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I. J. Doonan

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I. J. Doonan

NIWA
PO Box 14 901
Wellington

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EXECUTIVE SUMMARY

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This report summarises the methods used and results given to the Ministry of Fisheries (MFish) as part of Objective 2 of Project ENV1999/01: *To provide weekly within season estimates of total captures, releases, and deaths by sex and area for New Zealand (Hooker's) sea lions taken in the southern squid trawl fishery beginning two (2) weeks after the start of the 1999/2000 fishery until 30 May 2000. Estimates of the confidence intervals and coefficient of variation of the point estimates must also be provided.*

The squid season in SQU 6T started in February and was closed in early March 2000. Six in-season reports were provided to MFish using data from MFish observers. In-season estimates of total kills were estimated from the fraction of observed tows that caught Hooker's sea lions times the total number of tows. The data were collected on a weekly basis by companies and collated by the Seafood Industry Council (SeaFIC). The final in-season estimate of total kills of Hooker's sea lions in the squid management area SQU 6T was 71 with a *c.v.* of 16% and a 95% confidence limits of 45–96 (31 female, *c.v.* = 24%, 95% confidence limits of 14–48). For SQU 1T, as of 8 March, there were an estimated 3 kills (*c.v.* = 85%).

The SQU 6T strike rate (kills per 100 tows) reported by MFish observers was 6.0 (*c.v.* = 16%) which was up substantially on previous years (maximum 4.4 in 1998), but in line with an increasing trend in the strike rate since 1993 (statistically significant at the 5% level). Reasons for the increasing trend are unknown. In comparison, industry observers had a strike rate of 3.8 (*c.v.* 18%), up substantially on those for previous years.

A retrospective check of the in-season method in the last three squid seasons, 1997 to 1999, showed that the in-season method provides an adequate estimate. The check used the tow-by-tow records from TCEPR and observer logbooks from the squid season in SQU 6T.

Only observed captures of dead animals were reported, so no within season estimates of captures and releases are provided here.

1. INTRODUCTION

The squid season in the southern waters of New Zealand operates on the shelf around the Snares Islands and the Auckland Islands (Figure 1). The fishery runs from either January or February through to April or May. The depth distribution of trawls has a major peak at 170 m and a minor one at 420 m. An exclusion zone around the Auckland Islands (in SQU 6T) prevents fishing close to the primary breeding rookeries.

Breeding concentrates the adult sea lion population at the rookeries: this begins in late November when adult males establish territories. Males leave in February, but females stay on to suckle their pups. During suckling, about 50% of the females are foraging at sea.

The sea lion foraging area overlaps with squid fishing on the Auckland Islands Shelf and results in incidental captures of sea lions (*see* Figure 1). To restrict the impact on the population size of sea lions, the squid fishery is closed when the total number of sea lion deaths from incidental capture in squid trawls exceeds a level set before each squid season (currently 67). To monitor the total number of deaths, an estimate is made weekly during the season from observer data and company reports of total trawls all of which are collated by SEAFIC.

A new feature in the 2000 season was the trialling of marine mammal exclusion devices (MMED) on a large proportion of the fleet. Initially, the primary analysis estimated the total kills of Hooker's sea lions separately for vessels with MMEDs and for those vessels without MMEDs, i.e., two strike rates were estimated. However, part way through the season the primary analysis changed so that the influence of having a MMED was ignored, i.e., a common strike rate for all vessels was used (as requested by MFish).

This report summarises the method and results of the in-season estimation of the total number of deaths of Hooker's sea lions from squid trawling. Validation of the in-season method was carried out using the 1997 to 1999 tow-by-tow records collected for MFish. The tow-by-tow data for the 2000 season were not available at the time of writing, so data for previous years must be used instead.

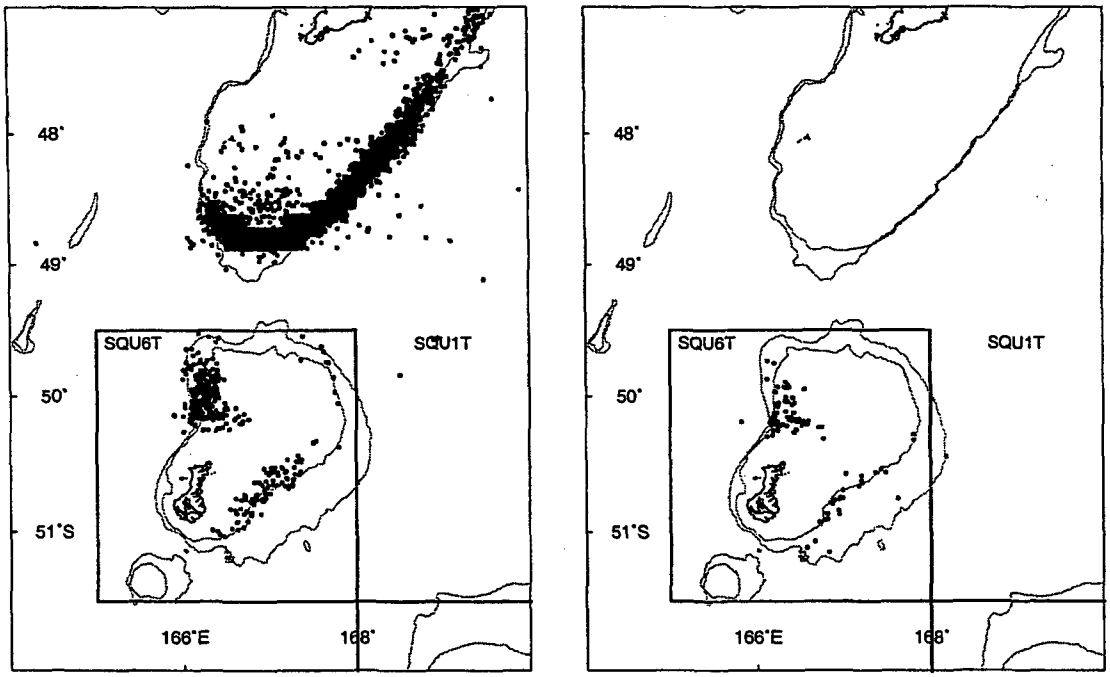

Figure 1: The trawl positions in the 1999 southern squid trawl fisheries (dots in left graph) and the positions that MFish observers have observed Hooker's sea lions caught in squid trawls since 1993 (dots in right graph). The depth contours (faded lines) are at 250 m and 500 m.

2. METHODS

2.1 Data

All vessels in the southern squid trawl fishery report daily captures of Hooker's sea lions to the SeaFIC weekly. The following attributes from the SeaFIC database were used to categorise the data:

- date
- area (SQU 1T or SQU 6T)
- used a MMED
- type of observer on board (none, MFish, industry, both)

For each category, the following data were collected:

- number of tows in a day
- number of tows that captured a sea lion
- number of sea lions captured and released alive
- number of sea lions captured and dead
- number of female sea lions captured and released alive
- number of female sea lions captured and dead

The Ministry of Fisheries receives the following information on the numbers of Hooker's sea lions captured in the southern squid trawl fishery:

- daily reports of captures from MFish scientific observers on board squid vessels
- daily reports of captures from vessels carrying industry observers.

This information was received on a weekly basis and compared with the SeaFIC data, where possible. The data were checked and converted into a form suitable for the in-season analysis.

Data for previous years were extracted from the following sources:

1. observed Hooker's sea lion capture data:
   EMPRESS database *obs_lfs* developed and administered by NIWA
2. observed fishing effort data:
   MFish Observer EMPRESS database *obs*
3. total fishing effort data
   MFish Trawl Catch and Effort database
   EMPRESS database *squid* developed and maintained by NIWA from Trawl Catch Effort Processing Return (TCEPR) records in the MFish Catch and Effort database

2.2 In-season calculations

At the end of each week t, three variables will be estimated for males and females separately and for each of the two observer types, MFish and industry:

- total captures (T_c)
- total number of Hooker's sea lions released (T_r)
- total number of Hooker's sea lions killed (T_k)

The method described below will be used to estimate these three variables. For example, to estimate the number killed using MFish observer data:

$$T_k = N_t p_{k,t}$$

where N_t is the total number of observed tows by MFish observers up to week t, and $p_{k,t}$ is the fraction of the tows in which Hooker's sea lions were killed, that is,

$$p_{k,t} = \frac{a_{k,t}}{m_t}$$

where m_t is the number of observed tows by MFish observers up to week t and a_k is the number of observed Hooker's sea lion deaths by MFish observers.

Random sampling, if this occurred at all, was in the choice of vessel to observe and when to observe it, not with individual tows. Thus, tows were observed in clusters, i.e., all tows for a vessel over some time period. This would not matter if consecutive tows were independent, and although this cannot be assumed automatically, it is assumed here because data are not available by tow or by clusters of tows. Thus, the sampling distribution was approximated by the binomial model. This was considered appropriate because generally only one Hooker's sea lion is caught in a single tow, but if any large serial correlations are present for consecutive tows, then the variance estimate will be biased. For positive correlations, the estimate is biased low, but it is biased high if the correlation is negative.

Thus, the coefficient of variation of T_k is given by:

$$c.v. = \sqrt{\frac{1-p_k}{mp_k}(1-\frac{m}{N})}$$

where the t suffix has been suppressed for clarity.

No formula can be expressed for the 95% confidence intervals, so these are estimated by a simulation procedure in which the true value of p_k is made equal to the estimated one. This procedure incorporates the effect of the sampling fraction (that is, the proportion of tows which are observed) and is equivalent to the $(1-\frac{m}{N})$ term in the *c.v.* formula. The simulation also incorporates the fact that a_k Hooker's sea lions have been observed by observers to be killed, so that the lower confidence limit cannot be lower than a_k. In general, this does not include those kills reported by non-observers (none in 1999).

The primary calculation uses MFish observer data and ignores whether a MMED was used or not. An alternative calculation can be made using MFish observer data, but as a two-part calculation, one for vessels which used a MMED and another for vessels without a MMED. These sub-totals are then added to get the grand total.

Weekly within season estimates were submitted to the Manager Science Policy within two working days of receipt of the within season Hooker's sea lion capture data from the SeaFIC.

2.3 Performance of the in-season estimate (SQU 6T)

In another objective of this project, Baird (2000) estimated the total kills for the 1999 squid season in SQU 6T from TCEPR and observer logbook data. These estimates are compared with the in-season estimates. Because of time delays in the loading of TCEPR and observer data into the databases, checking of the 2000 season was not possible at the time of writing this report. The logbook data are considered more accurate because logbooks are filled out at the time of each tow and give the position of the tow. Comparison of the total kills for the two data sources, logbook against company reports (which are verbal and are related to a day's activity), shows the accuracy of the in-season method. In theory, checks on species identification can be done on carcasses (both sea lions and seals) brought back to New Zealand for auditing. However, time lags in this work means that results are not available for the 1999 or 2000 data. Therefore, the species identification and the sex reported here are from the MFish observer records.

Doonan (1998, 1999) estimated the total tows and kills for the 1997 and 1998 season using the TCEPR and observed logbook data.

Another important aspect is the spatial coverage of the observed tows. This should be in the same proportions as that for the fleet in case there are spatial differences in strike rates in the area, e.g., the strike rate may be reduced when fishing takes place further away from the rookeries. This was investigated in a simple way by comparing the latitude profile of the positions of tows for the fleet in 1999 with that for MFish observed tow positions in 1999. The analysis used the same TCEPR and observer logbook data as used above. Similar plots for the 1997 and 1998 season were given by Doonan (1998, 1999).

3. RESULTS

3.1 In-season calculations

Six reports were made (Table 1); the first reported on data up to 6 February 2000 and the last on data up to 8 March. Note that in Table 1 the total reported kills was the same as that observed by MFish observers, but this does not mean that industry observers saw none

because both types of observers can be on board the same vessel at the same time. Industry observers reported a total of 18 sea lions in the season.

For SQU 6T, the total estimated number of kills of Hooker's sea lions was 71 (*c.v.* = 16%), of which 31 (*c.v.* = 24%) were female. The 95% confidence limits were 45–96 for all sea lions, and 14–48 for female sea lions. MFish observer coverage was 35.3 %. One capture (male) was reported for the Snares Islands part of the squid fishery (SQU1T), which scales up to an estimated total of three (*c.v.* 83%) as of 8 March.

Table 1: In-season calculations of kills of Hooker's sea lions over the 2000 squid season in SQU 6T from data collated by SeaFIC. "Observed" refers to MFish observers. Reported total kills' is the number reported to SeaFIC which includes kills observed by MFish and industry observers and those observed by vessel captains

Data to date	Observed kills	Observed tows	Total tows	Estimated total kills	Reported total kills
6 February	3	49	246	15	3
13 February	6	130	540	10	6
20 February	8	215	768	29	8
27 February	10	278	921	33	10
5 March	25	395	1 148	73	25
8 March	25	420	1 191	71	25

3.2 Comparison of MFish and industry observer strike rates

The strike rate reported by MFish observers in SQU 6T was 5.95 sea lions per 100 tows (*c.v.* = 16%). Industry observers (40% coverage) reported a strike rate of 3.79 (*c.v.* = 18%), which is 63.7% of that for MFish observers (Table 2).

Table 2: Reported strike rates of Hooker's sea lions (kills per 100 tows) for MFish (or MAF) observers and industry observers in SQU 6T during the squid season, and the ratio of strike rates, industry/MFish. Data are from SeaFIC collated reports Note that some data from each observer type overlap with each other where both types of observers were on the same vessel at the same time and observed the same sea lion

Year	MFish observers	Industry observers	Ratio (%)
1993	2.0	0.8	40
1994	0.7	0.4	57
1995	2.9	1.0	34
1996	2.3	0.9	39
1997	3.7	1.2	32
1998	4.4	0.5	10
1999	3.5	0.9	26
2000	6.0	3.8	64

Differences in strike rates were tested for statistical significance using a *t*-test, assuming that animal captures in a tow are binomially distributed so that the estimate of the strike rate has a normal distribution when sample sizes are large, as here. For 2000, the strike rates were not statistically significantly different at the 5% level.

For previous years, the strike rates were statistically significantly different at the 5% level for each of the years 1996 to 1998, but not significantly different for each of the years

1993–95 and 1999. Low MFish observer coverage in 1993–95 meant that the chance of detecting significant differences was low but combining the 1993–95 data does give a significant difference. Combining data assumes that the strike rate was the same over these years.

3.3 Performance of the in-season method

For the 1997 to 1999 squid seasons in SQU 6T, the in-season monitoring gave similar results to that using the TCEPR and observer logbook data (Table 3).

Table 3: The squid fishery in SQU 6T, 1997–99: comparison of total tows and estimated total kills from two sources, in-season (i.e., SeaFIC) and logbook (i.e., TCEPR and observer logbook data). "Observer" refers to MFish observers

	Year	In-season	Logbook	Difference (% of logbook)
Estimated kills	1997	125	124	-1
	1998	62	62	0
	1999	14	13	-8
Total number of tows	1997	3585	3326	-8
	1998	1394	1412	1
	1999	392	395	1

The distribution of observed tows with latitude showed some differences from that for the fleet (Figure 2), but these differences are not major given the relatively low number of tows in the 1999 season. Thus, at this crude level, the observed data approximately covered the area in the same proportion as the fleet data and so there should be no overt bias in the estimated strike rate.

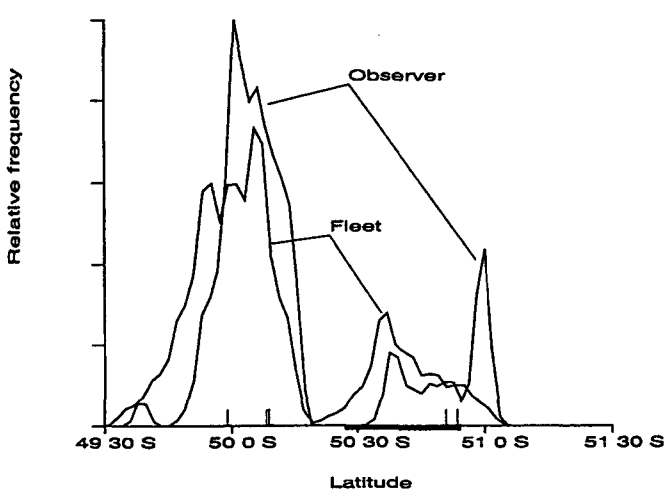

Figure 2: Check of observed tows over the fleet's tow distribution for SQU 6T in the 1999 squid season (January to March), the latitude profile of MFish observed tows and the fleet's latitude profile. The profiles have been normalised so that the area under each is 1.0. Short arrows just above the x-axis show the latitude where sea lions (5) were observed by MFish observers to be caught. Solid bar shows the latitudinal extent of the Auckland Islands.

4. DISCUSSION

All indications are that the in-season method has worked well in the past and there is no apparent reason why this should not be so this year also. For the past three seasons, 1997–99, the in-season estimate of total kills has been different from that using the logbook data by, at most, one (Table 3). The total number of tows can be out by as much as 8%, but this is well within any *c.v.* for the kills estimate (Table 3). Although not shown, 8% errors have occurred twice for the number of observed tows: in 1997 (but cancelled out by an opposing 8% error in the total tows so that the estimate of total kills had a 1% error) and in 1999. At other times, the differences between data sources were within about 1%. The spatial distribution of SQU 6T observer coverage in the past three seasons has also been approximately the same as for the total fishery (Doonan, 1998, 1999). The latter is important because there are indications that strike rates decrease for increasing distances north of the Auckland Islands, so that uneven observer coverage may bias estimates of total kills.

The strike rate reported by MFish observers in SQU 6T for 2000 is the highest recorded (6 sea lions per 100 tows compared with the previous highest of 4.4 in 1998), but it is in line with the trend of increasing strike rates from 1993 to 1998 (*see* Table 2, Figure 3). The increase in strike rate with year was re-estimated using strike rates from 1993 to 2000. The estimate was an increase of 0.6 per 100 tows per year which is statistically significant (*t*-test at the 5% level). Why strike rates are increasing is unknown and investigating the cause needs further data (e.g., sightings of sea lions in the sea from fishing vessels) which is unlikely to be at hand for past years.

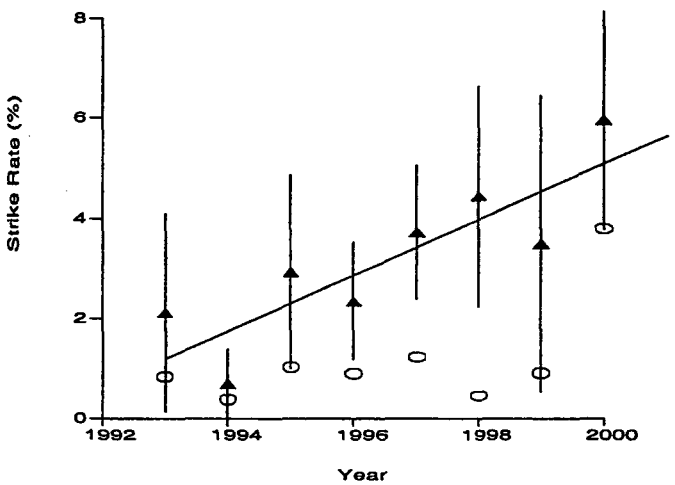

Figure 3: Strike rates (kills per 100 tows) against year for MFish observers (filled triangles) and industry observers (open circles) with the regression line for the 1993 to 2000 MFish observer data. Vertical lines are ± 2 standard errors for the MFish observer strike rates

The industry observer strike rate for 2000 is lower than that for MFish observers, but it is not statistically different. In previous years, the industry observer strike rates have been much lower than those reported by MFish observers (with the exception of reported strike rates in 1994) and in the earlier years industry observer strike rates were considered in the monitoring of the fishery.

5. ACKNOWLEDGMENTS

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6. REFFERENCES

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