, when almost 40% of all incidental captures were recorded, with about 20% each in July and September.

Hoki trawl fisheries were concentrated in Cook Strait, on the west and east coasts of South Island, on the Stewart-Snares shelf, and north of Auckland Islands. All observed fur seal captures in hoki fisheries in 2011–12 occurred in Cook Strait, around South Island and on the Stewart-Snares shelf, with a high number of observed captures in Cook Strait. Compared with the total 200 (95% c.i.: 98 to 417) estimated fur seal captures across all of the different hoki fishing areas, trawlers targeting hoki in Cook Strait had 116 (95% c.i: 37 to 316) estimated captures and an estimated capture rate of 6.66 (95% c.i: 2.12 to 18.09) fur seals per 100 tows in the most recent fishing year. These data were consistent with findings in previous years, highlighting that hoki fisheries, in particular in Cook Strait, continued to contribute the majority of fur seal captures in New Zealand trawl fisheries.

High numbers of observed and estimated fur seal captures were also evident in the southern blue whiting fishery. This target fishery was small and had the lowest fishing effort of any trawl fishery included in this assessment. Trawl effort in 2011–12 was lower than in other recent years, with 952 tows fished, compared with about 1100 annual tows between 2008–09 and 2010–11. Observer coverage was high throughout the reporting period – at least 30% of tows were observed in most fishing years. In 2011–12, observer effort was 70.2%.

Although lower than the 36 observed fur seal captures in the previous fishing year, the 25 observed captures in 2011–12 were the second highest value in the reporting period, equating to a capture rate of 3.74 fur seals per 100 tows. The corresponding estimates were 61 (95% c.i.: 25 to 237) estimated captures and an estimated capture rate of 6.42 (95% c.i.: 2.63 to 24.89) fur seals per 100 tows. Observed and estimated fur seal captures in this target fishery were high in most years, i.e., considering the size of the fishery.

The southern blue whiting fishery operated in discrete areas in subantarctic waters around Bounty and Campbell islands, and to the north of Campbell Island. Throughout the year, all fishing effort occurred in August and September, with the greatest proportion of tows fished in the latter month. Observer coverage reflected the fishing effort in both months, and fur seal captures were observed in August and September. The highest proportion of observed captures was in August when about 80% of observed captures were recorded.

In the different fishery-areas, trawlers targeting southern blue whiting in waters around Bounty Islands had the highest estimated fur seal captures and capture rates, with the latter greatly exceeding estimates for other fishery-areas. Estimated capture rates for the Bounty Islands fishery exceeded 20 fur seals per 100 tows in all fishing years in the period between 2002–03 and 2011–12. The highest estimated capture rate was also for this target-area fishery, with 69.22 estimated fur seals per 100 tows in 2004–05. In 2011–12, the estimated capture rate for this southern blue whiting fishery was 26.30 fur seal per 100 tows.

In addition to hoki and southern blue whiting trawl fisheries, estimated captures were also high (i.e., over 70) for trawl fisheries targeting middle-depth species (Appendix A.5, Table A-5). These target fisheries conducted 6554 tows in 2011–12, and this fishing effort is similar to that in most of the preceding fishing years. There were eight observed fur seal captures in the most recent fishing year, with 76 (95% c.i.: 30 to 187) estimated captures, and an estimated capture rate of 1.16 (95% c.i.: 0.46 to 2.85) fur seal per 100 tows.

The spatial distribution of the middle-depth target fisheries was similar to that of the hoki fisheries, with most fishing effort in Cook Strait and off both South Island's coasts, and also in southern South Island waters and on the Stewart-Snares Shelf. Fishing effort was evenly distributed throughout the year, with about 10% of tows conducted most months. Observed fur seal captures occurred predominantly between June and September, with over 50% of observed captures documented in August. Seven of the eight observed captures in 2011–12 occurred on the South Island west coast, with the remaining capture observed on the Stewart-Snares shelf. Overall, the number of estimated captures and estimates capture rates in middle-depth target fisheries have been comparatively low since 2009–10.

In comparison with the aforementioned target fisheries, estimated fur seal captures were considerably lower in the other trawl fisheries, including squid, ling, hake, mackerel, scampi, deepwater, and inshore target fisheries. Inshore trawl fisheries operated around New Zealand's entire coastline, and observer coverage in 2011–12 showed a marked decrease to 0.4%, the lowest observer effort in the four most recent years. There were 39 (95% c.i.: 2 to 159) estimated captures in inshore trawl fisheries in 2011–12, with large uncertainty surrounding this estimate. In squid fisheries in southern and subantarctic waters, there were 25 (95% c.i.: 12 to 53) estimated fur seal captures in the most recent fishing year, similar to the 24 (95% c.i.: 12 to 56) estimated captures the previous year. Estimated captures in ling trawl fisheries were also similar to those in the previous year, with 17 (95% c.i.: 3 to 58) estimated captures in 2011–12.

The remaining target fisheries had less than 10 estimated fur seal captures in 2011–12. Capture estimates were particularly low in deepwater trawl fisheries, with 2 (95% c.i.: 0 to 10) estimated fur seal captures in 2011–12, similar to the number of estimated captures in the previous three fishing years. These target fisheries had relatively high observer coverage throughout the 10-year study period, reaching almost 42% in 2007–08. Since then, observer effort has ranged from about 25% (most recently) to 38%, with no observed captures over this recent period.

3.2.3 Fur seal model covariates

The assessment of covariates included in the fur seal model confirmed differences in capture probabilities across fishing areas and target fisheries (Appendix C). For the different fishing areas, the Bounty Islands fishery had the highest associated area coefficient, indicating that the capture rate probability was over 12 times higher in this fishing area than on the Stewart-Snares shelf. The capture rate probability was also high in the subantarctic fishing area, with a seven times higher capture rate relative to the Stewart-Snares shelf. For the different target fisheries, the highest coefficient was in squid fisheries, revealing a capture rate probability that was over 2.5 times higher than that of the hoki-hake-ling target fisheries. Other trawl fisheries had relatively low target coefficients, excepting the jack mackerel fishery.

Considering the combination of area and target coefficients provides additional information about the capture rate probability. For the southern blue whiting fishery that was concentrated around Bounty Islands, the target coefficient of 0.7 was low compared with hoki-hake-ling target fisheries. This low value and the high area coefficient indicate that the high fur seal capture rate around Bounty Islands was related to the fishing area, rather than the target fishery.

Other covariates that influenced fur seal captures were distance from shore and day of the year (Appendix C). Distance from shore, included as a four-level factor, had the highest coefficient associated with tows conducted in coastal waters (less than 25 km from shore), with a capture rate probability 1.5 times higher than that for distances fished between 25 and 90 km from shore. For distances beyond 90 km distance from shore, the coefficients were markedly lower at 0.8 and 0.2 for the far and the ocean categories, respectively. The covariate day of the year was included in the model to account for seasonal variation in the capture probability. This covariate greatly influenced fur seal captures, with a distinct peak in August and September (Figure 7). This peak corresponded with observer data, which also revealed a seasonal peak in observed captures in these two months (see Appendix A-2, Figure A-2).

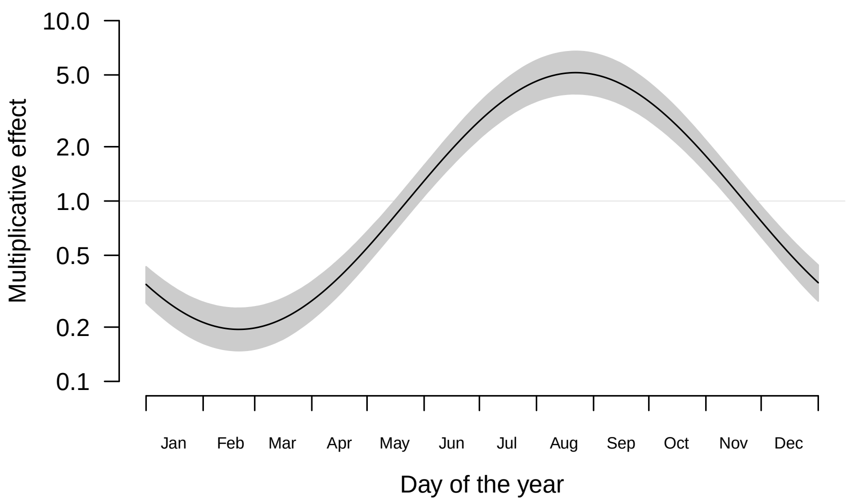


Figure 7: The multiplicative effect of the covariate day of the year included in the fur seal capture model for the period between 2002–03 and 2011–12 (shading indicates 90% confidence interval).

	Early SLED retention, π_1			Late SLED retention, π_2		
	Mean	Median	95% c.i	Mean	Median	95% c.i.
Single SLED retention	0.20	0.20	0.11–0.35			
Split SLED retention	0.19	0.18	0.10–0.31	0.14	0.09	0.01–0.60

Table 10: Estimated SLED retention probabilities from the sea lion capture models of the Auckland Islands squid fishery, including the model with a single SLED retention probability and the model with early and late sled retention probabilities (i.e., for the periods up to and including the cut-off year, 2004–05, 2005–06, or 2006–07).

3.3 New Zealand sea lion captures

In 2011–12, there was one observed sea lion capture in New Zealand trawl fisheries, resulting in the release of a live male sea lion that was incidentally captured on the Stewart-Snares shelf (see Appendix A). This single observed capture reflected the lowest number of incidental sea lion captures in the 17-year assessment period. It occurred in the fishing year with the highest observer coverage, with 42% of tows observed in 2011–12. In this fishing year, fishing effort was lower than in the previous year, but similar to that in other recent years, with 5456 tows being conducted. Over the 17 years of data, fishing effort across all trawl fisheries included in the assessment of incidental sea lion captures decreased considerably following relatively high effort in the first 11 years. Since the decrease in 2006–07, fishing effort has remained relatively constant at around 6000 tows per year.

3.3.1 Auckland Islands squid fishery

There were no observed sea lion captures in the Auckland Island squid fishery in 2011–12, the same finding as in 2010–11 (see Appendix A.14, Table A-14). Throughout the reporting period, this trawl fishery was characterised by the highest number of observed sea lion captures across all trawl fisheries. In recent years, the number of observed captures has decreased below 10 observed captures per fishing year since 2004–05. Fishing effort in the Auckland squid fishery decreased at the same time, declining from over 2400 tows per year between 2003–04 and 2005–06 to generally less than 1500 tows annually. In 2011–12, 1281 tows were conducted that targeted squid in the Auckland Islands fishery.

Observer coverage remained relatively high in recent years, ranging from 25 to 47%; it was 44% in the 2011–12 fishing year. The highest observer effort in the Auckland Islands squid trawl fishery was in 2000–01, when 99% of tows were observed. This level of observer effort was unusually high, as observer coverage generally varied around 30 to 40% in most years from 1995–96 to 2011–12.

Statistical modelling of sea lion captures in the Auckland Islands squid fishery involved two different models, one with a single SLED retention probability and the other model with split probabilities (early and late). Results from both models were combined with equal weight (see Appendix E.1).

Mean SLED retention probabilities were similar between the single SLED retention model and the early period of the split retention model, with a similar uncertainty around the mean (Table 10). In comparison, SLED retention probabiliy values (i.e., mean and median values) were lower for the late period in the split retention model, but the associated uncertainty was markedly higher.

Combining the two models resulted in a mean estimate of 43 (95% c.i.: 2 to 206) sea lion interactions in 2011–12 (Table A-14). This estimate was lower than the value in the previous year of 60 (95% c.i.: 4 to 278) sea lion interactions. With the most recent mean estimate the number of sea lion interactions continued to decrease in recent fishing year, while the uncertainty around the estimated mean values remained high.

The estimated strike rate in 2011–12 was 3.3 sea lion per 100 tows (95% c.i.: 0.2 to 16.2), 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 four sea lions (95% c.i.: 0 to 11).

3.3.2 Campbell Island southern blue whiting fishery

The fishing season in the southern blue whiting fishery around Campbell Island is from August to November each year. As it extends past the end of the standard fishing year at the end of September, data for this fishery were organised by calendar year. In 2012, there were no observed sea lion captures in this fishery, following high numbers of observed captures in the two preceding years, when 11 and six sea lion captures were recorded by observers (in 2010 and 2011, respectively). Within the fishing season across all years, almost all observed sea lion captures occurred in September. The fishing effort in the Campbell Island southern blue whiting fishery was lower in 2012 than in the previous year, with 575 compared with 886 tows fished. It was, however, consistent with the annual tow effort in this fishery overall. Observer coverage in 2012 was the highest level in the entire reporting period with 76% of all tows observed. In contrast, observer effort in most previous years generally did not exceed 40%.

Capture estimates in the southern blue whiting fishery were derived using a simple Bayesian model, as the limited number of observed captures prevented the development of a more complex statistical model. As observer data did not support the inclusion of vessel-year random effects, this model included a single random year effect. In 2012, there were zero (95% c.i.: 0 to 1) estimated sea lion captures in the Campbell Island southern blue whiting fishery, with a corresponding estimated mean strike rate of 0.1 (95% c.i.: 0.0 to 0.4) sea lion per hundred tows (Table A-15). These estimates reflect a marked reduction in estimated captures and estimated strike rates from the two most recent years, i.e., in comparison with values in 2010, when (observed and) estimated sea lion captures were the highest values in the data series. Overall, capture estimates have shown some fluctuation throughout the study period, with an initial increase in 2004 and 2005, high capture estimates in 2007, 2010 and 2011, and low values in 2009.

3.3.3 Other trawl fisheries

Sea lion capture estimates were also derived for trawl fisheries targeting scampi around Auckland Islands, other non-squid Auckland Islands trawl fisheries, and the trawl fishery operating on the Stewart-Snares shelf (see Appendix A.16 to A.18). Estimates for these three fisheries were derived using ratio estimates.

In the scampi trawl fishery, there were no observed sea lion captures in 2011–12 (Appendix A.16). This finding is consistent with the previous two fishing years, and there have been few observed sea lion captures in this fishery in general. The number of tows targeting scampi has remained relatively constant throughout the 17 years of data, with between 1300 and 1400 tows conducted per year. Observer coverage of this fishery has also been consistently low, with the highest observer coverage at 15% in 1996–97 and in 2010–11. In 2011–12, 10% of all tows were observed in this fishery. Throughout the fishing year, there were distinct peaks in observed sea lion captures in November, March, and June, when considering the entire data series.

The estimated number of captures in 2011–12 was 7 (95% c.i.: 2 to 15) sea lions, and this capture estimate was similar to those in previous fishing years. The estimated strike rate was also similar to previous estimates, with 0.6 (95% c.i.: 0.2 to 1.2) estimated sea lion captures per 100 tows (e.g., compared with 0.6 (95% c.i.: 0.1 to 1.1) estimated sea lion captures per 100 tows in 2010–11).

In the other non-squid Auckland Islands trawl fisheries, there were no observed sea lion captures in the 2011–12 fishing year (Appendix A.17). These fisheries were characterised by few observed sea lion captures overall, with only three capture records since 1995–1996. The capture estimates for these fisheries were also low, for both the estimated number of captures and the estimated strike rate. Fishing

Table 11: Estimated sea lion captures and interactions, in 2010–11 and 2011–12, 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.
2010–11				
Auckland Islands squid trawl	4	0–11	60	4–278
Campbell Island southern blue whiting trawl	15	8–25	15	8–25
Auckland Islands scampi trawl	8	2–16	8	2–16
Stewart Snares shelf trawl	1	0–4	1	0–4
Other Auckland Islands trawl	0	0–2	0	0–2
All trawl	28	17–41	84	26–299
2011–12				
Auckland Islands squid trawl	2	0–7	43	2–206
Campbell Island southern blue whiting trawl	0	0–1	0	0–1
Auckland Islands scampi trawl	7	2–15	7	2–15
Stewart Snares shelf trawl	2	1–4	2	1–4
Other Auckland Islands trawl	0	0–1	0	0–1
All trawl	13	5–22	53	11–217

effort in these fisheries has varied over time, with low numbers of tows conducted in recent fishing years (30 to 66 tows annually in the last 5 years). The 57 tows fished in 2011–12 are a marked reduction from fishing effort in the previous year, when 131 tows were fished. At the same time, observer effort has been relatively high in recent years, ranging from 30% in 2011–12 to 66% in the 2009–10 fishing year.

The only observed sea lion capture in the most recent fishing year occurred in trawl fisheries operating on the Stewart-Snares shelf (Appendix A.18). This fishery had few observed captures in preceding years, even though tow effort has been relatively high, with over 2000 tows fished annually in recent years. Observer coverage in this fishery has consistently been above 30% since 2007–08, with the highest observer coverage of 50% in 2011–12. In this most recent fishing year, there were an estimated two (95% c.i.: 1 to 4) sea lion captures on the Stewart-Snares shelf, with an estimated strike rate of 0.1 (95% c.i.: 0.0 to 0.2) sea lions per 100 tows. The most recent capture estimates were similar to those in preceding years, i.e., in the three previous fishing years.

3.3.4 Estimated sea lion captures and interactions in all trawl fisheries

Total estimates of sea lion captures in all trawl fisheries were derived by combining the five fishing strata (Table 11, Appendix A.13). The total mean number of estimated sea lion captures in 2011–12 was 13 (95% c.i.: 5 to 22), with a corresponding estimated strike rate of 0.2 (95% c.i.: 0.1 to 0.4) sea lion per 100 tows. The capture estimate in 2011–12 was highest in the Auckaland Islands scampi trawl fishery. High observer coverage in the Campbell Island southern blue whiting trawl fishery, and no observed captures, resulted in a relatively low estimate of 0 (95% c.i.: 0 to 1) sea lion captures in 2011–12. Estimates in the other four strata were similar between the two most recent fishing years.

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 2011–12 fishing year, there were a total of 53 (95% c.i.: 11 to 217) 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.

4. DISCUSSION

4.1 Common dolphin captures

Over the 17-year reporting period between 1995–96 and 2011–12, there were 124 observed common dolphin captures in the large-vessel mackerel fishery on North Island's west coast. This total includes five observed common dolphin captures in the most recent fishing year, which occurred in four separate incidents. Fishing effort in 2011–12 was similar to that in the previous year, but lower than in most years over the 17 years of data. At the same time, observer coverage in 2011–12 was at an unprecedented high level as 79% of all tows were observed, compared with annual observer effort of about 30% in other recent fishing years.

The current bycatch assessment was updated from previous analyses by including data from the most recent fishing year, 2011–12, to derive total capture estimates of common dolphin in the North Island jack mackerel trawl fishery. Consistent with previous assessments (Thompson & Abraham 2009b, Thompson et al. 2010c, Thompson et al. 2011, Thompson et al. 2013a), the model fitted the observer data well, and the observed and modelled data sets showed close correspondence. The high observer coverage in 2011–12 further confirmed the suitability of the two-stage Bayesian model, as model estimates from this fishing year were consistent with those in earlier years when observer effort was markedly lower.

There were 7 (95% c.i.: 5 to 14) estimated common dolphin captures in 2011–12, with a corresponding estimated capture rate of 0.43 (95% c.i.: 0.30 to 0.85) common dolphins per 100 tows. These capture estimates reflect a substantial decrease from the previous fishing year, which had 60 (95% c.i.: 24 to 113) estimated common dolphin captures and an estimated capture rate of 3.86 (95% c.i.: 1.55 to 7.29) common dolphins per 100 tows (see Table A-1). The most recent estimates were also amongst the lowest values in the entire data set, and similar to low estimates at the start of this period, when fishing effort was low and there were few observed common dolphin captures.

Following the high capture estimates in 2002–03 and 2003–04 (146 (95% c.i.: 61 to 276) and 106 (95% c.i.: 47 to 191) estimated common dolphin captures), estimates have gradually decreased over time to the low values in the most recent fishing year. An exception to this overall decline in capture estimates was the 2010–11 fishing year, which had an unusually high number of estimated common dolphin captures and a high estimated capture rate. These high estimates were related to the random year effect that was included in the common dolphin capture model to account for unexplained variation across fishing years. The year effect is influenced by the observed event rate (the number of capture events per observed tow), which increased in the 2010–11 fishing year, from less than one capture event per 100 tows (since 2004–05) to 1.30 events per 100 tows; it declined again (below one) in the 2011–12 fishing year (Figure 8).

The observed capture event rate has been relatively low since 2005–06, and the number of common dolphins per observed capture event has also decreased since 2007–08 (Figure 8). Common dolphin captures in this trawl fishery typically involve multiple captures per capture event, most frequently two or three common dolphins. In the two most recent fishing years, however, most capture events involved single individuals, resulting in a low mean number of 2.0 (95% c.i.: 1.6 to 2.4) common dolphins per capture event over the 17 years of data (Appendix B).

The persistence of the decreasing trend in common dolphin captures and the underlying reasons for this decrease remain unknown. Observed and estimated captures have shown some fluctuation over time, and it is possible that the current low values reflect some of this temporal variation. Possible reasons for the decline in captures include a shift in the distribution of common dolphins in recent years from areas targeted by the jack mackerel trawl fishery to other regions. Common dolphin in New Zealand waters (and elsewhere) have been shown to exhibit seasonal and interannual movement, and the reduction in incidental captures of common dolphin could be related to this regional emigration.

In the present assessment, one of the key recommendations to reduce common dolphin bycatch in the large-vessel mackerel fishery was the increase in headline depth. Of the potential factors that influence

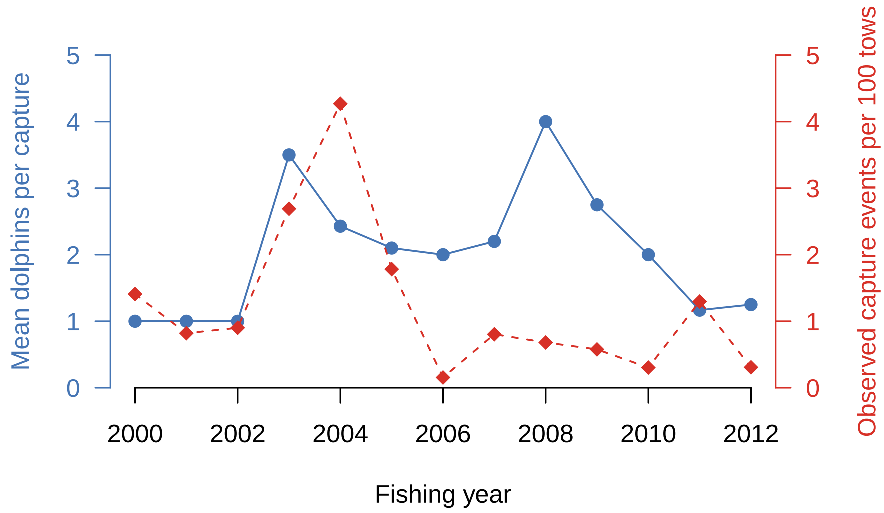


Figure 8: Observed number of common dolphin per capture event and observed capture event rate (observed capture events per 100 tows) by fishing year for the jack mackerel trawl fishery on the North Island east coast.

common dolphin captures in this fishery, headline depth had the greatest explanatory power. This finding is consistent with previous analyses (Thompson & Abraham 2009b, Thompson et al. 2010c, Thompson et al. 2011, Thompson et al. 2013a), and the model results clearly indicate that increasing the headline depth by 20 m would halve the common dolphin capture event probability. This mitigation method has not been adopted by the jack mackerel fleet to date, and headline depths have remained relatively constant in recent fishing years, at between 50 and 100 m. Nevertheless, operational procedures stipulated by the trawl fishing industry outline the risk posed by trawl nets being close to the surface, and also include mitigation methods aimed at reducing incidental common dolphin captures in the jack mackerel trawl fishery (Deepwater Group 2011). These mitigation methods include avoidance of offal and waste discharge, moving to other areas when common dolphins are sighted, efficient setting and hauling of trawl gear, and no setting or hauling of trawl gear between 2.30 and 4.30 am.

4.2 New Zealand fur seal captures

Incidental captures of New Zealand fur seals occurred across a range of commercial trawl fisheries and fishing areas within New Zealand's EEZ in 2011–12. This fishing year had a total of 82 observed fur seal captures across all trawl fisheries (excluding inshore fisheries with flatfish targets), and the observed capture rate was 0.91 fur seals per 100 tows. In comparison, observers recorded 73 fur seal captures in 2010–11, equating to an observed capture rate of 0.98 fur seal per 100 tows. The numbers of observed fur seal captures have been similar in recent fishing years, while fishing effort has also remained relatively constant since 2007–08, with a slight decrease in 2011–12, when 84 179 tows were conducted. Observer coverage in recent years showed also little variation and was about 10%, with 10.7% observer effort in 2011–12.

Capture estimates for 2011–12 included 442 (95% c.i.: 256 to 789) estimated fur seal captures and an estimated capture rate of 0.53 (95% c.i.: 0.30 to 0.94) fur seals per 100 tows. Both estimates reflect a slight increase from the number of estimated captures and estimated capture rate in 2010–11 of 427 (95% c.i.: 246 to 743) fur seals and 0.50 (95% c.i.: 0.29 to 0.86) fur seals per 100 tows.

The current bycatch estimates included inshore fisheries (excluding flatfish targets) for the second time (see also Thompson et al. 2013a). These fisheries were characterised by high fishing effort and no or low observer coverage throughout the entire reporting period (see Appendix A.12). In recent fishing years, observer coverage increased to some extent, exceeding 1% in the three fishing years from 2008–09 to

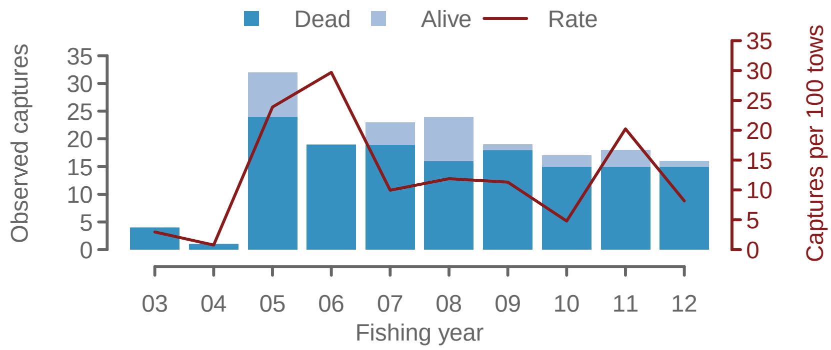


Figure 9: Annual time series of observed fur seal captures and capture rate, in the hoki trawl fishery operating in Cook Strait between 2002–03 and 2011–12.

2010–11, before declining again to 0.4% in 2011–12. At the same time, inshore fisheries consistently contributed a significant proportion of the overall effort (e.g., 32 676 tows of a total 84 179 tows fished in 2011–12). Even though the increases in observer coverage allowed the inclusion of these fisheries in the current estimation, the low observer effort remains a concern, i.e., given the consistently high fishing effort in inshore trawl fisheries.

Of the different target fisheries included in the bycatch estimation, hoki trawl fisheries continued to have the highest numbers of observed and estimated fur seal captures in 2011–12 (see Appendix A.3). Fishing effort has remained relatively high in these fisheries, and the increase in the number of observed fur seal captures in 2011–12 corresponded with an increase in tow effort. Nevertheless, the observed capture rate in this fishing year was 1.28 fur seals per 100 tows, the lowest capture rate for the entire 10-year reporting period. At the same time, the hoki target fisheries contributed the largest proportion of estimated captures, with 200 (95% c.i.: 98 to 417) of the total 442 (95% c.i.: 256 to 789) estimated fur seal captures occurring in these fisheries. Hoki target fisheries were consistently characterised by high capture estimates throughout the entire reporting period, contributing about half of the overall capture estimates in each fishing year. Capture estimates for 2011–12 were well within the 95% confidence interval of previous estimates, but showed a slight increase from the previous fishing year, with a capture rate of 1.77 (95% c.i.: 0.87 to 3.68) fur seal per 100 tows.

Hoki trawl fisheries operate in Cook Strait, the South Island east and west coasts, and in southern to subantarctic waters, including Auckland Islands and the Stewart-Snares shelf. The area and target strata with the highest estimate of fur seal captures continued to be the hoki trawl effort in Cook Strait (Figure 9). This fishery showed a decrease in the observed capture rate from a high value of 20 fur seals per 100 tows in 2010–11 to 8.16 fur seal captures per 100 tows in 2011–12. Nevertheless, the increase in fishing effort over these two years resulted in an increase in the estimated captures from 98 (95% c.i.: 34 to 254) estimated captures in 2010–11 to 116 (95% c.i.: 37 to 316) fur seal captures in 2011–12 (see Table D-23).

Southern blue whiting fisheries also had high numbers of observed and estimated captures (see Appendix A.4). The number of observed captures remained high at 25 fur seals in 2011–12, even though it was a decrease from the 36 observed fur seal captures in the previous fishing year. Twelve of the observed captures occurred in the Bounty Islands area, and the capture rate for this area-target fishery was 15 fur seals per 100 tows (Table D-23); the estimated capture rate was 26.30 (95% c.i.: 6.98 to 128.90) fur seals per 100 tows in the 2011–12 fishing year.

4.3 New Zealand sea lion captures and interactions

In the 17 years of data, most observed sea lion captures in New Zealand trawl fisheries have been in the Auckland Islands squid fishery. Although this fishery has been characterised by a high number of observed sea lion captures over time, there have been no observed captures in the two most recent fishing

	Mean	2.5%	50%	97.5%
2010–11				
Interactions	60.4	4	36	278
Attributed mortalities, 20% DR	54.6	4	34	247
Attributed mortalities, 35% DR	44.5	3	28	195
Attributed mortalities, 50% DR	35.0	3	22	155
Attributed mortalities, 82% DR	13.5	1	9	54
Captures	3.6	0	3	11
Exclusions	56.9	3	32	270
Strike rate, %	3.83	0.30	2.31	17.43
2011–12				
Interactions	42.6	2	25	206
Attributed mortalities, 20% DR	37.2	3	23	177
Attributed mortalities, 35% DR	30.5	2	18	143
Attributed mortalities, 50% DR	23.9	2	14	109
Attributed mortalities, 82% DR	9.0	0	6	39
Captures	2.0	0	2	7
Exclusions	40.1	1	23	209
Strike rate, %	3.31	0.22	1.95	16.22

Table 12: Predicted total interactions, attributed interactions at discount rates (DR) of 20%, 35%, 50%, and 82%, captures, exclusions, and strike rate for the 2010–11 and 2011–12 fishing years in the Auckland Islands squid fishery. Presented are the mean and selected percentiles of the posterior distribution.

years, 2010–11 and 2011–12. Owing to the significant number of sea lion captures in this fishery, several mitigation and management measures have been introduced, including SLEDs that are fitted to trawl nets. This device was introduced in 2000–01 to provide an exit for sea lions that were incidentally captured in the trawl net. The use of SLEDs means that the total number of sea lions that may have been captured but were able to escape is unknown. This lack of data is accounted for in the sea lion capture model as it includes an estimate of the SLED retention probability, π (a measure of the effectiveness of the SLEDs), to estimate total sea lion captures and interactions.

Since they were first introduced, SLEDs have undergone audits and been modified to incorporate improvements to increase their efficacy (Clement & Associates 2007). To account for these changes in SLED design, two models were used to estimate sea lion captures in the Auckland Islands squid fishery: a model with a single SLED retention probability, and a modified model with a split SLED retention probability. The latter model involved early and late SLED retention probabilities associated with a cut-off date in the three-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. Comparing the early and late retention probabilities estimated by the split model showed that the late SLED retention probability was lower than the early one, but it also had a markedly greater uncertainty, with a mean value of 0.14 and a 95% confidence interval of 0.01 to 0.60 (see Table 10).

The uncertainty associated with the retention probability illustrates how it is increasingly difficult to provide reliable estimates of sea lion interactions. As the capture rate depends on both the SLED retention probability and the strike rate, 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 2011–12 fishing year, the 95% confidence interval of the estimated number of interactions in the Auckland Islands squid fishery was 2 to 206 sea lions. Similarly, the 95% confidence interval of the strike rate was 0.2 to 16.2 sea lions per 100 tows. This range includes the mean value of the estimated strike rate for all the years from 1995–96 to 2011–12, making it impossible to determine whether the strike rate has changed relative to previous years.

Another limitation is that the modelling is based on the assumption that fishing effort before the introduction of SLEDs is comparable with more recent fishing effort, considering the sea lion interactions. As the period before the introduction of SLEDs becomes more distant in time and contributes a decreasing proportion of data to the data series, this assumption becomes less and less tenable. As a consequence, it it increasingly difficult to use the strike rate and interactions as suitable measures for monitoring the performance of the Auckland Islands squid trawl fishery. Other metrics such as the attributed mortalities that also depend on the strike rate show a similarly high uncertainty (Table 12).

Estimates of the number of captures are not affected by these limitations, and the number of estimated captures of 2 (95% c.i.: 0 to 7) sea lions in 2011–12 was the lowest value of all the years in the data series. The low estimated captures in both 2010–11 and 2011–12 correspond with there being no observed sea lion captures in the Auckland Islands squid fishery in those years, at a time when observer effort was relatively high at 34 and 44%, respectively. The Auckland Islands squid fishery, primarily through the use of SLEDs, has been effective at reducing the number of sea lion captures. Concomitant with the low number of estimated sea lion captures in this fishery, was the low number of estimated captures across all commercial trawl fisheries in the most recent fishing year.

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APPENDIX A

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	1.16	0.49 – 3.94
1996–97	230	70.4	0	0	0.00	0	0–3	0.12	0.00 – 1.30
1997–98	560	38.9	0	0	0.00	2	0–9	0.27	0.00 – 1.61
1998–99	350	24.0	0	0	0.00	3	0–15	0.89	0.00 – 4.29
1999–00	412	17.2	1	1	1.41	8	1–28	1.91	0.24 – 6.80
2000–01	974	12.5	1	1	0.82	11	1–36	1.13	0.10 – 3.70
2001–02	1 577	7.0	1	1	0.90	29	2–91	1.86	0.13 – 5.77
2002–03	2 249	9.9	21	6	9.42	146	61–276	6.51	2.71 – 12.27
2003–04	2 309	7.1	17	7	10.37	106	47–191	4.59	2.04 – 8.27
2004–05	2 424	23.1	21	10	3.74	81	44–131	3.34	1.82 – 5.41
2005–06	2 117	30.6	2	1	0.31	11	2–31	0.51	0.09 – 1.46
2006–07	2 167	28.7	11	5	1.77	52	22–101	2.42	1.02 – 4.66
2007–08	2 164	34.0	20	5	2.72	42	24–70	1.95	1.11 – 3.23
2008–09	1 820	38.1	11	4	1.59	27	13–49	1.46	0.71 – 2.69
2009–10	2 189	30.1	4	2	0.61	26	6–60	1.20	0.27 – 2.74
2010–11	1 551	29.9	7	6	1.51	60	24–113	3.86	1.55 – 7.29
2011–12	1 649	79.0	5	4	0.38	7	5–14	0.43	0.30 – 0.85

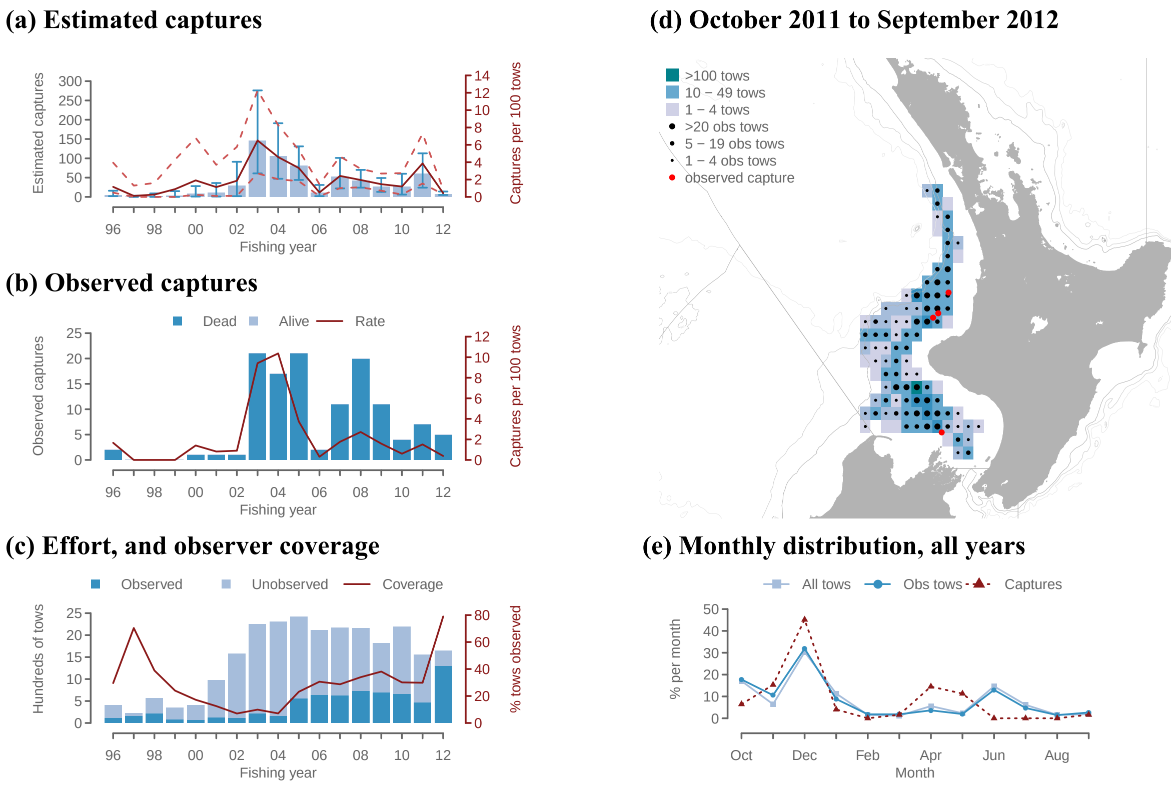


Figure A-1: Annual time series of (a) estimated common dolphin captures, (b) observed common dolphin captures and the capture rate, and (c) trawl effort and observer coverage, in the west coast North Island jack mackerel fishery from 1995–96 to 2011–12. In map (d) average effort is plotted in a blue 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.

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	129 757	5.2	68	1.00	877	529–1419	0.68	0.41–1.09
2003–04	120 819	5.4	84	1.29	1071	644–1754	0.89	0.53–1.45
2004–05	120 177	6.4	200	2.61	1514	943–2459	1.26	0.78–2.05
2005–06	109 925	6.2	143	2.10	955	591–1561	0.87	0.54–1.42
2006–07	103 328	7.6	73	0.93	547	333–916	0.53	0.32–0.89
2007–08	89 432	10.1	141	1.56	778	477–1355	0.87	0.53–1.52
2008–09	87 489	11.2	72	0.74	549	307–955	0.63	0.35–1.09
2009–10	92 802	9.7	72	0.80	484	272–911	0.52	0.29–0.98
2010–11	85 982	8.6	73	0.98	427	246–743	0.50	0.29–0.86
2011–12	84 179	10.7	82	0.91	442	256–789	0.53	0.30–0.94

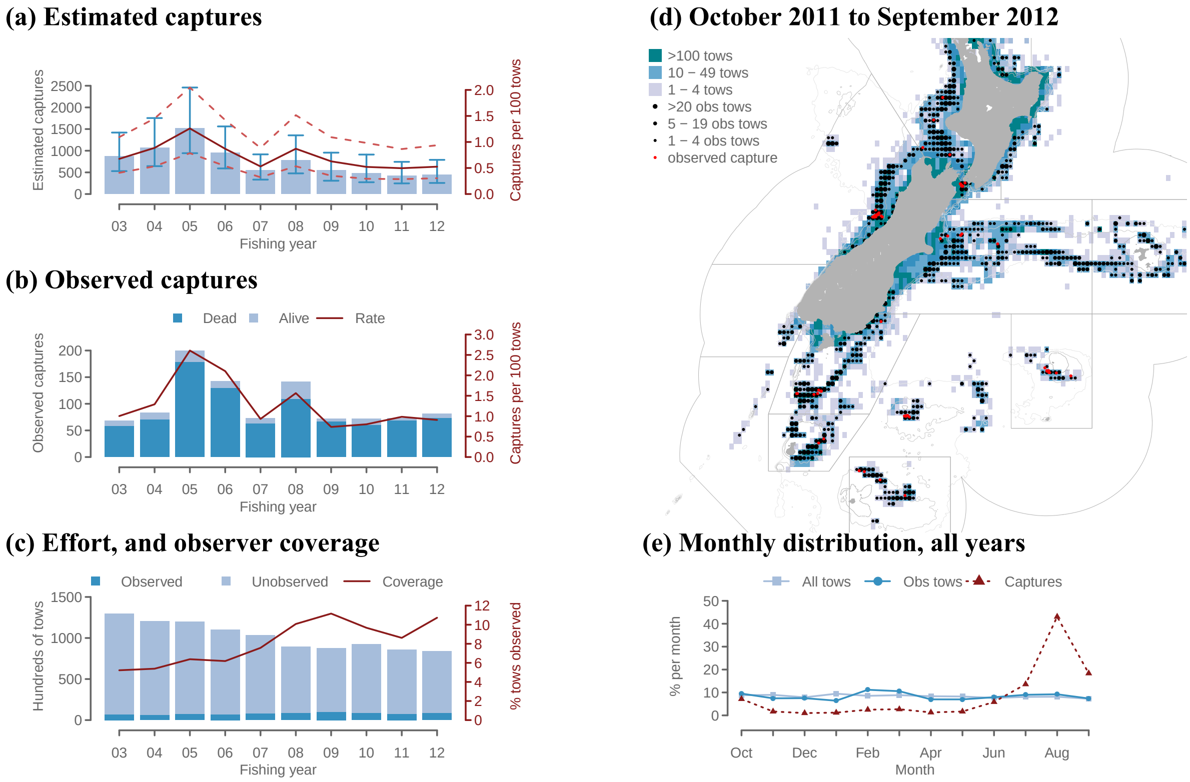


Figure A-2: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in all trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

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	27 747	9.3	45	1.74	601	335–1041	2.17	1.21–3.75
2003–04	22 496	10.4	49	2.10	707	384–1249	3.14	1.71–5.55
2004–05	14 522	14.6	120	5.65	766	409–1446	5.27	2.82–9.96
2005–06	11 582	15.4	62	3.47	429	217–880	3.70	1.87–7.60
2006–07	10 596	16.6	29	1.65	253	119–518	2.38	1.12–4.89
2007–08	8 772	21.3	58	3.10	311	152–625	3.55	1.73–7.12
2008–09	8 171	20.3	37	2.24	202	95–444	2.47	1.16–5.43
2009–10	9 954	20.7	30	1.46	173	88–349	1.74	0.88–3.51
2010–11	10 397	16.5	24	1.40	172	79–344	1.66	0.76–3.31
2011–12	11 323	22.8	33	1.28	200	98–417	1.77	0.87–3.68

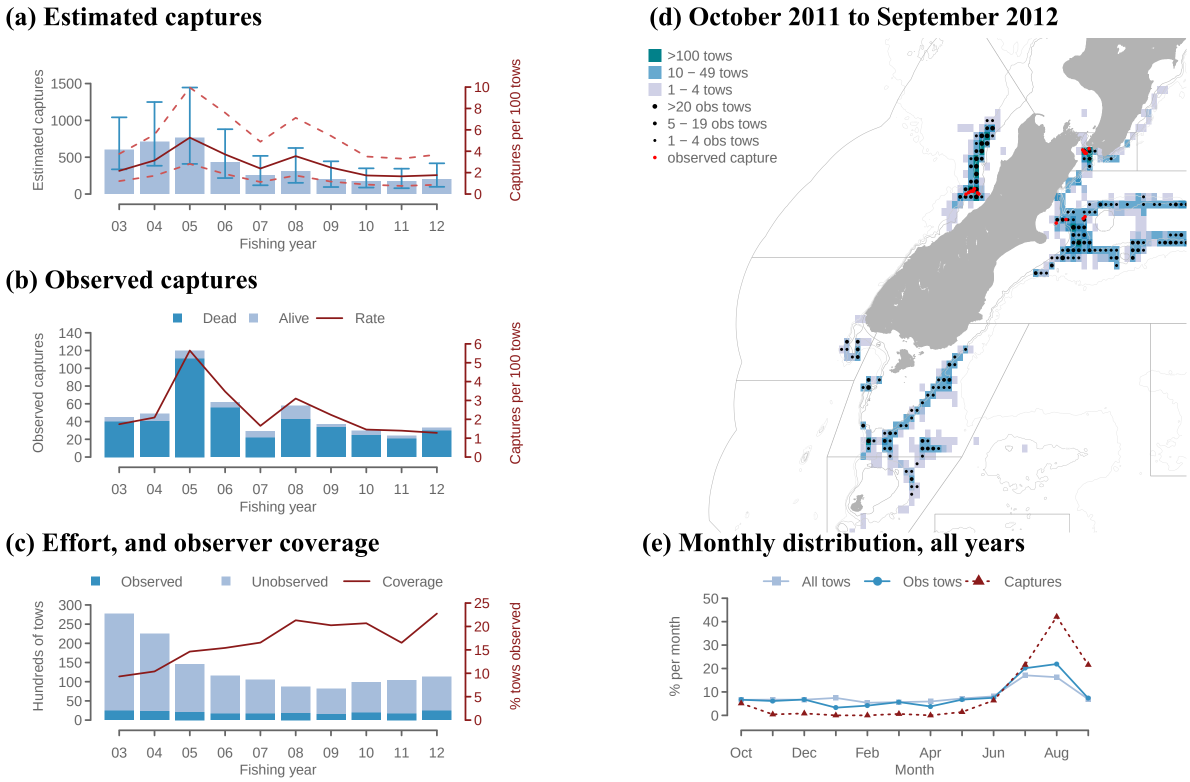


Figure A-3: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in hoki trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

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	20	8–65	3.15	1.25–10.19
2003–04	740	32.2	13	5.46	33	13–106	4.45	1.76–14.32
2004–05	870	38.5	33	9.85	103	35–431	11.79	4.02–49.55
2005–06	624	34.8	52	23.96	67	52–125	10.79	8.33–20.04
2006–07	630	35.4	13	5.83	25	13–70	3.91	2.06–11.11
2007–08	818	40.2	24	7.29	102	25–462	12.41	3.06–56.49
2008–09	1 187	24.9	17	5.74	108	24–359	9.11	2.02–30.25
2009–10	1 114	35.5	16	4.04	98	20–406	8.83	1.80–36.45
2010–11	1 171	36.9	36	8.33	72	38–235	6.15	3.25–20.07
2011–12	952	70.2	25	3.74	61	25–237	6.42	2.63–24.89

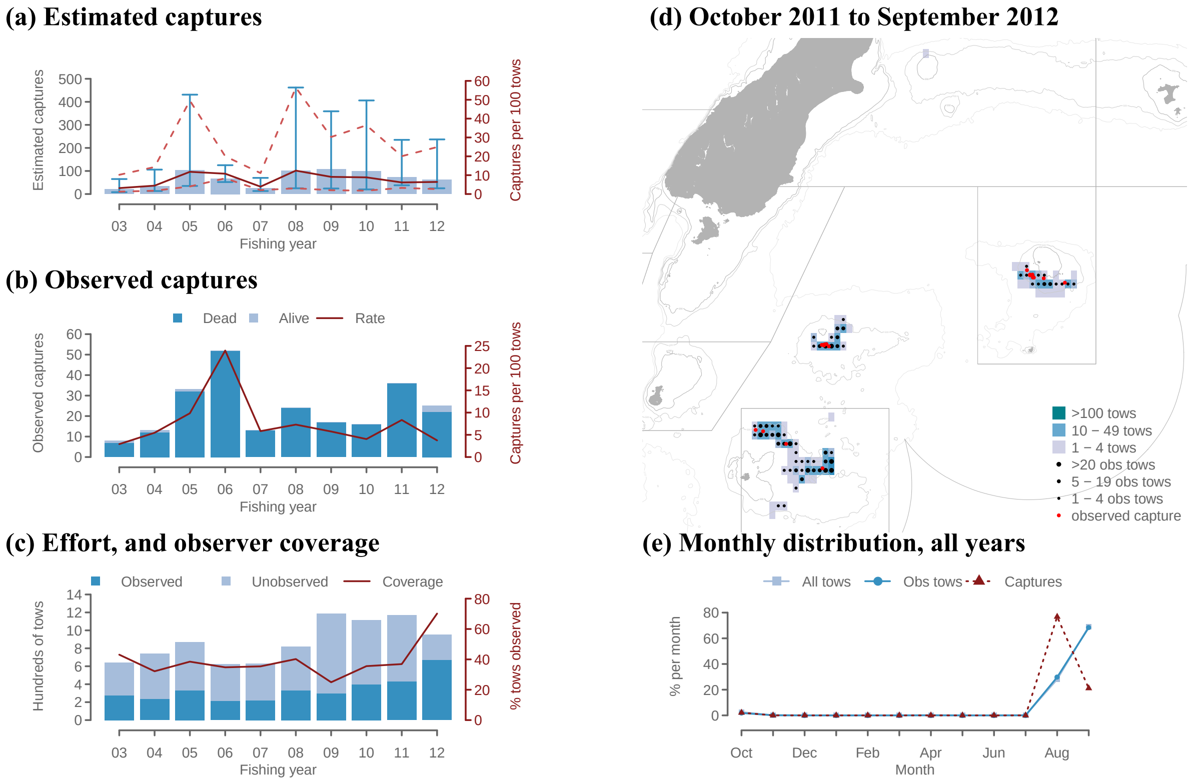


Figure A-4: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in southern blue whiting trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage 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.

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	11 166	3.1	1	0.29	102	36–244	0.91	0.32–2.19
2003–04	9 199	2.1	0	0.00	126	42–302	1.36	0.46–3.28
2004–05	9 182	2.4	10	4.50	211	88–458	2.30	0.96–4.99
2005–06	8 378	6.2	4	0.76	159	59–385	1.90	0.70–4.60
2006–07	8 164	4.5	3	0.81	100	39–214	1.23	0.48–2.62
2007–08	7 413	6.1	9	2.00	140	60–298	1.89	0.81–4.02
2008–09	7 232	10.1	1	0.14	109	35–279	1.51	0.48–3.86
2009–10	7 210	12.3	5	0.56	89	31–229	1.23	0.43–3.18
2010–11	7 248	8.5	2	0.32	81	28–194	1.12	0.39–2.68
2011–12	6 554	11.6	8	1.05	76	30–187	1.16	0.46–2.85

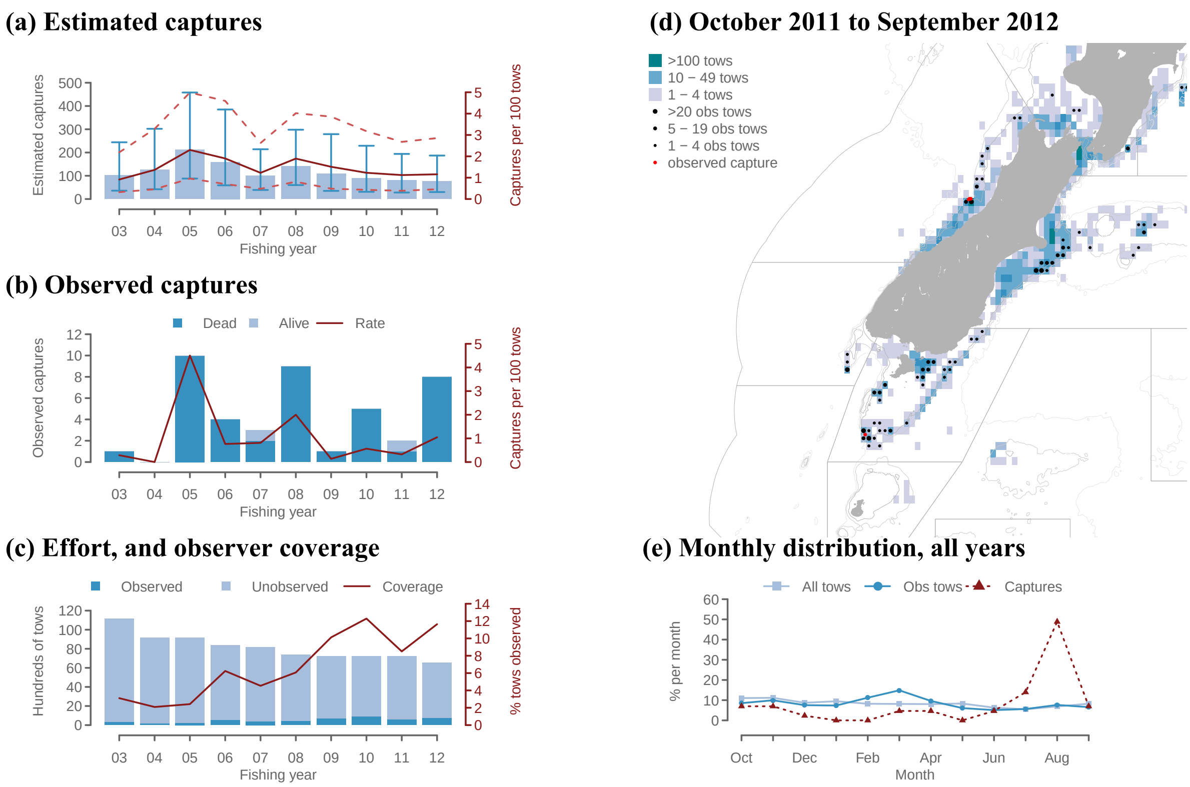


Figure A-5: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in middle depths trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage 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.

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	59	27–115	0.70	0.32–1.37
2003–04	8 334	21.2	17	0.96	94	49–174	1.12	0.59–2.09
2004–05	10 489	23.9	16	0.64	168	83–312	1.60	0.79–2.98
2005–06	8 570	15.7	4	0.30	103	45–209	1.21	0.53–2.44
2006–07	5 906	21.8	8	0.62	44	21–83	0.74	0.36–1.41
2007–08	4 236	34.3	6	0.41	34	15–71	0.80	0.35–1.68
2008–09	3 867	33.5	1	0.08	21	6–49	0.54	0.16–1.27
2009–10	3 789	28.1	8	0.75	36	16–76	0.95	0.42–2.01
2010–11	4 213	29.8	8	0.64	24	12–46	0.57	0.28–1.09
2011–12	3 505	39.3	8	0.58	25	12–53	0.70	0.34–1.51

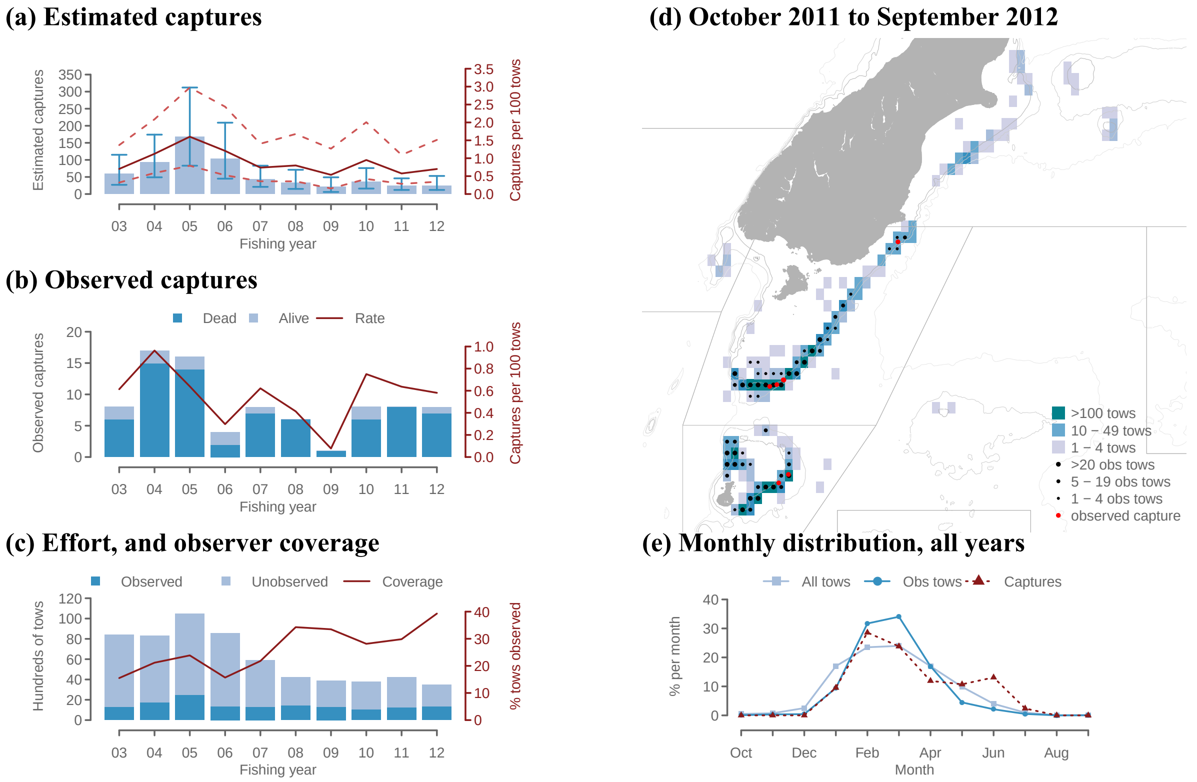


Figure A-6: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in squid trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

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	8	0–36	1.32	0.00–5.76
2003–04	568	3.9	0	0.00	15	0–75	2.65	0.00–13.20
2004–05	984	7.7	10	13.16	52	17–148	5.31	1.73–15.04
2005–06	1 394	8.1	2	1.77	39	10–111	2.81	0.72–7.96
2006–07	1 656	9.5	12	7.64	41	17–98	2.48	1.03–5.92
2007–08	2 232	10.8	4	1.66	39	12–101	1.76	0.54–4.53
2008–09	1 409	10.3	0	0.00	23	5–62	1.65	0.35–4.40
2009–10	1 194	16.7	6	3.02	24	8–78	1.98	0.67–6.53
2010–11	1 103	9.3	2	1.94	18	4–57	1.64	0.36–5.17
2011–12	947	16.8	1	0.63	17	3–58	1.75	0.32–6.12

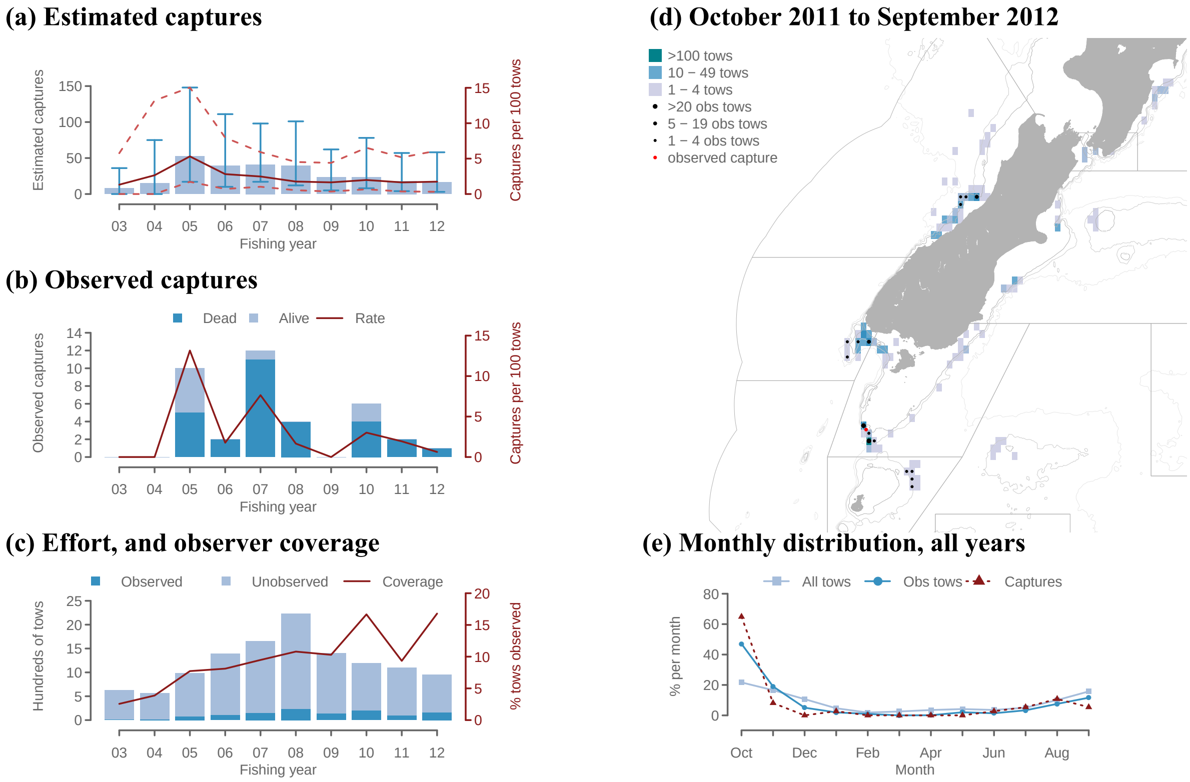


Figure A-7: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in ling trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

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	1.21	0.32–3.31
2003–04	1 641	8.5	0	0.00	13	2–41	0.80	0.12–2.50
2004–05	1 551	6.1	2	2.11	32	7–85	2.03	0.45–5.48
2005–06	1 360	30.9	11	2.62	34	15–82	2.53	1.10–6.03
2006–07	1 604	18.4	4	1.36	19	6–46	1.17	0.37–2.87
2007–08	1 542	25.6	28	7.11	50	32–96	3.25	2.08–6.23
2008–09	1 764	19.9	5	1.42	21	7–57	1.20	0.40–3.23
2009–10	821	40.1	4	1.22	11	4–32	1.40	0.49–3.90
2010–11	868	26.2	1	0.44	12	2–36	1.35	0.23–4.15
2011–12	645	34.9	1	0.44	8	1–23	1.19	0.16–3.57

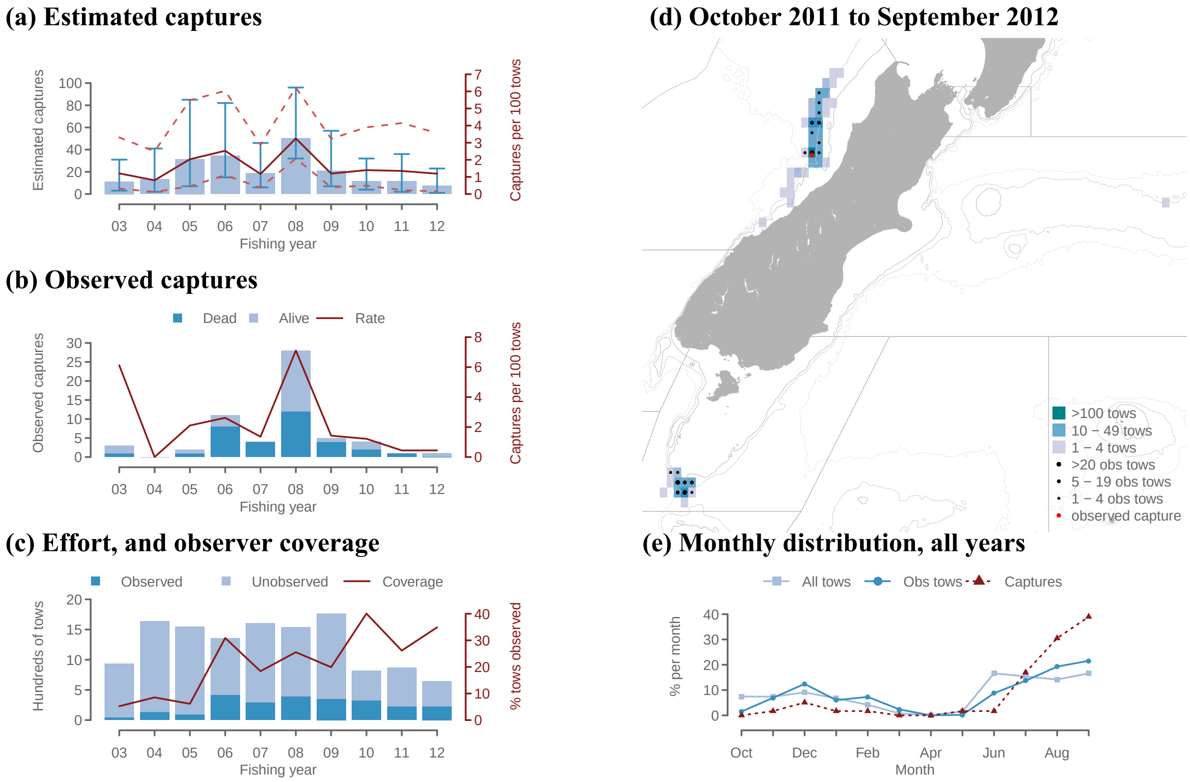


Figure A-8: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in hake trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

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	4–40	0.53	0.13–1.30
2003–04	2 383	6.4	2	1.32	14	4–34	0.61	0.17–1.43
2004–05	2 509	22.2	5	0.90	25	9–56	0.99	0.36–2.23
2005–06	2 808	25.2	6	0.85	26	10–61	0.94	0.36–2.17
2006–07	2 711	29.0	2	0.25	13	3–38	0.48	0.11–1.40
2007–08	2 651	30.8	7	0.86	32	11–102	1.19	0.41–3.85
2008–09	2 170	37.5	8	0.98	16	9–32	0.72	0.41–1.47
2009–10	2 406	32.5	2	0.26	5	2–13	0.22	0.08–0.54
2010–11	1 880	31.5	0	0.00	3	0–11	0.16	0.00–0.59
2011–12	2 032	76.2	5	0.32	8	5–20	0.40	0.25–0.98

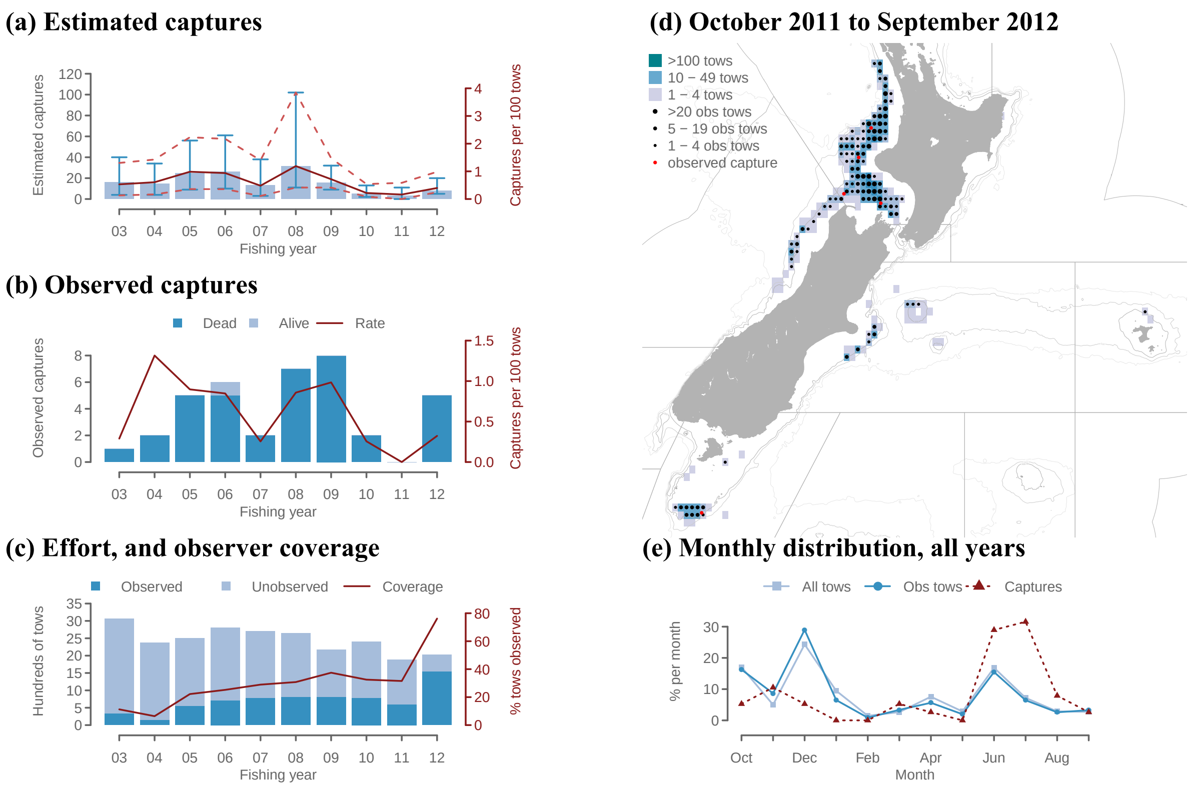


Figure A-9: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in mackerel trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

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	23	1–110	0.50	0.02–2.38
2005–06	4 846	6.7	0	0.00	7	0–27	0.15	0.00–0.56
2006–07	5 119	7.5	0	0.00	7	0–24	0.13	0.00–0.47
2007–08	4 802	10.8	1	0.19	10	1–34	0.21	0.02–0.71
2008–09	3 972	9.8	1	0.26	6	1–21	0.15	0.03–0.53
2009–10	4 240	8.2	1	0.29	6	1–19	0.13	0.02–0.45
2010–11	4 445	11.9	0	0.00	4	0–18	0.10	0.00–0.40
2011–12	4 493	9.9	1	0.22	7	1–26	0.16	0.02–0.58

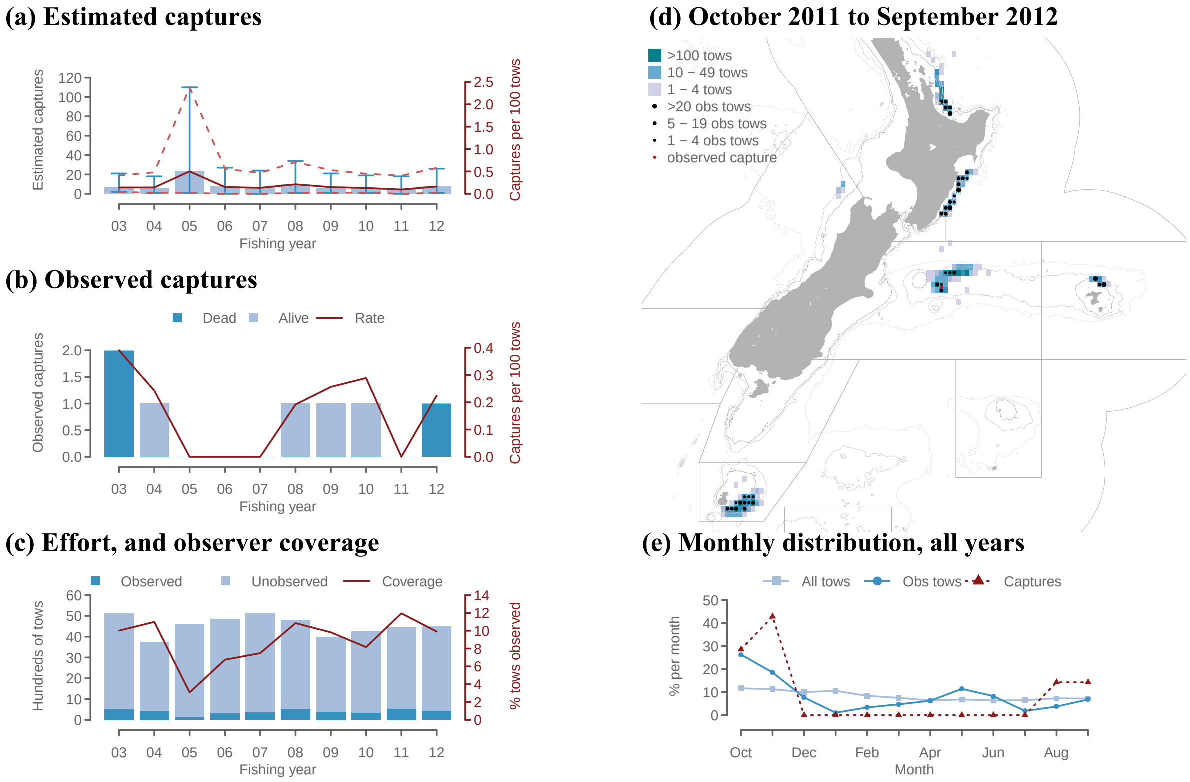


Figure A-10: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in scampi trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

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	8 855	15.1	0	0.00	3	0–15	0.04	0.00–0.17
2003–04	7 996	15.5	2	0.16	6	2–20	0.08	0.03–0.25
2004–05	8 405	19.0	4	0.25	16	4–66	0.19	0.05–0.79
2005–06	8 284	15.2	2	0.16	9	2–31	0.10	0.02–0.37
2006–07	7 356	31.0	2	0.09	3	2–7	0.04	0.03–0.10
2007–08	6 728	41.7	4	0.14	7	4–16	0.10	0.06–0.24
2008–09	6 129	38.5	0	0.00	3	0–14	0.04	0.00–0.23
2009–10	6 015	35.4	0	0.00	2	0–12	0.04	0.00–0.20
2010–11	4 174	28.6	0	0.00	2	0–12	0.06	0.00–0.29
2011–12	3 629	24.6	0	0.00	2	0–10	0.05	0.00–0.28

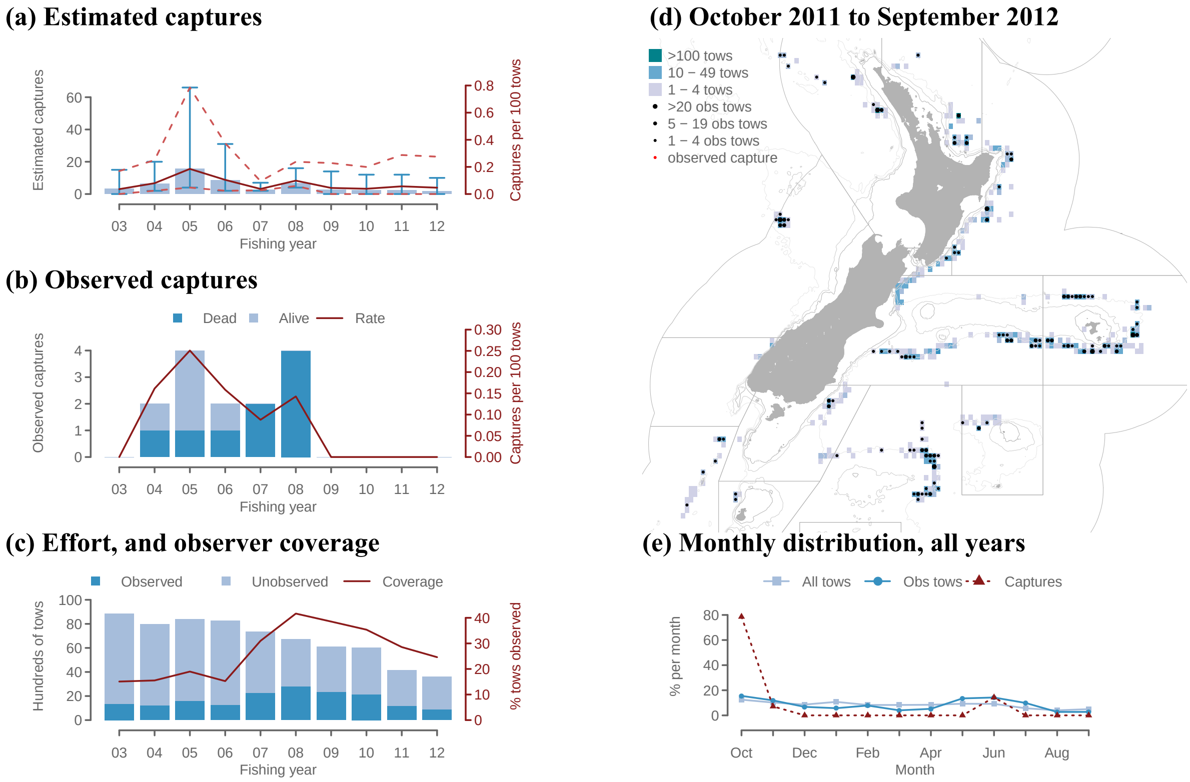


Figure A-11: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in deepwater trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

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	36 390	0.0	0	0.00	48	3–191	0.13	0.01–0.52
2003–04	37 542	0.0	0	0.00	58	4–235	0.15	0.01–0.63
2004–05	40 747	0.0	0	0.00	119	9–479	0.29	0.02–1.18
2005–06	39 176	0.3	0	0.00	80	5–320	0.20	0.01–0.82
2006–07	35 830	0.8	0	0.00	44	3–172	0.12	0.01–0.48
2007–08	31 369	0.4	0	0.00	54	4–214	0.17	0.01–0.68
2008–09	33 061	3.5	2	0.17	41	4–151	0.12	0.01–0.46
2009–10	35 927	1.4	0	0.00	39	2–165	0.11	0.01–0.46
2010–11	34 940	1.3	0	0.00	38	2–152	0.11	0.01–0.44
2011–12	32 676	0.4	0	0.00	39	2–159	0.12	0.01–0.49

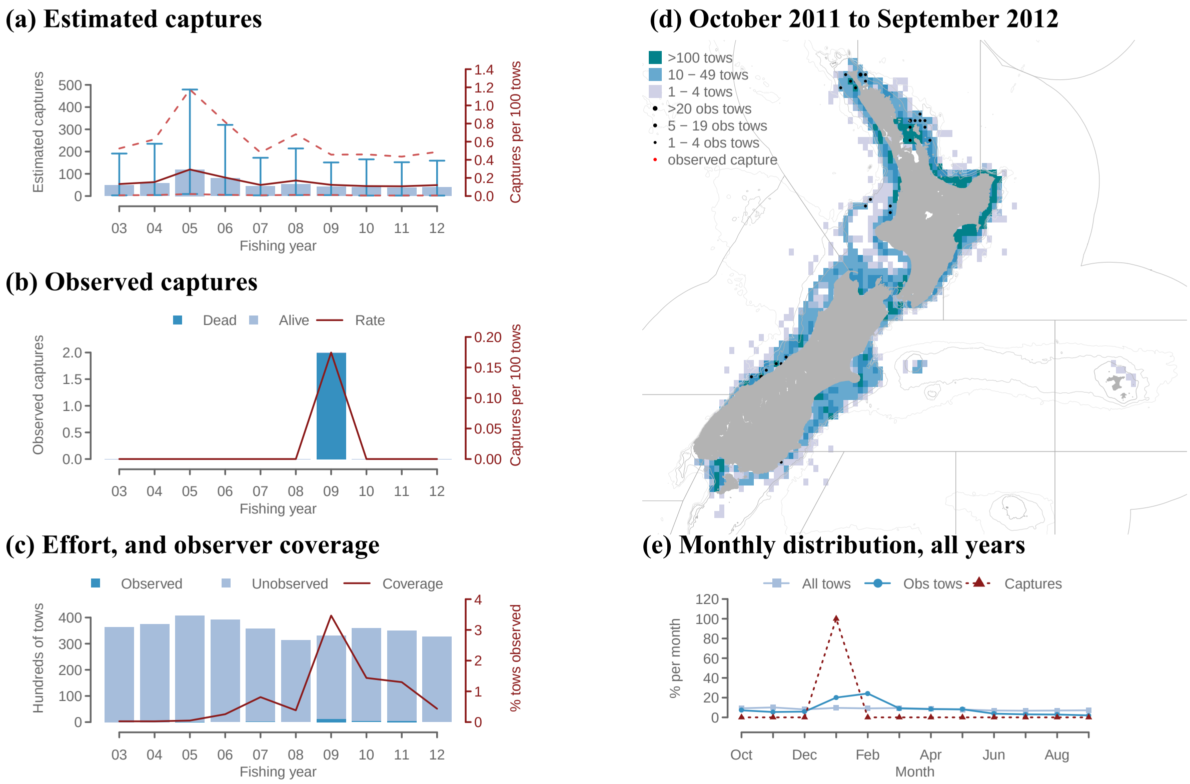


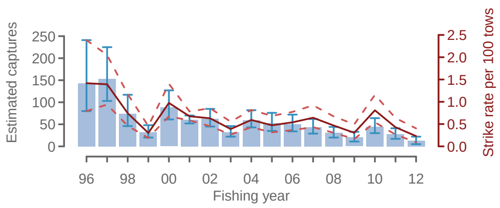
Figure A-12: Annual time series of (a) estimated fur seal captures, (b) observed fur seal captures and the capture rate, and (c) trawl effort and observer coverage, in inshore trawl fisheries from 2002–03 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

A.13 Sea lion captures in all trawl fisheries

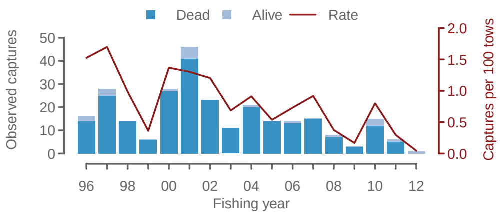
Table A-13: Annual trawl effort, observer coverage, observed number of sea lion captures, observed capture rate (sea lion per 100 tows), estimated sea lion captures and interactions, and the estimated strike rate (with 95% confidence intervals), from all trawl fisheries, in the five estimated strata.

		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	10 108	10	16	1.5	143	80–241	143	79–243	1.4	0.8–2.4
1996–97	10 975	15	28	1.7	153	103–225	153	100–226	1.4	0.9–2.1
1997–98	9 977	14	14	1.0	74	46–117	75	44–121	0.7	0.5–1.2
1998–99	10 559	16	6	0.4	32	20–48	32	18–49	0.3	0.2–0.5
1999–00	9 046	23	28	1.4	88	61–127	88	59–130	1.0	0.7–1.4
2000–01	8 932	40	46	1.3	60	52–70	82	57–113	0.7	0.6–0.8
2001–02	9 946	19	23	1.2	63	45–85	93	60–137	0.6	0.5–0.9
2002–03	8 311	19	11	0.7	32	22–46	60	36–93	0.4	0.3–0.6
2003–04	10 036	23	21	0.9	60	43–82	219	117–389	0.6	0.4–0.8
2004–05	11 118	23	14	0.5	53	35–76	186	93–342	0.5	0.3–0.7
2005–06	9 316	21	14	0.7	50	34–72	172	86–331	0.5	0.4–0.8
2006–07	6 736	24	15	0.9	43	29–62	117	54–230	0.6	0.4–0.9
2007–08	6 545	33	8	0.4	31	20–44	135	38–510	0.5	0.3–0.7
2008–09	6 677	27	3	0.2	20	11–33	110	24–455	0.3	0.2–0.5
2009–10	5 541	34	15	0.8	45	30–64	156	50–542	0.8	0.5–1.2
2010–11	6 460	31	6	0.3	28	17–41	84	26–299	0.4	0.3–0.6
2011–12	5 456	42	1	0.0	13	5–22	53	11–217	0.2	0.1–0.4

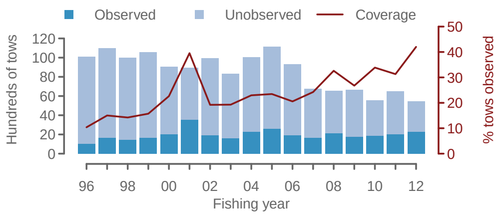
(a) Estimated captures



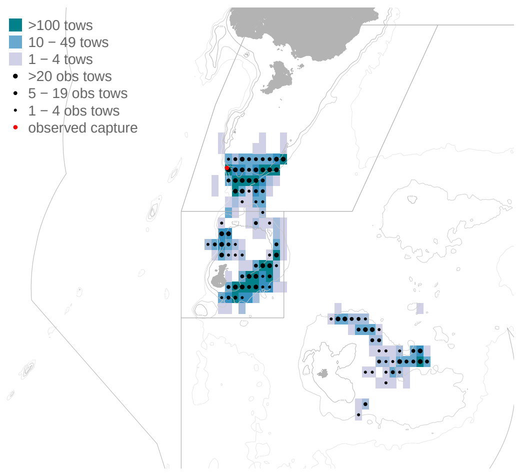
(b) Observed captures



(c) Effort, and observer coverage



(d) October 2011 to September 2012



(e) Monthly distribution, all years

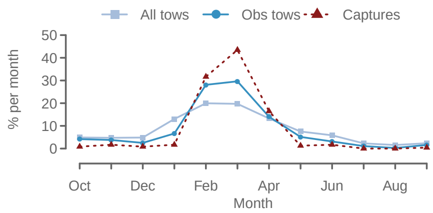


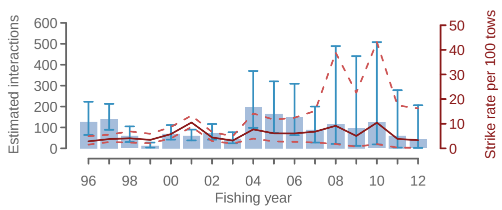
Figure A-13: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in all trawl fisheries from 1995–96 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage is indicated with black dots, and observed captures with red dots. Plot (e) shows mean monthly distribution of total effort, observed effort and observed captures.

A.14 Sea lion interactions in the Auckland Islands squid fishery

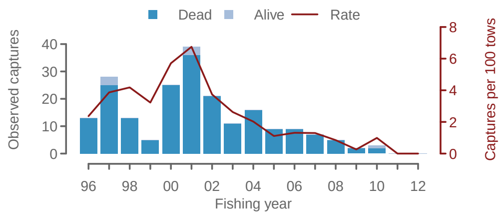
Table A-14: Annual trawl effort, observer coverage, observed number of sea lion captures, observed capture rate (sea lions per 100 trawls), estimated sea lion captures and interactions, and the estimated strike rate (with 95% confidence intervals), in the Auckland Islands squid fishery.

		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	4 466	12	13	2.4	127	64–224	127	64–223	2.9	1.5–4.9
1996–97	3 716	19	28	3.9	140	92–212	140	89–213	3.8	2.6–5.5
1997–98	1 441	22	13	4.2	59	32–102	59	30–105	4.1	2.4–6.9
1998–99	402	39	5	3.2	14	7–26	14	4–28	3.5	2.1–5.9
1999–00	1 206	36	25	5.7	70	45–108	70	42–111	5.8	4.0–8.7
2000–01	583	99	39	6.7	39	39–40	61	38–90	10.5	8.7–13.3
2001–02	1 648	34	21	3.7	42	29–62	73	42–116	4.4	2.9–6.6
2002–03	1 470	29	11	2.6	19	13–28	46	24–77	3.2	1.9–4.9
2003–04	2 594	30	16	2.0	40	26–60	200	98–370	7.7	4.0–14.2
2004–05	2 706	30	9	1.1	31	17–53	165	73–320	6.1	2.8–11.7
2005–06	2 462	28	9	1.3	27	15–45	149	63–309	6.1	2.6–12.5
2006–07	1 320	41	7	1.3	16	9–26	89	28–200	6.8	2.4–15.2
2007–08	1 265	47	5	0.8	12	6–21	116	21–489	9.2	1.8–38.9
2008–09	1 925	40	2	0.3	7	2–16	97	12–441	5.0	0.7–22.6
2009–10	1 190	25	3	1.0	13	5–26	124	19–508	10.4	1.7–43.1
2010–11	1 586	34	0	0	4	0–11	60	4–278	3.8	0.3–17.4
2011–12	1 281	44	0	0	2	0–7	43	2–206	3.3	0.2–16.2

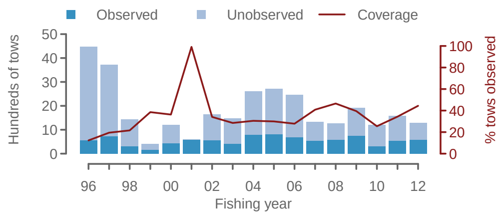
(a) Estimated interactions



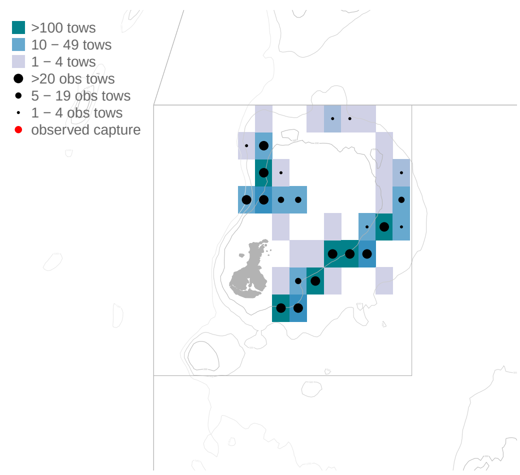
(b) Observed captures



(c) Effort, and observer coverage



(d) October 2011 to September 2012



(e) Monthly distribution, all years

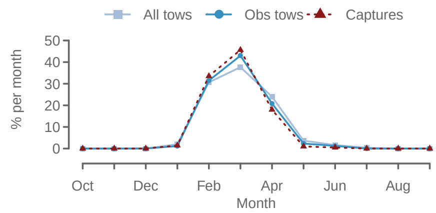


Figure A-14: Annual time series of (a) estimated sea lion interactions, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in the Auckland Islands squid fishery from 1995–96 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer 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.

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	1	0–4	0.2	0.0–1.0
1997	641	34	0	0	1	0–4	0.1	0.0–0.7
1998	963	29	0	0	1	0–5	0.1	0.0–0.6
1999	788	28	0	0	1	0–5	0.1	0.0–0.8
2000	447	52	0	0	0	0–2	0.1	0.0–0.7
2001	672	60	0	0	0	0–2	0.1	0.0–0.5
2002	980	28	1	0.4	4	1–11	0.4	0.0–1.3
2003	599	43	0	0	0	0–3	0.1	0.0–0.6
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	0.3–4.2
2007	544	32	6	3.5	17	8–32	3.1	1.1–6.3
2008	557	41	2	0.9	5	2–11	0.8	0.1–2.2
2009	627	20	0	0	1	0–6	0.2	0.0–1.0
2010	550	43	11	4.7	25	15–37	4.3	2.1–7.3
2011	886	39	6	1.7	15	8–25	1.6	0.6–3.1
2012	575	76	0	0	0	0–1	0.1	0.0–0.4

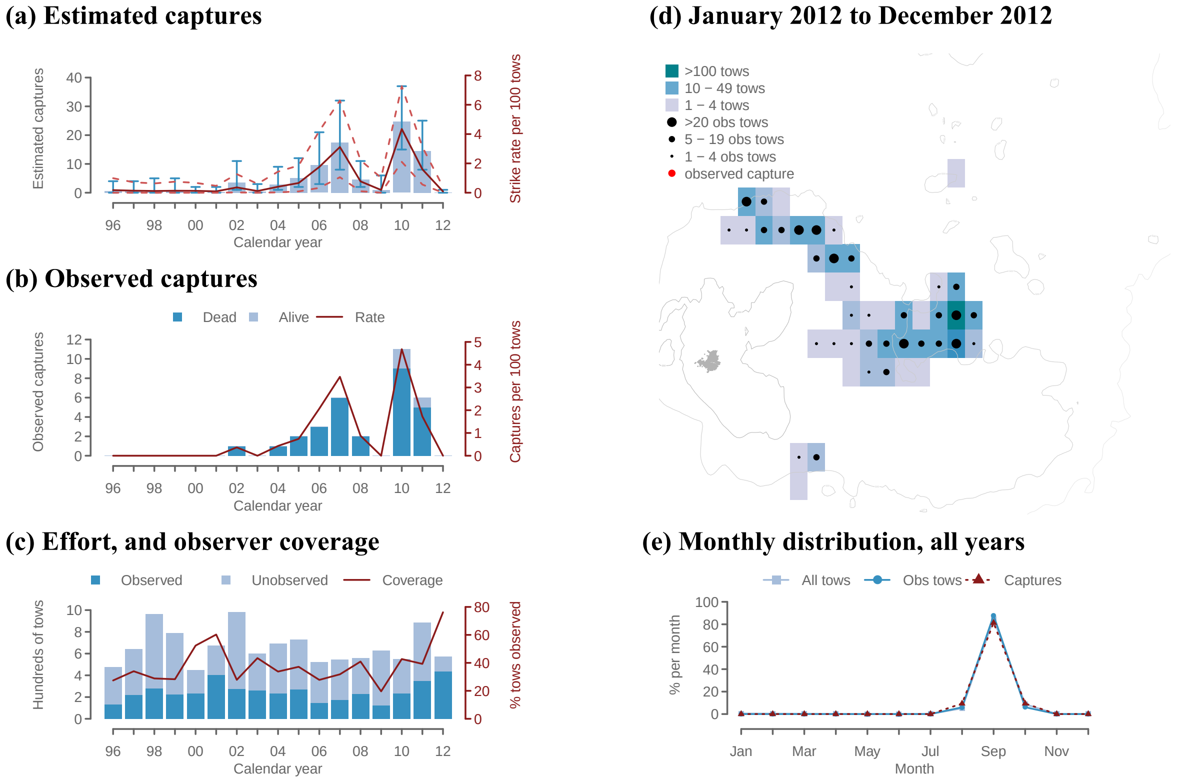


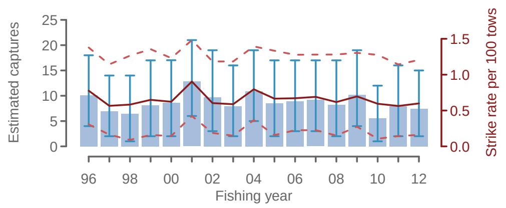
Figure A-15: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in the Campbell Island southern blue whiting fishery from 2000 to 2012. In map (d) average effort is plotted in a blue colour scale, observer 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.

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

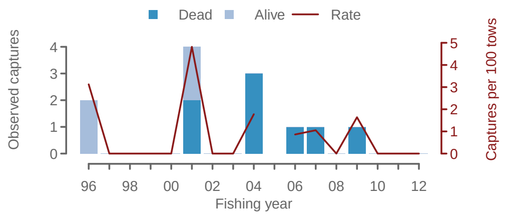
Table A-16: Annual trawl effort, observer coverage, observed number of sea lion captures, observed capture rate (sea lion per 100 tows), estimated sea lion captures, and the estimated strike rate (with 95% confidence intervals), in the trawl fisheries near the Auckland Islands targeting scampi.

		Observed			Est. captures		Est. strike rate	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995–96	1 306	5	2	3.1	10	4–18	0.8	0.3–1.4
1996–97	1 224	15	0	0	7	2–14	0.6	0.2–1.1
1997–98	1 107	12	0	0	6	1–14	0.6	0.1–1.3
1998–99	1 254	2	0	0	8	2–17	0.6	0.2–1.4
1999–00	1 383	5	0	0	9	2–17	0.6	0.1–1.2
2000–01	1 417	6	4	4.8	13	6–21	0.9	0.4–1.5
2001–02	1 604	9	0	0	10	3–19	0.6	0.2–1.2
2002–03	1 351	11	0	0	8	2–16	0.6	0.1–1.2
2003–04	1 363	12	3	1.8	11	5–19	0.8	0.4–1.4
2004–05	1 275	0	-	-	8	2–17	0.7	0.2–1.3
2005–06	1 331	9	1	0.9	9	3–17	0.7	0.2–1.3
2006–07	1 328	7	1	1.1	9	3–17	0.7	0.2–1.3
2007–08	1 327	7	0	0	8	2–17	0.6	0.2–1.3
2008–09	1 457	4	1	1.6	10	4–19	0.7	0.3–1.3
2009–10	940	10	0	0	6	1–12	0.6	0.1–1.3
2010–11	1 401	15	0	0	8	2–16	0.6	0.1–1.1
2011–12	1 244	10	0	0	7	2–15	0.6	0.2–1.2

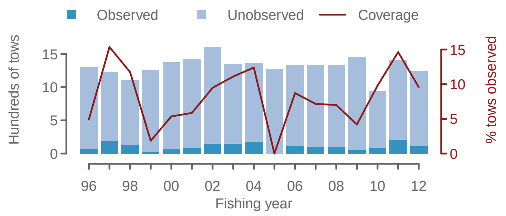
(a) Estimated captures



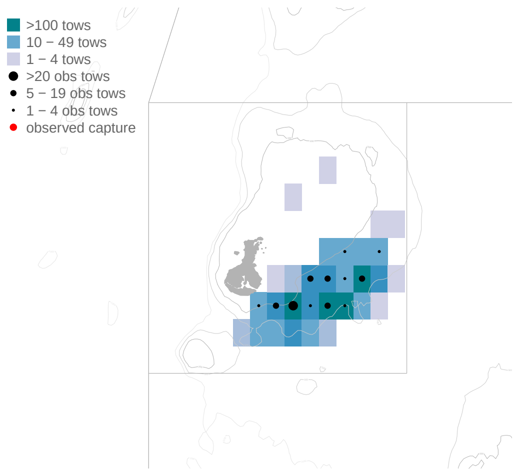
(b) Observed captures



(c) Effort, and observer coverage



(d) October 2011 to September 2012



(e) Monthly distribution, all years

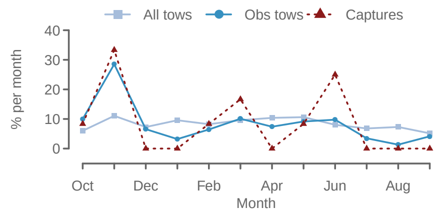


Figure A-16: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in the Auckland Islands scampi fishery from 1995–96 to 2011–12. In map (d) average effort is plotted in a blue colour scale, observer coverage 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.

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	406	6	1	4.0	3	1–6	0.6	0.2–1.5
1996–97	296	4	0	0	1	0–4	0.4	0.0–1.4
1997–98	684	17	1	0.8	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	0	3	0–8	0.3	0.0–1.1
2000–01	578	7	0	0	2	0–7	0.4	0.0–1.2
2001–02	589	4	0	0	2	0–7	0.4	0.0–1.2
2002–03	543	13	0	0	2	0–6	0.4	0.0–1.1
2003–04	289	17	0	0	1	0–4	0.3	0.0–1.4
2004–05	170	7	0	0	1	0–3	0.4	0.0–1.8
2005–06	39	15	0	0	0	0–1	0.3	0.0–2.6
2006–07	38	5	0	0	0	0–1	0.4	0.0–2.6
2007–08	147	45	0	0	0	0–2	0.2	0.0–1.4
2008–09	121	50	0	0	0	0–2	0.2	0.0–1.7
2009–10	77	66	0	0	0	0–1	0.1	0.0–1.3
2010–11	131	37	0	0	0	0–2	0.3	0.0–1.5
2011–12	57	30	0	0	0	0–1	0.3	0.0–1.8

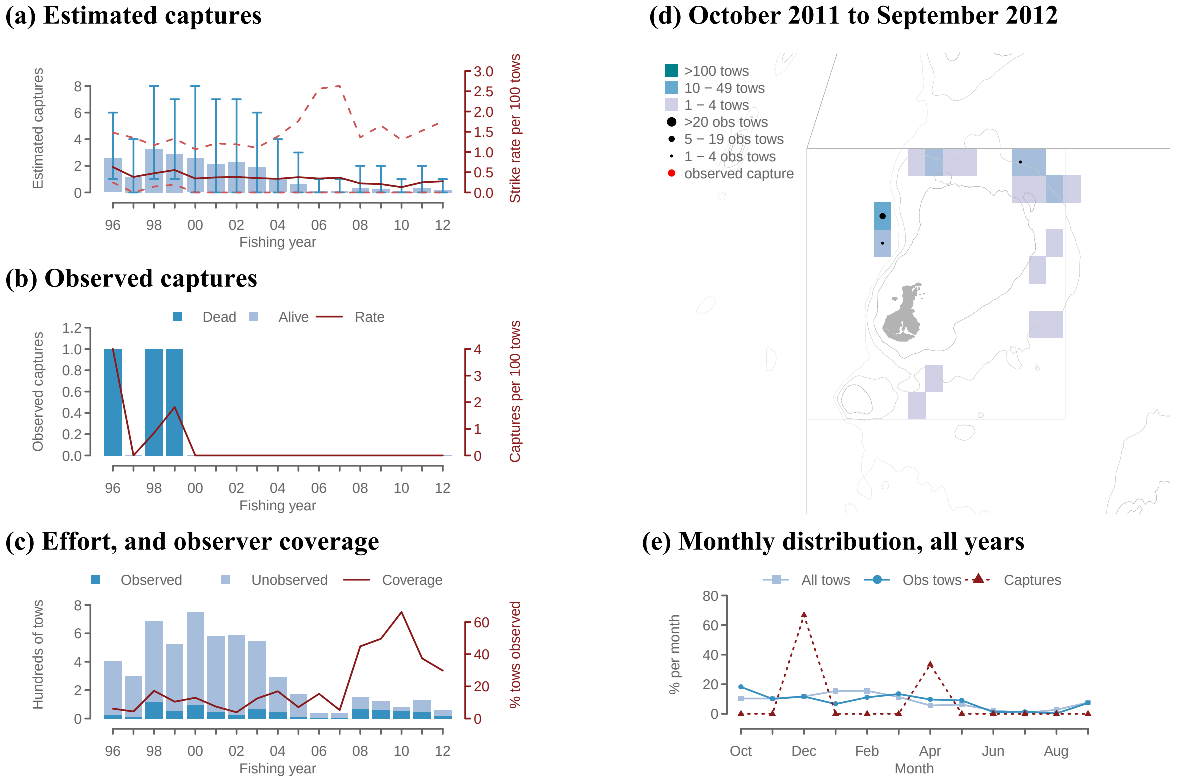


Figure A-17: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in Auckland Islands trawl fisheries not targeting squid or scampi from 1995–96 to 2011–12. In map (d) average effort is plotted in a blue 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.

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	3 456	8	0	0	3	0–7	0.1	0.0–0.2
1996–97	5 098	10	0	0	4	0–10	0.1	0.0–0.2
1997–98	5 782	10	0	0	5	1–11	0.1	0.0–0.2
1998–99	7 590	16	0	0	6	1–12	0.1	0.0–0.2
1999–00	5 260	23	3	0.2	7	3–12	0.1	0.1–0.2
2000–01	5 682	43	3	0.1	6	3–10	0.1	0.1–0.2
2001–02	5 125	18	1	0.1	5	1–10	0.1	0.0–0.2
2002–03	4 348	16	0	0	3	0–8	0.1	0.0–0.2
2003–04	5 100	21	1	0.1	5	1–10	0.1	0.0–0.2
2004–05	6 241	24	3	0.2	7	4–13	0.1	0.1–0.2
2005–06	4 963	19	1	0.1	5	1–9	0.1	0.0–0.2
2006–07	3 506	24	1	0.1	3	1–7	0.1	0.0–0.2
2007–08	3 249	36	1	0.1	3	1–6	0.1	0.0–0.2
2008–09	2 547	31	0	0	2	0–5	0.1	0.0–0.2
2009–10	2 784	43	1	0.1	2	1–5	0.1	0.0–0.2
2010–11	2 456	36	0	0	1	0–4	0.1	0.0–0.2
2011–12	2 299	50	1	0.1	2	1–4	0.1	0.0–0.2

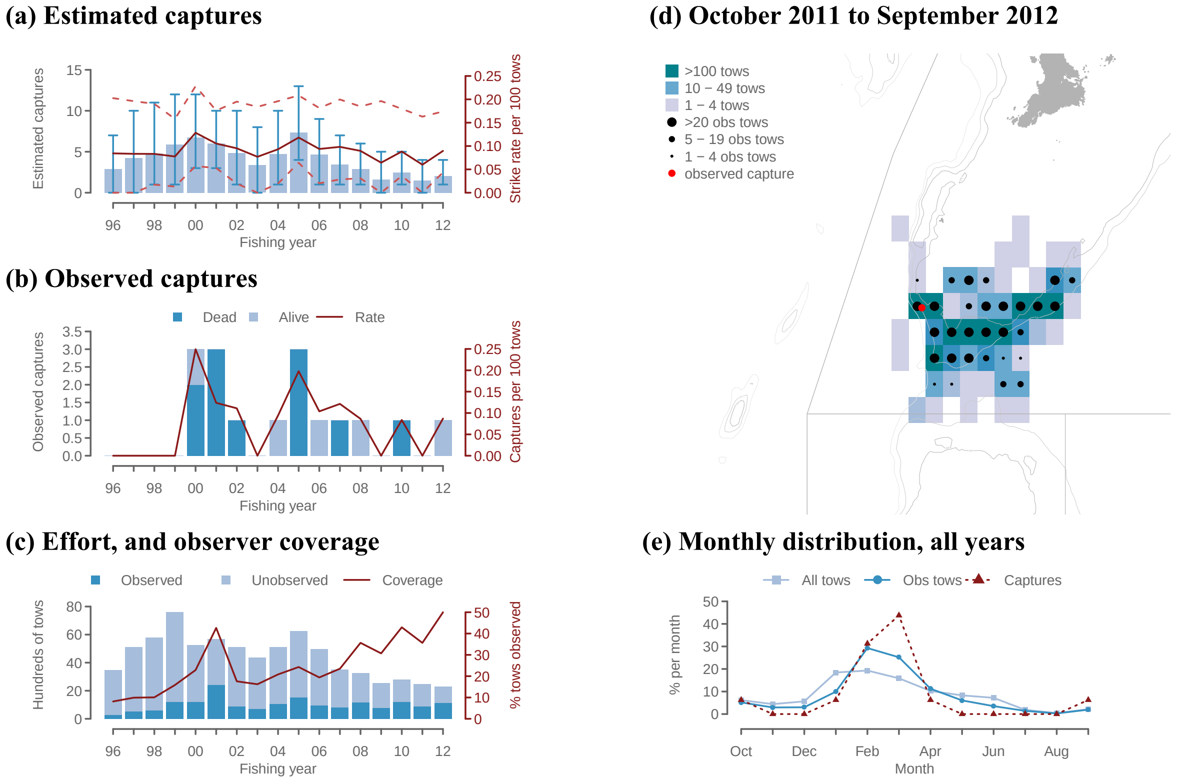


Figure A-18: Annual time series of (a) estimated sea lion captures, (b) observed sea lion captures and the capture rate, and (c) trawl effort and observer coverage, in all trawl fisheries on the Stewart-Snares shelf from 1995–96 to 2011–12. In map (d) average effort is plotted in a blue colour scale, 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	2.001	1.992	1.592	2.448
Mean event rate, (events per 100 tows)	0.246	0.238	0.123	0.422
1995–96 base rate (events per 100 tows)	0.589	0.412	0.062	2.153
1996–97 base rate (events per 100 tows)	0.307	0.193	0.017	1.286
1997–98 base rate (events per 100 tows)	0.278	0.180	0.015	1.116
1998–99 base rate (events per 100 tows)	0.248	0.166	0.013	0.965
1999–00 base rate (events per 100 tows)	0.573	0.401	0.057	2.135
2000–01 base rate (events per 100 tows)	0.416	0.307	0.050	1.406
2001–02 base rate (events per 100 tows)	0.377	0.287	0.044	1.261
2002–03 base rate (events per 100 tows)	1.448	1.298	0.410	3.348
2003–04 base rate (events per 100 tows)	0.812	0.733	0.253	1.847
2004–05 base rate (events per 100 tows)	0.534	0.498	0.208	1.064
2005–06 base rate (events per 100 tows)	0.109	0.092	0.016	0.301
2006–07 base rate (events per 100 tows)	0.252	0.229	0.078	0.542
2007–08 base rate (events per 100 tows)	0.199	0.182	0.062	0.441
2008–09 base rate (events per 100 tows)	0.182	0.163	0.053	0.410
2009–10 base rate (events per 100 tows)	0.123	0.108	0.026	0.313
2010–11 base rate (events per 100 tows)	0.274	0.249	0.088	0.602
2011–12 base rate (events per 100 tows)	0.067	0.059	0.018	0.159
Headline depth, $\beta_{headline}$	-0.035	-0.035	-0.047	-0.024
Log trawl duration, $\beta_{duration}$	1.278	1.271	0.561	2.033
Light condition, relative to dark				
Light, $\exp(\beta_{light})$	0.215	0.204	0.099	0.392
Black, $\exp(\beta_{black})$	1.034	0.963	0.409	2.048
Sub-area, relative to north				
South, $\exp(\beta_{south})$	0.528	0.500	0.249	0.974

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, $1/\theta$	15.294	15.161	11.102	20.213
Mean rate, μ (captures per 100 tows)	0.424	0.424	0.314	0.536
Vessel/year effect standard deviation	0.669	0.668	0.520	0.828
2002–03 base rate (captures per 100 tows)	0.345	0.338	0.218	0.507
2003–04 base rate (captures per 100 tows)	0.432	0.423	0.275	0.641
2004–05 base rate (captures per 100 tows)	0.723	0.711	0.467	1.054
2005–06 base rate (captures per 100 tows)	0.524	0.513	0.335	0.768
2006–07 base rate (captures per 100 tows)	0.360	0.353	0.225	0.530
2007–08 base rate (captures per 100 tows)	0.561	0.552	0.369	0.802
2008–09 base rate (captures per 100 tows)	0.352	0.345	0.219	0.519
2009–10 base rate (captures per 100 tows)	0.313	0.307	0.197	0.462
2010–11 base rate (captures per 100 tows)	0.313	0.306	0.188	0.475
2011–12 base rate (captures per 100 tows)	0.314	0.308	0.196	0.465
Sine(doy) coefficient	-1.264	-1.264	-1.505	-1.021
Cosine(doy) coefficient	-1.043	-1.043	-1.277	-0.818
Area coefficients relative to Stewart-Snares shelf				
East Coast SI	1.076	1.055	0.697	1.573
West Coast SI	0.541	0.525	0.327	0.834
Auckland Islands	0.263	0.252	0.137	0.451
West Coast NI	0.175	0.162	0.073	0.355
Subantarctic	7.480	6.361	1.949	19.664
Campbell Island	1.026	0.869	0.280	2.736
Cook Strait	1.885	1.786	0.936	3.384
Puysegur	1.113	1.056	0.550	1.994
Bounty Islands	12.575	10.510	3.236	34.681
Target coefficients relative to Hoki/Hake/Ling				
Squid	2.484	2.398	1.452	3.993
Deepwater	0.006	0.003	0.000	0.024
Middle depth	0.892	0.869	0.568	1.329
Jack mackerel	1.374	1.320	0.709	2.355
Southern blue whiting	0.702	0.597	0.203	1.804
Scampi	0.400	0.366	0.134	0.865
Inshore	0.228	0.180	0.024	0.717
Distance coefficients relative to Near (between 25 km and 90 km)				
Coastal (< 25 km)	1.534	1.497	0.978	2.307
Far (between 90 km and 180 km)	0.874	0.862	0.623	1.196
Ocean (> 180 km)	0.252	0.239	0.118	0.460
Interaction term				
Deepwater/Subantarctic	0.761	0.678	0.266	1.720

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

Table D-21: 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.
2007–08									
Hoki	8 358	1 816	21.7	58	3.19	311	152–625	3.72	1.82–7.48
Hake	1 499	382	25.5	28	7.33	50	32–96	3.34	2.13–6.40
SBW	818	329	40.2	24	7.29	102	25–462	12.41	3.06–56.49
Middle depth	5 911	347	5.9	9	2.59	140	60–298	2.37	1.02–5.04
Squid	4 234	1 452	34.3	6	0.41	34	15–71	0.80	0.35–1.68
Ling	1 794	221	12.3	4	1.81	39	12–101	2.19	0.67–5.63
Jack mackerel	2 643	809	30.6	7	0.87	32	11–102	1.19	0.42–3.86
Scampi	3 284	298	9.1	1	0.34	10	1–34	0.31	0.03–1.04
Deepwater	3 416	1 406	41.2	4	0.28	7	4–16	0.19	0.12–0.47
Inshore	14 836	76	0.5	0	0.00	54	4–214	0.36	0.03–1.44
2008–09									
Hoki	7 955	1 655	20.8	37	2.24	202	95–444	2.54	1.19–5.58
Hake	1 748	349	20.0	5	1.43	21	7–57	1.21	0.40–3.26
SBW	1 187	296	24.9	17	5.74	108	24–359	9.11	2.02–30.25
Middle depth	5 813	648	11.1	1	0.15	109	35–279	1.88	0.60–4.80
Squid	3 861	1 295	33.5	1	0.08	21	6–49	0.54	0.16–1.27
Ling	1 250	143	11.4	0	0.00	23	5–62	1.86	0.40–4.96
Jack mackerel	2 154	813	37.7	8	0.98	16	9–32	0.72	0.42–1.49
Scampi	2 793	267	9.6	1	0.37	6	1–21	0.21	0.04–0.75
Deepwater	2 849	1 066	37.4	0	0.00	3	0–14	0.10	0.00–0.49
Inshore	15 887	867	5.5	2	0.23	41	4–151	0.26	0.03–0.95
2009–10									
Hoki	9 406	2 055	21.8	30	1.46	173	88–349	1.84	0.94–3.71
Hake	817	327	40.0	4	1.22	11	4–32	1.41	0.49–3.92
SBW	1 114	396	35.5	16	4.04	98	20–406	8.83	1.80–36.45
Middle depth	5 642	700	12.4	5	0.71	89	31–229	1.57	0.55–4.06
Squid	3 789	1 066	28.1	8	0.75	36	16–76	0.95	0.42–2.01
Ling	1 014	180	17.8	6	3.33	24	8–78	2.33	0.79–7.69
Jack mackerel	2 403	782	32.5	2	0.26	5	2–13	0.22	0.08–0.54
Scampi	2 460	203	8.3	1	0.49	6	1–19	0.23	0.04–0.77
Deepwater	3 186	1 115	35.0	0	0.00	2	0–12	0.07	0.00–0.38
Inshore	18 047	443	2.5	0	0.00	39	2–165	0.22	0.01–0.91
2010–11									
Hoki	9 916	1 694	17.1	24	1.42	172	79–344	1.74	0.80–3.47
Hake	862	227	26.3	1	0.44	12	2–36	1.36	0.23–4.18
SBW	1 171	432	36.9	36	8.33	72	38–235	6.15	3.25–20.07
Middle depth	5 692	402	7.1	2	0.50	81	28–194	1.43	0.49–3.41
Squid	4 213	1 257	29.8	8	0.64	24	12–46	0.57	0.28–1.09
Ling	1 006	102	10.1	2	1.96	18	4–57	1.80	0.40–5.67
Jack mackerel	1 878	593	31.6	0	0.00	3	0–11	0.16	0.00–0.59
Scampi	2 626	322	12.3	0	0.00	4	0–18	0.16	0.00–0.69
Deepwater	2 444	804	32.9	0	0.00	2	0–12	0.10	0.00–0.49
Inshore	17 968	78	0.4	0	0.00	38	2–152	0.21	0.01–0.85
2011–12									
Hoki	10 664	2 457	23.0	33	1.34	200	98–417	1.87	0.92–3.91
Hake	645	225	34.9	1	0.44	8	1–23	1.19	0.16–3.57
SBW	952	668	70.2	25	3.74	61	25–237	6.42	2.63–24.89
Middle depth	5 281	582	11.0	8	1.37	76	30–187	1.44	0.57–3.54
Squid	3 505	1 377	39.3	8	0.58	25	12–53	0.70	0.34–1.51
Ling	855	136	15.9	1	0.74	17	3–58	1.93	0.35–6.78
Jack mackerel	2 027	1 544	76.2	5	0.32	8	5–20	0.40	0.25–0.99
Scampi	3 002	183	6.1	1	0.55	7	1–26	0.24	0.03–0.87
Deepwater	2 060	573	27.8	0	0.00	2	0–10	0.08	0.00–0.49
Inshore	17 720	79	0.4	0	0.00	39	2–159	0.22	0.01–0.90

Table D-22: 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.
2007–08									
Cook Strait	3 756	250	6.7	24	9.60	239	89–561	6.37	2.37–14.94
West coast South Island	6 956	944	13.6	57	6.04	152	95–257	2.19	1.37–3.70
East coast South Island	13 998	1 352	9.7	15	1.11	167	77–342	1.19	0.55–2.44
Stewart-Snares	6 513	1 529	23.5	13	0.85	71	34–140	1.09	0.52–2.15
Bounty Islands	298	156	52.3	17	10.90	81	17–446	27.19	5.70–149.67
Campbell Island	559	230	41.1	7	3.04	16	7–60	2.90	1.25–10.73
West coast North Island	9 485	922	9.7	1	0.11	19	5–48	0.20	0.05–0.51
Subantarctic islands	1 825	879	48.2	5	0.57	15	5–64	0.80	0.27–3.51
Auckland Islands	3 030	861	28.4	2	0.23	11	3–32	0.36	0.10–1.06
Puysegur	373	13	3.5	0	0.00	6	0–28	1.72	0.00–7.51
2008–09									
Cook Strait	4 244	177	4.2	19	10.73	203	74–489	4.78	1.74–11.52
West coast South Island	6 516	1 187	18.2	18	1.52	73	37–137	1.12	0.57–2.10
East coast South Island	13 267	1 632	12.3	8	0.49	95	43–197	0.72	0.32–1.48
Stewart-Snares	6 032	1 427	23.7	5	0.35	39	16–81	0.65	0.27–1.34
Bounty Islands	646	215	33.3	17	7.91	95	19–349	14.66	2.94–54.02
Campbell Island	620	124	20.0	0	0.00	9	0–36	1.46	0.00–5.81
West coast North Island	8 725	1 118	12.8	4	0.36	14	6–30	0.16	0.07–0.34
Subantarctic islands	1 493	480	32.2	0	0.00	8	0–34	0.53	0.00–2.28
Auckland Islands	3 678	997	27.1	1	0.10	9	2–26	0.24	0.05–0.71
Puysegur	276	42	15.2	0	0.00	5	0–29	1.93	0.00–10.52
2009–10									
Cook Strait	4 474	434	9.7	17	3.92	150	56–374	3.35	1.25–8.36
West coast South Island	7 242	1 089	15.0	7	0.64	58	25–117	0.80	0.35–1.62
East coast South Island	14 751	1 487	10.1	12	0.81	92	44–195	0.63	0.30–1.32
Stewart-Snares	6 754	1 902	28.2	18	0.95	60	31–115	0.89	0.46–1.70
Bounty Islands	679	163	24.0	10	6.13	85	11–395	12.52	1.62–58.17
Campbell Island	537	226	42.1	2	0.88	6	2–22	1.13	0.37–4.10
West coast North Island	9 166	811	8.8	2	0.25	9	3–25	0.10	0.03–0.27
Subantarctic islands	1 624	659	40.6	4	0.61	11	4–31	0.67	0.25–1.91
Auckland Islands	2 270	443	19.5	0	0.00	6	0–20	0.25	0.00–0.88
Puysegur	381	53	13.9	0	0.00	7	0–38	1.73	0.00–9.97
2010–11									
Cook Strait	4 630	148	3.2	18	12.16	142	53–333	3.07	1.14–7.19
West coast South Island	8 293	804	9.7	3	0.37	74	28–156	0.89	0.34–1.88
East coast South Island	13 889	1 302	9.4	4	0.31	71	28–157	0.51	0.20–1.13
Stewart-Snares	6 084	1 323	21.7	11	0.83	39	20–74	0.65	0.33–1.22
Bounty Islands	420	155	36.9	31	20.00	58	31–222	13.72	7.38–52.87
Campbell Island	968	364	37.6	4	1.10	12	4–34	1.21	0.41–3.51
West coast North Island	8 708	605	6.9	0	0.00	7	0–24	0.08	0.00–0.28
Subantarctic islands	886	306	34.5	1	0.33	7	1–29	0.80	0.11–3.27
Auckland Islands	3 302	848	25.7	1	0.12	7	1–18	0.20	0.03–0.55
Puysegur	596	56	9.4	0	0.00	10	0–46	1.73	0.00–7.72
2011–12									
Cook Strait	4 534	232	5.1	16	6.90	152	52–368	3.34	1.15–8.12
West coast South Island	8 396	1 468	17.5	22	1.50	85	44–172	1.01	0.52–2.05
East coast South Island	13 381	1 259	9.4	5	0.40	76	32–166	0.57	0.24–1.24
Stewart-Snares	6 323	1 683	26.6	9	0.53	41	19–91	0.65	0.30–1.44
Bounty Islands	224	100	44.6	12	12.00	46	12–223	20.32	5.36–99.56
Campbell Island	646	458	70.9	4	0.87	6	4–19	1.01	0.62–2.94
West coast North Island	9 404	1 488	15.8	3	0.20	10	3–28	0.10	0.03–0.30
Subantarctic islands	745	330	44.3	9	2.73	11	9–19	1.47	1.21–2.55
Auckland Islands	2 588	716	27.7	2	0.28	7	2–18	0.25	0.08–0.70
Puysegur	470	90	19.1	0	0.00	9	0–40	1.86	0.00–8.51

Table D-23: Total effort, observed effort, observed captures, and estimated captures of New Zealand fur seals 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	4 108	135	3.3	4	2.96	266	86–640	6.49	2.09–15.58
Hoki	West coast SI.	7 862	923	11.7	18	1.95	162	74–307	2.06	0.94–3.90
Hoki	East coast SI.	9 941	863	8.7	13	1.51	103	47–212	1.04	0.47–2.13
SBW	Bounty Islands	24	0	0	0	-	6	0–47	26.22	0.00–195.83
Middle depth	Cook Strait	1 136	1	0.1	0	0.00	30	5–92	2.61	0.44–8.10
Middle depth	East coast SI.	2 785	30	1.1	0	0.00	27	5–85	0.96	0.18–3.05
Squid	Stewart-Snares	3 279	503	15.3	7	1.39	24	11–47	0.75	0.34–1.43
Inshore	East coast SI.	7 501	1	0.0	0	0.00	23	1–96	0.31	0.01–1.28
Middle depth	West coast SI.	1 819	0	0	0	-	21	3–69	1.14	0.16–3.79
Hake	West coast SI.	516	36	7.0	3	8.33	9	3–26	1.74	0.58–5.04
Squid	East coast SI.	1 753	50	2.9	0	0.00	19	3–52	1.06	0.17–2.97
Middle depth	Stewart-Snares	978	138	14.1	1	0.72	12	2–41	1.24	0.20–4.19
SBW	Campbell Island	606	269	44.4	8	2.97	14	8–34	2.27	1.32–5.61
Hoki	Stewart-Snares	2 414	433	17.9	3	0.69	19	6–52	0.79	0.25–2.15
Inshore	Cook Strait	1 990	0	0	0	-	12	0–56	0.59	0.00–2.81
Ling	Stewart-Snares	124	0	0	0	-	2	0–10	1.27	0.00–8.06
Inshore	Stewart-Snares	1 489	0	0	0	-	7	0–33	0.44	0.00–2.22
Jack mackerel	West coast NI.	2 293	218	9.5	0	0.00	6	0–19	0.28	0.00–0.83
Ling	Puysegur	88	0	0	0	-	3	0–24	3.76	0.00–27.27
Hoki	Puysegur	494	55	11.1	6	10.91	23	6–74	4.58	1.21–14.98
Inshore	West coast SI.	1 670	0	0	0	-	3	0–14	0.18	0.00–0.84
Squid	Auckland Islands	1 466	416	28.4	0	0.00	2	0–8	0.13	0.00–0.55
Inshore	West coast NI.	6 638	0	0	0	-	3	0–16	0.05	0.00–0.24
Ling	East coast SI.	37	0	0	0	-	1	0–4	1.64	0.00–10.81
Deepwater	Subantarctic	1 157	139	12.0	0	0.00	3	0–14	0.24	0.00–1.21
Jack mackerel	West coast SI.	386	53	13.7	0	0.00	7	0–25	1.85	0.00–6.48
Middle depth	West coast NI.	1 771	75	4.2	0	0.00	6	0–21	0.33	0.00–1.19
Squid	Puysegur	1 420	311	21.9	1	0.32	11	1–41	0.77	0.07–2.89
Middle depth	Subantarctic	37	5	13.5	0	0.00	6	0–57	15.69	0.00–154.05
Scampi	East coast SI.	909	257	28.3	2	0.78	5	2–17	0.55	0.22–1.87
Scampi	Auckland Islands	1 399	150	10.7	0	0.00	1	0–6	0.08	0.00–0.43
Ling	West coast SI.	27	0	0	0	-	1	0–5	2.22	0.00–18.52
Squid	Subantarctic	236	19	8.1	0	0.00	2	0–12	1.04	0.00–5.08
Jack mackerel	East coast SI.	175	32	18.3	1	3.12	2	1–7	1.09	0.57–4.00
Hake	East coast SI.	96	8	8.3	0	0.00	1	0–6	0.90	0.00–6.25
Scampi	Cook Strait	247	7	2.8	0	0.00	1	0–4	0.25	0.00–1.62
Middle depth	Puysegur	136	7	5.1	0	0.00	1	0–8	0.88	0.00–5.88
Hake	Stewart-Snares	149	0	0	0	-	1	0–8	0.94	0.00–5.37
Ling	Subantarctic	180	16	8.9	0	0.00	1	0–7	0.64	0.00–3.89
Hoki	Auckland Islands	1 140	63	5.5	0	0.00	1	0–6	0.10	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	0–2	0.09	0.00–0.71
Ling	Auckland Islands	27	0	0	0	-	0	0–0	0.07	0.00–0.00
Ling	West coast NI.	16	0	0	0	-	0	0–1	0.73	0.00–6.25
Inshore	Puysegur	84	0	0	0	-	0	0–3	0.41	0.00–3.57
Deepwater	East coast SI.	1 552	214	13.8	0	0.00	0	0–1	0.00	0.00–0.06
Deepwater	Cook Strait	168	0	0	0	-	0	0–1	0.02	0.00–0.60
Deepwater	Stewart-Snares	629	34	5.4	0	0.00	0	0–1	0.01	0.00–0.16
Deepwater	West coast NI.	288	124	43.1	0	0.00	0	0–0	0.00	0.00–0.00

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Table D-23: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2003–04										
Hoki	Cook Strait	4 213	130	3.1	1	0.77	359	119–840	8.53	2.82–19.94
Hoki	West coast SI.	6 844	1 336	19.5	27	2.02	191	91–379	2.79	1.33–5.54
Hoki	East coast SI.	7 153	549	7.7	17	3.10	121	53–264	1.69	0.74–3.69
SBW	Bounty Islands	34	9	26.5	9	100.00	18	9–74	53.02	26.47–217.65
Middle depth	Cook Strait	1 378	0	0	0	-	45	7–154	3.24	0.51–11.18
Middle depth	East coast SI.	1 679	11	0.7	0	0.00	25	4–79	1.50	0.24–4.71
Squid	Stewart-Snares	4 533	951	21.0	10	1.05	53	24–107	1.16	0.53–2.36
Inshore	East coast SI.	6 883	7	0.1	0	0.00	24	1–102	0.35	0.01–1.48
Middle depth	West coast SI.	1 520	3	0.2	0	0.00	25	4–79	1.65	0.26–5.20
Hake	West coast SI.	608	53	8.7	0	0.00	9	0–33	1.50	0.00–5.43
Squid	East coast SI.	579	3	0.5	0	0.00	11	1–41	1.97	0.17–7.08
Middle depth	Stewart-Snares	622	29	4.7	0	0.00	13	1–48	2.03	0.16–7.72
SBW	Campbell Island	706	229	32.4	4	1.75	15	4–55	2.11	0.57–7.79
Hoki	Stewart-Snares	1 912	96	5.0	0	0.00	17	3–47	0.87	0.16–2.46
Inshore	Cook Strait	1 771	0	0	0	-	14	0–71	0.80	0.00–4.01
Ling	Stewart-Snares	180	8	4.4	0	0.00	2	0–13	1.29	0.00–7.22
Inshore	Stewart-Snares	2 031	0	0	0	-	10	0–47	0.48	0.00–2.31
Jack mackerel	West coast NI.	2 247	140	6.2	0	0.00	10	1–27	0.43	0.04–1.20
Ling	Puysegur	112	0	0	0	-	9	0–59	7.65	0.00–52.70
Hoki	Puysegur	145	32	22.1	3	9.38	7	3–27	5.08	2.07–18.62
Inshore	West coast SI.	1 967	0	0	0	-	4	0–20	0.22	0.00–1.02
Squid	Auckland Islands	2 595	792	30.5	7	0.88	13	7–25	0.48	0.27–0.96
Inshore	West coast NI.	7 205	0	0	0	-	5	0–25	0.07	0.00–0.35
Ling	East coast SI.	34	0	0	0	-	2	0–15	5.46	0.00–44.19
Deepwater	Subantarctic	1 064	201	18.9	2	1.00	6	2–17	0.53	0.19–1.60
Jack mackerel	West coast SI.	87	9	10.3	2	22.22	4	2–14	5.14	2.30–16.09
Middle depth	West coast NI.	1 751	53	3.0	0	0.00	7	0–21	0.38	0.00–1.20
Squid	Puysegur	251	0	0	0	-	6	0–27	2.58	0.00–10.76
Middle depth	Subantarctic	66	8	12.1	0	0.00	11	0–78	16.19	0.00–118.22
Scampi	East coast SI.	623	205	32.9	0	0.00	3	0–13	0.42	0.00–2.09
Scampi	Auckland Islands	1 450	169	11.7	1	0.59	2	1–8	0.17	0.07–0.55
Ling	West coast SI.	44	0	0	0	-	1	0–6	2.01	0.00–13.64
Squid	Subantarctic	332	17	5.1	0	0.00	9	0–46	2.78	0.00–13.86
Jack mackerel	East coast SI.	11	0	0	0	-	0	0–1	0.84	0.00–9.09
Hake	East coast SI.	766	34	4.4	0	0.00	3	0–12	0.39	0.00–1.57
Scampi	Cook Strait	45	0	0	0	-	0	0–2	0.37	0.00–4.44
Middle depth	Puysegur	125	27	21.6	0	0.00	1	0–4	0.53	0.00–3.20
Hake	Stewart-Snares	166	53	31.9	0	0.00	1	0–9	0.68	0.00–5.42
Ling	Subantarctic	97	11	11.3	0	0.00	1	0–6	0.93	0.00–6.19
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	0.46	0.00–5.26
Deepwater	Bounty Islands	295	26	8.8	0	0.00	1	0–5	0.19	0.00–1.69
Ling	Auckland Islands	21	0	0	0	-	0	0–0	0.04	0.00–0.00
Ling	West coast NI.	12	0	0	0	-	0	0–1	0.60	0.00–8.33
Inshore	Puysegur	19	0	0	0	-	0	0–1	0.38	0.00–5.26
Deepwater	East coast SI.	1 461	96	6.6	0	0.00	0	0–1	0.00	0.00–0.07
Deepwater	Cook Strait	98	0	0	0	-	0	0–0	0.02	0.00–0.00
Deepwater	Stewart-Snares	370	84	22.7	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-23: (*continued*)

		Tows	Observed				Est. captures		Est. capture rate	
			No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2004–05										
Hoki	Cook Strait	3 082	134	4.3	32	23.88	394	125–1004	12.79	4.06–32.58
Hoki	West coast SI.	3 939	1 013	25.7	63	6.22	203	108–415	5.14	2.74–10.54
Hoki	East coast SI.	5 121	714	13.9	14	1.96	105	43–249	2.05	0.84–4.86
SBW	Bounty Islands	100	52	52.0	24	46.15	69	24–392	69.22	24.00–392.03
Middle depth	Cook Strait	1 083	1	0.1	0	0.00	65	11–202	5.98	1.02–18.65
Middle depth	East coast SI.	1 688	7	0.4	0	0.00	44	10–125	2.62	0.59–7.41
Squid	Stewart-Snares	5 858	1 573	26.9	8	0.51	82	36–162	1.40	0.61–2.77
Inshore	East coast SI.	7 049	2	0.0	0	0.00	56	3–238	0.80	0.04–3.38
Middle depth	West coast SI.	1 554	74	4.8	9	12.16	47	17–118	3.05	1.09–7.59
Hake	West coast SI.	784	86	11.0	2	2.33	21	4–62	2.71	0.51–7.91
Squid	East coast SI.	1 515	61	4.0	3	4.92	51	13–137	3.39	0.86–9.04
Middle depth	Stewart-Snares	1 004	46	4.6	0	0.00	32	5–102	3.18	0.50–10.16
SBW	Campbell Island	758	280	36.9	9	3.21	33	10–112	4.37	1.32–14.78
Hoki	Stewart-Snares	996	113	11.3	2	1.77	26	5–87	2.60	0.50–8.73
Inshore	Cook Strait	1 516	11	0.7	0	0.00	22	0–110	1.47	0.00–7.26
Ling	Stewart-Snares	435	67	15.4	3	4.48	14	3–46	3.25	0.69–10.57
Inshore	Stewart-Snares	2 381	0	0	0	-	19	0–88	0.79	0.00–3.70
Jack mackerel	West coast NI.	2 378	528	22.2	5	0.95	22	8–53	0.91	0.34–2.23
Ling	Puysegur	197	4	2.0	0	0.00	16	0–88	8.07	0.00–44.68
Hoki	Puysegur	292	58	19.9	9	15.52	28	9–110	9.72	3.08–37.68
Inshore	West coast SI.	2 554	0	0	0	-	11	0–48	0.42	0.00–1.88
Squid	Auckland Islands	2 693	805	29.9	1	0.12	8	1–23	0.31	0.04–0.85
Inshore	West coast NI.	6 672	0	0	0	-	10	0–47	0.16	0.00–0.70
Ling	East coast SI.	51	0	0	0	-	5	0–37	9.19	0.00–72.55
Deepwater	Subantarctic	1 156	323	27.9	4	1.24	15	4–65	1.28	0.35–5.62
Jack mackerel	West coast SI.	68	17	25.0	0	0.00	2	0–11	2.96	0.00–16.18
Middle depth	West coast NI.	1 685	48	2.8	1	2.08	12	2–38	0.73	0.12–2.26
Squid	Puysegur	296	63	21.3	4	6.35	15	4–58	5.05	1.35–19.60
Middle depth	Subantarctic	60	5	8.3	0	0.00	8	0–63	12.65	0.00–105.04
Scampi	East coast SI.	1 248	63	5.0	0	0.00	5	0–21	0.39	0.00–1.68
Scampi	Auckland Islands	1 275	0	0	0	-	6	0–28	0.43	0.00–2.20
Ling	West coast SI.	128	0	0	0	-	7	0–40	5.10	0.00–31.25
Squid	Subantarctic	67	1	1.5	0	0.00	8	0–45	11.67	0.00–67.16
Jack mackerel	East coast SI.	9	4	44.4	0	0.00	0	0–2	2.40	0.00–22.22
Hake	East coast SI.	311	9	2.9	0	0.00	6	0–35	2.06	0.00–11.25
Scampi	Cook Strait	186	0	0	0	-	12	0–89	6.50	0.00–47.85
Middle depth	Puysegur	129	0	0	0	-	3	0–19	2.25	0.00–14.73
Hake	Stewart-Snares	143	0	0	0	-	4	0–21	2.46	0.00–14.69
Ling	Subantarctic	51	2	3.9	0	0.00	3	0–18	5.91	0.00–35.29
Hoki	Auckland Islands	318	2	0.6	0	0.00	1	0–8	0.37	0.00–2.52
Jack mackerel	Stewart-Snares	53	8	15.1	0	0.00	1	0–5	1.66	0.00–9.43
Deepwater	Bounty Islands	398	86	21.6	0	0.00	0	0–4	0.12	0.00–1.01
Ling	Auckland Islands	77	0	0	0	-	1	0–6	1.04	0.00–7.79
Ling	West coast NI.	9	0	0	0	-	0	0–2	1.94	0.00–22.22
Inshore	Puysegur	18	0	0	0	-	0	0–2	1.11	0.00–11.11
Deepwater	East coast SI.	1 374	121	8.8	0	0.00	0	0–1	0.01	0.00–0.07
Deepwater	Cook Strait	103	0	0	0	-	0	0–1	0.03	0.00–0.97
Deepwater	Stewart-Snares	239	66	27.6	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-23: (*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	236	70–662	12.01	3.56–33.62
Hoki	West coast SI.	3 545	802	22.6	23	2.87	108	48–232	3.06	1.35–6.54
Hoki	East coast SI.	4 902	724	14.8	12	1.66	62	26–140	1.27	0.53–2.86
SBW	Bounty Islands	94	82	87.2	51	62.20	56	51–91	59.18	54.26–96.81
Middle depth	Cook Strait	688	0	0	0	-	26	3–90	3.81	0.44–13.09
Middle depth	East coast SI.	2 107	57	2.7	1	1.75	63	13–196	2.99	0.62–9.30
Squid	Stewart-Snares	4 477	644	14.4	2	0.31	57	21–124	1.27	0.47–2.77
Inshore	East coast SI.	6 793	0	0	0	-	36	2–150	0.54	0.03–2.21
Middle depth	West coast SI.	1 170	28	2.4	0	0.00	25	3–80	2.14	0.26–6.84
Hake	West coast SI.	1 146	332	29.0	8	2.41	30	11–78	2.64	0.96–6.81
Squid	East coast SI.	1 356	9	0.7	0	0.00	29	5–89	2.13	0.37–6.56
Middle depth	Stewart-Snares	1 214	303	25.0	2	0.66	25	6–78	2.06	0.49–6.43
SBW	Campbell Island	510	135	26.5	1	0.74	11	1–48	2.07	0.20–9.42
Hoki	Stewart-Snares	776	136	17.5	1	0.74	12	2–40	1.50	0.26–5.15
Inshore	Cook Strait	1 756	7	0.4	0	0.00	18	0–92	1.05	0.00–5.24
Ling	Stewart-Snares	618	97	15.7	2	2.06	15	3–51	2.50	0.49–8.25
Inshore	Stewart-Snares	1 997	0	0	0	-	11	0–54	0.55	0.00–2.70
Jack mackerel	West coast NI.	2 067	641	31.0	4	0.62	13	5–34	0.65	0.24–1.64
Ling	Puysegur	225	15	6.7	0	0.00	13	0–70	5.57	0.00–31.12
Hoki	Puysegur	108	34	31.5	7	20.59	10	7–33	9.69	6.48–30.58
Inshore	West coast SI.	2 568	10	0.4	0	0.00	9	0–38	0.34	0.00–1.48
Squid	Auckland Islands	2 462	685	27.8	2	0.29	6	2–15	0.24	0.08–0.61
Inshore	West coast NI.	5 587	74	1.3	0	0.00	5	0–21	0.09	0.00–0.38
Ling	East coast SI.	99	0	0	0	-	4	0–22	4.34	0.00–22.25
Deepwater	Subantarctic	987	134	13.6	1	0.75	7	1–28	0.69	0.10–2.84
Jack mackerel	West coast SI.	209	6	2.9	0	0.00	5	0–27	2.54	0.00–12.92
Middle depth	West coast NI.	806	12	1.5	1	8.33	5	1–15	0.59	0.12–1.86
Squid	Puysegur	203	6	3.0	0	0.00	6	0–32	3.02	0.00–15.76
Middle depth	Subantarctic	22	2	9.1	0	0.00	10	0–92	47.08	0.00–418.41
Scampi	East coast SI.	1 511	96	6.4	0	0.00	3	0–13	0.18	0.00–0.86
Scampi	Auckland Islands	1 332	116	8.7	0	0.00	3	0–14	0.23	0.00–1.05
Ling	West coast SI.	148	0	0	0	-	5	0–25	3.19	0.00–16.89
Squid	Subantarctic	41	0	0	0	-	5	0–38	12.25	0.00–92.74
Jack mackerel	East coast SI.	436	58	13.3	2	3.45	6	2–23	1.46	0.46–5.28
Hake	East coast SI.	15	1	6.7	0	0.00	0	0–1	0.84	0.00–6.67
Scampi	Cook Strait	71	0	0	0	-	1	0–10	1.99	0.00–14.08
Middle depth	Puysegur	157	2	1.3	0	0.00	5	0–29	3.08	0.00–18.47
Hake	Stewart-Snares	174	87	50.0	3	3.45	4	3–9	2.17	1.72–5.17
Ling	Subantarctic	16	0	0	0	-	0	0–4	3.12	0.00–25.00
Hoki	Auckland Islands	18	3	16.7	0	0.00	0	0–1	0.38	0.00–5.56
Jack mackerel	Stewart-Snares	86	3	3.5	0	0.00	1	0–6	1.29	0.00–6.98
Deepwater	Bounty Islands	365	99	27.1	1	1.01	2	1–6	0.44	0.27–1.64
Ling	Auckland Islands	76	1	1.3	0	0.00	0	0–3	0.62	0.00–3.95
Ling	West coast NI.	46	0	0	0	-	1	0–4	1.28	0.00–8.70
Inshore	Puysegur	114	0	0	0	-	1	0–4	0.46	0.00–3.51
Deepwater	East coast SI.	1 338	224	16.7	0	0.00	0	0–1	0.01	0.00–0.07
Deepwater	Cook Strait	168	4	2.4	0	0.00	0	0–1	0.03	0.00–0.60
Deepwater	Stewart-Snares	275	7	2.5	0	0.00	0	0–0	0.01	0.00–0.00
Deepwater	West coast NI.	331	114	34.4	0	0.00	0	0–0	0.00	0.00–0.00

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Table D-23: (*continued*)

		Tows	Observed				Est. captures		Est. capture rate	
			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	52–410	7.55	2.50–19.73
Hoki	West coast SI.	2 116	515	24.3	0	0.00	33	7–100	1.57	0.33–4.73
Hoki	East coast SI.	4 726	639	13.5	4	0.63	45	14–121	0.95	0.30–2.56
SBW	Bounty Islands	51	38	74.5	8	21.05	12	8–42	22.91	15.69–82.35
Middle depth	Cook Strait	740	2	0.3	0	0.00	23	2–84	3.05	0.27–11.35
Middle depth	East coast SI.	1 967	51	2.6	1	1.96	32	7–91	1.60	0.36–4.63
Squid	Stewart-Snares	2 925	705	24.1	6	0.85	23	10–46	0.77	0.34–1.57
Inshore	East coast SI.	5 519	26	0.5	0	0.00	21	1–85	0.38	0.02–1.54
Middle depth	West coast SI.	1 715	24	1.4	0	0.00	30	6–84	1.76	0.35–4.90
Hake	West coast SI.	1 069	160	15.0	4	2.50	17	6–44	1.61	0.56–4.12
Squid	East coast SI.	1 491	37	2.5	2	5.41	18	4–47	1.17	0.27–3.15
Middle depth	Stewart-Snares	1 316	142	10.8	2	1.41	13	4–33	1.00	0.30–2.51
SBW	Campbell Island	559	181	32.4	5	2.76	12	5–41	2.20	0.89–7.33
Hoki	Stewart-Snares	1 198	205	17.1	2	0.98	17	4–53	1.42	0.33–4.42
Inshore	Cook Strait	1 344	1	0.1	0	0.00	7	0–37	0.54	0.00–2.75
Ling	Stewart-Snares	640	122	19.1	11	9.02	23	12–58	3.60	1.88–9.06
Inshore	Stewart-Snares	1 780	0	0	0	-	7	0–36	0.40	0.00–2.02
Jack mackerel	West coast NI.	2 136	585	27.4	1	0.17	5	1–13	0.23	0.05–0.61
Ling	Puysegur	207	18	8.7	1	5.56	7	1–38	3.30	0.48–18.36
Hoki	Puysegur	24	3	12.5	0	0.00	1	0–5	2.52	0.00–20.83
Inshore	West coast SI.	2 960	57	1.9	0	0.00	5	0–25	0.18	0.00–0.84
Squid	Auckland Islands	1 318	537	40.7	0	0.00	1	0–6	0.10	0.00–0.46
Inshore	West coast NI.	5 661	81	1.4	0	0.00	3	0–14	0.06	0.00–0.25
Ling	East coast SI.	228	0	0	0	-	4	0–23	1.92	0.00–10.09
Deepwater	Subantarctic	1 218	821	67.4	2	0.24	3	2–6	0.21	0.16–0.49
Jack mackerel	West coast SI.	432	183	42.4	1	0.55	5	1–21	1.23	0.23–4.86
Middle depth	West coast NI.	712	54	7.6	0	0.00	2	0–7	0.26	0.00–0.98
Squid	Puysegur	19	2	10.5	0	0.00	0	0–2	1.36	0.00–10.53
Middle depth	Subantarctic	18	10	55.6	0	0.00	0	0–2	1.26	0.00–11.11
Scampi	East coast SI.	1 989	107	5.4	0	0.00	4	0–16	0.19	0.00–0.80
Scampi	Auckland Islands	1 329	95	7.1	0	0.00	3	0–13	0.21	0.00–0.98
Ling	West coast SI.	80	0	0	0	-	2	0–10	2.51	0.00–12.50
Squid	Subantarctic	109	0	0	0	-	1	0–7	1.12	0.00–6.42
Jack mackerel	East coast SI.	110	17	15.5	0	0.00	2	0–18	2.09	0.00–16.36
Hake	East coast SI.	229	72	31.4	0	0.00	1	0–4	0.26	0.00–1.75
Scampi	Cook Strait	78	17	21.8	0	0.00	0	0–3	0.48	0.00–3.85
Middle depth	Puysegur	97	20	20.6	0	0.00	1	0–5	0.81	0.00–5.15
Hake	Stewart-Snares	166	55	33.1	0	0.00	1	0–4	0.42	0.00–2.41
Ling	Subantarctic	51	0	0	0	-	2	0–15	3.84	0.00–29.41
Hoki	Auckland Islands	11	5	45.5	0	0.00	0	0–0	0.23	0.00–0.00
Jack mackerel	Stewart-Snares	22	0	0	0	-	0	0–2	1.28	0.00–9.09
Deepwater	Bounty Islands	222	118	53.2	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	0.38	0.00–3.85
Inshore	Puysegur	36	4	11.1	0	0.00	0	0–1	0.31	0.00–2.78
Deepwater	East coast SI.	748	92	12.3	0	0.00	0	0–1	0.00	0.00–0.13
Deepwater	Cook Strait	163	4	2.5	0	0.00	0	0–0	0.02	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-23: (*continued*)

		Tows	Observed				Est. captures		Est. capture rate	
			No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2007–08										
Hoki	Cook Strait	1 845	201	10.9	24	11.94	195	64–491	10.59	3.47–26.62
Hoki	West coast SI.	1 390	463	33.3	23	4.97	45	26–94	3.23	1.87–6.76
Hoki	East coast SI.	4 156	696	16.7	7	1.01	61	20–160	1.47	0.48–3.85
SBW	Bounty Islands	200	98	49.0	17	17.35	80	17–446	40.10	8.50–223.01
Middle depth	Cook Strait	599	7	1.2	0	0.00	33	4–124	5.55	0.67–20.71
Middle depth	East coast SI.	1 882	154	8.2	6	3.90	45	16–109	2.39	0.85–5.79
Squid	Stewart-Snares	2 412	861	35.7	6	0.70	21	9–51	0.88	0.37–2.11
Inshore	East coast SI.	3 777	8	0.2	0	0.00	21	1–94	0.56	0.03–2.49
Middle depth	West coast SI.	1 348	72	5.3	3	4.17	36	9–100	2.64	0.67–7.42
Hake	West coast SI.	1 070	319	29.8	25	7.84	46	28–91	4.29	2.62–8.50
Squid	East coast SI.	539	0	0	0	-	10	1–34	1.80	0.19–6.31
Middle depth	Stewart-Snares	1 013	81	8.0	0	0.00	19	3–62	1.88	0.30–6.12
SBW	Campbell Island	559	230	41.1	7	3.04	16	7–60	2.90	1.25–10.73
Hoki	Stewart-Snares	758	332	43.8	3	0.90	7	3–21	0.93	0.40–2.77
Inshore	Cook Strait	1 108	0	0	0	-	9	0–43	0.83	0.00–3.88
Ling	Stewart-Snares	691	134	19.4	3	2.24	12	3–35	1.75	0.43–5.07
Inshore	Stewart-Snares	1 319	0	0	0	-	10	0–49	0.75	0.00–3.71
Jack mackerel	West coast NI.	2 192	716	32.7	1	0.14	8	2–23	0.38	0.09–1.05
Ling	Puysegur	217	13	6.0	0	0.00	4	0–20	1.87	0.00–9.22
Hoki	Puysegur	10	0	0	0	-	0	0–2	1.77	0.00–20.00
Inshore	West coast SI.	2 562	14	0.5	0	0.00	8	0–33	0.30	0.00–1.29
Squid	Auckland Islands	1 265	589	46.6	0	0.00	3	0–11	0.21	0.00–0.87
Inshore	West coast NI.	6 025	53	0.9	0	0.00	6	0–25	0.09	0.00–0.41
Ling	East coast SI.	250	3	1.2	0	0.00	13	0–63	5.38	0.00–25.20
Deepwater	Subantarctic	1 684	832	49.4	4	0.48	7	4–15	0.39	0.24–0.89
Jack mackerel	West coast SI.	263	76	28.9	6	7.89	13	6–38	4.84	2.28–14.45
Middle depth	West coast NI.	968	22	2.3	0	0.00	4	0–15	0.45	0.00–1.55
Squid	Puysegur	15	0	0	0	-	0	0–2	0.94	0.00–13.33
Middle depth	Subantarctic	21	11	52.4	0	0.00	1	0–13	5.70	0.00–61.90
Scampi	East coast SI.	1 891	182	9.6	0	0.00	4	0–18	0.20	0.00–0.95
Scampi	Auckland Islands	1 327	93	7.0	1	1.08	6	1–23	0.45	0.08–1.73
Ling	West coast SI.	321	0	0	0	-	6	0–26	1.72	0.00–8.10
Squid	Subantarctic	2	2	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Jack mackerel	East coast SI.	169	14	8.3	0	0.00	10	0–73	6.03	0.00–43.20
Hake	East coast SI.	272	14	5.1	2	14.29	3	2–6	0.99	0.74–2.21
Scampi	Cook Strait	65	23	35.4	0	0.00	0	0–3	0.65	0.00–4.62
Middle depth	Puysegur	80	0	0	0	-	2	0–13	2.42	0.00–16.25
Hake	Stewart-Snares	157	49	31.2	1	2.04	1	1–5	0.95	0.64–3.18
Ling	Subantarctic	56	33	58.9	1	3.03	2	1–8	3.17	1.79–14.29
Hoki	Auckland Islands	191	124	64.9	1	0.81	1	1–4	0.69	0.52–2.09
Jack mackerel	Stewart-Snares	14	3	21.4	0	0.00	0	0–1	0.37	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	0–5	0.41	0.00–2.66
Ling	West coast NI.	64	0	0	0	-	1	0–5	1.47	0.00–7.81
Inshore	Puysegur	44	0	0	0	-	0	0–1	0.22	0.00–2.27
Deepwater	East coast SI.	1 062	281	26.5	0	0.00	0	0–1	0.01	0.00–0.09
Deepwater	Cook Strait	127	19	15.0	0	0.00	0	0–0	0.02	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-23: (*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	140	46–372	7.22	2.37–19.14
Hoki	West coast SI.	1 173	502	42.8	11	2.19	24	12–52	2.01	1.02–4.44
Hoki	East coast SI.	3 860	570	14.8	4	0.70	28	8–76	0.74	0.21–1.97
SBW	Bounty Islands	403	120	29.8	17	14.17	95	19–349	23.47	4.71–86.60
Middle depth	Cook Strait	841	4	0.5	0	0.00	48	4–198	5.74	0.48–23.54
Middle depth	East coast SI.	2 081	236	11.3	1	0.42	34	9–91	1.65	0.43–4.37
Squid	Stewart-Snares	1 808	530	29.3	1	0.19	12	3–31	0.66	0.17–1.71
Inshore	East coast SI.	4 426	308	7.0	1	0.32	17	1–70	0.38	0.02–1.58
Middle depth	West coast SI.	995	38	3.8	0	0.00	17	2–56	1.67	0.20–5.63
Hake	West coast SI.	1 004	210	20.9	3	1.43	16	4–48	1.64	0.40–4.78
Squid	East coast SI.	121	3	2.5	0	0.00	4	0–21	3.33	0.00–17.36
Middle depth	Stewart-Snares	1 003	251	25.0	0	0.00	8	0–27	0.76	0.00–2.69
SBW	Campbell Island	620	124	20.0	0	0.00	9	0–36	1.46	0.00–5.81
Hoki	Stewart-Snares	808	299	37.0	3	1.00	9	3–25	1.12	0.37–3.09
Inshore	Cook Strait	1 264	0	0	0	-	9	0–41	0.71	0.00–3.24
Ling	Stewart-Snares	377	73	19.4	0	0.00	4	0–18	0.95	0.00–4.77
Inshore	Stewart-Snares	1 532	84	5.5	1	1.19	6	1–26	0.41	0.07–1.70
Jack mackerel	West coast NI.	1 817	696	38.3	4	0.57	8	4–17	0.44	0.22–0.94
Ling	Puysegur	166	0	0	0	-	5	0–28	2.76	0.00–16.87
Hoki	Puysegur	8	0	0	0	-	0	0–4	4.61	0.00–50.00
Inshore	West coast SI.	2 807	292	10.4	0	0.00	5	0–22	0.19	0.00–0.78
Squid	Auckland Islands	1 925	761	39.5	0	0.00	5	0–17	0.24	0.00–0.88
Inshore	West coast NI.	5 846	183	3.1	0	0.00	3	0–16	0.06	0.00–0.27
Ling	East coast SI.	207	16	7.7	0	0.00	5	0–22	2.50	0.00–10.63
Deepwater	Subantarctic	1 219	417	34.2	0	0.00	3	0–13	0.21	0.00–1.07
Jack mackerel	West coast SI.	204	81	39.7	4	4.94	7	4–20	3.43	1.96–9.80
Middle depth	West coast NI.	767	70	9.1	0	0.00	2	0–7	0.24	0.00–0.91
Squid	Puysegur	4	1	25.0	0	0.00	0	0–2	3.93	0.00–50.00
Middle depth	Subantarctic	65	6	9.2	0	0.00	0	0–3	0.59	0.00–4.62
Scampi	East coast SI.	1 306	204	15.6	0	0.00	2	0–10	0.14	0.00–0.77
Scampi	Auckland Islands	1 457	61	4.2	1	1.64	4	1–15	0.27	0.07–1.03
Ling	West coast SI.	265	0	0	0	-	4	0–16	1.54	0.00–6.04
Squid	Subantarctic	1	0	0	0	-	0	0–0	0.73	0.00–0.00
Jack mackerel	East coast SI.	52	1	1.9	0	0.00	0	0–3	0.70	0.00–5.77
Hake	East coast SI.	470	61	13.0	2	3.28	4	2–18	0.91	0.43–3.83
Scampi	Cook Strait	29	2	6.9	0	0.00	0	0–1	0.49	0.00–3.45
Middle depth	Puysegur	59	41	69.5	0	0.00	0	0–2	0.28	0.00–3.39
Hake	Stewart-Snares	274	78	28.5	0	0.00	0	0–2	0.14	0.00–0.73
Ling	Subantarctic	43	7	16.3	0	0.00	0	0–3	0.87	0.00–6.98
Hoki	Auckland Islands	155	114	73.5	0	0.00	0	0–2	0.14	0.00–1.29
Jack mackerel	Stewart-Snares	81	35	43.2	0	0.00	0	0–1	0.16	0.00–1.23
Deepwater	Bounty Islands	243	95	39.1	0	0.00	0	0–1	0.05	0.00–0.41
Ling	Auckland Islands	88	46	52.3	0	0.00	0	0–0	0.03	0.00–0.00
Ling	West coast NI.	56	1	1.8	0	0.00	0	0–3	0.84	0.00–5.36
Inshore	Puysegur	11	0	0	0	-	0	0–1	0.51	0.00–9.09
Deepwater	East coast SI.	744	233	31.3	0	0.00	0	0–1	0.00	0.00–0.13
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	167	70.8	0	0.00	0	0–0	0.00	0.00–0.00

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Table D-23: (*continued*)

		Tows	Observed				Est. captures		Est. capture rate	
			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	103	35–273	6.33	2.15–16.74
Hoki	West coast SI.	2 097	658	31.4	4	0.61	29	9–72	1.37	0.43–3.43
Hoki	East coast SI.	4 369	617	14.1	7	1.13	29	12–63	0.67	0.27–1.44
SBW	Bounty Islands	394	89	22.6	10	11.24	85	10–392	21.52	2.54–99.51
Middle depth	Cook Strait	1 020	76	7.5	0	0.00	36	3–155	3.55	0.29–15.20
Middle depth	East coast SI.	2 263	243	10.7	1	0.41	29	7–83	1.30	0.31–3.67
Squid	Stewart-Snares	2 259	760	33.6	8	1.05	24	12–54	1.08	0.53–2.39
Inshore	East coast SI.	5 079	271	5.3	0	0.00	15	0–66	0.30	0.00–1.30
Middle depth	West coast SI.	855	82	9.6	0	0.00	10	1–37	1.20	0.12–4.33
Hake	West coast SI.	546	135	24.7	3	2.22	10	3–30	1.86	0.55–5.49
Squid	East coast SI.	299	2	0.7	0	0.00	6	0–22	2.05	0.00–7.36
Middle depth	Stewart-Snares	887	241	27.2	4	1.66	11	4–32	1.24	0.45–3.61
SBW	Campbell Island	535	226	42.2	2	0.88	6	2–22	1.13	0.37–4.11
Hoki	Stewart-Snares	1 238	433	35.0	2	0.46	11	2–34	0.88	0.16–2.75
Inshore	Cook Strait	1 585	0	0	0	-	8	0–39	0.51	0.00–2.46
Ling	Stewart-Snares	295	128	43.4	3	2.34	6	3–21	2.16	1.02–7.12
Inshore	Stewart-Snares	1 685	68	4.0	0	0.00	6	0–30	0.36	0.00–1.78
Jack mackerel	West coast NI.	2 213	710	32.1	2	0.28	4	2–9	0.18	0.09–0.41
Ling	Puysegur	124	6	4.8	0	0.00	4	0–30	3.59	0.00–24.21
Hoki	Puysegur	5	2	40.0	0	0.00	0	0–2	3.08	0.00–40.00
Inshore	West coast SI.	3 309	100	3.0	0	0.00	6	0–27	0.18	0.00–0.82
Squid	Auckland Islands	1 189	303	25.5	0	0.00	4	0–16	0.35	0.00–1.35
Inshore	West coast NI.	6 296	4	0.1	0	0.00	4	0–18	0.06	0.00–0.29
Ling	East coast SI.	225	37	16.4	3	8.11	9	3–38	3.86	1.33–16.90
Deepwater	Subantarctic	1 383	567	41.0	0	0.00	2	0–11	0.15	0.00–0.80
Jack mackerel	West coast SI.	63	26	41.3	0	0.00	1	0–4	1.11	0.00–6.35
Middle depth	West coast NI.	479	5	1.0	0	0.00	1	0–5	0.23	0.00–1.04
Squid	Puysegur	34	1	2.9	0	0.00	1	0–9	3.20	0.00–26.47
Middle depth	Subantarctic	42	10	23.8	0	0.00	0	0–3	0.75	0.00–7.14
Scampi	East coast SI.	1 446	106	7.3	1	0.94	3	1–12	0.23	0.07–0.83
Scampi	Auckland Islands	941	92	9.8	0	0.00	1	0–7	0.12	0.00–0.74
Ling	West coast SI.	283	9	3.2	0	0.00	2	0–10	0.83	0.00–3.53
Squid	Subantarctic	4	0	0	0	-	0	0–1	3.38	0.00–25.00
Jack mackerel	East coast SI.	52	17	32.7	0	0.00	0	0–3	0.69	0.00–5.77
Hake	East coast SI.	33	5	15.2	0	0.00	0	0–1	0.39	0.00–3.03
Scampi	Cook Strait	73	5	6.8	0	0.00	1	0–8	1.42	0.00–10.96
Middle depth	Puysegur	96	43	44.8	0	0.00	0	0–3	0.34	0.00–3.12
Hake	Stewart-Snares	226	187	82.7	1	0.53	1	1–2	0.50	0.44–0.88
Ling	Subantarctic	17	0	0	0	-	0	0–2	1.11	0.00–11.76
Hoki	Auckland Islands	62	3	4.8	0	0.00	0	0–3	0.62	0.00–4.84
Jack mackerel	Stewart-Snares	73	28	38.4	0	0.00	0	0–1	0.14	0.00–1.37
Deepwater	Bounty Islands	285	74	26.0	0	0.00	0	0–2	0.08	0.00–0.70
Ling	Auckland Islands	16	0	0	0	-	0	0–1	0.22	0.00–6.25
Ling	West coast NI.	15	0	0	0	-	0	0–1	0.74	0.00–6.67
Inshore	Puysegur	90	0	0	0	-	1	0–4	0.56	0.00–4.44
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-23: (*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	98	34–254	6.13	2.13–15.96
Hoki	West coast SI.	2 810	552	19.6	3	0.54	43	11–117	1.53	0.39–4.16
Hoki	East coast SI.	4 132	737	17.8	3	0.41	24	7–65	0.59	0.17–1.57
SBW	Bounty Islands	175	61	34.9	31	50.82	57	31–222	32.83	17.71–126.89
Middle depth	Cook Strait	1 106	26	2.4	0	0.00	32	4–119	2.92	0.36–10.76
Middle depth	East coast SI.	2 323	177	7.6	0	0.00	25	5–70	1.06	0.22–3.01
Squid	Stewart-Snares	2 174	683	31.4	7	1.02	17	9–33	0.77	0.41–1.52
Inshore	East coast SI.	4 702	0	0	0	-	13	0–55	0.28	0.00–1.17
Middle depth	West coast SI.	881	17	1.9	0	0.00	12	1–38	1.31	0.11–4.32
Hake	West coast SI.	684	127	18.6	0	0.00	9	0–30	1.32	0.00–4.39
Squid	East coast SI.	395	15	3.8	0	0.00	3	0–14	0.83	0.00–3.54
Middle depth	Stewart-Snares	772	147	19.0	2	1.36	9	2–26	1.18	0.26–3.37
SBW	Campbell Island	928	364	39.2	4	1.10	12	4–34	1.26	0.43–3.66
Hoki	Stewart-Snares	992	232	23.4	0	0.00	6	0–20	0.56	0.00–2.02
Inshore	Cook Strait	1 740	0	0	0	-	9	0–42	0.51	0.00–2.41
Ling	Stewart-Snares	265	92	34.7	2	2.17	4	2–12	1.36	0.75–4.53
Inshore	Stewart-Snares	1 596	0	0	0	-	4	0–20	0.26	0.00–1.25
Jack mackerel	West coast NI.	1 570	474	30.2	0	0.00	1	0–5	0.09	0.00–0.32
Ling	Puysegur	231	7	3.0	0	0.00	8	0–41	3.39	0.00–17.76
Hoki	Puysegur	76	1	1.3	0	0.00	1	0–7	1.06	0.00–9.21
Inshore	West coast SI.	3 345	4	0.1	0	0.00	7	0–29	0.20	0.00–0.87
Squid	Auckland Islands	1 585	543	34.3	1	0.18	4	1–11	0.23	0.06–0.69
Inshore	West coast NI.	6 435	74	1.1	0	0.00	4	0–18	0.06	0.00–0.28
Ling	East coast SI.	96	0	0	0	-	2	0–12	2.43	0.00–12.50
Deepwater	Subantarctic	767	293	38.2	0	0.00	2	0–12	0.28	0.00–1.56
Jack mackerel	West coast SI.	118	32	27.1	0	0.00	1	0–7	0.99	0.00–5.93
Middle depth	West coast NI.	513	0	0	0	-	1	0–6	0.27	0.00–1.17
Squid	Puysegur	57	16	28.1	0	0.00	0	0–3	0.82	0.00–5.26
Middle depth	Subantarctic	32	3	9.4	0	0.00	2	0–14	5.09	0.00–43.83
Scampi	East coast SI.	1 198	115	9.6	0	0.00	1	0–7	0.10	0.00–0.58
Scampi	Auckland Islands	1 401	205	14.6	0	0.00	2	0–11	0.17	0.00–0.79
Ling	West coast SI.	340	0	0	0	-	2	0–9	0.65	0.00–2.65
Squid	Subantarctic	2	0	0	0	-	0	0–1	3.04	0.00–50.00
Jack mackerel	East coast SI.	72	28	38.9	0	0.00	0	0–3	0.40	0.00–4.17
Hake	East coast SI.	57	6	10.5	1	16.67	2	1–11	3.51	1.75–19.30
Scampi	Cook Strait	27	2	7.4	0	0.00	1	0–7	2.25	0.00–25.93
Middle depth	Puysegur	63	31	49.2	0	0.00	1	0–5	1.19	0.00–7.94
Hake	Stewart-Snares	94	90	95.7	0	0.00	0	0–0	0.01	0.00–0.00
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	0	0–4	0.19	0.00–1.53
Jack mackerel	Stewart-Snares	118	59	50.0	0	0.00	0	0–2	0.16	0.00–1.69
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	0–0	0.17	0.00–0.00
Ling	West coast NI.	19	0	0	0	-	0	0–1	0.69	0.00–5.26
Inshore	Puysegur	146	0	0	0	-	0	0–3	0.31	0.00–2.05
Deepwater	East coast SI.	914	224	24.5	0	0.00	0	0–1	0.00	0.00–0.11
Deepwater	Cook Strait	94	30	31.9	0	0.00	0	0–0	0.01	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

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Table D-23: (*continued*)

			Observed				Est. captures		Est. capture rate	
		Tows	No. obs	% obs	Capt.	Rate	Mean	95% c.i.	Mean	95% c.i.
2011–12										
Hoki	Cook Strait	1 747	196	11.2	16	8.16	116	37–316	6.66	2.12–18.09
Hoki	West coast SI.	3 207	1 087	33.9	13	1.20	52	21–122	1.61	0.65–3.80
Hoki	East coast SI.	4 326	829	19.2	4	0.48	26	9–70	0.60	0.21–1.62
SBW	Bounty Islands	173	80	46.2	12	15.00	45	12–223	26.30	6.94–128.90
Middle depth	Cook Strait	868	7	0.8	0	0.00	25	2–110	2.92	0.23–12.67
Middle depth	East coast SI.	2 054	202	9.8	0	0.00	24	5–70	1.18	0.24–3.41
Squid	Stewart-Snares	1 983	799	40.3	6	0.75	15	7–33	0.78	0.35–1.66
Inshore	East coast SI.	4 078	2	0.0	0	0.00	13	0–58	0.33	0.00–1.42
Middle depth	West coast SI.	941	85	9.0	7	8.24	15	8–31	1.55	0.85–3.29
Hake	West coast SI.	505	85	16.8	1	1.18	8	1–23	1.52	0.20–4.56
Squid	East coast SI.	218	5	2.3	0	0.00	5	0–26	2.33	0.00–11.93
Middle depth	Stewart-Snares	824	243	29.5	1	0.41	10	1–40	1.25	0.12–4.86
SBW	Campbell Island	646	458	70.9	4	0.87	6	4–19	1.01	0.62–2.94
Hoki	Stewart-Snares	1 247	285	22.9	0	0.00	5	0–20	0.37	0.00–1.61
Inshore	Cook Strait	1 763	0	0	0	-	8	0–38	0.45	0.00–2.16
Ling	Stewart-Snares	242	89	36.8	1	1.12	4	1–18	1.52	0.41–7.44
Inshore	Stewart-Snares	1 627	3	0.2	0	0.00	6	0–29	0.38	0.00–1.78
Jack mackerel	West coast NI.	1 640	1 288	78.5	3	0.23	4	3–7	0.24	0.18–0.43
Ling	Puysegur	241	12	5.0	0	0.00	7	0–37	3.03	0.00–15.35
Hoki	Puysegur	98	49	50.0	0	0.00	1	0–10	1.03	0.00–10.20
Inshore	West coast SI.	3 256	35	1.1	0	0.00	7	0–33	0.22	0.00–1.01
Squid	Auckland Islands	1 283	570	44.4	2	0.35	4	2–9	0.29	0.16–0.70
Inshore	West coast NI.	6 942	39	0.6	0	0.00	5	0–22	0.07	0.00–0.32
Ling	East coast SI.	67	0	0	0	-	2	0–19	3.65	0.00–28.36
Deepwater	Subantarctic	563	196	34.8	0	0.00	2	0–10	0.29	0.00–1.78
Jack mackerel	West coast SI.	124	87	70.2	1	1.15	2	1–5	1.26	0.81–4.03
Middle depth	West coast NI.	517	17	3.3	0	0.00	1	0–5	0.21	0.00–0.97
Squid	Puysegur	19	1	5.3	0	0.00	0	0–3	1.35	0.00–15.79
Middle depth	Subantarctic	33	0	0	0	-	0	0–1	0.43	0.00–3.03
Scampi	East coast SI.	1 681	43	2.6	1	2.33	4	1–13	0.21	0.06–0.77
Scampi	Auckland Islands	1 244	119	9.6	0	0.00	3	0–13	0.22	0.00–1.05
Ling	West coast SI.	232	20	8.6	0	0.00	2	0–7	0.78	0.00–3.02
Squid	Subantarctic	2	2	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Jack mackerel	East coast SI.	120	66	55.0	0	0.00	1	0–12	1.24	0.00–10.00
Hake	East coast SI.	1	1	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Scampi	Cook Strait	51	21	41.2	0	0.00	1	0–8	1.76	0.00–15.69
Middle depth	Puysegur	39	28	71.8	0	0.00	0	0–1	0.10	0.00–2.56
Hake	Stewart-Snares	139	139	100.0	0	0.00	0	0–0	0.00	0.00–0.00
Ling	Subantarctic	13	0	0	0	-	0	0–1	0.44	0.00–7.69
Hoki	Auckland Islands	21	5	23.8	0	0.00	0	0–1	0.25	0.00–4.76
Jack mackerel	Stewart-Snares	143	103	72.0	1	0.97	1	1–3	0.83	0.70–2.10
Deepwater	Bounty Islands	51	20	39.2	0	0.00	0	0–1	0.07	0.00–1.96
Ling	Auckland Islands	19	13	68.4	0	0.00	0	0–0	0.08	0.00–0.00
Ling	West coast NI.	19	2	10.5	0	0.00	0	0–2	1.04	0.00–10.53
Inshore	Puysegur	54	0	0	0	-	0	0–1	0.21	0.00–1.85
Deepwater	East coast SI.	835	111	13.3	0	0.00	0	0–1	0.00	0.00–0.12
Deepwater	Cook Strait	83	8	9.6	0	0.00	0	0–0	0.01	0.00–0.00
Deepwater	Stewart-Snares	118	22	18.6	0	0.00	0	0–0	0.00	0.00–0.00
Deepwater	West coast NI.	270	138	51.1	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-24: 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, $1/\theta$	2.550	2.457	0.997	4.697
Vessel/year effect standard deviation	0.538	0.544	0.185	0.886
1995–96 base rate (captures per 100 tows)	1.061	0.990	0.483	2.056
1996–97 base rate (captures per 100 tows)	1.992	1.916	1.058	3.451
1997–98 base rate (captures per 100 tows)	1.645	1.532	0.700	3.194
1998–99 base rate (captures per 100 tows)	1.422	1.286	0.470	3.208
1999–00 base rate (captures per 100 tows)	3.183	2.978	1.546	5.935
2000–01 base rate (captures per 100 tows)	4.628	4.495	2.605	7.393
2001–02 base rate (captures per 100 tows)	1.820	1.729	0.898	3.276
2002–03 base rate (captures per 100 tows)	1.169	1.094	0.516	2.289
2003–04 base rate (captures per 100 tows)	2.564	2.469	1.339	4.427
2004–05 base rate (captures per 100 tows)	1.964	1.850	0.858	3.739
2005–06 base rate (captures per 100 tows)	1.466	1.387	0.636	2.722
2006–07 base rate (captures per 100 tows)	1.497	1.404	0.599	2.973
2007–08 base rate (captures per 100 tows)	1.186	1.084	0.418	2.515
2008–09 base rate (captures per 100 tows)	0.554	0.496	0.143	1.291
2009–10 base rate (captures per 100 tows)	1.394	1.242	0.386	3.254
2010–11 base rate (captures per 100 tows)	0.471	0.390	0.056	1.332
2011–12 base rate (captures per 100 tows)	0.196	0.164	0.024	0.548
Tow duration	0.632	0.631	0.308	0.972
Distance to colony	-0.616	-0.617	-1.066	-0.161
Subarea, relative to north and east area	0.435	0.428	0.294	0.613
SLED retention probability	0.204	0.196	0.110	0.345
Split SLED retention probabilities				
Extra dispersion, $1/\theta$	2.560	2.425	1.124	4.916
Vessel/year effect standard deviation	0.545	0.548	0.193	0.876
1995–96 base rate (captures per 100 tows)	1.033	0.976	0.452	1.947
1996–97 base rate (captures per 100 tows)	1.678	1.613	0.905	2.821
1997–98 base rate (captures per 100 tows)	1.453	1.380	0.658	2.724
1998–99 base rate (captures per 100 tows)	1.326	1.231	0.489	2.704
1999–00 base rate (captures per 100 tows)	2.470	2.334	1.248	4.536
2000–01 base rate (captures per 100 tows)	3.604	3.471	1.919	6.055
2001–02 base rate (captures per 100 tows)	1.568	1.501	0.812	2.692
2002–03 base rate (captures per 100 tows)	1.112	1.055	0.509	2.014
2003–04 base rate (captures per 100 tows)	2.204	2.115	1.193	3.691
2004–05 base rate (captures per 100 tows)	1.747	1.665	0.857	3.111
2005–06 base rate (captures per 100 tows)	1.404	1.348	0.665	2.456
2006–07 base rate (captures per 100 tows)	1.444	1.376	0.615	2.698
2007–08 base rate (captures per 100 tows)	1.374	1.284	0.470	2.777
2008–09 base rate (captures per 100 tows)	0.832	0.762	0.211	1.846
2009–10 base rate (captures per 100 tows)	1.541	1.413	0.476	3.348
2010–11 base rate (captures per 100 tows)	0.829	0.738	0.136	2.012
2011–12 base rate (captures per 100 tows)	0.860	0.763	0.136	2.078
Tow duration	0.608	0.606	0.286	0.943
Distance to colony	-0.638	-0.634	-1.093	-0.195
Subarea, relative to north and east area	0.445	0.438	0.303	0.630
Late SLED retention probability	0.139	0.092	0.012	0.598
Early SLED retention probability	0.187	0.180	0.100	0.314
SLED change, at end of this year	2006	2007	2005	2007