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CENSUS AND POPULATION ESTIMATION OF HOOKER'S SEA LION AT THE AUCKLAND ISLANDS, DECEMBER 1992 - FEBRUARY 1993

by

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by
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ABSTRACT

A census of the populations of Hooker's sea lions *(Phocarctos hookeri)* at the principal rookeries in the Auckland Islands was taken between 11 December 1992 and 5 February 1993. Several methods of counting were used at all rookeries, and the most effective at each rookery was selected as the standard for future use. Pup production at Sandy Bay, Enderby Island, has remained stable at around 400 animals per year for the last 13 years. This season the error bounded estimate of pup population size is 408 with 95% Confidence Interval (C.I.) of 404-411. At Dundas Island, the principal rookery, counts in 1991-92 suggested a pup production of about 2000. This year only 3 visits were possible. The error bound estimate is 1804 with 95% C.I. 1613-1996. This is probably an underestimate. Aerial photographs were taken using a kite-borne camera. The efficacy of this method is demonstrated.

Statistical analysis and calculation of the error bound estimate of pups and the revised estimate of sea lion abundance was carried out by D.M. Gibson, MAF Fisheries, Wellington.

1. INTRODUCTION

The world population of Hooker's sea lion *(Phocarctos hookeri* Gray, 1844) occupies a triangular range extending from Cook Strait, south east to Campbell Island (52°33'S 169°09'E), south west to Macquarie Island (54°37'S 158°54'E) and is centred on the Auckland Islands (50°29'-50°59'S 165°52'-166°20'E) 248 nautical miles (460 km) south of New Zealand, where the three main breeding rookeries are located. These are at Dundas Island (50°34.6'S 166°19.2'E), where approximately 2000 pups are born annually; Enderby Island (50°30'S 166°18'E) approximately 400 pups per season; and Figure of Eight Island (50°45.8'S 166°01.4'E) where about 100 pups are born each season. Breeding also occurs at Campbell Island and, to a lesser extent, at the Snares Islands where fewer than ten pups are born annually. For this reason the Snares are not considered as a rookery area in the strict sense.

It is possible that the Hooker's sea lion population was never large when compared with other pinnipeds such as fur seals. Although skeletal remains of sea lions have been found at pre-European Maori archaeological sites in the South Island and on both coasts of the North Island as far north as Houhora, no historical evidence of breeding rookeries has yet been found in mainland New Zealand. The distribution of archaeological sea lion material is consistent with the current distribution and range of Hooker's sea lion.

Although Dundas Island, the principal rookery, is only 1.5 nautical miles (2.8 km) east and in the lee of Auckland Island, it is exposed to West Wind Drift generated oceanic swells reflected around the northern ends of Auckland and Enderby Islands. Dundas Island, which lacks fresh water, is surrounded by a coastal rock reef and shoal water (Plate 1). Strong currents (z 4 kts) set past the island on the ebb and flood tides. The combination of these factors with wind produces a very confused sea which can make landings hazardous. (Plate 1)

Enderby Island, 5 nautical miles (9.26 km) north of Dundas Island, in Port Ross, has a protected south shore with a 400 m long accessible sand beach, a tolerable climate and potable water. For these reasons, Enderby Island was chosen as the study site for this project. Observations have been carried out there since the 1979/80 season, as logistic support permitted (Plate 2).

Figure of Eight Island, at the head of Carnley Harbour, is about 35 nautical miles (64.8 km) distant from the two major northern rookeries. Although a small rookery has been known to exist on the island since the mid 19th century (Musgrave 1866) its distance from the study sites in the north mean landings there have been limited by the availability of logistic support.

During the 1991/92 season, the main rookery at Dundas Island was visited three times. During these visits it was discovered that the sea lion pup population was substantially larger than previously recorded. This increase did not reflect a sudden population boom, rather, the timing of the visits was more appropriate to the seasonal behaviour of the sea lions and the bulk of the population on Dundas Island was observed before females and pups began to disperse from the rookery.

The broad purpose of the field work this 1992/3 season was to verify the observations of 1991/2 and to revise the estimates of the total sea lion population.

2. SEASONAL CYCLE

Hooker's sea lion males land at the rookeries in November and establish territories which they defend vigorously throughout the breeding season (Plate 3). Pregnant females assemble at locations such as S.E. (Pebble) Point on Enderby Island in large numbers before moving onto the rookeries to pup. This movement usually occurs in the first two weeks of December and continues until about 25 December.

On landing at the rookery, females assemble into large groups or pods which initially occupy about 15-20% only of the total beach area (Plate 4). Females pup within 1-5 days of landing. Seven to ten days following pupping the females come into oestrus and are mated by the males.

The mean pupping date, that is the time by which about half the pups expected at any rookery will have been born, occurs around 25 December. Pupping and mating will continue through into the second week of January after which births tail off rapidly. All pupping has ceased by the third week in January. At that time, large territorial males have moved away from the rookery area, aggression amongst males has declined markedly and the rookery begins to break up as animals disperse.

About 10 days after birth, pups, which develop very quickly, begin to form pods on the margins of male territories. These pods serve several purposes: they keep all pups in groups easily located by females returning from sea; they increase the physical mass of pup groups, thereby making them more visible and less vulnerable to trampling by males; and, in cold weather they reduce the surface area to volume of pups allowing them to thermoregulate more effectively. Podding of pups tends to spread the population on the rookery such that groups of females move apart and the territories of incumbent beachmaster males become more wide-spread. In this way the animals in the rookery will gradually disperse along the beaches until up to 80% of the beach area will be occupied by breeding animals (Plate 5).

As breeding activity declines and beachmasters move away from the rookery, their place is taken by younger, socially-immature adult males which maintain territories around groups of females, but only rarely manage to mate.

From the second week in January, males begin leaving the rookery and occupy haulouts such as those at East Bay, Enderby Island, and Rose Island. These haulouts are, for the most part, used exclusively by males, except for small groups of non-breeding or post-parous females in transit to and from feeding grounds at sea. The presence of females at these haulouts is temporary only.

From the third week in January, females begin taking pups from the rookery area and leaving them at safe sites in the bush where they can be readily relocated when females return from feeding excursions at sea. At Enderby Island, females move their pups to locations up to 2 km from the rookery, often in very heavy scrub. At Dundas and Figure of Eight Islands, females move their young off the islands to Auckland Island as soon as the pups become competent swimmers.

Between February and October, females movements away from the Auckland Islands are constrained by the requirements of their pups. Males roam widely at sea feeding alone, or in small groups until they are ready to take up breeding territories once again.

3. PERSONNEL, LOGISTICS, AND SCHEDULE

The team working on this project was:

M.W. Cawthorn (Leader)	DoC, Wellington, New Zealand
R. M. Warneke	Victoria, Australia
P. Ensor	Lyttelton, New Zealand
D.M. Gibson	MAF Fisheries Wellington
S. Hay	DoC, Te Anau, New Zealand

Transport between New Zealand and the Auckland Islands was provided by MAF Fisheries (r.v. *Tangaroa),* Southern Heritage Tours Ltd. (m.v. *Pacific Ruby,* and the m.v. *Frontier Spirit.*

Personnel	Dep. Bluff	Vessel	Arr. Enderby	Dep. Enderby	Vessel	Arr. Bluff
Cawthorn	7 Dec. '92	*Tangaroa*	11 Dec. '92	5 Feb. '93	*Frontier Spirit*	7 Feb. '93
Warneke	7 Dec. '92	*Tangaroa*	11 Dec. '92	5 Feb. '93	*Frontier Spirit*	7 Feb. '93
Ensor	7 Dec. '92	*Tangaroa*	11 Dec. '92	5 Feb. '93	*Frontier Spirit*	7 Feb. '93
Gibson	16 Dec. '92	*Pacific Ruby*	18 Dec. '92	9 Jan. '93	*Pacific Ruby*	11 Jan. '93
Hay	7 Jan. '93	*Pacific Ruby*	9 Jan. '93	5 Feb. '93	*Frontier Spirit*	7 Feb. '93

At the Auckland Islands, passages between islands were made using two small boats supplied by DoC Southland. A 3.5 m Stabicraft was not suitable for use in choppy weather. The 4.5 m Savage "Gannet", with 15 hp outboard motor, proved to be an excellent, although underpowered, seaboat. Powered by a 20-25 hp outboard it would be an ideal craft for interisland work at the Auckland Islands.

4. OBJECTIVES

The objectives of this study were to make observations of Hooker's sea lions, along similar lines to those in previous seasons, to provide an updated census and estimate of the Hooker's sea lion population. The objectives agreed by DoC were:

1. Full and comprehensive censuses at major rookeries and minor rookery if logistic support permits.

2. Verification of census data by marking experiments, and on-site kite photography, weather permitting.

3. Revised population estimate of Hooker's sea lion, based on the above.

4. Marking of statistically valid number of animals at each rookery, including double marking.

5. At least 3 visits per month to Dundas Island rookery, weather permitting - at leader's discretion.

6. Examination of a variety of different indices to determine which has greatest statistical power to determine short and long term trends in pup production.

7. Development of standardised field techniques.

5. METHODS

5.1 Area and Period of Study

The team was based at Sandy Bay, Enderby Island. Observations there began on 12 December 1992 and continued until 4 February 1992.

Counts were not made at Sandy Bay rookery on the 29 December; 16, 17, 20, 21, and 23 January. On these days team members were either travelling to Auckland Island, weather bound, disrupted by the arrival of m.v. *Pacific Ruby* and DoC *Staff,* attempting mechanical repairs to generators, or were elsewhere on Enderby Island.

Three visits were made to Dundas Island on 25 December 1992, 2 January 1993 and 18 January 1993. After this date further visits were not possible because of poor weather conditions.

A single visit to conduct a census on Figure of Eight Island was made on our behalf by Rodney Russ, Rowley Taylor, and Steve Broni on 7 January 1993.

5.2 Daily routine

Three counting activities were undertaken throughout the season.

1. Daily counts at Sandy Bay (Enderby Island) rookery.
2. Two hourly counts at Sandy Bay to monitor in detail movement and distribution of animals across the beach.
3. Regular observations of sea lions at specific locations around the North and East coasts of Enderby Island.

Two hourly counts were conducted between 0800 and 2000 hours, weather permitting. Standard counts were made daily between 1300 and 1400 hours. Initially it was hoped to be able to check for the presence of sea lions at locations other than the Sandy Bay rookery every 2 days. However the schedule was such that this was done only twice each week. Priority was given to trips to Dundas Island when weather permitted, so other work was deferred on that day.

5.3 Counting methods

5.3.1 Single Total Count (STC)

Using the natural subdivisions of the beach and sward at Sandy Bay as a guide, a single continuous count of animals on the rookery was made from one end of the beach to the other. Males were counted first, then the process was repeated for females and pups.

5.3.2 Repeated Total Counts (RTC)

The procedure as for Single total counts, except that counts would be repeated no fewer than three times each for males, females, and pups as counters moved along the length of the rookery.

5.3.3 Triple Stratified Count (TSC)

Three creeks, flowing from the sward across the beach to the sea, divide the Sandy Bay rookery into 4 easily defined areas. Through the season, females and pups form dense pods and will move frequently, between pods and areas, especially if disturbed by males or bad weather. Normally, movement along the rookery is from east to west (Fig. 1).

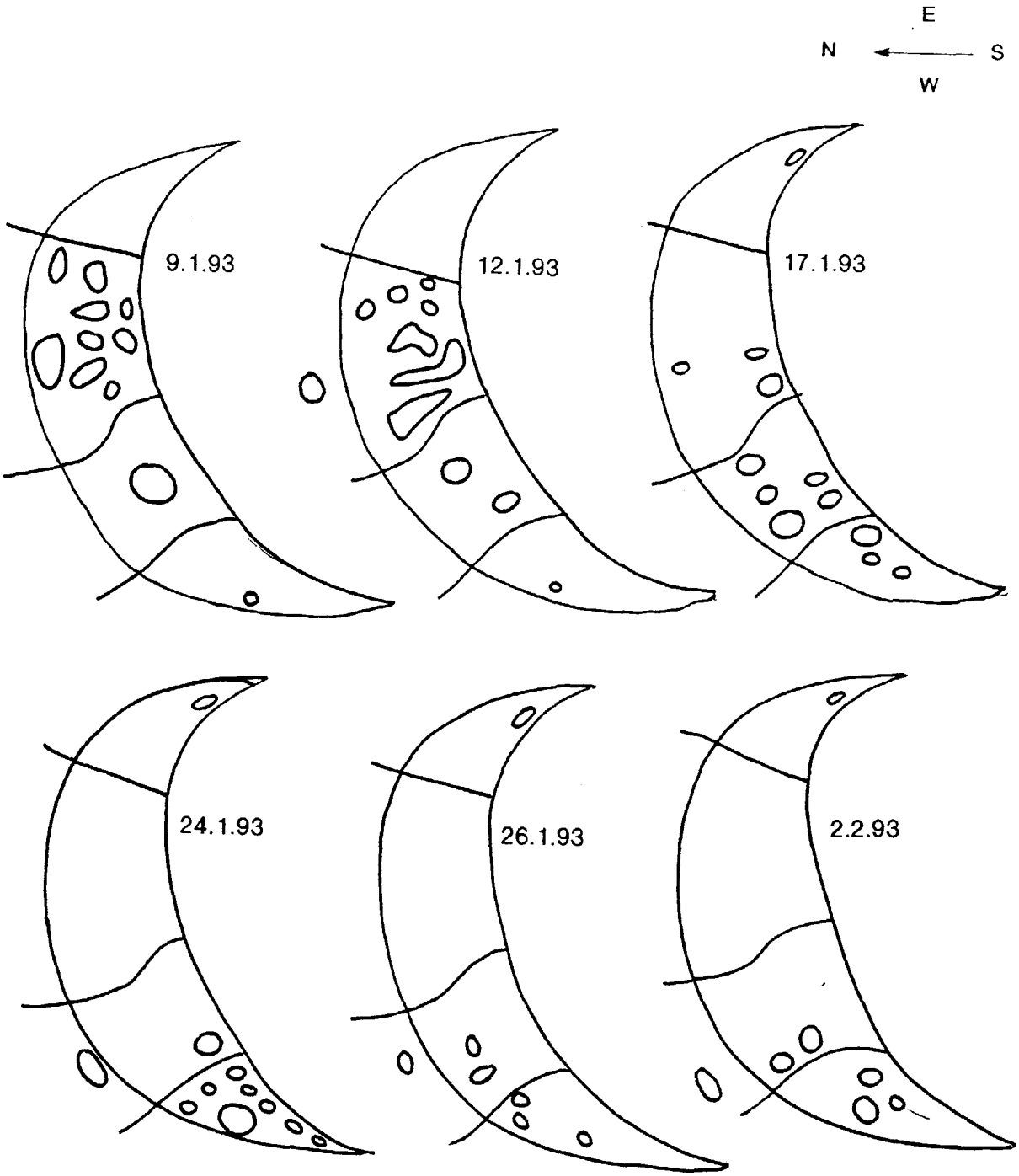

Figure 1. **Movement of female pods, Sandy Bay rookery, Enderby Island.**

To improve counting accuracy and reduce variation between counters, reference pegs were placed along the sward/beach margin. These marked beach transects which subdivided the areas of beach in which the bulk of the population was located into bands. Animals were then counted band by band within each area. A single count of males in each band was made. No fewer than three counts would then be made of females in each band, as the counter moved the length of the rookery. The same process was then repeated for pups.

5.3.4 Effect of podding

Podding - the grouping together, in close proximity, of females and pups - is a feature of Hooker's sea lion. It is usual if the air temperature is low, if rain is falling or if wind induces a wind-chill factor, lowering the temperature. This behaviour affects counting accuracy for, on occasions, pods of adult females may be two animals deep and in pup pods, up to three animals deep.

In fine weather with clear sky and sunshine, all sea lions on the rookery tend to spread out to keep cool. Thus counting accuracy is greatly improved in warm weather.

Of major importance to counting accuracy is the elevation of the counter above the beach. At Sandy Bay, the sward margin is about 3 m above the beach. This improved vantage point is sufficient to allow accurate counting over the 50 m, or so, between the sward edge and the sea. Accuracy is also enhanced by the use of binoculars, which allow visual separation of animals of the same colour in pods or close aggregations.

5.3.5 Recording method

This season, one counter recorded numbers directly onto paper as he worked along each band, while all others used mechanical hand-tallies or click-counters. Team members became used to one or other method to record count data, and persisted with that method for the duration of the census.

The use of click-counters was standardised between the three counters. Data from hand-tallies were recorded separately for males, females, and pups as each band was completed. This allowed the variation between individual counters to be determined in each band. The advantages from using the click-counters are:

1. The counter's visual continuity is not disrupted by having to record numbers during counts of large pods.
2. There are no errors of addition incorporated into the tallies.
3. The counter records the numbers "blind" and, therefore, is less influenced by previous counts, or tempted to round up figures.

The only perceived disadvantage in using mechanical counters is the possibility of mechanical malfunction in the field. However, this is something which can generally be rectified, if it occurs.

It is believed that the advantages gained using click-counters greatly outweigh the disadvantages and they should be used as standard procedure.

5.4 Marking method

A standardised marking method for sea lions was established in 1980, and has continued in use since. Allflex small sheep ear tags are applied to the upper posterior

margins of the fore flippers. All tags are coated with a wide spectrum antibiotic cream (Garramycin) before application.

Considerable care must be exercised when applying tags. The flippers of seals have an important function in facilitating heat transfer, they are highly vascularised and enervated. A group of blood vessels (cubital and ulnar veins and their branches) pass down the flipper posterior to the radius and ulnar bones. Near these are the ulnar nerves. Tags must be placed so the tag margin is level with the trailing edge of the flipper and 2-3 tag diameters below the axillary insertion of the flipper. The tag must be placed so it passes through the tissue at right angles to the flipper surface (Plate 6).

Mistagging will be manifested in any of four different ways:

1. The tag will pierce major blood vessels and heavy bleeding will occur.
2. The tag will damage a nerve, and the pup will extend its flipper with difficulty and be reluctant to place weight upon it when walking.
3. If the tag is placed too low down the flipper it will interfere with proper flexion and will impede walking.
4. If the tag is placed at the correct height, but too far anterior on the flipper, close to the ulnar bone, it will inevitably be angled and tear out of the flipper. This may lead to infection and possibly to permanent damage.

Using an Allflex "Retractomatic" tag applicator, tagging is rapid and atraumatic. Pups normally show no interest in the newly applied marks and continue with their activities as if nothing has happened.

5.5 Mark recapture

On 4 January 1993, while all pups born at Sandy Bay were still on the beach and had not yet ventured into the water, and before any other pups from other rookeries were known to have immigrated to Enderby Island, a sample of 150 pups was double marked with a tag in each foreflipper. These pups were released back into the population immediately after tagging. Double marked pups form the basis of mark recapture experiments and will also provide a measure of tag loss.

On 13 January 1993 counts were made using the subdivided census areas described above (see 5.3.3), and the proportion of the pup population in each band calculated. To reduce, as far as possible, the chance of repeat sightings of mobile pups moving from band to band during counts, a total of 20 minutes only was allocated for resighting experiments. A fixed number of resights were stratified by pup abundance in each band. A sample size of 310 was chosen to give 95% certainty of being within 5% of the true value.

Using Zeiss 10 x 80 binoculars, observers recorded tag numbers while moving in a box pattern (2-3 m lateral separation) through each band, between each visual transect.

Initial trials recorded marks as "Tagged Readable", "Tagged Unreadable" and "Untagged". These were confounded as soon as it rained. The tags became wet, and sand adhered to the tag face, obscuring the numbers. This system was abandoned, and a simple "Tagged" and "Untagged" system was employed.

For the Mark Recapture estimates (13-15 January 1993) the pups in the rookery were assumed to be a closed population fulfilling all criteria for a Petersen Estimate of the pup

be taken at regular intervals covering, at least, the area in which all pups are concentrated. This is particularly important at the Dundas Island rookery where approximately 83% of the breeding population of sea lions hauls-out during the season. Dundas Island has very low relief and observers may have difficulty getting a clear view of all pups and adult females on the beach.

5.6.1 Aerial photography

Aerial photography of seals has been used in censuses of seal colonies in many parts of the world. The technique is relatively straight forward. A camera equipped aircraft will make a number of passes over a rookery taking a series of overlapping high quality photographs which can be stereoscopically analysed.

D.M. Gibson chartered an aircraft from N.Z. Aerial Mapping Ltd, Hastings, to take a series of vertical aerial photographs of the rookeries at Enderby and Dundas Islands for an independent population assessment. The aircraft made three flights to the Auckland Islands on 7 January 1993, 11 January 1993, and 13 January 1993. On the first flight, the weather turned bad after the aircraft had arrived on site. The low cloud ceiling and rain over Dundas Island only permitted a series of oblique photographs to be taken. Verticals from the operational altitude of 2000 feet were aborted. On the 11 and 13 January the aircraft was able to complete its runs and, before departing, the pilot reported that good aerial photograph runs had been achieved. We were requested to collect "ground truth" census data coinciding with the flights. The photographs are being analysed by D.M. Gibson.

Photography of sub-antarctic sea lion rookeries in the Auckland Islands from fixed-wing aircraft is complicated by the distance from base, rapidly changing weather over the targets, and the need to verify numbers of animals photographed with ground truth counts.

5.6.2 Kite Photography

Because of the problems of using aircraft photography, kiteborne cameras have been tested. They were found to be a very cost-effective method of photographing breeding sea lions. There is also the advantage that ground teams can work "weather windows" in conditions which would preclude the use of aircraft. At the same time, ground teams can effectively collect large quantities of ancillary corroborative information.

The kites, chosen for manoeuvrability and efficiency, are parafoil designs. These are flown from two lines and, depending on wind strength, can be flown with great stability at any angle between about 90° and 45° from the operator. This allows the kites to be effectively steered over inaccessible parts of the rookery.

The automatic camera used is suspended from a yoke beneath the kite and hangs vertically irrespective of the kite angle. The camera is triggered by a radio signal from the ground. On completion of the operation, the kite and camera can be easily stored in a small backpack.

Two photographs were taken at Dundas Island on 25 December 1992 before extreme turbulence caused the unit to land heavily temporarily disabling the camera. Each photograph, taken from an altitude of approximately 80 m, covers an area of approximately 4600 m2 (Plates 7 and 8). Animals are easily discernible and counting is simple.

5.7 Dundas Island

The first priority at Dundas Island this season was to accurately count the population. Time constraints and weather conditions did not allow any tagging to be undertaken at that rookery this season. Three visits were made to the island on 25 December 1992, 2 January 1993, and 18 January 1993. Poor weather, fogs, and rough seas prohibited any further visits.

5.8 Figure of Eight Island

It was not possible for the team to travel the 35 nautical miles to Figure of Eight Island in Carnley Harbour. However Rodney Russ of Southern Heritage Tours, aboard m.v. *Pacific Ruby* offered to land at Figure of Eight and conduct a count on our behalf. At 1800 hours on 7 January 1993 Russ, Rowley Taylor, and Steve Broni landed on the island, and made two counts of pups and single counts of mature males, subadult males and females. The counts were as follows:

	(1 st count)	(2nd count)
Pups	67	60
Mature males	17	
Immature males	13	
Females	59	

6. RESULTS AND DISCUSSION

6.1 Census results

Early results this season (table 1) showed variations between individual counters (see Fig. 3). There were two probable causes for these: (a) pups were obscured by their mothers, and (b) the density of animals on the beach coupled with counting method caused variations.

Table 1 Results of census of pups on Enderby Island.

	Counter										Total	
	BW		DG		MC		PE		SH			
Date	Mean	S.E. of Mean	Mean	S.E. of Mean	Mean	S.E. of Mean	Mean	S.E. of Mean	Mean	S.E. of Mean	Mean	S.E. of Mean
DEC 1992												
13	7.50	.50	–	–	10.00	–	10.00	–	–	–	8.75	.75
14	18.00	2.00	–	–	18.33	.47	–	–	–	–	18.27	.47
15	–	–	–	–	–	–	–	–	–	–	–	–
16	–	–	–	–	27.47	.83	22.00	1.47	–	–	26.32	.88
17	26.00	1.22	–	–	36.82	.76	–	–	–	–	33.93	1.42
18	37.17	1.01	–	–	57.90	1.64	48.00	.97	–	–	49.55	2.04
19	–	–	–	–	75.25	2.58	54.00	1.00	–	–	71.00	3.49
20	–	–	–	–	84.27	1.56	86.17	1.87	–	–	84.94	1.19
21	88.38	1.67	–	–	99.75	2.26	106.6	3.59	–	–	97.05	2.08
23	132.0	3.29	119.0	2.31	167.1	4.79	153.8	3.92	–	–	151.1	4.58
24	181.5	1.59	177.7	8.28	201.0	3.98	168.8	1.75	–	–	182.4	2.46
26	–	–	–	–	270.0	2.82	–	–	–	–	270.0	2.82
27	247.7	2.61	243.8	7.82	264.0	3.71	242.6	6.06	–	–	251.0	3.45
28	248.7	2.73	–	–	283.8	5.59	272.3	1.20	–	–	272.2	5.12
30	338.6	1.64	337.0	6.00	352.9	2.05	331.0	2.04	–	–	341.0	1.84
JAN 1993												
1	–	–	–	–	373.0	1.67	–	–	–	–	373.0	1.67
2	385.0	–	396.7	7.54	396.6	3.90	–	–	–	–	395.9	3.19
3	385.7	1.78	377.0	6.40	400.5	2.74	384.2	1.68	–	–	384.3	2.34
5	378.0	–	–	–	–	–	386.0	6.81	–	–	384.0	5.21
6	383.0	–	–	–	–	–	403.0	–	–	–	393.0	10.00
7	392.0	–	–	–	407.0	–	387.0	–	–	–	395.3	6.01
8	400.5	3.48	–	–	398.0	5.28	377.3	17.15	–	–	393.3	5.48
9	–	–	–	–	415.0	.00	–	–	–	–	415.0	.00
10	378.3	2.95	–	–	383.3	5.89	398.0	2.83	–	–	386.5	3.33
11	387.5	3.20	–	–	413.5	3.25	409.3	4.21	–	–	402.2	2.93
12	368.3	5.07	–	–	–	–	–	–	–	–	368.3	5.07
13	370.3	.25	–	–	383.2	3.88	373.3	3.09	–	–	375.3	2.15
15	377.3	3.75	–	–	358.5	2.06	380.8	4.01	–	–	372.2	3.44
19	377.0	3.00	–	–	383.3	3.04	376.3	1.18	337.0	–	375.6	3.55
22	384.9	5.87	–	–	390.2	3.80	379.1	3.41	–	–	385.8	2.56
24	–	–	–	–	328.7	3.98	–	–	–	–	328.7	3.98
26	–	–	–	–	117.0	.00	–	–	–	–	117.0	.00
28	–	–	–	–	152.0	.00	–	–	–	–	152.0	.00
30	–	–	–	–	152.3	.63	–	–	–	–	152.3	.63
FEB 1993												
1	–	–	–	–	87.00	.00	–	–	–	–	87.00	.00
2	–	–	–	–	54.00	–	–	–	–	–	54.00	–

The pupping curve for Enderby Island (Fig. 2) incorporates data from three members of the team of four. The fourth member of the team was inexperienced and did not complete the data series. For this reason, the partial data series was not used in the construction of this figure.

In the first three weeks (after day 1) of the season, new pups were being born at an increasing rate to about day 33, when the rate began to level off (Fig. 2). At this time new pups stay in close contact with their mothers who are feeding them regularly day and night. Depending on the elevation of the observer, a pup can be obscured when only 2-3 m away. During this period, counts of pups will tend to underestimate true numbers. At Enderby Island, the elevated sward edge, which is about 3.5 m asl. provides a good viewpoint to cover the rookery, especially if binoculars are used to aid visual separation of like coloured individuals when counting. Nevertheless, observers must be aware of the possibility of obscured pups and allow for longer observation times.

At Dundas Island where the beach rises gradually from sea level to approximately 1 m at the sward edge, counting pups around the mean pupping date is very difficult. Seven to ten days after birth pups begin to pod, the adults on both rookeries are more widespread and observers have better access to pods on the seaward side of the beach.

Table 2 Results of census on Dundas Island.

	Counters											
	MC				PE				BW*			
Date	N	Range	Mean	SE	N	Range	Mean	SE	N	Range	Mean	SE
Pups												
25 Dec. 1992	7	840 1018	924	20.87	–	–	–	–	1	774	774	–
2 Jan. 1993	6	1109 1590	1375	30.0	3	1141 1246	1187	23.36				
18 Jan. 1993	2	1900 1958	1979	20.50	2	1924 2055	1990	46.31	2	1624 1675	1650	18.03
Females												
25 Dec. 1992	7	1200 1386	1303	27	3	1480 1540	1510	14.14	4	957 1211	1080	47
2 Jan. 1993	4	1680 1790	1730	22	2	1572 1481	1542	30.33				
Males												
25 Dec. 1992	1	241							1	241		
2 Jan. 1993									2	205 208	207	1

* Click-counter not used

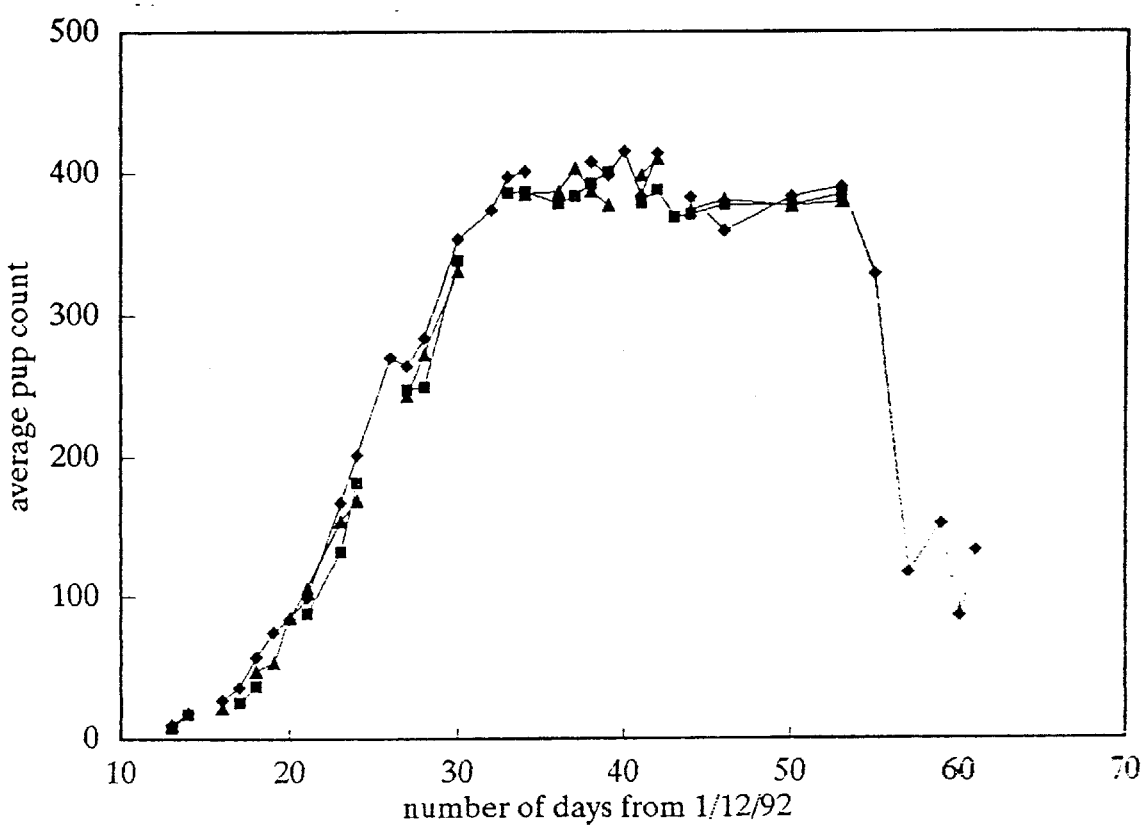

Figure 2 **Hooker's sea lion pupping curve for Enderby island, 1992/93 season.**

This season, during visits to Dundas Island on 2 January and 18 January, counters were able to take advantage of this behaviour to work among pods of females and pups from both the landward and seaward sides. Counts on those two days are considered more reliable than on 25 December 1992. Dundas Island counts are given in Table 2.

Up to the mean pupping date, cows and pups on Enderby Island form very close pods, particularly if the weather is poor. The rookery at this time will occupy only about 10% of the available beach area. During the first 12 days on Enderby Island, counters worked continuously from one end of the rookery to the other when counting. In the past, subdivisions of the beach have been made to assist counting. However, this season the areas of greatest density were subdivided into narrow bands as an aid to counting, and to improve accuracy and reduce variation between counters (Fig. 3). This was particularly successful and the method has been adopted as a standard procedure.

6.2 Verification of censuses: Mark Recapture, Mark Loss

6.2.1 Mark Recapture

Estimates of the pup population were made using Petersen Estimates and Bailey's adjustment of the Petersen Estimate (Caughley 1977), see Table 3.

After calculating the pup population at Sandy Bay, we conducted exhaustive marking of pups. This was a final check of the population of the study rookery, and ensured that as many pups as possible could be identified. A total of 397 pups were marked. At 20 January 1993 the operation was stopped, to be sure that all pups marked: (a) had been born at the Sandy Bay rookery and none had begun swimming; and (b) no pups from other rookeries, (e.g., Dundas Island), had arrived to augment the Enderby population.

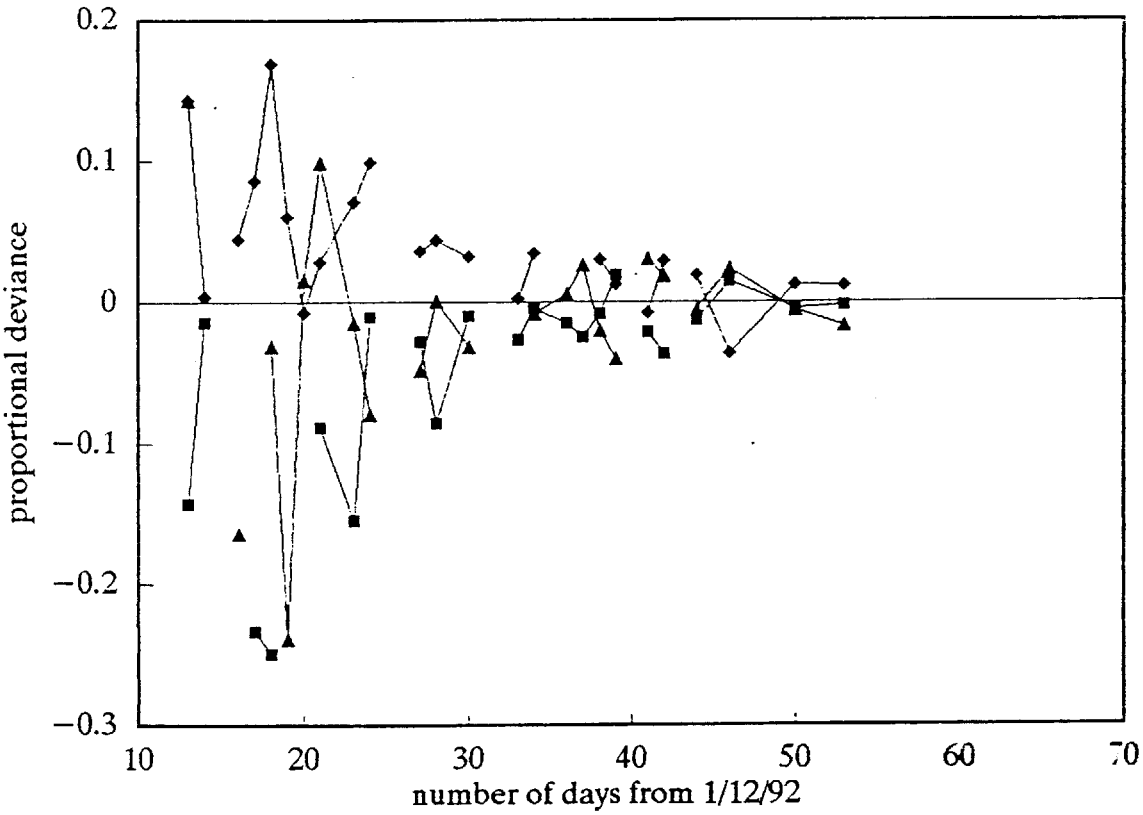

Figure 3 Daily percentage deviance from grand mean on Enderby Island, 1992/93.

South East Point (Pebble Point) is used by pregnant females as a staging area before they move to Sandy Bay to pup. Each year, a small number of pups may be born there. However, the number of animals which pup at S.E. Point varies between seasons and,

Table 3 Mark Recapture estimates, Sandy Bay pup population.

Date	Petersen Estimate $(N = \frac{Mn}{m})$	Bailey/Petersen $(N = \frac{M(n+1)}{m+1})$	SE
13 January 1993	N = 396.26	N = 392.65	37.16
	N = 468.75	N = 463.85	46.96
	N = 393.75	N = 391.01	32.36
14 January 1993	N = 412.18	N = 410.0	29.68
	N = 410.81	N = 407.14	30.57
15 January 1993	N = 429.36	N = 426.82	19.40
	N = 388.46	N = 386.44	27.71
	$\bar{x}$ = 414.22	$\bar{x}$ = 415.24	

N = population size (unknown)
M = marked sample
m = marks recaptured
n = sample size

for this reason, it has, to date, been considered an extension of Sandy Bay Rookery. Twentyfour pups born at S.E. Point this year were double marked with the intention of observing their breeding behaviour three to four years hence. If the young females marked there return to S.E. Point to pup then that location should be seriously considered as a developing rookery. If not, its status will remain uncertain and it will continue to be regarded as an extension of the main rookery 3 km to the west.

The total number of pups marked on Enderby Island was 421.

6.2.2 Mark Loss

Only one (0.72%) of 138 pups resighted from the double marked sample (n = 150) was known to have lost a tag from one flipper in the 31 days between marking (4 January 1993) and the team's departure (4 February 1993).

6.3 Error bound estimates of pups at rookeries

The data set used for analysis of census results consists of original counts, plus single counts for pups, females and males. Because the results of two counters (D.G. and S.H.) were incomplete they were eliminated from the data set and only those of team members who spent their entire season at the Auckland Islands retained.

For all calculations it was assumed that the breeding season on the rookery commenced on 1 December 1992. Time was measured in days from 1 December 1992. Pups accumulate on the beach and reach some maximum during late January, around 42 days from 1 December. This type of process can be modelled by the logistic equation

$$P_t = \frac{A}{1 - Ce^{-kt}}$$

where A is the maximum number of pups produced during the season, k the steepness of the curve, C a constant that scales the value of k, and t the number of days since 1 December. To reduce the number of parameters to be estimated, the value of C was set to 1300 so that expected value of k would lie close to 0.2.

As the season progresses the number of pups on the beach begins to decline. This depresses the estimate of A reducing it below the true maximum. To investigate this effect the equation was fitted to the data series truncated at 40, 45, 50 and 55 days. In addition to this the series was also truncated at 42 days, the day on which the maximum count was recorded when more than one counter made a count. The results by counter for the different levels of truncation are shown below

Truncation	MC		BW		PE	
	A	K	A	K	A	K
40	419	(0.292)	413	(0.284)	409	(0.284)
45	411	(0.294)	393	(0.289)	406	(0.285)
50	405	(0.296)	390	(0.290)	401	(0.286)
55	395	(0.299)	389	(0.291)	397	(0.288)

From this it can be seen that the values of A and K are negatively correlated. All the values lie within the range 389 to 419, about 7% of the minimum.

Aggregating over counter and truncating the series at 42 days gave the following estimates of the annual pup production at the Sandy Bay rookery on Enderby Island

A	Asymptotic 95% Confidence Interval
408	404-411

The lower limit of the asymptotic 95% confidence interval lies above 404 indicating that pup production was probably at least 404.

Fitting the logistic equation to the 3 data points available for Dundas Island gave values of

A	Asymptotic 95% Confidence Interval
1804	1613-1996

when C was fixed at 1300 and k at 0.289. One counter produced counts that were very different from the others. If these data are omitted the estimate of A with the same values of k and C was found to be 1759. If k is allowed to vary the value of A is substantially reduced to 1526 with an associated value for k of 0.355. These results must be examined with caution as there are only 3 data points from which 2 parameters are being estimated.

6.4 Pup mortality

At all rookeries, the principal causes of pup mortality in the first two months of life are starvation and accidental deaths from trampling by adult males. At Enderby Island, other causes are assault by subadult or socially immature males, and suffocation in rabbit burrows. At Dundas Island, an obvious additional cause of death is getting stuck in mud wallows. During our visit to Dundas Island on 18 January 1993, 24 pups were found trapped in one large wallow. All were saved and returned to their parents close by. Final counts of pup deaths are listed in Table 4.

Table 4 Final counts of pup deaths.

Enderby Island (Sandy Bay)		Dundas Island	
Burrows	4	Trampling, Unknown	60
Starvation, Trampling	7	Wallows	6
Assault	5		
Total	16	Total	66
Estimated pup population	408	Estimated pup population	1804
Percentage 16/408 = 3.92%		Percentage 66/1804 = 3.66%	

If the 24 pups rescued from the wallow on Dundas Island are added to that total the observed mortality would be 90/1804 or 4.99%.

Of the pups found dead on Enderby Island, 5 were marked. None of these marked pups had lost either tag. It is believed that the effect of mortality on tag loss in the first two months post partum is insignificant.
The observed mortality on both rookeries is a minimum estimate only.

6.5 Revised estimate of sea lion abundance

The total pup production for the 1992/93 season is estimated as follows

Figure of Eight	67
Dundas Island	2000
Campbell Island	150
Sandy Bay, Enderby Island	408
South East Point	25
Snares Island	10
Total	2660

Using a constant male survival to age 3 of 0.9 and constant female survival rate to age 3 of 0.81 the estimated total number of juveniles is 5899, see Gibson and Cawthorn (1992) for details of method. The adult abundance is then expressed as a function of the pregnancy rate per female. If this is set to 0.65 the number of adult females is then 4092 giving a total adult population abundance of 8184 with an assumed sex ratio of 1:1. With these parameter values the estimated total adult population abundance is then 8184 + 5899 = 14083 exclusive of the pups born this season. This estimate is lower than the one presented in Gibson and Cawthorn (1992) which is due to the slightly lower pup count this season.

This amount of variation in pup counts can be caused by several factors. The counts with the largest uncertainty are those from Dundas Island as these have not yet been verified by another method. These counts form the largest proportion of the total pup production. The observed variation could also be the result of a lower pregnancy rate which would indicate that the population could be larger than is currently thought. Alternatively there may be other rookeries, as yet unknown, and that the pup production on Dundas represents a variable fraction of the whole.

6.6 Changes in sea lion abundance through the day

During the breeding season, the abundance of males on the beach/rookery alters little throughout the day. Incumbent beachmasters and territorial bachelor males will not move from their territories until the breeding season wanes and the rookery begins to disperse in the third week of January.

Females, however, are required to feed to maintain the physiological requirements of lactation. At about 10-12 days post-partum they begin to make short, two day, feeding sojourns away from their pups. These gradually extend to up to 4-5 days at sea with an onshore interval of 2-3 days. In any day, numbers of females ashore appear to be greatest between 1000 and 1600 hours. From about 1530 onward, groups of females will move out of "harem" areas and gravitate toward the tide-wash. Depending upon the numbers of intervening bachelors and their persistence in attempting to sequester and

mate females, most of the females will be successful in making a frantic dash into the water.

Traffic of females from rookery to sea during the night is unknown. However, greatest numbers return between 1000 and 1300 hours.

6.7 Changes in abundance with the weather

During warm weather, Hooker's sea lions congregate on the beaches in loose pods and aggregations. With the onset of cool or wet weather the immediate reaction of females is to form dense pods of up to 40 animals, sometimes 2 deep. Similarly, pups will pod in large groups occasionally numbering over 100 individuals, and 3 deep. If weather deteriorates and rain becomes heavy, or is mixed with sleet or hail, both males and females leave the beach and take to sea returning after the showers have passed. Alternatively females take their pups and seek shelter in the forest.

On 25 January 1993 a low pressure system of 985 hPa crossed the Auckland Islands bringing with it torrential rain. The following day the population on the rookery at Enderby Island had altered dramatically (Figs. 3 and 4). Pup numbers had declined by 69%, females by 68% and males by 29%. Females and pups had moved up to 300 m inland through the forest into the *Cassinia* scrub. Males moved either onto the open sward or into the fringing vegetation surrounding the sward.

The rookery at Sandy Bay, Enderby Island, faces due south. During spring tides southerly winds push high seas across the beach forcing a general movement of all animals on the rookery to the rear of the beach and up onto the sward. During these episodes the population on the rookery is reduced to a thin aggregation clustered along the rear of the beach with the bulk of females and pups on the sward 3 m above. If storms are severe enough, as happened in 1990, the entire beach may be covered in enormous windrows of kelp *Durvillea* sp. and *Macrocystis* sp. The kelp sinks down into the beach sand causing the beach to prograde. Sea lions have an obvious antipathy to crossing the slimy piles of rotting kelp and the animals redistribute to avoid the mess.

6.8 Changes in sea lion abundance through the season

In November, beachmaster and first ranked bachelor males take up territories on the rookery and await the arrival of the females. Male numbers increase gradually until the first week in January when approximately 150-160 males may be present on the rookery. From this point, male numbers are augmented by an influx of socially immature adult males. As breeding and aggression declines, the number of males declines until the second week in February when the rookery is largely deserted. Abundance of females increases rapidly between 5 December and the mean pupping date (25 December), when approximately 50% of the expected number of pups will have been born (Fig. 4). By the fourth week of December, females will be making regular feeding regular feeding excursions to sea and approximately 20% of the females with pups will be absent from the rookery at any time. From the third week in January, females begin moving their pups away from the rookery and numbers begin to decline steadily. This decline may be accelerated if bad weather intervenes, as occurred on 25 Jan. 1993 (Fig. 4). By the second week of February most pups and females will have departed from the rookery.

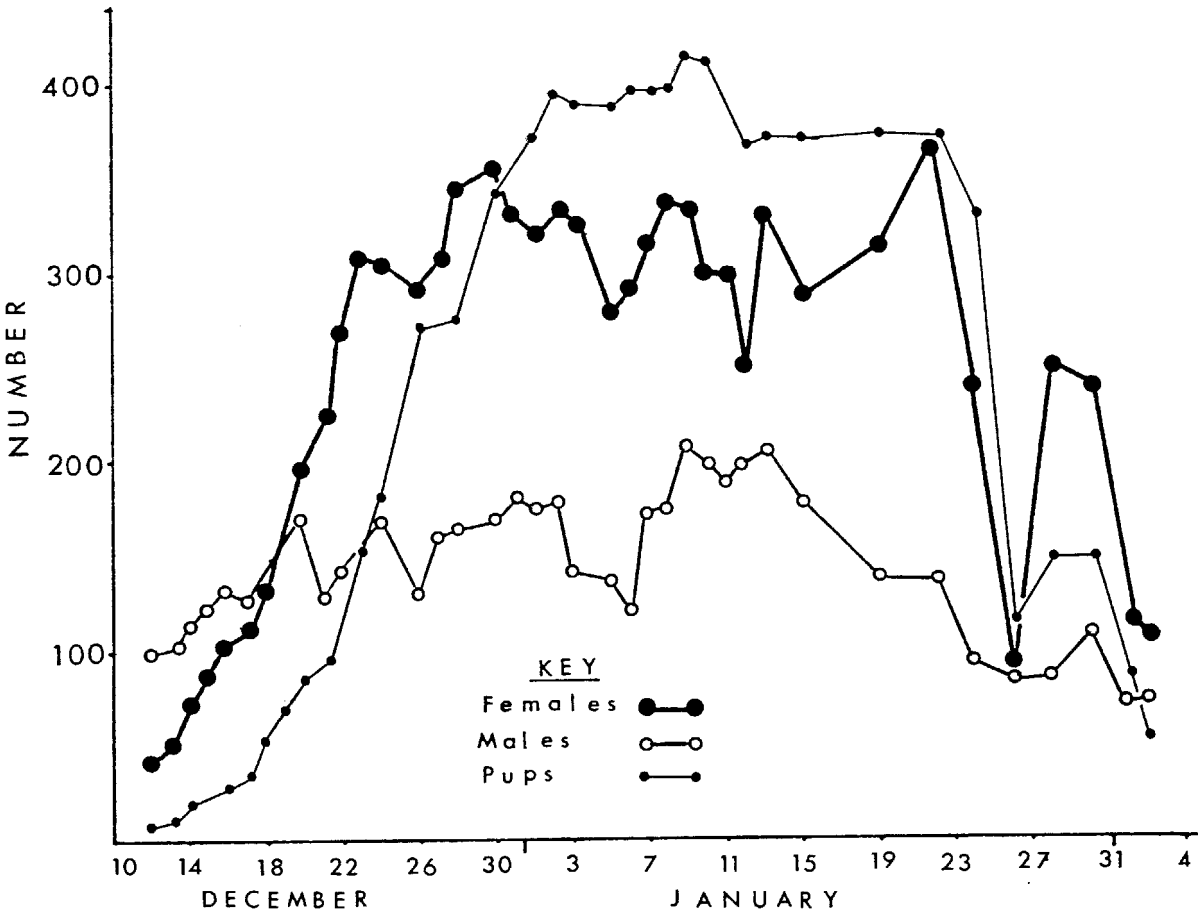

Figure 4 Abundance of sea lions during the season, Sandy Bay, Enderby Island.

7. STANDARDISED CENSUS TECHNIQUE

Census techniques for Hooker's sea lions vary between islands and are predicated by topography, vegetation cover and animal behaviour. The following are the standardised techniques recommended for future censuses at each of the Auckland Island rookeries.

7.1 Sandy Bay, Enderby Island

7.1.1 Triple Stratified Count (TSC)

Using the creeks which cross the sward and beach as natural boundaries, divide the beach and sward from west to east into numbered divisions. Depending where the bulk of the sea lion population is located on the beach, subdivide these divisions into bands using a series of easily visible pegs driven into the sward edge at the rear of the beach. It is not necessary that these bands are of equal width, rather they serve as an aid to counting with improved accuracy and reduced variation between individual counters.

All counts should be conducted from the sward edge some 3 m above the beach. It is recommended that mechanical click-counters be used at all times.

In each division and band make three repeat counts of males, working along the beach, band-by-band, then back across the sward to the starting point.

In each division and band make at least three repeat counts of females before moving on to the next band. Repeat the process identically when counting pups.

7.1.2 Total Count

If time available is too short to make a TSC, then a Total Count should be made. Using a click-counter, make single or repeated counts of males, females, and pups while moving continuously from one end of the rookery to the other.

7.2 Dundas Island

Counting at Dundas Island is difficult because of the low terrain (maximum altitude approx. 7 m), the small size of the island (approx. 220 x 100 m) and the large number of sea lions hauled out there (approximately 83% of the breeding population). It is recommended that this standardised procedure be followed for any future counts. Aerial photography using kite-borne cameras should be used in conjunction with ground counts on this island whenever conditions permit.

The island is readily divisible into three easily identified regions: beach, sward, and knoll. The **beach** used by most breeding animals is at the south end of the island. It is a crescentic expanse of shelly sand tapering into cobbles and boulders at the northern extremities. The **sward** is comprised of Poa tussock and is raised 30-60 cm above the beach. The sward occupies an oval roughly 100 m long from north to south. At its centre is the **knoll**, the southern half of which is surrounded by and separated from the sward by a series of naturally occurring linked wallows and sink-holes in the peat. These drain to the eastern side of the island. The vegetation on the knoll includes megaherbs (predominantly *Stilbocarpa* sp.), stunted *Hebe elliptica* bushes and shoulder high Poa tussock.

When counting sea lions on Dundas Island a **single** starting point is chosen. Counters work each geographical region separately, moving in **opposite directions** to one another. Counts of pups, females and males are made in that order. If time permits,

repeat counts of pups and females should be made. As soon as counts in one region are completed counters move, e.g., from beach to sward, and repeat the process exactly. The density of vegetation on the knoll requires that counters quarter the entire area by zig-zagging across the knoll from margin to margin, from one end to the other. Considerable care must be taken during this phase as some sink holes are over 2 metres deep.

Counters must not communicate with each other until all have completed every section.

7.3 Figure of Eight Island

Figure of Eight Island, situated at the north end of Carnley Harbour, is an unusual rookery site in that the island has no surrounding sand beach and is totally bush covered with a mixture of rata, *coprosma*, ferns, and grasses. The rookery, which has been in existence on this island since at least 1860 (Musgrave 1866), is located at the north-eastern end of the island, in rata forest. Counting the animals at this rookery is very difficult.

From the landing on rocks at the southeastern end of the island counters must space themselves evenly across the island and proceed north, quartering back and forth to search the bush for pups and females. Counters should divide the rookery area into zones and, if possible, conduct repeat counts of pups and females in these zones, taking care to avoid overlaps. Click-counters should be used at all times.

Because of the terrain on Figure of Eight Island and the dense bush cover, male territories are hard to distinguish and males are very pugnacious. Figure of Eight Island is the most dangerous rookery of all in the Auckland Islands and considerable caution should be taken by anybody working with sea lions on this island.

8. COMMENTS AND CONCLUSIONS

The results of this seasons work show that on Enderby Island the methods of census, here proposed as Standard Methods, successfully reduce the variability between counters when working where terrain gives the advantage of altitude. The methodology is readily applied in the field and the results are statistically reliable.

At the Dundas Island rookery, the low topography gives no elevated viewpoint. Without resorting to construction of tower-like structures, counts must be made using a different method. Using this proposed standard method, all personnel have an equal chance of counting all visible pups and adults. However, the problems discussed above (low elevation, distance from animals, and obscured animals) all contribute to an under-estimate of the population on this rookery. These problems can be offset to some degree by using kite aerial photography, and by the observers having the skill and experience to work with confidence on the crowded rookery. Observers must be able to recognise the nuances of behaviour: whether a threat will terminate in an attack, where territorial boundaries lie and how to cross them, and simply, being able to handle sea lions properly. These skills are not learned overnight and, because of differences between species, they are not too easily derived from work with other pinnipeds.

Counts and census data collected at the Auckland Islands have shown little change over the last 50 years and especially over the last 13 years. The rookery at Sandy Bay annually provides 400-420 pups and the population appears stable. Dundas Island carries 80-83% of the breeding population. Because of the general inaccessibility of the island, visits have been short duration. "Counts are all subject to changeable negative bias arising from variations in the timing of the census relative to the rate of immigration of pups (and their mothers) . . ." Gibson and Cawthorn (1992).

This season, time on Dundas Island was limited to 3 visits only by bad weather. These visits covered the mean pupping date (extrapolated from Enderby Island) of 25 December 1992, 2 January 1993, and 18 January 1993 respectively. On the last visit, animals were well spread over the rookery and counts were believed to be reliable. Of the three experienced counters, the two using mechanical click-counters recorded higher numbers than the third who recorded directly onto paper. Although the reason for this variation is unclear, it is felt that click-counters allow better visual continuity when working over large aggregations. For this reason alone they should be used at all times. Counts when combined gave a total of 1800 animals with a 95% confidence interval ranging from about 1600 to 2000. The maximum tallies recorded by the two counters using mechanical click-counters ranged from 1958 to 2005, which we believed to be reliable counts. Given the constraints discussed above, they are probably underestimates of the true pup population on Dundas Island this 1992-93 season.

The use of aerial photography is undeniably necessary when using sea lion pups as a population index. The two options, aircraft-borne cameras and those slung from kites both have merits. Aircraft can be worked from mainland New Zealand to take high quality photographs of rookeries within a day. They are also not influenced by sea state, the major impediment to interisland travel by ground parties at the Auckland Islands. Analysis of photographs is repeatable and can be done according to strict scientific design. Nevertheless, the short-term unpredictability of weather in the subantarctic can have a profound affect on the distribution and abundance of sea lions on rookeries (see 6.7). This behaviour can introduce major biases into the interpretation of aerial

photographs taken as one-off snapshots. Advantages of using kite-borne cameras for aerial photography are that the results are repeatable, and photography can be carried out during short, fair spells in weather. The equipment is inexpensive compared to the operational costs of aircraft and there is the added advantage of ground teams being able always to "groundtruth" photographs while gathering valuable ancillary information. The photographs can be of comparable quality to those taken from aircraft and they can be examined with the same scientific rigour.

The major impediment to getting good counts and photograph series on Dundas Island to date, has been inadequate small boats. Ground parties need a seaworthy craft suitable for 4 persons and equipment. This year, the "Gannet" (see section 3.) proved ideal. It is light enough to be manhandled onto beaches and is very sea worthy. Its performance however was limited by modification to the transom so it would accept short-shaft motors and the limited power of the outboard motor supplied. With a 25 HP motor more than 3 visits to Dundas Island would have been achieved. Any small craft used in the subantarctic must be supplied with proper safety equipment including, auxiliary motor, EPIRB (electronic position indicating radio beacon) with satellite compatibility, and a full set of offshore flares. As the first line of contact in that area is with fishing vessels, ground parties must also be equipped with marine radios and VHF handsets covering all marine emergency bands.

Continuity of data collection on sea lions in the subantarctic should be maintained and adequate resources put aside to do so. The present data base spans little more than one decade. This is inadequate for descriptions and predictions of long-term demographic changes. Future work should investigate the movements and feeding behaviour of males, especially large adults, and the breeding life of females and males. This will require permanent marking of individuals, either by branding, or the use of subcutaneous transponder tags. Ideally one should be augmented by the other. The relationship of juveniles and fishing vessels also requires study. As long as there is a squid fishery, incidental catches of sea lions will probably continue. An understanding of sea lion behaviour around vessels is overdue. Funding for such work could be drawn from both governmental and private agencies.

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