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Incidental catch of Hooker's sea lion in the southern trawl fishery for squid, summer 1994

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress

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1. SUMMARY

A total of 32 (standard error, 18) Hooker's sea lions was estimated to have been killed by trawling during the 1994 southern fishery for squid from MAF Fisheries observer data (9% of the tows were observed). When company observer data (47% coverage) were used, the total was estimated at 17, with a standard error of 5. There are no statistically significant differences between these estimates.

The 1994 kill rate of Hooker's sea lions was not significantly different from previous years (1988–93) for MAF Fisheries observer data, but it was lower for the 1994 industry observer data.

The kill rate was estimated progressively through the season (in-season estimation) to monitor kills against the limit of 63 (31 female). This used the number of vessels in the area each day because the number of tows was unavailable in real time. These estimates were inaccurate because of the error in the estimate of vessel-days for MAF Fisheries observers.

Simulations showed that 10% observer coverage is inadequate for estimating the total number of Hooker's sea lions caught. If a simulated fishery is closed when the estimated number of kills reaches 63 and this estimate is based on a 10% coverage, then the true number of kills at closure varies widely. For example, with 126 potential kills in a full season of 4700 tows, the true number of kills at closure had a *c.v.* of 37%, an average of 68, with 95% in the range 28–126. For 50% observer coverage, the *c.v.* was 13%, the average 64, and 95% in the range 49–81.

2. INTRODUCTION

Hooker's sea lions feed on the Auckland Islands Shelf and breed mainly on the Auckland Islands. Males begin arriving at the breeding colonies in early November and females in late November. By late January, the sea lions start dispersing from the rookery sites (Cawthorn 1993).

Between January and May, a trawl fishery for squid operates on the shelves around the Snares and Auckland Islands, at depths of 150–250 m. On the Auckland Islands Shelf, Hooker's sea lions are accidentally caught in trawls. This area is defined as that between latitudes 49° 30'S and 51° 30'S, and between longitudes 165°E and 168°E and is about half the SQU6T squid area. A limit of 63 sea lions (31 female) can be caught in a season. This limit was set by agreement between the Minister of Conservation and the Minister of Fisheries.

This paper estimates the total number of kills of Hooker's sea lions from squid trawling on the Auckland Islands Shelf. Two data sources were used: MAF Fisheries observers and company observers. This report also gives the in-season estimates, which were necessary to monitor total number of kills through the season against the limit. This in-season calculation used vessel-days for fishing effort (i.e., the number of vessels in a day that were in the area) because the number of tows was not available in real time.

The kill per tow rate for 1994 was compared to that for previous years. No month or year differences have been seen in previous years.

Simulations were used to investigate the precision of observer coverage at 10% coverage (the value for MAF Fisheries observer coverage in 1994) and at 50% (the value for the company observer coverage).

3. DATA

3.1 Noon reports

Vessels reported their noon position to the Fisheries Control Centre (FCC). Some vessels also reported their number of tows in the Auckland Islands zone, but not all. Hence, only the number of vessels in the area each day (vessel-days) was available for the in-season calculations.

The number of Hooker's sea lions observed to be caught, the gender of each animal, and the position and time of capture were reported to the FCC (within 24 hours) by MAF Fisheries observers.

3.2 MAF Fisheries observer data

Vessels record various data for each tow, such as date, time, position, and catch on Total Catch Effort and Processing Record forms (TCEPR). Such data are available only well after a season has finished because of collecting and processing constraints. MAF Fisheries observers and paired observers (one MAF Fisheries observer and one company observer) also collected these data for tows that they observed (company observers did not collect these data).

Hooker's sea lion captures are recorded by MAF Fisheries observers on separate nonfish bycatch forms. Thus, the total number of tows, number of observed tows, and the number of Hooker's sea lions killed for each day can be determined.

3.3 Company observer data

Observer schemes are run privately by each fishing company. The Fishing Industry Board (FIB) collated weekly data from them during the season. For each day, these data gave the number of observed kills of Hooker's sea lions, the number of tows observed, and the total number of tows. Numbers of tows and captures observed by MAF Fisheries observers were also reported.

4. METHODS

4.1 Estimation of kills

The total number of kills was estimated by

$$X\frac{a}{m}$$

where X is the total effort (which is either the number of tows or, for the in-season calculations, vessel-days), m is the observed effort, and a is the number of observed kills. For the in-season calculation, the number of kills was re-estimated progressively through the season as new data came in.

An approximate variance, based on treating the observed tows as sampling by clusters, is given by

$$X^2\,\frac{1-f}{n\bar{m}^2}\;\frac{\sum_i(a_i - pa_i)^2}{n-1}$$

where f is the fraction of tows or vessel-days observed, n the number of observed clusters, a_i the kills, $p = \sum_i a_i / \sum_i m_i$, m_i the effort in the ith observed cluster, and $\bar{m}$ $= \sum_i m_i/n$ (section 3.12 in Cochran 1977).

Tows were observed in clusters, i.e., all tows for a vessel during a time period. Random sampling, if this occurred at all, is in the choice of vessel to observe and when to observe it, not with individual tows. This would not matter if consecutive tows were independent, but this cannot be assumed automatically. For an unbiased estimate of variance, the clusters need to be independent which strictly means using all tows in an observer's trip. However, this gives too few clusters, so 15 consecutive tows on the same vessel (the equivalent of about 5 day's tows) were used for the MAF Fisheries observer data. The company observer data were summarised over the fleet by day, not by vessel, so 5 consecutive days were used for clusters. Because correlations are likely to be strongest for tows that are closest in time and space, 5 days should be long enough to ensure statistical independence.

4.2 Kill rate by month and year

An ANOVA was performed on kill rates per tow with month and year categories. Kill rate was logit transformed with a correction made for integer data. The data on kills before 1994 are from Baird (1994, table 2), but with four kills excluded because they had no month recorded. These are MAF Fisheries observer data for 1988–93. For 1994, two data sets were used; one from MAF Fisheries observers and one from company observers.

4.3 Simulation model

Simulations were used to explore the performance of different levels of observer coverage at choosing the right time to close a fishery. A season was characterised by the number of potential kills and tows that could be done in a full season. When the estimated number of kills, calculated progressively through the season, reached 63, the fishery would be closed. This estimate varied about the true number, so if the true number of kills was less than 63, then the fishery would be closed early which would result in a loss of potential squid catch. Alternatively, if there were more than 63 true kills, then the fishery would be closed later than it should. To some, these extra kills constitute an unacceptable loss to the population of Hooker's sea lions.

Two sampling coverages were used, 10% and 50% (based on MAF Fisheries and company observer coverage for the summer of 1994). A full season was assumed to have 4700 tows (again, this is about the 1994 total). The potential kills for a full season were 31, 50, and 126. These represented seasons when only half the limit is caught, those which are close to the limit but still below it, and those which could catch twice the limit and so should close early. Each kill was allocated to a randomly chosen tow, but a tow could have no more than one kill. In squid trawling, there have been no reports of more than one animal caught in a tow.

5. RESULTS

5.1 Kills observed by MAF Fisheries observers

A difficulty with the data is that the three sources of MAF Fisheries observed kills (noon reports, nonfish bycatch forms, and company observer data) did not match. My best interpretation of the data is that there were three MAF Fisheries observed kills, two of which were female.

Noon reports were available during the season and were used for initial estimates of kills. In retrospect, they are best treated as strictly provisional. These reports covered 1/2/1994 to 30/4/1994, with three kills observed by MAF Fisheries observers (Table 1A), one male, one female, and another with unknown gender. Vessels reported a further five kills and the capture of another sea lion which may have survived.

However, the nonfish bycatch forms show only two Hooker's sea lions killed (Table 1B), one on 15/3/1994 with the same position given in Table 1A and another on 29/3/1994. The latter had a position that was the same as the second one reported on 29/3/1994 in Table 1A and was a female. Hence, the first entry for 29/3/1994 in Table 1A (time 1330) may be a duplicate as it is not recorded in Table 1B, and two kills on one day is unlikely given that there were only three for the full season. (Position or time can not be used because they hardly ever match.) On this date, paired observers were used and the company observer recorded only one kill (Table 1C). It seems safe to assume that there was only one MAF Fisheries observed kill on the 29/3/1994 and that it was a female, i.e., there were only two MAF Fisheries observed kills in the noon reports.

The company observers (Table 1C) also reported a kill on 14/2/1994 for a paired observer team and, although it was recorded in the noon reports on 15/2/1994, it was not marked as MAF Fisheries observed. Perhaps only the company observer saw this one and so it was not recorded by the MAF Fisheries observer. The tows this team observed are counted as MAF Fisheries observer data, so the kill should be included in the MAF Fisheries observed kills. Thus, there were three MAF Fisheries observed kills, of which two were females and one a male.

5.2 Estimates of total number of kills

For the in-season calculations, the progressive estimates of total kills to date through the season was inadequate (Figure 1) because there were only three kills in real time and each gave a vertical line (two occurred on the same day). The same poor representation occurs if the MAF observer kills are used instead. The true line would be a series of steps, which occur at the time of each kill, and flat between each jump, without any decrease between them. For scanty data, this will occur only if the observer coverage is constant through the whole season, which is not the case here. With eight observed kills, as in the company observer data, a better form is found. Hence, observing too few kills, which depends on a combination of observer coverage and the kill rate per tow, results in poor estimates through the season.

The in-season had a total of 1738 vessel-days of which 17.1% were observed (Table 2). The estimate of total kills for the season was 18, rounded to nearest integer. For female Hooker's sea lions only, the number killed in the season was 6, rounded to the nearest integer, but this would double if the animal with unknown gender was female.

In the MAF Fisheries observer data, 433 tows were observed from a total of 4660 (9.3% coverage, Table 3). Kills were estimated at 32, to the nearest integer, with a standard error of 18. The estimated number of females killed was 22 (standard error, 15).

For the 1994 summer season, the distribution of MAF observed tows by latitude was similar to that for the fleet on the Auckland Islands Shelf (Figure 2). A similar match occurs if this is done for each month.

The company observers reported eight kills of Hooker's sea lions and observed 47% of the 4397 tows (*see* Table 3). The total number of tows was about 5% lower than that reported in the logbooks (TCEPR data), but is close enough not to affect the estimate of total kills compared with error from sampling variation. The estimated total number of kills was 17, with a standard deviation of 5.

Table 1: Reported captures of Hooker's sea lions: their date, time, and position of capture; whether observed by at least one MAF Fisheries observer (Y) or not (N); gender (M=male, F=female) and life status. -, no data. Data from noon reports (A), MAF Fisheries observer nonfish bycatch forms (B), and from company observers (C). MAF=both MAF Fisheries observers, MIX= one MAF Fishery and one company observer, Company=two company observers

A

Date	Observed by MAF	Time	Latitude	Longitude	Sex	Status
15/2/1994	N	1210	50' 00'	166' 20'	F	Dead
21/2/1994	N	0805	50' 10'	166' 12'	M	Dead
27/2/1994	N	1210	50' 13'	166' 25'	-	Dead
15/3/1994	Y	1620	51' 02'	166' 13'	M	Dead
18/3/1994	N	2140	50' 16'	166' 06'	F	Dead
26/3/1994	N	2230	50' 46'	166' 55'	M	Dead
26/3/1994	N	2330	50' 11'	166' 10'	-	-
29/3/1994	Y	1330	50' 09'	166' 27'	F	Dead
29/3/1994	Y	1030	50' 13'	166' 10'	-	Dead

B

Date	Time	Latitude	Longitude	Sex	Status
15/3/1994	1620	51' 02'	166' 13'	M	Dead
29/3/1994	1030	50' 13'	166' 10'	F	Dead

C

	Number of kills observed	
Date	MIX	Company
14/2/1994	1	0
21/2/1994	0	1
27/2/1994	0	1
1/3/1994	0	1
18/3/1994	0	1
26/3/1994	0	1
27/3/1994	0	1
29/3/1994	1	0

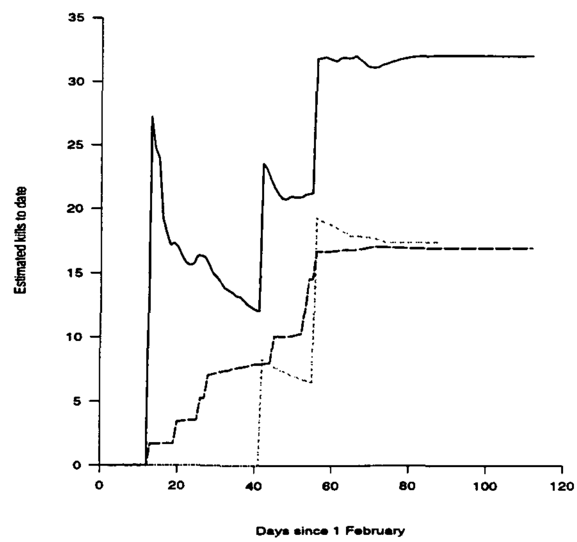

Figure 1: Progressive estimates through the season of total kills of Hooker's sea lions for the in-season calculation (faded line), MAF Fisheries observer data (solid line), and for company observer data (long-dashed line).

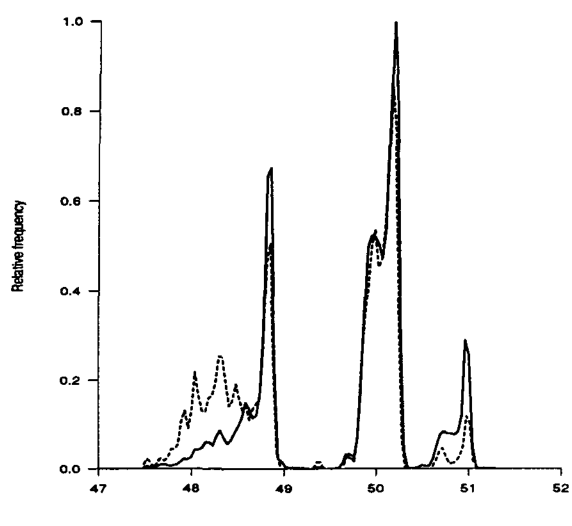

Figure 2: Frequency of latitude position for observed tows (dotted line) compared with that for the fleet (solid line). To the right of latitude 49°30' is the Auckland Islands Shelf; to the left is the Snares Islands shelf.

Table 2: Noon reports data for the 1993–94 season of the southern squid fishery: weekly total vessel-days for the fleet and for observed vessels (i.e., those with at least one MAF Fisheries observer), and MAF Fisheries observed kills of Hooker's sea lions. Date is for Sunday, the start of the week. Vessel-days taken from the weekly SQU 6T reports (1994 season) collated from noon reports by Bob Johnson, MAF Fisheries

Week starting	Vessel-days Fleet	Vessel-days Observed	Observed kills
30/1/1994	16	0	0
6/2/1994	131	3	0
13/2/1994	141	11	0
20/2/1994	186	21	0
27/2/1994	161	21	0
6/3/1994	239	38	0
13/3/1994	180	42	1
20/3/1994	152	42	0
27/3/1994	178	42	2
3/4/1994	169	40	0
10/4/1994	137	29	0
17/4/1994	45	9	0
24/4/1994	3	0	0
Totals	1 738	298	3

Table 3: **For area 6T, 1994, number of tows (TCEPR data), observed tows(%) and number of killed Hooker's sea lions (HSL) reported by MAF Fisheries observers. For company observers; number of tows, observed tows(%), and observed kills of Hooker's sea lions. - no data.**

	MAF observers			Company observers		
Month	Total tows	% tows observed	No. HSL	Total tows	% tows observed	No. HSL
January	0	-	0	0	-	0
February	1546	6	1	1509	57	3
March	2200	12	2	2092	42	5
April	914	9	0	793	43	0
May	4	0	0	3	0	0
Total	4664	9	3	4397	47	8

5.3 Comparison of the 1994 kill rate with that for past years

Before the 1993-94 season, kill rates showed no significant difference between month or year. This remained so when MAF Fisheries observer data for 1994 were added (Table 4A). However, the company observer data showed a significant difference in rates between years, which was caused by a lower rate for 1994.

5.4 Simulation results

For 31 kills in a full season (i.e., 31 kills if the season is not closed early), 10% observer coverage gave only a 2% chance of a closed season: there was no chance of a closed season with 50% coverage. Hence, at this low kill rate, falsely estimating that the limit of 63 has been reached is not likely.

However, when kills are close to the limit of 63, problems arise. For 50 kills in a full season, 10% coverage gave a 24% chance of early closure. There should be no closed season because the true number of kills is less than the limit. Further, there is even a small chance that a season will be closed with a loss of more than 40% of the tows for the season, or that the true number of kills is under half the limit (Figure 3 C and D). With 50% coverage, only 4% of the seasons were closed early. This reflects the difference in precision between 10% and 50% observer coverage.

The problem changes when kills for a full season are well above the limit, so that the fishery should be closed sometime during the season. For 126 kills in a full season, about half the seasons were closed early and the others late and this did not depend on the level of observer coverage; but the spread in the true numbers of kills at closure was

Table 4: ANOVA of Hooker's sea lion kills by year and month for January 1988 to May 1994, using MAF Fisheries observer data for 1994 (A) and again with company data for 1994 (B). Pr(F) is the probability level for the the F value.

	Source of variation	Degrees of freedom	Sum of squares	Mean square	F	Pr(F)
A	Year	6	8.92	1.49	2.24	0.09
	Month	4	5.65	1.41	2.13	0.12
	Residuals	18	11.95	0.66		
B	Year	6	17.26	2.88	4.09	0.01
	Month	4	5.60	1.40	1.99	0.14
	Residuals	18	12.66	0.70		

larger for 10% coverage (*c.v.* 37%, 95% between 28 and 126) than for 50% coverage (*c.v.* 13%, 95% between 49 and 81) (Figure 3A). On average, both have a little over 63 kills per season. A similar pattern applies to the tows lost or gained (which roughly relates to squid catch if one assumes a constant catch per tow) compared to the number done at exactly 63 true kills (Figure 3B).

6. DISCUSSION

6.1 Accuracy of in-season estimates

The in-season calculation for the total number of kills, 18, is clearly inaccurate as 32 was estimated from the MAF Fisheries observer data which is taken as definitive. The cause seems to be the inaccurate tabulation of vessel-days used in the in-season calculation, as repeating the in-season calculation gave 32 total kills when the observed vessel-days from the observer data were used instead of those from the FCC noon reports. I do not know why this discrepancy occurs.

The other discrepancy in the in-season estimation is the errors in the reported MAF Fisheries observed kills: the missed observed kill on 15/2/1994 (14/2/1994 in the company observer data) and the duplicated kill on 19/3/1994. These change the season's profile of the cumulative number of kills and increases the errors for timing a season closure, should there be one. The difference this makes is seen in the cumulative number of kills over the season for the in-season and MAF Fisheries observer data (*see* Figure 1).

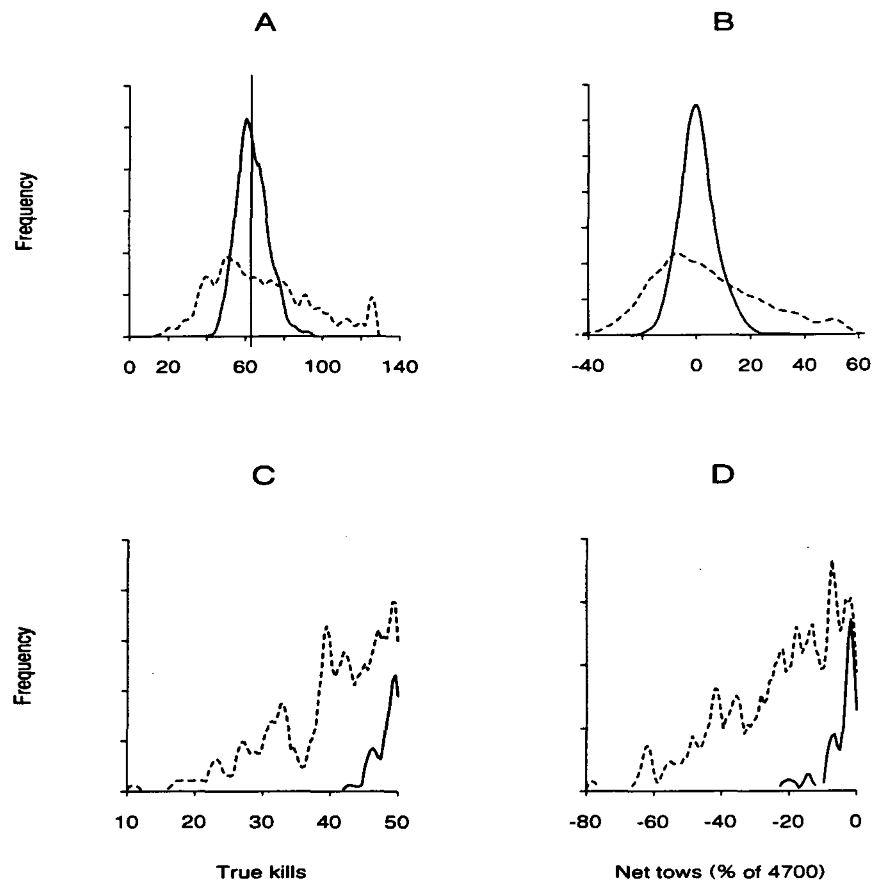

Figure 3: **Distribution of true number of kills of Hooker's sea lions and net tows when a simulated fishery is stopped at 63 estimated kills. Net tows of −20% means that the fishery was stopped before 63 true kills such that a further 20% of 4700 tows (the full season's total) could have been done if the fishery was stopped later at exactly 63 true kills. The solid lines are 10% observer coverage of tows and the dotted lines are 50% coverage. The simulations ran with 126 potential kills in a full season of 4700 tows, A and B, and with 50 potential kills, C and D. For C and D, most simulations went the full season with 50 kills and 4700 tows (76% for 10% coverage, 96% for 50% coverage), so for clarity, only the distributions of the closed seasons are shown.**

6.2 Comparison of MAF Fisheries and company observer estimates

The two estimates of total number of kills, 17 and 32, are not statistically significantly different. This reflects the imprecision of the estimate from the MAF fisheries observer data. For 10% coverage and 32 kills in a full season (i.e., MAF observer values), the simulation model gave a 95% range for the estimated number of kills of 0–70. Similarly, for the company observer values, the simulation model gave a 95% range of 8–25 kills, making 32 total kills unlikely. Hence, the best estimate is 17 total kills because this estimate is from data that had the higher observer coverage.

6.3 Observer coverage

The precision of estimates is not an academic exercise because for three of the past seven seasons for which there are data, the estimated total number of kills was greater than 63, i.e., in 1989, 1990, and 1992 (Baird 1994). Thus, the true number of kills may approach or be greater than the limit of 63 in some years, with closed seasons a possibility.

What observer coverage is needed depends on the precision wanted and the cost. A coverage of 10% is inadequate with a 37% *c.v.* for true kills at closure in a simulated fishery. For the 1994 season, 10% observer coverage gave a *c.v.* of about 50% in the estimated total number of kills. Naturally, more coverage gives greater precision (but at greater cost). At 50% coverage, the *c.v.* is about 13% for the number of true kills at closure in a simulated fishery.

However, high precision is not strictly needed in the long term if the effect of the extra kills over the limit on the population of Hooker's sea lions is cancelled out by an equal number below the limit in the next year. The risk in this is that balancing does not happen in consecutive years, e.g., there may be a run of years when the number of kills is over the limit. The wide range in numbers of true kills over the limit for late closures and the loss in potential squid catch for closures that are too early must also be accepted.

7. ACKNOWLEDGMENTS

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