MINISTRY OF FISHERIES

Te Tautiaki i nga tini a Tangaroa

Incidental capture of *Phocarctos hookeri* (New Zealand sea lions) in New Zealand commercial fisheries, 2001–02

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NIWA
Private Bag 14901
Wellington

EXECUTIVE SUMMARY

This report addresses Specific Objective 1 of ENV2001/02: "to estimate and report the total numbers of captures, releases, and deaths of *Phocarctos hookeri* caught in fishing operations, including separate estimates for SQU 6T and other areas, as appropriate, during the 2001/02 fishing year, including confidence limits and an investigation of any statistical bias in the estimate."

Of the 28 vessels targeting squid (*Nototodarus* spp.) in SQU 6T during February–April 2002, 11 carried observers. Data from observed tows where no Sea Lion Exclusion Device (SLED) was used or a SLED was used with the cover net closed were used to estimate the total capture of New Zealand sea lions. This coverage represented 26% of the 1645 tows made in the season. Observers reported 22 New Zealand sea lion captures (all landed dead), but 2 of these were ignored in the analysis: one was dead before capture and another was caught on an unobserved tow. Of the 20 sea lions used in the analysis, 12 were females, 5 were males, and the sex of three was undetermined. Fourteen sea lions were caught in separate tows, and the remaining six sea lions were caught in two tows, with a maximum of four in one tow at the end of the season.

The 20 captures resulted in a seasonal mean catch rate of 0.047 sea lions per tow (s.e. = 0.013) and an estimated total of 74 New Zealand sea lion captures (deaths) (95% confidence intervals of 53–112, c.v. = 24%). The mean catch rate for 2002 was similar to that seen in recent years, other than 2001. There was no evidence of statistical bias in the estimate.

Two New Zealand sea lions were landed dead during observed tows in other fishery areas: one male from a squid trawl off the Stewart-Snares shelf in February 2002 and one (unsexed) from a southern blue whiting (*Micromesistius australis*) tow off Campbell Rise in September 2002; this latter record was the first reported capture of a sea lion from this fishery.

1. INTRODUCTION

Statutory obligations require the Ministry of Fisheries (MFish) to monitor the bycatch of associated or dependent species during commercial fishing operations in New Zealand waters. The Ministry of Fisheries Scientific Observer Programme collects data on the incidental catch of New Zealand (Hooker's) sea lions (*Phocarctos hookeri*) as part of its monitoring programme.

The southern squid (*Nototodarus sloanii*) trawl fishery is based off the Stewart-Snares shelf and around the Auckland Islands in SQU 6T in depths of about 150–300 m during January to May. The Total Allowable Commercial Catch for SQU 6T has been about 30 000 t since 1990–91. Annual reported catches peaked in 1993–94 and 1994–95 when at least 30 000 t were reported. Since then reported catches have declined and reached a low of 950 t in 1998–99 that resulted from reduced squid abundance and the early closure of the fishery as a management measure for New Zealand sea lions (Annala et al. 2003). Landings from this area totalled 11 502 t in 2001–02.

Breeding populations of New Zealand sea lions are located primarily in the Auckland Islands group, with smaller populations at Campbell Island. Breeding begins in late November when adult males establish territories. Males leave in February, but females stay on to suckle their pups and about 50% are foraging at sea at any one time. Pup production estimates in 2002 showed a 20% decline over the previous season and the mean population estimate (and 95% confidence intervals) for 2001–02 was 11 376 (9896–13 058) (I. Wilkinson, Department of Conservation, pers. comm.). In addition to a significant decline in pup production, pup mortality rates were three times the norm, at about 33% by mid February (I. Wilkinson, Department of Conservation, pers. comm.).

Proximity of the southern squid trawl fishery with the foraging grounds of the New Zealand sea lions has resulted in incidental catches of these marine mammals. Vessels operate under a code of practice designed to minimise marine mammal capture and are restricted to fishing outside a 12 n. mile zone around the Auckland Islands. In recent squid fishing seasons, mitigation devices known as Sea Lion Exclusion Devices (SLEDs) (Anon. 2002) have been used in the trawl nets as part of at-sea trials to test the effectiveness of the device in ejecting live sea lions. When a SLED is in place, the net has a cover net which provides a potential escape route for the animals when it is left open.

New Zealand sea lions are nearly always caught singly and are usually landed dead. A maximum allowable level of fishing related mortality (MALFiRM) for New Zealand sea lions has been in place since 1993. The observed capture of sea lions during the squid fishery season is monitored to provide weekly within-season estimates of the total capture of sea lions, based on Ministry of Fisheries observed captures and commercial tow data from the Seafood Industry Council (Doonan 2001). The fishery is closed if this within-season estimate nears the MALFiRM determined for that year, as happened in all seasons since 1996, except for the 1999 season.

As part of the operational plan to monitor the incidental capture of New Zealand sea lions in the 2002 squid fishery at SQU 6T, the Ministry of Fisheries and Department of Conservation set a MALFiRM of 79 sea lions (Anon. 2002). This plan stipulated the following.

- At least five vessels were to be observed (all without a SLED) to provide observer coverage of 20% of the total seasonal tows. Vessels were to be randomly selected from two groups, based on the use of bottom nets and midwater nets. This coverage would provide the catch rate of New Zealand sea lions for the fleet.
- Another five vessels were to conduct SLED trials, and any New Zealand sea lion captures from these vessels would be recorded against the MALFiRM.
- All other vessels were to fish with or without a SLED; if a SLED was used, the cover net had to be kept open.

2. METHODS

2.1 Data sources and treatment for 2001–02

Data used for the analyses undertaken to estimate the total numbers caught included observed New Zealand sea lion capture data, observed fishing effort data, and total fishing effort data. The observer data were extracted from the MFish *obs* and *obs_lfs* databases, and the commercial data were extracted from the MFish Trawl Catch and Effort database *warehou* based on Trawl Catch Effort and Processing Returns (TCEPR) completed by commercial fishers.

Data were extracted for the target fisheries in which incidental captures of New Zealand sea lions were recorded by MFish scientific observers during the fishing year (1 October–30 September) 2001–02 in the southern squid trawl fishery in SQU 6T and on the Stewart-Snares shelf, and in the southern blue whiting (*Micromesistius australis*) trawl fishery off the Campbell Rise in SBW 6I.

The following observer data were extracted by target species for each fishing operation: trip, tow (or set and number of hooks), gear type, latitude and longitude, date and time, vessel identifier and nationality, number of New Zealand sea lions, life status (alive or dead), handling code (released, discarded, or retained), and sex, as recorded by MFish observers. Data collected by the fishing industry for the within-season estimation (see Baird & Doonan 2002) were used to determine which tow used a SLED.

Under the Conservation Services Programme administered by the Department of Conservation, dead New Zealand sea lions from the squid SQU 6T fishery are returned for autopsy. The report from this work (Duignan et al. 2003) provided verification of species identification and sex of 83% of the captures reported by observers and was used to update the *obs_lfs* database.

The following total fishing effort data for each fishing operation were extracted: trip, event, target species, gear type, gear parameters, latitude and longitude, date, time, and vessel identifier and nationality. All data were error checked and erroneous data were amended where possible; for example, where position data of some fishing operations were identified as obvious outliers, the latitudes and longitudes were amended with reference to fishing operations before and after the incorrect data. Where the numbers of tows recorded in the TCEPR database were fewer than those in the observer database, as occurred in data for several individual vessels, the data for those observed tows that were missing from the TCEPR records were incorporated into the commercial data.

2.2 Data analysis

The extracted data were stratified by target fishery, gear type (where appropriate), area, and month for each target fishery area. In previous years, some estimators used for this work (for example, Baird 2001) have been used with caution due to the relative observer coverage. For example, where the sampling fraction (of observed effort over total effort) is low (for example, less than 10%), then extrapolation from the observed effort to that of the whole fleet in that stratum may be unwise, in that errors in the sample estimators will have a high leverage on the final total estimate for that stratum. Furthermore, if vessels show different marine mammal bycatch rates (and in some fisheries, some vessels have higher bycatch rates than others) then, where there are many vessels operating, the observer coverage needs to include several vessels — ideally in a representative way. Therefore, it was necessary to investigate the spread of observer and total effort data, by area, number of fishing operations, and number of vessels. Estimates of incidental capture rates, total estimates, and associated variance can be calculated only where there is confidence in the use of the bootstrap method.

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The mean bycatch rate of New Zealand sea lions per observed tow ($\bar{y}$) is estimated by the ratio-of-means estimator:

$$\bar{y} = \frac{\sum c_i}{\sum n_i}$$

where n_i is the number of observed tows, and c_i is the number of observed incidental captures of sea lions. Then the total catch of sea lions, $\hat{T}$, is estimated by

$$\hat{T} = N\bar{y} \qquad \text{with estimated variance} \qquad Var(\hat{T}) = N^2 s_b^2 (1 - n/N)$$

where N is the total number of tows and s_b^2 is the sample variance of the bycatch rate. These are standard results from finite sampling theory (Cochran 1977, Manly 1992). The variance of the observed bycatch rate was estimated by bootstrapping (randomly resampling the observed data 1000 times, after Efron & Tibshirani (1993)), and thus this estimate of variance takes into account the sample size.

The coefficient of variation (c.v.) is given by: $\qquad c.v. = \dfrac{\sqrt{Var(\hat{T})}}{\hat{T}}$

Any statistical bias in the estimate was investigated using a double bootstrap method with 1000 replications (after Efron & Tibshirani 1993). Confidence limits around the total estimate were determined using the method used by Doonan (2003) and given by Wendell & Schmee (2001), which is based on random sampling from a finite population and uses a hypergeometric distribution. Under such conditions it gives the exact bounds with the shortest length.

Given the two distinct areas of fishing activity in SQU 6T, one to the north of the Auckland Islands and one to the southeast, the data were divided at 50° 30' S to determine if there was any difference in catch rates between the two areas. Observer coverage and sea lion catch rates by gear type and nationality were also investigated.

3.   RESULTS

3.1   Incidental captures of New Zealand sea lions, 2001–02

Summary statistics are given in Table A1 in Appendix A. MFish observers reported 22 New Zealand sea lion captures from observed fishing operations:
- 20 were observed caught in squid trawls in the Auckland Islands part of SQU 6T (12 females, 5 males, and 3 of unknown sex); 1 female was reported from a tow that the observer did not observe and another female was observed caught but deemed to have been already dead when caught (MFish observer comments and Duignan et al. (2003)),
- 1 male was observed caught in a squid trawl off the Stewart-Snares shelf, and
- 1 sea lion (sex unknown) was observed caught during a southern blue whiting trawl off the Campbell Rise at the end of September 2002.

3.1.1 New Zealand sea lions and the southern squid trawl fishery in SQU 6T

3.1.1.1 Description of the fishery

Twenty-eight vessels participated in the southern squid trawl fishery in SQU 6T from February to April, with 1645 tows reported from this area between February and April 2002. Vessels from Korea (11) and New Zealand (3) completed more tows along the southeastern edge of the Auckland Islands Shelf than to the north of the Auckland Islands where 3 Japanese and 8 CIS vessels carried out most of their fishing. The effort of three Polish vessels was split relatively evenly between the two areas.

Sea Lion Exclusion Devices (SLEDs) were used in this fishery on some vessels in accordance with the operational plan for the management of the SQU 6T fishery (Anon. 2002). Of the 564 observed tows in SQU 6T, 168 used no SLED, 120 used a SLED with the cover net open to allow any caught animals to escape, 255 used SLEDs with the cover net tied down, and, for the remaining 21 tows, the use of a SLED was unknown. Observed tows with no SLED and those with a SLED with the cover net tied down are used to estimate the sea lion capture rates, given that any caught animals may have had the potential to escape from tows that used a SLED, but had the cover net left open. Thus, a total of 423 tows are used as "observed", which represents about 26% observer coverage. The distribution of the start positions of observed tows, including those that captured New Zealand sea lions, is shown in Figure B1 in Appendix B.

Commonwealth of Independent States (CIS) vessels accounted for more than 50% of all tows, with another 15% each on Korean and New Zealand vessels, 14% on Polish vessels, and the remaining 4% on Japanese vessels. About 53% of observed tows were on 4 CIS vessels (5 observed trips), and the remainder of the observed effort was on 5 observed trips on 4 Korean vessels (20%), 1 trip on a Polish vessel (15%), and 2 trips on 2 Japanese vessels (12%). No New Zealand vessels had observer coverage. About 70% of all tows and 75% of observed tows used midwater nets.

Observed CIS vessels used midwater nets and fished mainly in waters north of the shelf edge, whereas most observed Korean bottom tows and Polish midwater tows were off the southeastern edge (Figure B2). Observed Japanese effort was in both areas, and one vessel used all bottom nets whereas the other alternated between midwater and bottom nets. Sixty percent of observed tows used SLEDs with the cover net tied down, and about 86% of these tows used midwater nets.

3.1.1.2 New Zealand sea lion incidental captures and estimates

MFish observers reported 22 New Zealand sea lion captures, all landed dead. One of these New Zealand sea lions was caught on an unobserved tow and another had been dead sometime. These two animals are not included in the discussions and analyses to follow.

Most incidents were of single captures, but one observed tow caught two sea lions and one caught four. Midwater tows accounted for 18 of the 20 observed captures, including the multiple captures. Tows with no SLEDs accounted for 13 of the captures. Eight of the 11 observed vessels reported captures, with a range of 1 to 8 sea lions per vessel. Observed CIS tows accounted for 14 sea lions, Korean tows caught 3 sea lions, Japanese tows caught 2 sea lions, and the Polish vessel caught 1. Of the 17 New Zealand sea lions for which autopsy reports were available, 12 were females and 5 were males.

Daily catch rates were higher at the start of the fishery and at the end when the two multiple captures resulted in the closure of the fishery because the within-season estimation indicated that the MALFiRM set for the season had been exceeded (Baird & Doonan 2002).

No differences were seen in the mean catch rates by nation, by area (north or south of 50° 30' S), by month, or by net type (Figure B3). Similarly there was no difference in the mean catch rates between tows with or without SLEDs. Differences between vessels with New Zealand sea lion catches were not obvious (Figure B4); however, there were large differences in the number of tows observed per vessel (and per trip). For the February-April season, based on observed tows without a SLED and those with a SLED and the cover net tied down, an estimated 74 New Zealand sea lions were caught (c.v. = 24%) (Table A1) with 95% confidence limits (after Wendell & Schmee 2001) of 53 and 112.

An initial investigation indicated no obvious bias in the estimator: the use of a bootstrap loop procedure resulted in a bias estimate of 0.00037, with 95% confidence limits of -0.00085 and 0.00081, which compared favourably with the distribution of the 1000 replications of the estimate (Figure B5). The ratio of the bias estimate to the standard error was 0.031; as a rule of thumb, bias of less than 0.25 standard errors can be ignored (Efron & Tibshirani 1993).

3.1.2 New Zealand sea lions and the southern squid trawl fishery off the Stewart-Snares shelf, 2001–02

Thirty-five vessels targeted squid in the southern squid trawl fishery in 2001–02. These vessels completed 3514 tows on the Stewart-Snares shelf, with effort concentrated during January-April 2002. These months accounted for 90% of the effort and vessels used bottom nets for 58% of these tows.

Observers were present on 12 vessels during January-April and covered 23% of the effort. During these months, most of the fishing effort was reported from the 12 Korean vessels (45% of all tows) and 8 CIS vessels (33%), with the remainder from 9 New Zealand vessels (10%), 3 Polish vessels (8%), and 3 Japanese vessels (4%). The observer coverage was concentrated on 5 CIS vessels (47% of all observed tows) and 4 Korean vessels (37%), with another 11% on 2 Japanese vessels and 5% on 1 Polish vessel. No New Zealand vessels were observed. The Polish and CIS vessels generally used midwater trawl nets, whereas the Japanese and Korean preferred bottom nets.

One male New Zealand sea lion was observed caught and landed dead off the southern edge of the Stewart-Snares shelf, in a midwater net in February 2002.

3.1.3 New Zealand sea lions and the southern blue whiting trawl fishery off the Campbell Rise, 2001–02

Vessels targeted southern blue whiting on the spawning grounds on the Campbell Rise (SBW 6I) during August-October 2002 (Baird 2003). Of the 18 vessels fishing in this season, 8 were CIS, 6 were Japanese, 3 were Polish, and the nationality of 1 vessel was unknown. Nearly 90% of all southern blue whiting effort was expended in SBW 6I, where CIS vessels accounted for 50% of all tows. Midwater nets were used on 98% of all tows.

Observers were placed on three CIS vessels, three Japanese vessels, and one Polish vessel. All 273 observed tows (which represented 33% of all effort) used midwater nets, and 63% of the observed effort was on CIS vessels. One New Zealand sea lion was observed caught and landed dead from a tow off the northeastern edge of the Campbell Rise. This is the first report of a New Zealand sea lion capture from this area. The animal was not returned for autopsy.

4. DISCUSSION

Estimates are provided here only for the incidental captures of New Zealand sea lions in the SQU 6T squid fishery in 2001–02 because catches in other fishery areas were too low.

Observed data for the SQU 6T fishery were restricted to those tows which had no SLED or used a SLED with the cover net closed, such that a captured New Zealand sea lion could not escape other than by swimming back out of the net. The use of a SLED or otherwise is not known for the rest of the fleet, though the operational plan for 2002 stated that only a selection of vessels would use a SLED with the cover net tied down for at-sea trials, and that other vessels would fish with a SLED and the cover net open or without a SLED.

The spatial coverage of the fleet was well represented by the spatial coverage of the observed tows off the northern edge of the shelf, but less so off the southeastern edge (see figure 2 in Doonan 2003) where New Zealand vessels (which were not observed) carried out 81% of their effort and represented about 31% of effort in these waters.

Analysis of an 11 year dataset of New Zealand sea lion captures in the SQU 6T trawl fishery (under MFish project ENV2000/02) indicated that, apart from year (season), the major factor in explaining the variance in the estimates was the distance between the start position of the tow and the position of the nearest rookery (M. H. Smith, NIWA, pers. comm.). These data show that for 2002 the distribution of the observed tows relative to the distance from the rookery was similar to that for the whole fleet.

The within-season estimate for 2002 was 84 sea lions with 95% confidence intervals of 59 and 119 (Baird & Doonan 2002); this estimate was based on 22 captures and compares favourably with that presented here (74 sea lions (with 95% confidence intervals of 53–112)).

5. ACKNOWLEDGMENTS

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Appendix A: Summary of New Zealand sea lion data for 2001–02

Table A1: Summary of New Zealand sea lion capture data for 2001–02. Note that point estimates are given for the two target fishery areas for which one sea lion was reported.

Fishery	Total no. tows	No. observed tows	% tows observed	No. sea lions observed caught	Mean bycatch rate	Standard error	Estimated number caught	c.v. (%)
Squid trawl fisheries								
SQU 6T	1 645	423	26	20	0.047	0.013	78	24
STEW	3 160	735	23	1	0.001	–	–	–
Southern blue whiting trawl fishery								
SBW 6I	833	273	33	1	0.004	–	–	–

* STEW is the Stewart-Snares shelf and SBW 6I is the Campbell Rise fishery area for southern blue whiting (see Annala et al. 2003 for area).

Appendix B: SQU 6T squid trawl fishery, 2002

Table B1: Fishing effort, observed effort, and mean bycatch rates (numbers of sea lions per tow) for the southern squid trawl fishery in SQU 6T where observed tows are those with no SLED or with a SLED and the cover net tied down, 2002.

Month	Total no. tows	No. observed tows	% tows observed	No. sea lions observed caught	Mean bycatch rate	Standard error	Estimated number caught	c.v. (%)
February	535	121	23	5	0.041	0.017	22	37
March	737	188	26	4	0.021	0.011	16	44
April	373	114	31	11	0.097	0.043	36	37
Total	1 645	423	26	20	0.047	0.013	78	24

Table B2: Fishing effort, observed effort, and mean bycatch rates (numbers of sea lions per tow) for the southern squid trawl fishery in SQU 6T, 1993–2002. Note that slightly different estimation methods were used prior to the 1998 season.

Year*	Total no. tows	% tows observed	No. observed caught	Mean bycatch rate	Standard error	Estimated no. caught	c.v. (%)
1993	666	29	5	0.020	–	17 (7–36)	–
1994	4 660	9	3	0.007	–	32 (8–91)	–
1995	3 999	7	8	0.029	–	109 (41–191)	–
1996	4 450	12	13	0.023	–	101 (47–155)	–
1997	3 710	20	29	0.037	–	124	18
1998	1 413	24	15	0.045	0.010	63	22
1999	395	40	5	0.032	0.010	12	33
2000	1 206	36	25	0.058	0.010	70	17
2001†	580	51	33	0.111	0.020	64	12
2002	1 645	26	20	0.047	0.013	74	24

* Mean bycatch rates and total estimates (with 95% confidence intervals) for 1993 are from Baird (1996); note that three sea lion captures in the scampi fishery around the Auckland Islands were added to the 1993 estimate. Mean bycatch rates and total estimates (with 95% confidence intervals) for 1994–96 are from Baird (1997). Data for 1997 are from Doonan (pers. comm.). Data for 1998–2001 are from Baird (1999, 2001, 2004) and Baird & Doonan (2002).

† Observed data given here are for the section of the fleet that used SLEDs with the cover net tied down, during January-April.
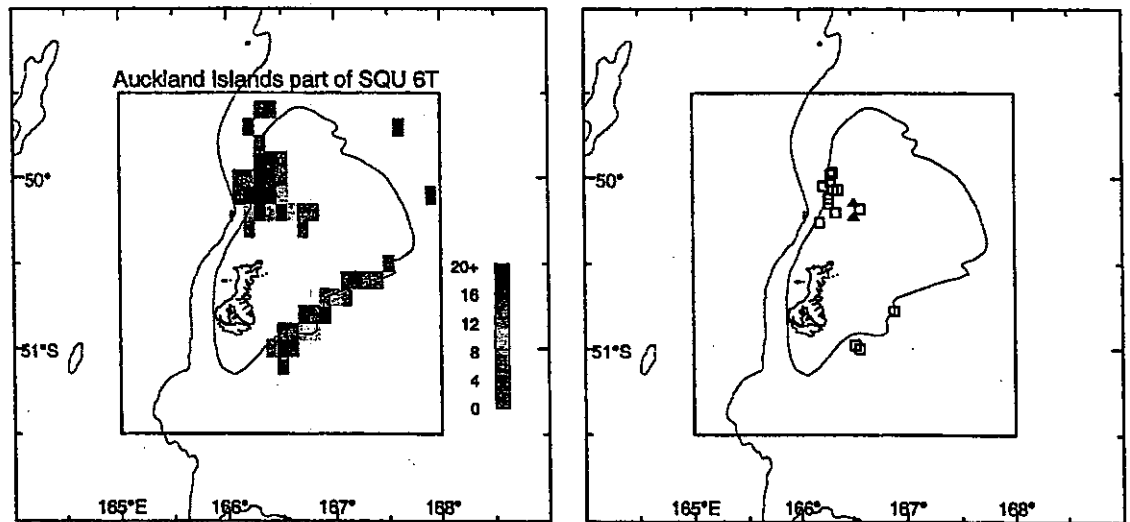
Figure B1: Distribution and density of squid trawling effort (number of tows in 0.1 degree cells), based on start of tow positions (left), and start positions of tows with single catches of New Zealand sea lion (□) and multiple catches (▲) (right), for the Auckland Islands part of SQU 6T, 2002.
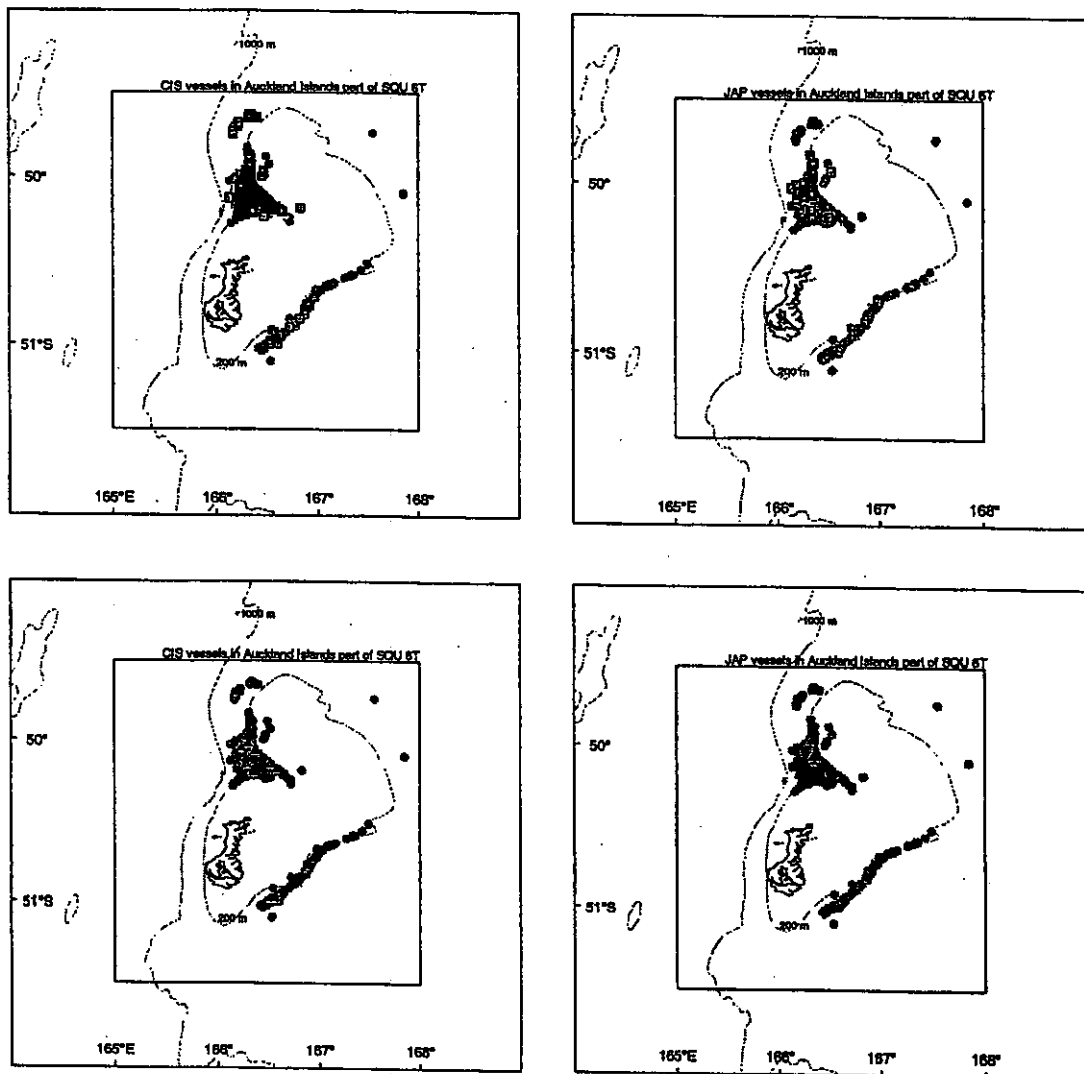
Figure B2: Start positions of observed tows used to calculate New Zealand sea lion catch rates (•), where upper plots show positions of midwater nets (□) and bottom nets (+), and lower plots show observed tows that caught sea lions (▲), by nation for the SQU 6T 2002 season.
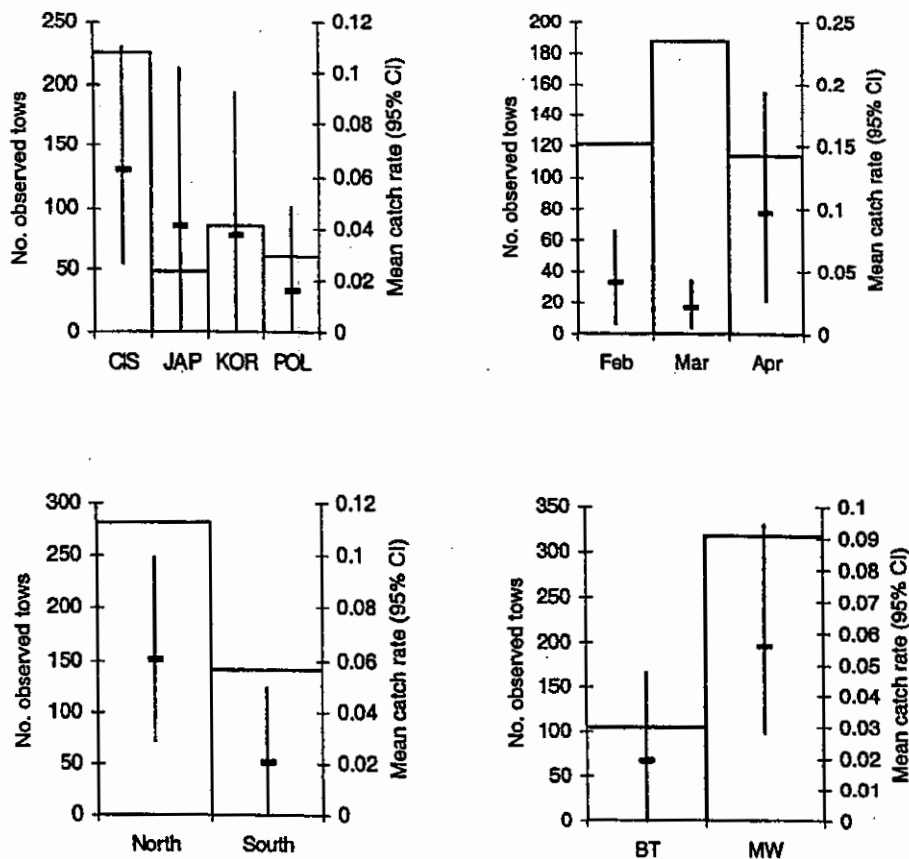
Figure B2 — continued.

Figure B3: Observed effort and mean catch rates (number of New Zealand sea lions per tow ± 95% confidence intervals) by nation (where CIS is Commonwealth of Independent States, JAP is Japan, KOR is Korea, POL is Poland), month, area, and net type (BT is bottom trawl and MW is midwater trawl) for the SQU 6T squid trawl fishery, 2002.
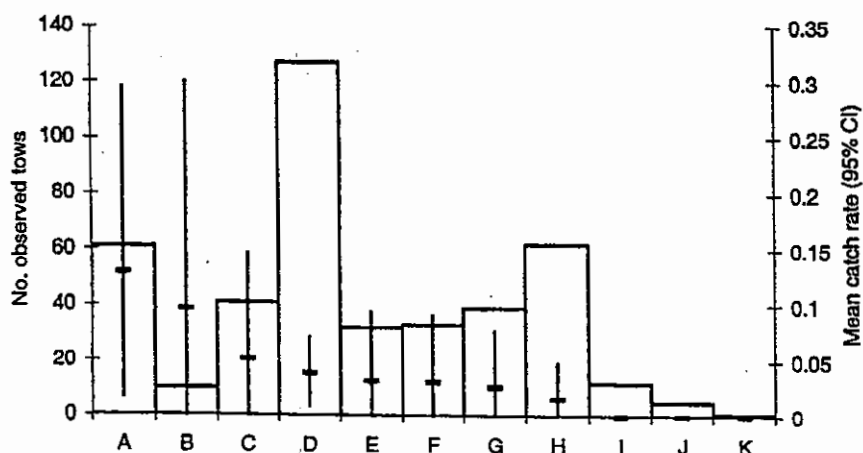

Figure B4: Observed effort and mean catch rates (number of New Zealand sea lions per tow ± 95% confidence intervals) for observed vessels in SQU 6T, February–April 2002.
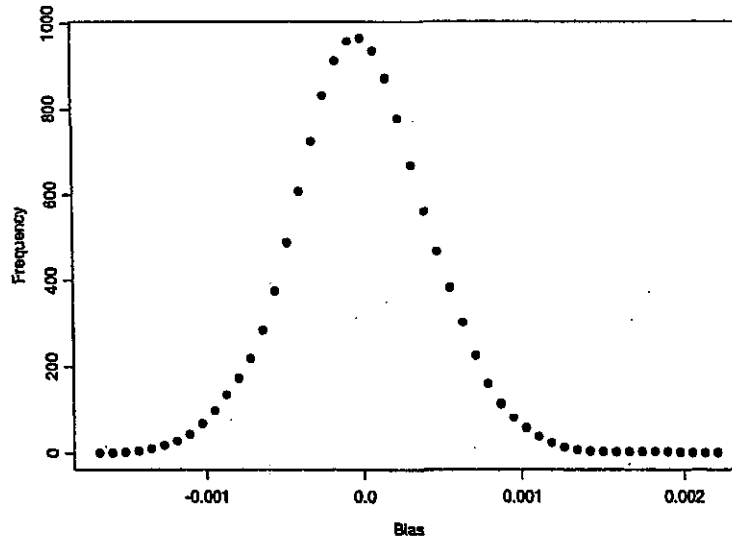
Appendix B — *continued*

Figure B5: Plot of the 1000 bootstrap replications of the mean catch rate of New Zealand sea lions in the SQU 6T squid fishery. The bias estimate was 0.00037, with 95% confidence intervals of –0.00085, 0.00081.