Research to assess the demographic parameters of New Zealand sea lions, Auckland Islands DRAFT REPORT Contract Number: POP 2010/01

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Abstract

The New Zealand sea lion (NZ sea lion), *Phocarctos hookeri*, is New Zealands' only endemic pinniped. It is classified as Nationally Critical (Baker et al. 2010) and is estimated to be the world's rarest sea lion (Geschke & Chilvers 2009). This report summarises the annual survey 2010-11 of the Auckland Island area with the objective to collect data to allow quantification and estimation of demographic parameters of all NZ sea lions from the Auckland Islands.

The pup production estimate for the Auckland Island NZ sea lion population in 2010-11 was 1550 ± 41, a decline on the 2009-10 estimate. 1550 is the second lowest pup production estimates ever recorded for NZ sea lions. Field sightings of previously tagged, branded and/or passive integrated transponder (PIT) tagged animals were collected and recorded. The NZ sea lion database has had the 2010-11 field season's data entered, checked and data extraction has occurred to allow for the estimation of survival of previously marked NZ sea lions and reproduction by known age female NZ sea lions.

1. Objectives

The objectives of the project were:

1. To collect field data that will allow quantification and estimation of:
   - pup production,
   - survival of previously marked New Zealand sea lions,
   - reproduction by known-age female New Zealand sea lions;
2. To maintain and update the New Zealand sea lion database; and
3. To make available field data for relevant modelling work;

Due to logistical constraints resulting in a change to the planned methodology for estimating pup production on Dundas Island this report also aims to determine if any correction factor needs to be applied to allow for direct comparisons to time series data.

2. Logistics

The scientific trip was split into two parts to allow changes in personnel: December 4th - January 10th, and January 10th - February 20th. The first science team comprised of three people: Nathan McNally (DOC, Otago), Elaine Leung (University of Otago) and Andy Maloney (Contractor). The second team comprised of six people: Louise Chilvers (DOC, MCT), Kerri Morgan (Massey University), Amelie Auge (Otago University), Chris Muller (Contractor), Myles Riki (DOC, West Coast Tai Poutini) and Dave Johnson (DOC, Te Anu). Transport during the season was aboard the Tiama and Evohe under charter to DOC R&D. All personnel were accommodated in the Sandy Bay hut.

A logistics restraint on this year's work was that a strong SE storm on 17th January, which lasted 2 days, dumped a 30m wide and 1m deep layer of kelp on the Sandy Bay beach behind the NZ sea lion team's boats. The weather then turned strong westerly for two weeks with both conditions restricting boat use until the 6th February. Even after this date boat launching and retrieval took all six field team members and could not be guaranteed on any day. Therefore members of the NZ sea lion team could not be left on Dundas Island because there was no guarantee that the big boat could be launched to go and pick up the other team members.

3. Methods

3.1 Collect data and maintain NZ sea lion sighting database to make field data available to allow modelling to estimate survival and reproductive ability of previously marked NZ sea lions.

3.1.1 Marking

New Zealand sea lion pups have been tagged at one month of age as part of a demographics study since 1979/80 at Sandy Bay, 1985/86 on Dundas Island and 1992/93 at SEP. Tagging has been intermittent and the numbers of animals tagged annually have varied from 0 to over 500 since 1979/80. Between 1979/80 and 1992/93 flipper tags used were uniquely numbered Alflex laser-marked button tags (Alflex NZ Ltd, Palmerston North, NZ), tagged in the right pectoral flipper only. In the 1997/98 and 1998/99 seasons the same tags were used but animals were tagged in both pectoral flippers. Since 1999/2000, uniquely numbered Dalton DAL 008 Jumbotags® coffin-shaped tags with a different colour each year (Dalton Supplies Ltd, Henley-on-Thames, UK) have been used to tag animals in both pectoral flippers. During the 1999/2000 season 297 pups and 135 adult females from Sandy Bay were also hot-iron branded (Wilkinson et al. 2011). Between 1999 to 2003 and in 2010 and 2011 pups were also injected with individually identifiable passive integrated transponders (PIT, Trovan, Ltd., Douglas, United Kingdom).

3.1.2 Presence and breeding status of marked animals

Daily tag resightings were conducted at Sandy Bay between 5th December and 16th February 2011. Daily resighting took up to four people, five hours a day to complete. All other areas around Enderby Island were surveyed at least once a week during December and early January each season and then surveyed at least once every second day from late January until the end of the field season. Resighting were undertaken at Dundas Island on 6 February 2011 when field staff were on the island. Resightings consisted of the date and place of sighting, the animals tag number, colour, shape and number of tags in which flippers, PIT presence (therefore alphanumerical series) or absence, animal sex and breeding status or behaviour. PIT tag checking was undertaken throughout the season. Given the need for close approach to scan for PIT tags (~10cm), there was a higher likelihood of getting access to all animals after mid-January, because until then the animals in the harem were packed so tight, with large territorial males defending areas, that many animals could not be accessed. All animals, whether they have tags or not are checked for PIT tags by passing the PIT reader over the hind quarters of a sleeping or otherwise distracted animal.

3.1.3 Presence and breeding status of marked animals away from known breeding areas

Presence and breeding status data were collected opportunistically from marked animals at all sites outside the breeding sites around the Auckland Islands when researchers were travelling near these areas. This year due to the limited ability to use the research boats, only Kekeno was visited by the NZ sea lion team. However, Otago University visited the Auckland Islands between the 13th and 26th of January 2011 and surveyed Carnley Harbour, the many inlets on the east coast of the Auckland Island and Ross Harbour, looking for information on sea lion diet (therefore specifically

looking for areas where sea lions inhabit), and provided data on any sightings they made (Kinsey 2011).

3.4 Update NZ sea lion sighting database

All sighting field data were verified, entered into the NZ sea lion database and data extracted for relevant modelling work. Data verification was performed both during the season and at the end of the season. End of season verification involved the following procedures:

- all data is sorted by individual animal (current tag) and duplications (same animal on the same date) deleted,
- number of tags checked and assessed (during the season if animals were still identified as having only been one flipper tag only seen notification was given to field staff to try and determine true tag number while the team were still in the field),
- colour and tag number matches checked,
- previous and original tag information entered where necessary for adult females, and
- class, tag year, age, tag location and status entered for all animals.

3.2 NZ sea lions pup production

There are two pupping areas (Northern Auckland Islands and Figure of Eight Island) at the Auckland Islands (Figure 1). Pups are born at Sandy Bay (50°30'S, 166°17'E) and South East Point (SEP) on Enderby Island (50°30'S, 166°19'E), Dundas Island (50°35'S, 166°19'E, Figure 1) and Figure of Eight Island (50°46'S, 166°01'E). Pup production at SEP and Figure of Eight Island was estimated using direct counts, whereas at Sandy Bay and Dundas Island the primary estimation method was a mark-recapture (M-R) estimate. For Sandy Bay, the M-R procedure was consistent with previous methodology (Chilvers 2011). Due to adverse weather conditions and the inability to move the transport boats from the Sandy Bay beach for several weeks, the Dundas M-R was undertaken on the 6th of February (rather than the planned date of 21st January), the M-R was undertaken in one day rather than over two days and two recapture counts by three people were undertaken rather than three counts by each person. Methods used to determine if any correction factor must be applied to allow for direct comparisons to time series data are outlined in section 3.2.3.

3.2.1 Direct counts

Direct counts were conducted at SEP using surveys during the breeding season (December 4th to January 20th). SEP is a small, open, rocky coastal area which is easily surveyed. All counts were conducted from the rocky beach margin, with hand tally counters and counts recorded. Pup production was based on the counts of live pups and the cumulative total of dead pups (Gales & Fletcher 1999; Chilvers et al. 2007).

The remote location of Figure of Eight Island (over 60 km south of Enderby Island) prevented multiple visits during a season. Pup production was based on the mean of separate counts conducted by three people around the entire island made on a single day on the 10th of January.

Pups were also counted at Kekeno on the main Auckland Island (6th February 2011). Reports of any pups were sought from albatross researchers based at Adams Island in Carnley Harbour and Carnley Harbour and East Coast inlets (Figure 1) by researchers on the Otago University boat the Polaris (Kinsey 2011).

3.2.2 Mark-recapture experiments

A single M-R experiment was conducted at Sandy Bay on the 15-16th January 2011 and at Dundas Island on the 6th February 2011. Pups were marked with circular, 6 cm-diameter, flexible vinyl discs that were glued to the crown of their heads with a fast-setting cyanoacrylic glue (Loctite 454).

Figure 1: The Auckland Islands showing areas where sea lions were sighted: Figure of Eight, Dundas, Enderby and Auckland Islands.

The number of pups marked was approximately 40% of previous pup production estimate at Sandy Bay (150 pups marked) and 20% at Dundas Island (200 pups marked). Marking was spread as evenly as possible through the breeding area (based on pup density and distribution). Most discs were shed a few days to weeks after the experiment. Recaptures involved three observers moving systematically through the entire sea lion pupping area counting pups, with each observer conducting two or three replicate counts. Each pup was classified as either marked or unmarked and a tally of each was maintained by each observer using two hand-tally counters. Only pups where the entire head was visible were included in the counts, to minimise the risk associated with undercounting unmarked pups. As the discs were clearly visible on the heads of pups if only part of the head is viewed there is a greater probability that a marked pup would be correctly identified than an unmarked pup. Any greater probability of viewing marked caps would lead to an overestimate of the proportion of marked pups and underestimate of pup production. Consequently, any pups that could not be categorised as marked or unmarked, i.e., where the entire head was not visible, were excluded from the count.

Results of each recapture were used to calculate a modified Petersen estimate (Chapman 1952) of pup production P_i namely

$$Pi = \left[\frac{(M = 1)(Ci + 1)}{(Ri + 1)} \right] - 1$$

where, for replicate i, M is the number of previously marked sea lion pups, C_i is the number of pups examined in the recapture sample, and R_i is the number of marked pups in the recapture sample. The overall estimate of pup production, P, is the mean of the Q individual estimates, i.e.,

$$P = \frac{\sum_{i=1}^{Q} Pi}{\mathrm{Q}}$$

The standard error, of P was calculated directly from the individual estimates (Chapman 1952), as:

$$SE = \sqrt{\frac{1}{Q(Q-1)} \sum_{i=1}^{Q} (Pi - P)^2}$$

(consistent with previous methodology Gales & Fletcher 1999, Chilvers et al. 2007, Chilvers 2011).

The assumptions for the M-R model were:
(1) all pups were born by mark-recapture dates;
(2) all pups were accessible for marking (i.e., capture probability was constant);
(3) all pups were mobile and mixed well after being marked;
(4) marks were not lost before M-R counts; and
(5) mortality was negligible and assumed to be zero in the time between marking and recapturing.

Numbers of pups known to have died up to the date of the M-R estimate were then added to produce a figure for total pup production (Chilvers 2011). All pups that died during the breeding season from Sandy Bay were counted and removed on a daily basis for autopsy, which resulted in the accurate assessment of numbers of dead pups from this site. For Dundas and Figure of Eight islands, dead pup numbers were estimated by counting all visible pup carcases the day of pup production estimate. Carcases were counted by up to four observers systematically covering the islands at the same time calling out and identifying carcases, so as not to overlap observer search areas, with one observer using a hand counter to tally the total carcase count.

To determine the accuracy of the mark-recapture procedure for NZ sea lions, mark-recapture estimates at Sandy Bay were validated by comparing the mark-recapture estimate taken at Sandy Bay with the number of pups flipper tagged at Sandy Bay as all live pups were tagged using coffin shaped Dalton DAL Jumbotags® (Dalton Supplies Ltd, Henley-on-Thames, United Kingdom) within 2 days of the mark-recapture.

3.2.3 Differences in methodology

The mark-recapture methodology at Dundas Island differed from that used in previous years (e.g. Chilvers 2011) in that it was completed on February 6th, 16 days later than planned. The logistical constraints meant no team could be left on Dundas Island over night for safety reasons. This meant no pups were tagged on Dundas Island, the mark-recapture was conducted on a single day rather than over two days, 200 caps were placed out on pups rather than 400 and three people completed two mark-recapture counts each rather than three.

In order to determine if any correction factor was needed to allow for direct comparisons to time series data, existing unpublished data on pup production at Dundas were analysed, including:

1) A comparison of data from a mark-recapture estimate of pup production conducted on Dundas Island during the 2009/10 season on the 13th of January and the standard mark-recapture undertaken 8 days later on the standard date of 21st January. All mark-recapture methodology of both mark-recaptures were the same as Chilvers (2011), apart from the differences in date.

2) A comparison of data from mark-recapture estimates of pup production conducted on Dundas Island during the 2001/02 season on the 21st, 23rd, 25th, 27th and 29th of January (previously unpublished). All mark-recapture methodology of the mark-recaptures were the same as Chilvers (2011), apart from the differences in date and on the 21st four people did two counts each, while on the 25th two people did four counts each rather than 3 people doing 3 counts each.

4. Results

4.1 Collect data and maintain NZ sea lion sighting database to make field data available to allow modelling to estimate survival and reproductive ability of previously marked NZ sea lions.

4.1.1 Marking

Pups have been tagged to provide a pool of known age individuals for the estimation of parameters such as survival, recruitment and reproductive rate as part of the long-term study. All live pups at Sandy Bay (360 by the 17th January) were tagged with yellow 'coffin' shaped Dalton 'Jumbo' tags with a letter and three-digit number combination. One month after tagging there was no tag loss recorded for any pup at Sandy Bay. The 360 pups at Sandy Bay were also PIT tagged. Thirty one pups were tagged on Figure of Eight Island with orange coffin shaped Dalton 'Jumbo' tags.

4.1.2 Sea lion counts

Daily counts of pups and adults (live and dead) were made from 4th December to 20th January at Sandy Bay at 9.30am each morning. Similarly, daily counts were made at South East Point from 4th December to 27th December, there after every second day until the 20th January and then a minimum of once a week. Counts were made at approximately one week intervals at East Bay and other areas around Enderby Island. Figure of Eight Island was counted on January 10th. Two researchers studying Albatross were located on Adams Island, Carnley Harbour during the same six week season (G. Elliot, K. Walker pers. comm.). Reports from this area yielded no tag resights and no sign of breeding. The Otago University boat the Polaris spent 10 days (15th January to 24th January 2011) travelling throughout the Auckland Islands (Carnley Harbour and East coast inlets) and reported no sign of (pups) breeding in any of these locations (Figure 1).

Sea lion counts at Figure of Eight Island were 34 females, 17 males and 71 live and 8 dead pups on the 10th of January 2011.

4.1.3 Resighting of previously marked individuals

Daily counts of all animals and resights of tags and brands on NZ sea lions were undertaken on Enderby Island to understand the composition of animals at this breeding site and to enable the calculation of survivability, recruitment and fecundity of animals. Field sightings of previously tagged, branded and/or passive integrated transponder (PIT) tagged animals were collected and recorded. The 2010-11 field season data has entered into the NZ sea lion, verified and data extraction has occurred to allow for the estimation of survival of previously marked NZ sea lions and reproduction by known age female NZ sea lions. Approximately 7538 resights made on 1125 animals previously tagged or branded (including 278 individuals identified from a PIT) were collected from Enderby Island. Five resights were collected from Dundas Island and three from Figure of Eight Island. Animals were checked at Kekeno on the main Auckland Island, however no tagged or branded animals were seen.

4.2 NZ sea lion pup production and mortality

Estimates of pup production were calculated for each breeding sites in the Auckland Islands between 10 January to 6 February (Tables 1 and 2, Figure 2). Mark recapture estimates have been used as the estimates of pup production from Sandy Bay and Dundas Island, while Figure of Eight Island and South East Point areas were estimated using direct counts. The total pup production estimate was 1550 ± 41 for 2011 (Figure 2).

On the 16th of January, the mark-recapture estimate at Sandy Bay was undertaken. The mark-recapture estimated 359 pups ± 7, there were 19 dead pups at that date giving a total pup production of 378 ± 7. 360 pups were tagged by the 17th of January. Comparison between M-R estimates and absolute pup numbers tagged on Sandy Bay showed a difference of 1 pup, demonstrating the accuracy of M-R methods for estimating pup production at colonial beach breeding sites (such as Dundas Island).

The mark recapture estimate at Dundas Island was completed on 6th February. The mark-recapture estimated 944 live pups ± 40 and 137 dead pups were counted giving a total estimate of 1081 ± 40 pups on the island. The area closest to Dundas Island where females and pups are known to swim to as pups get old enough (Kekeno), was visited on the same day as the mark-recapture on Dundas Island and eight pups were recorded, therefore these pups were added to the Dundas Island count, 1089 ± 40. Note, there has never been any evidence of females pupping at this site which is why these pups are assumed to be from Dundas Island and are added to the Dundas Island count. No pups were tagged on Dundas Islands.

All M-R assumptions were believed to be met for this mark-recapture: (1) all pups were born by mark-recapture dates (given this assumptions stands for 16 days earlier in the season it is assumed to stand on the 6th of February); (2) all pups were accessible for marking (given the data listed below this is believed to be true for all bar 0.8% of estimated pups – those being the 8 pups at Kekeno); (3) all pups were mobile and mixed well after being marked (pups were very mobile and mixed well on the day, the dead pup count was conducted between the pups being marked and the recapture counts being undertaken so there was time for pup mixing to occur);(4) marks were not lost before M-R counts (no marks were known to be lost during M-R counting); and (5) mortality was negligible and assumed to be zero in the time between marking and recapturing (again as this is assumed for an overnight M-R it is also assumed for a one day M-R). The assumption that all of these were meet is indicated from the standard error of the 2010/11 Dundas Island estimate being of similar magnitude to previous years (Table 1).

A direct count from Figure of Eight Island was made on the 10th January. 71 pups ± 2 + 8 dead pups were counted giving a total of 79 ± 2 pups.

Direct counts conducted up to and including the 15th of January at South East Point recorded 4 pups (2 confirmed dead, two absent) giving a total pup production estimate of 4 pups.

Pup mortality during the first 4 weeks of the 20010/11 season from Sandy Bay was 5% as of the 16th January (Table 2), by the 15th of Feb it was 8%.

The estimate of pup production from the Auckland Islands was 1550 ± 41, 15% lower between 2009/10 and 2010/11 (Figure 2).

Data relevant to determining if a correction factor to allow for direct comparisons to time series data was needed.

1) The number of dead pups counted on Dundas Is on the 6th February is a similar proportion of estimated pup production to the percentage of dead pups counted relative to the pup production estimate for Dundas in 2009/10 (11% dead 2010 vs 12.7% dead 16 days later in 2011). A similar proportion of mortality was also seen on Enderby Island. Together these indicate that there was no mass dispersal of live pups from Dundas in 2011 which would have resulted in a higher ratio of dead to remaining live pups.
2) The area closest to Dundas Island where females and pups are known to swim to as pups get old enough (Kekeno) had only 8 pups found on the same day as the mark-recapture on Dundas Island, indicating that mother pup movements away from Dundas Island had been very low or only just begun. This would have been expected as the weather conditions between 17th January and the 6th February had been exceptionally bad (even for the sub-antarctics) and would reduce females taking their pups to water as there would be a higher likelihood of them drowning. The total pup production estimate for Dundas included the 8 pups counted at Kekeno. No untagged pups, or mother and pup pairs had been observed at Sandy Bay.
3) Comparing two mark-recaptures at Dundas in 2010, one on the 13th January 2010 (1207 + 130 dead = 1337 ± 19) and the other on the 21st January 2010 (1212 + 151 dead = 1363 ± 35) showed there were no significant difference in estimated pup production between these two time periods although 8 days apart (ANOVA $F_{1,17}$ =0.015, p=0.9, Raw data available in Appendix 2)
4) Similarly, in 2002, the NZ sea lion team conducted a series of four extra mark-recaptures on Dundas Island between the 21st and 29th of January, these four mark-recaptures showed no downward trend (Figure 3, Raw data available in Appendix 3 Results: 21st 1395 + 361 dead = 1756 ± 31; 23rd 1468 + 366 dead = 1834 ± 44; 25th 1474 + 366 dead = 1840 ± 27; 27th 1459 + 395 dead = 1854 ± 30; 29th 1495 + 395 dead = 1890 ± 47).

These two mark-recapture comparisons indicate that mother and pup movements from Dundas Island do not occur in any significant numbers any time between 13th to 29th January. This is also backed by observational data as the NZ sea lion team has had team members living out on Dundas Island during the 01/02, 04/05, 05/06 and 06/07 season until the 2nd of February, and observed females and pups do leave Dundas Island but only in ones or twos a day (which would result in the 8 pups being recorded at Kekeno this season).

None of the data investigated here supports the need to apply a correction factor in order to allow for direct comparisons with pup production time series data.

5. Discussion

Gales and Fletcher (1999) describe pup counts over time at three breeding sites, and provide strong evidence that the pup numbers for SEP and Sandy Bay, Enderby Island drop after January, because pups are taken by their mothers up into the surrounding bush (therefore are difficult to count as they are hidden in the bush). It should be noted that Gales and Fletcher used count data of pups not mark-recapture estimates of total pup production, therefore being less reliable in estimating trends in total pup numbers present. The paper stated that Dundas is a more difficult island to access and count pups on:

> "Sea lions on Dundas Island were not censused as frequently as those on Enderby Island as access to the island was difficult and our stays relatively short. The counting methods were the same as those used on Sandy Bay, but the task itself was more difficult as the sea lions are more numerous at this site, form very large aggregations and there are no convenient vantage points of sufficient height offering a good view over the sea lions."(Gales and Fletcher 1999).

No evidence was presented to show a significant drop in pup numbers at Dundas, and, given the differences between the sites, there is no evidence to suggest the pattern described for Enderby should or does apply at Dundas. Gales and Fletcher (1999) also note that "Cows and pups moved into the surrounding rata forest and grasslands at the two Enderby Island colonies and those on Dundas Island moved more widely over the entire island", i.e. they did not point to movement of pups off the island.

If it was assumed that the Dundas Island pup production estimate had a similar decreasing trend to Sandy Bay and SEP this year, that would mean between the 29th of January (the last mark recapture in 2002) and the 6th of February (the day of this years mark-recapture), over 250 mother and pup pairs would have left Dundas Island. Such large movements are not supported by the data presented in this report, and we conclude that any error in pup production estimate due to changes in the methodology this season is unlikely to be significant, and thus the estimate presented here is directly comparable to previous time series data.

To further test the conclusion that the change in methodology this season did not result in a significant change to the total pup production estimate it is recommended that comparative M-R estimates be performed at Dundas on 17 January and 6 February 2012, or similar to Wilkinsons' 2002 experiment, several M-R experiments could be undertaken across this time period. Both of these research proposals are weather dependant.

Therefore the pup production estimate for 2011 is 1550±41, 15% lower than 2010, showing the NZ sea lion pup production at the Auckland islands continues to decline.

Table 1: Pup production estimates for Auckland Islands

Season	**Sandy Bay**			**Dundas Island**			**Figure of Eight Island**			**South East Point**		
	total	alive	dead	Total	alive	dead	total	alive	dead	Total	alive	dead
98/99	513	473	40	2186	1957	229	109	100	9	59	42	17
99/00	506	482	24	2163	2039	124	137	131	6	50	37	13
00/01	562	527	35	2148	1802	346	94	92	2	55	47	8
01/02	403	320	83	1756	1395	361	96	90	6	27	21	6
02/03	489	408	80	1891	1555	336	95	89	5	43	26	17
03/04	507	473	34	1869	1749	120	87	86	1	52	39	13
04/05	441	411	30	1587	1513	74	83	79	4	37	31	6
05/06	422	383	39	1581	1349	232	62	55	7	24	20	4
06/07	437	414	23	1693	1587	106	70	67	3	24	19	5
07/08	448 ± 5	425	23	1635 ± 44	1512	123	74 ± 1	72	2	18	13	5
08/09	301 ± 2	289	12	1132 ± 16	1065	67	54 ± 1	48	6	14	8	6
09/10	385 ± 6	364	21	1363 ± 35	1212	151	55 ± 1	48	7	5	1	4
10/11	**378** ± 7	**259**	**19**	**1089** ± **40**	**952**	**137**	**79** ± 2	**71**	**8**	**4**	**2**	**2**

Figure 2. Annual pup production for the Auckland Islands 1998/99 to 2010/11.

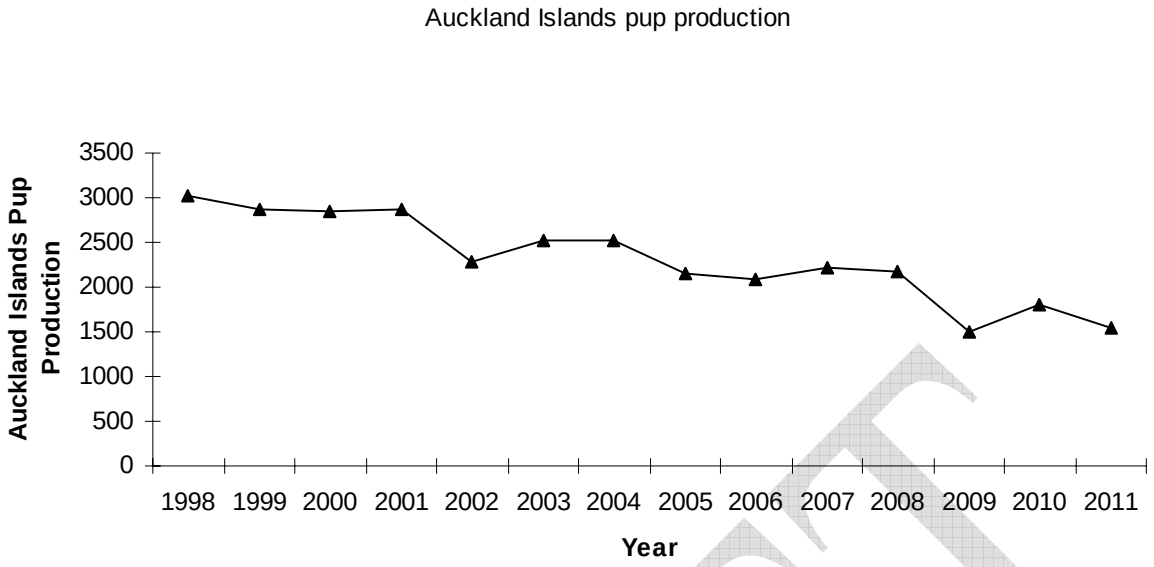
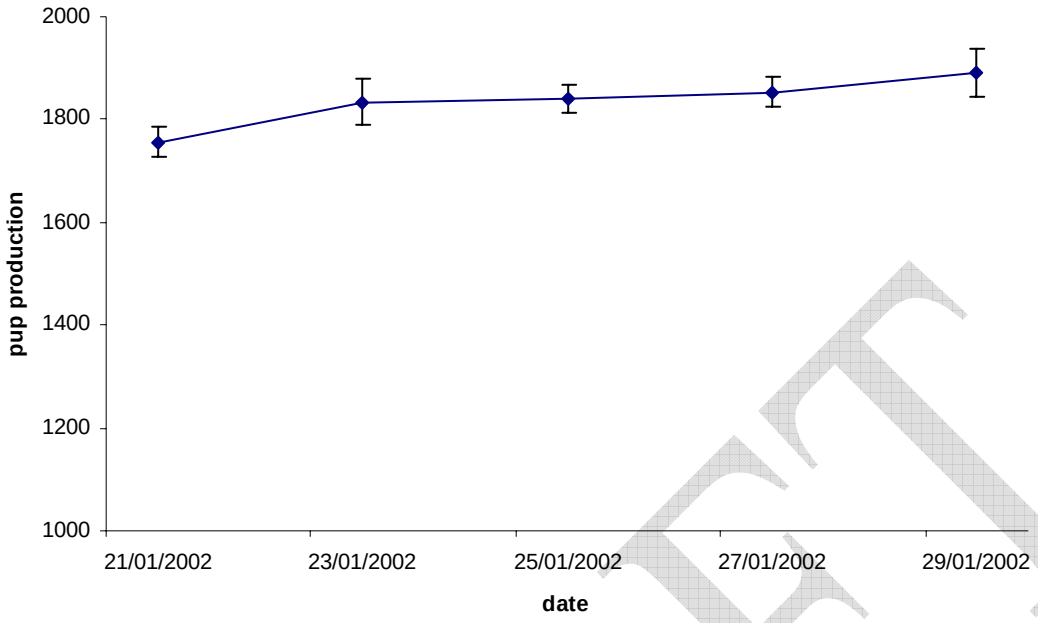


Table 2: Total pup production from the Auckland Islands (NB. These estimates do not include an estimate of pup production from Campbell Island).

Season	**Annual pup production**			**% Annual change in no. pups born**	**% Mortality at mark recapture estimate date**		**% Mortality at end of season (SB only)**
	Total	**Alive**	**Dead**		**Total**	**SB only**	
98/99	2867	2572	295	-5.1%	10%	8%	9%
99/00	2856	2689	167	-0.4%	6%	5%	11%
00/01	2859	2468	391	0.1%	14%	6%	10%
01/02	2282	1826	456	-20.2%	20%	21%	33%
02/03	2518	2078	438	10.3%	17%	16%	21%
03/04	2515	2347	168	-0.001%	7%	8%	15%
04/05	2148	2034	114	- 14.6%	5%	7%	12%
05/06	2089	1807	282	- 2.8%	14%	9%	16%
06/07	2224	2087	137	6.4%	6%	5%	16%
07/08	2175±44	2022	153	-2%	7%	5%	14%
08/09	1501±16	1410	91	- 31%	6%	4%	12%
09/10	1808±36	1625	183	+20%	10%	5%	15%
10/11	1550±41	1384	166	-15%	11%	5%	8%
Actual number of pups recorded as dead 10/11					166	19	30

Figure 3. Results of mark-recapture estimates undertaken at Dundas Island between 21/1/2002 and 29/1/2002. M-R estimates ± s.e.



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Appendix 1 Raw mark-recapture values (for Sandy Bay and Dundas) and direct counts (for Figure of Eight) for the 2010/11 season

	2010/11	
Sandy Bay	Marked	Unmarked
Pups capped / marked	148	
Counter 1a	56	87
1b	57	93
1c	68	82
Counter 2a	58	76
2b	62	94
2c	63	101
Counter 3a	94	121
3b	87	123
3c	92	131
Dundas		
Pups capped / marked	199	
Counter 1a	70	244
1b	100	379
Counter 2a	82	376
2b	98	371
Counter 3a	134	411
3b	117	453
Figure of Eight	Alive	Dead
Count 1	74	8
Count 2	72	8
Count 3	66	

Appendix 2 Raw mark-recapture values for two Dundas estimates undertaken on the 13th and 21st of January 2010.

	2010/11	
Dundas 13th January 2010	Marked	Unmarked
Pups capped / marked	389	
Counter 1a	238	475
1b	240	509
1c	241	468
Counter 2a	241	518
2b	202	382
2c	133	283
Counter 3a	152	352
3b	159	367
3c	179	382
Dundas 21st January 2010		
Pups capped / marked	387	
Counter 1a	127	238
1b	96	183
1c	72	175
Counter 2a	249	572
2b	227	552
2c	213	536
Counter 3a	181	359
3b	207	382
3c	167	332

Appendix 3 Raw mark-recapture values (for Dundas Is) undertaken during the during the 2001-02 season between the 21st and 29th of January.

Dundas 21 January 2002	Marked	Unmarked
Pups capped / marked	394	
Counter 1a	275	754
1b	257	653
Counter 2a	293	737
2b	282	599
Counter 3a	277	706
3b	250	711
Counter 4a	236	624
4b	228	547
Dundas 23 January 2002		
Pups capped / marked	396	
Counter 1a	237	561
1b	248	685
1c	255	675
Counter 2a	225	680
2b	204	683
2c	238	693
Counter 3a	230	580
3b	245	581
3c	246	603
Dundas 25 January 2002		
Pups capped / marked	399	
Counter 1a	268	619
1b	256	671
1c	242	658
1d	255	656
Counter 2a	265	778
2b	264	738
2c	266	745
2d	260	735
Dundas 27 January 2002		
Pups capped / marked	396	
Counter 1a	279	731
1b	270	709
1c	254	715
Counter 2a	255	718
2b	247	732
2c	244	737
Counter 3a	237	567
3b	219	560
3c	237	565
Dundas 29 January 2002		
Pups capped / marked	395	
Counter 1a	265	695
1b	224	684
1c	239	740
Counter 2a	245	749
2b	240	768
2c	255	755
Counter 3a	232	540
3b	249	568
3c	234	584