Auckland Islands 2021/22 New Zealand sea lion/pakake/ whakahao field research report

Conservation Services Programme pup count

Mel Young and Kat Manno

Department of Conservation
Te Papa Atawhai

New Zealand Government

Cover: Dundas Island. *Photo: Kat Manno*

DOC – 6944966

Document Revisions:

DOC-6944966

Revision	Affiliation	Date
Mel Young **Kat Manno**	Mountains to Sea, DOC	10 March 2022
Laura Boren	Mountains to Sea, DOC	15 March 2022
Simon Childerhouse	Cawthron Institute	25 March 2022
Kris Ramm	Mountains to Sea Manager, DOC	25 March 2022
Kat Manno	Mountains to Sea, DOC	2 April 2022

Citation:

Young MJ and Manno K (2022). Auckland Islands 2021/22 New Zealand sea lion field research report: Conservation Services Programme pup count. Department of Conservation, Dunedin. 34p.

Contents

1 Executive summary

This report summarises fieldwork undertaken as part of Conservation Services Programme (CSP) project POP2018-03 'New Zealand sea lion: Auckland Islands pup count' by the Department of Conservation. All scheduled New Zealand sea lion Threat Management Plan (TMP) fieldwork for the subantarctic islands was cancelled for the 2021/22 field season.

Five days of CSP fieldwork were completed on the Auckland Islands, from 6 to 10 January 2022, which allowed for mark-recapture estimates and direct counts of sea lion pups on Enderby, Dundas, and Figure of Eight Islands. However, the timing of the research was c. 10 days earlier than standardised counts due to vessel availability, and, therefore, not all pups had been born when counts occurred. Additional tasks, including incidental tag resightings, direct colony counts, and assessment of alternative materials for mark-recapture marking of pups were undertaken.

Total pup production for the Auckland Islands was estimated at **1759 ± 53.6 pups (mean ± 1SE)**, which includes an adjustment to account for the early date of the counts, and 43 pups found dead at the time of counts. This figure is approximately 8.1 % higher than the sum of mean direct counts and mark-recapture estimates without adjustment (minimum estimate = 1617 ± 49.4 pups). Both the adjusted and minimum estimates were higher than the minimum target of 1575 pups set in the *New Zealand sea lion Threat Management Plan* (DOC and MPI 2017).

Based on these estimates, Auckland Islands pup production has remained stable since 2009. Management actions to improve pup survival, which might improve population growth, including terrain trap mitigation and Ivermectin treatment, have not been achieved in the last three years. In addition, the last three seasons have not delivered the fieldwork necessary to support a robust analysis of pup and female survival, including pup morphometrics, flipper tagging and transponder insertion, and structured daily resighting effort for tagged animals. To this end, while the five-year objective to 'halt the decline' of the New Zealand sea lion has been achieved because pup production numbers have not dipped below site-specific measures of success, without continued animal marking and resighting of marked individuals there will be significant data

deficiency which will limit our ability to analyse demographic trends and effectiveness of interventions.

There are an increasing number of challenges to conducting work on New Zealand's subantarctic islands, particularly with respect to COVID-19 and public health restrictions, vessel availability and cost, and the ongoing commitment to improving health and safety systems for remote island work. It is imperative that a full season of subantarctic fieldwork be conducted in 2022/23 so that New Zealand sea lion population and demographic research, as well as interventions to improve survival of pups, can be implemented and assessed.

2 Introduction

The *New Zealand sea lion Threat Management Plan* (TMP) is a strategic programme of work, agreed to by the Minister for Primary Industries and Minister of Conservation, that aims to promote the recovery and ensure the long-term viability of Nationally Vulnerable New Zealand sea lions/pakake/whakahao *Phocarctos hookeri* (DOC and MPI 2017). This work is supported by the Conservation Services Programme population project CSP POP2018-03, with the specific objective of estimating New Zealand sea lion (NZSL) pup production at Enderby, Figure of Eight, and Dundas Islands (DOC 2021).

Approximately 68% of the total population of New Zealand sea lions breed on the Auckland Islands in New Zealand's subantarctic. There are estimated to be approximately 12,000 NZ sea lions and approximately 2,000 breeding females in the population, and Fisheries New Zealand reports occasional incidental captures of adult females in the Squid 6T fishery near the Auckland Islands during the annual breeding season. Annual pup counts, resightings of marked individuals, direct counts of mature animals, and assessment of breeding colonies are used to measure the success of TMP objective to recover and grow the sea lion population.

Site-specific TMP goals for the Auckland Islands are that NZ sea lion pup numbers and female demographics continue to improve from the 2014 count. These goals are measured using two methods:

a. *Adult female survival rate and pup survival rate improve*. Survival rates are determined from resightings of marked individuals, with marking occurring when

pups are approximately 3 weeks old, and resightings of marked sea lions are collected daily over the field season.

b. *Pup numbers are consistently above 1575 (2014 pup count) and ideally over 1965 (2017 pup count).* Pup production numbers are determined using direct counts of live and dead pups, and mark-recapture experiments.

In addition, across the New Zealand sea lion range, the TMP aims to:

- *Reduce pup mortality from terrain traps (natural holes);*
- *Investigate and recommend actions to reduce pup mortality;*
- *Determine estimates of cryptic mortality and sea lion exclusion device (SLED) efficacy affecting adult female sea lions;*
- *Understand the role of climate change and fisheries on the nutritional status of New Zealand sea lions;*
- *Continue development and establishment of new breeding colonies, and;*
- *Improve the threat status of New Zealand sea lions from Nationally Critical to Not Threatened.*

Field teams have been deployed to the Auckland Islands annually since 1994/95 to estimate pup production, undertake marking and tag/transponder resightings, and to determine mortality rates at each of the colonies. Estimates of pup production at the Auckland Islands derived from mark-recapture methods and direct counts of live and dead pups indicated a decline from the 1998 estimate of 3021 pups to a low of 1501 pups in 2009, but estimates have stabilised more recently at approximately 1600-1700 pups (DOC and MPI 2017).

There are a variety of anthropogenic and natural threats to New Zealand sea lions which need to be addressed to recover the population (Roberts 2015) and previous investigations indicated that 12-32% of sea lion pups die by two months of age (Chilvers et al. 2007). A comprehensive study of pup mortality conducted at Enderby Island has determined that approximately 60% of pup mortality in the first few months of life is due to *Klebsiella pneumoniae* infection (Michael et al. 2019), and a 2016-2018 study determined that Ivermectin (Ivomec, Boehringer Ingelheim Animal Health New Zealand, Auckland) treatment could improve pup survival from the disease (Michael et al. 2021). The Quantitative Risk Assessment of Threats to New Zealand Sea Lions (Roberts and Doonan 2016) determined that management would need to address multiple threats in order to meet the goals of the TMP. Standardised and focused effort on counting pups, marking pups with flipper tags and transponders, and resighting

female sea lion tags and transponders, are needed for long-term monitoring of population status and effectiveness of management actions (Chilvers and Meyer 2017, DOC and MPI 2017).

There have now been five Auckland Islands field seasons since the start of the TMP in 2017/18. In the last five seasons, two seasons have been more than 30 days long, two have been less than 10 days, and one season was missed due to COVID-19. The length of field seasons has varied since 1994/95, depending on the monitoring and research priorities identified at the time. A 'reduced' season usually ranges from two to four weeks and includes a baseline pup count, morphometrics, tagging and transponder marking of pups. A 'long' season is typically three months, including population monitoring, interventions, fecundity and demographic research, along with other research focused on pup and female mortality, foraging behaviour of adult females, or other topics. Table 1 outlines the breadth of the monitoring, intervention and research work completed from 2017/18 to 2021/22.

Table 1. A summary of the Auckland Islands research and monitoring tasks and their completion according to Conservation Services Programme (CSP) and New Zealand sea lion Threat Management Plan (TMP) objectives, 2017/18 to 2021/22. Opp. = opportunistic, Exp = experiment, ✕ = not measured.

Trip length (# days)		**82 days**	**53 days**	**10 days**	**0 days**	**5 days**
Conservation Services Programme Tasks	**Island(s)**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**
Daily direct counts of all age classes, live or dead (# days)	Enderby Island	72 days	25 days	10 days	0 days	1 day
Pup birthing dates (whole colony)	Enderby Island	✓	✕	✕	✕	✕
Cumulative count of dead pups (# days)		✕	Opp. (5d)	Opp. (3d)	✕	Opp. (5d)
Mark-recapture estimate of pups (timing -/+ days from standard, # of replicates)	Enderby Island	✓ (-0d, 9)	✓ (-0d, 10)	✓ (+1d, 1)	✕	✓ (-10d, 21)
	Dundas Island	✓ (-0d, 9)	✓ (-0d, 10)	✓ (+2d, 2)	✕	✕
Direct counts of live and dead pups (timing -/+ days from standard)	Enderby Island	✓ (-0d, 9)	✓ (-0d, 10)	✓ (+3d, 1)	✕	✓ (-9d, 14)
	Dundas Island	✓ (-0d, 4)	✓ (-0d, 5)	✓ (+2d, 1)	✕	✓ (-11d, 6)
	Figure of Eight Island	✕	✕	✓ (+16d, 1)	✕	✓ (-2d, 1)
Pup mass and morphometrics (# achieved/# goal)	Enderby Island	100/100	100/100	98/100	✕	✕
	Dundas Island	100/100	100/100	100/100	✕	✕
	Figure of Eight Island	0/63	0/65	26/53	✕	✕
Threat Management Plan Tasks	**Island(s)**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**
Pup tagging and transponder insertion (# achieved/# goal)	Enderby Island	309/309	312/312	284/285	✕	✕
	Dundas Island	400/400	400/400	200/400[1]	✕	✕
	Figure of Eight Island	0/63	55/65	26/53[1]	✕	✕
Resighting effort (# hours, across # days)	Enderby Island	Not recorded	155h, 53d	< 7h, 10d	✕	<4 h, 2 d
	Dundas Island	Not recorded	2h, 1d	0h, 0d	✕	0h, 0d
	Figure of Eight Island	Not recorded	<1h, 1d	0h, 0d	✕	0h, 0d
Mark resighting (tag resight) events (including duplicates, excluding pups)[2]	Enderby Island	5383	3281	232	0	48
Unique tags/brands resighted (excluding duplicates and pups)	Enderby Island	867	839	172	✕	48
	Dundas Island	0	5	✕	✕	✕
	Figure of Eight	6	2	✕	✕	✕
Unique transponders resighted (excluding duplicates and pups)	Enderby Island	79	36	11	✕	✕
Shark scar library	Enderby Island	✕	✓	✓	✕	✕
Pup post-mortem investigations	Enderby Island	✓	✓	Opp. (1)	✕	✕
Terrain trap mitigation	Enderby Island	✓	✓	✕	✕	✕
Ivermectin dosing	Enderby Island	Exp.	✕	✕	✕	✕

[1] Tagging only, no animals were transponder marked at Dundas or Figure of Eight Islands.
[2] Extracted from Dragonfly NZSL database, including flipper tags, brands, and transponders.

3 Trip logistics

Auckland islands tagging, mark-recapture, and resighting surveys are focused on sea lion colonies at Sandy Bay (Enderby Island) and Dundas Island. Additional surveys are traditionally conducted around the perimeter of Enderby Island, and at Figure of Eight Island in Carnley Harbour.

No field teams were sent to the Auckland Islands in 2020/21 due to Health & Safety issues and the COVID-19 pandemic, which has resulted in data deficiency for pup production, mortality investigations, Ivermectin interventions, and female survival estimates. This cancelled season occurred on the back of a reduced 2019/20 field season (as a result of financial constraints and vessel availability) which yielded limited data compared with the previous years (Table 1).

Budget reprioritisation in the Department resulted in the cancellation of TMP fieldwork in the subantarctic in December 2021, but the Conservation Services Programme funding for this project (CSP POP2018-03) remained in place. To remain within the CSP budget, the planned trip was shortened and shifted to fit the availability of the *Evohe* in January 2022. Confirmation of trip feasibility and vessel availability was secured less than a month prior to departure.

The trip was re-focused to deliver:

- Pup mark-recapture and direct counts at Sandy Bay, Enderby Island;
- Direct counts of pups at Dundas Island;
- Direct counts of all age classes at Sandy Bay, Enderby Island;
- Opportunistic resighting events for tagged animals on Enderby Island.

The field team comprised Kat Manno (DOC: Expedition Leader, TMP coordinator), Mel Young (DOC: Field Team Leader), Simon Childerhouse (Contractor: Cawthron Institute), Andy Hirschberg (DOC: Raukapuka/Geraldine), and Anne-Sophie Pagé (Volunteer: Massey University). An offer was extended to Te Rūnanga o Ngāi Tahu to nominate a representative for the trip, but they were unable to find a suitable candidate at such short notice.

The field team boarded *Evohe* at Bluff on 4 January and disembarked on 6 January at Sandy Bay, Enderby Island, returning to Bluff on 13 January 2022. The following islands were visited:

- Enderby Island: 6-7 January 2022 (overnight stay)
- Dundas Island: 7 January 2022
- Figure of Eight Island: 8 January 2022
- Main Auckland Island at Camp Cove: 8 January 2022
- Enderby Island: 9 and 10 January 2022

Due to time constraints and the scope of the CSP project, some monitoring and research tasks were not completed this year. These tasks included:

- Daily direct counts of sea lions of all age classes at Sandy Bay, Enderby Island (December-January)
- Cumulative daily counts of pup births and deaths (December-January)
- Assessment of female fecundity and mother-pup linkages (December-January)
- Ivermectin dosing of one-week old pups at Sandy Bay, Enderby Island (December-January)
- Pup post-mortems to determine causes of mortality (December-February)
- Pup tagging (transponders, flipper tags) of all pups at Sandy Bay, Enderby Island (January)
- Pup tagging (transponders, flipper tags) of 100 male and 300 female pups at Dundas Island (January)
- Pup measuring (straight length, girth, mass) of 50 male and 50 female pups on Enderby and Dundas Islands (January)
- Pup shelter trial on Enderby Island (December – January)
- Pup planks and terrain mitigation on Enderby Island (January – February)

4 Methods

The reduced field season and suboptimal timing of the expedition affected the ability of the team to undertake direct counts and mark-recapture tasks on standardised dates. The following tasks were achieved according to field protocols, with modified dates:

- Pup mark-recapture: 6-7 January 2022 (9-10 days earlier than standard 16 January)
- Direct counts of live and dead pups, Sandy Bay, Enderby Island: 6-7 and 9-10 January 2022 (6-10 days earlier than standard 16 January)

- Direct counts of adult and sub-adult male sea lions, Sandy Bay, Enderby Island: 6 January 2022
- Direct counts of female sea lions, Sandy Bay, Enderby Island: 6 and 9 January 2022
- Direct counts of live and dead pups, Dundas Island: 7 January 2022 (11-14 days earlier than standard 18-21 January)
- Direct counts of live and dead pups, Figure of Eight Island: 8 January 2022 (2 days earlier than standard 10 January)

4.1.1 Rationale for applying an adjustment index to count and mark-recapture data

On each day of counting on Enderby Island in January 2022, a subset of pups were observed with umbilicus attached, or placenta was seen in the colony, indicating that pupping was not complete for the season. Both direct count and mark-recapture methods to estimate pup production have the assumption that all pups are born prior to counts taking place. To understand the effect of the earlier date on the 2022 results for direct counts and mark-recapture, daily direct pup counts (daily live pups plus cumulative dead pups) from the 2015/16 and 2016/17 Enderby season[3] were summed per day and divided by the sum of the total number of pups (live plus dead) counted in both years, to indicate the cumulative proportion of each year's pups counted at the colony on each calendar day.

Assuming that: (a) total pup counts reach a plateau by 11 January annually (Figure 1), and (b) pupping dates are similar between each of the three islands, Table 2 outlines the mean proportion of pups expected to be counted on each calendar day, and the adjustment index applied to the 2021/22 count data.

'Adjusted' pup production estimates are presented in addition to 'minimum' mean direct counts and mark-recapture estimates to account for the premature date of the 2021/22 counts; daily direct counts of pups, and cumulative direct counts of dead pups in the 2015/16 and 2016/17 season are presented in Figure 1. The adjustment index was calculated by dividing the actual count or recapture result (live estimate + total dead) per event by the adjustment index for the date of the count, and then taking the mean and 1SE of these adjusted individual counts or recaptures.

[3] These two seasons were used for standardisation as we have high confidence in the quality of the data (these data were collected by experienced teams and error-checked by Simon Childerhouse).

Table 2. Mean proportions of total pups counted each calendar day at Enderby in the 2015/16 and 2016/17 seasons, and based on these data, the adjustment index for data collected in the 2021/22 season.

Calendar day	Mean proportion of the season's total pups counted	Adjustment index
6 January	91.2%	count/0.912
7 January	92.0%	count/0.92
8 January	91.8%	count/0.918
9 January	91.8%	count/0.918
10 January	93.4%	count/0.934

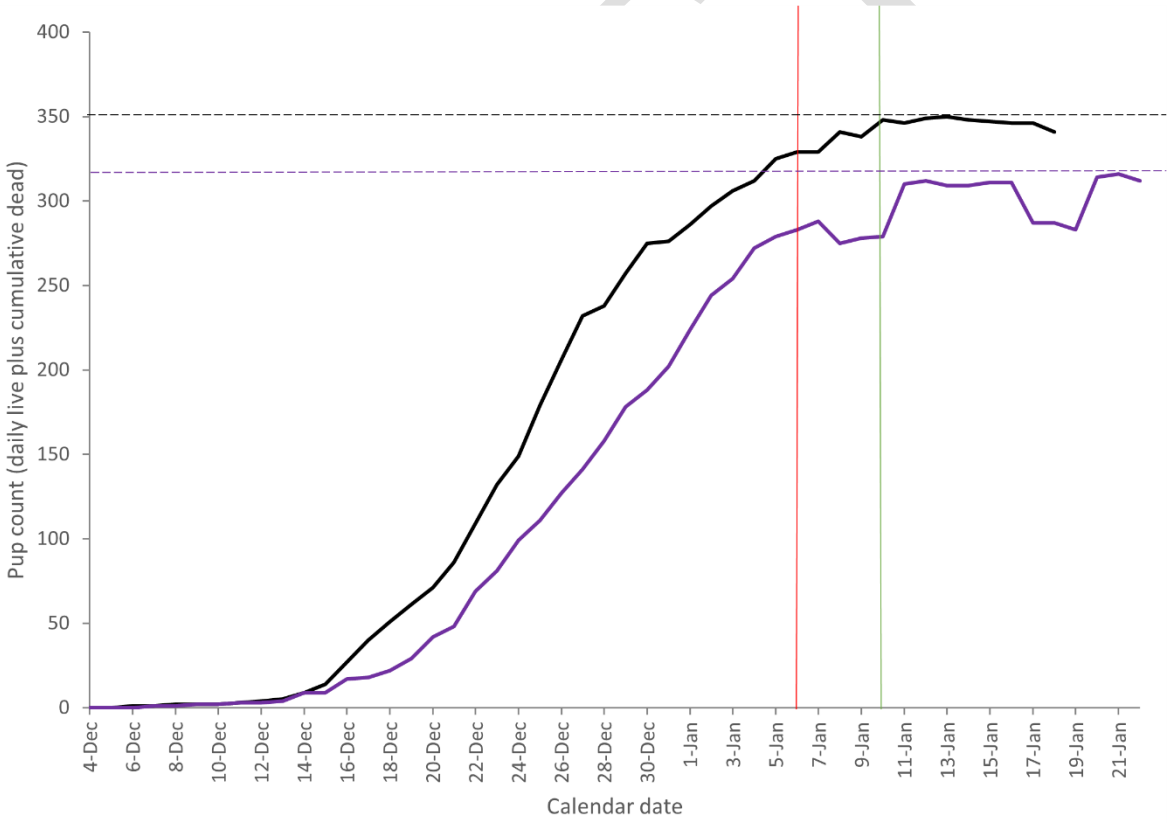

Figure 1. Daily direct counts of New Zealand sea lion pups (daily live plus cumulative dead) in 2015/16 (purple line) and 2016/17 (black line) seasons at Sandy Bay, Enderby Island. The horizontal dashed lines indicate the reported maximum number of pups counted in each season. The red line indicates 6 January, the date of the first direct counts in the 2021/22 season, and the green line indicates the last counts on 10 January 2022.

4.1.2 Direct count methods

Multiple direct counts of live and dead pups at Sandy Bay on Enderby and Dundas Island (Appendix 1) were undertaken per Operator, using a handheld tally counter. Due to the boggy and undulating terrain, combined team counts of live and dead pups were undertaken on Figure of Eight Island and around Enderby Island to maintain the health and safety of field personnel.

Standard error in the difference of means (SEDM = $\sqrt{((SE_1)^2 + (SE_2)^2)}$) were used to calculate overall standard errors for pup counts summed across islands, as outlined by Chilvers (2012).

In addition, direct counts of females, sub-adult males, and adult males were undertaken with replicates at Sandy Bay on Enderby Island (Appendix 1) and means ± 1SE (= SD/$\sqrt{n}$) were calculated.

4.1.3 Mark-recapture methods

White 5cm diameter PVC caps were glued to the heads of pups on 6 January 2022, according to the *New Zealand sea lion and fur seal pup tagging and sampling SOP* (n = 114 caps). Each Operator counted capped and uncapped pups concurrently on each walk through the Sandy Bay colony, with a minimum of three walk-throughs per Operator, on 6 and 7 January 2022 (Appendix 2).

A mark-recapture estimate and standard error (± 1SE) were calculated for Sandy Bay, Enderby Island, using the Lincoln-Petersen estimator (Chapman 1952), outlined by Chilvers (2012).

Because a relatively new team were involved with undertaking the mark-recapture experiment, several data integrity measures were taken, including: (a) undertaking a series of trial recaptures to allow new field team members to get their eye in, and (b) a minimum of three resightings/recaptures per Observer were conducted to assess variance between individuals (Appendix 2).

4.1.4 Assessment of biodegradable pup caps

To test the efficacy and longevity of attachment of biodegradable pup caps as an alternative to PVC caps, 5cm diameter white canvas caps were glued to the dorsum of a

subset pups also fitted with a PVC head cap, according to the *New Zealand sea lion and fur seal pup tagging and sampling SOP* (with approved modifications).

4.1.5 Opportunistic observations

The following opportunistic tasks were achieved but were considered incomplete/incidental:

- Direct counts of live and dead pups, Enderby Island, whole island: 10 January 2022;
- Trial of biodegradable white canvas pup caps, Enderby Island: 6-7 January 2022;
- Resightings of tagged animals, Enderby Island: 6, 9, 10 January 2022.

5 Results and Discussion

5.1 Estimates of pup production

Estimates of pup production using direct counts and mark-recapture are presented for each colony in the Auckland Islands for the 2021/22 season in Sections 5.1.1 to 5.1.4.

5.1.1 Sandy Bay, Enderby Island

Table 3. Summary of pup production estimates for Sandy Bay, Enderby Island, for 2021/22, including live pup estimates using mark-recapture and mean direct counts, the maximum number of dead pups counted per day, and the adjusted estimate according to the day of the count as presented in Table 2.

Method	Date	Number of counts (observers)	Start/end time	Live pup estimate ± 1SE	Max. total dead pups	Adjusted live and dead pup estimate ± 1SE
Mean direct count	6/1/22	14 (5)	12:10/13:23	288 ± 4.9	5	321 ± 5.4
Mean mark-recapture[4]	**6/1/22 7/1/22**	**21 (4)**	**20:21/20:58 7:25/8:05**	**320 ± 5.6**	**5**	**355 ± 6.1**
Mean direct count	9/1/22	9 (3)	15:30/16:32	302 ± 4.3	3	338 ± 4.7
Mean direct count	10/1/22	10 (5)	9:40/9:50 14:38/14:51	301 ± 5.3	(8)[5]	330 ± 5.4

[4] See Appendix 2

[5] A maximum of eight dead pups were seen by the team in 2022; five pups counted on 6 January and three pups counted on 9 January. The pups were not marked in any way, so we do not know if any of the three pups from 9 January were duplicate counts from 6 January.

Pups were counted over four field days at Sandy Bay. The mean estimated pup production for Sandy Bay, Enderby Island using mark-recapture is **355 ± 6.1** pups, including five dead pups seen during counts until 7 January, although the proportion of dead pups is likely an underestimate due to the very short period of observation. This estimate is c. 5-7% higher than the adjusted mean direct counts undertaken on 9 and 10 January 2022.

A total of 114 mark-recapture caps were deployed on the heads of pups, with none of the caps observed to have fallen off prior to recapture events. As many resightings were undertaken so that new staff could become familiar with the resighting technique, the variance between days, and variance between Operators were assessed, and accordingly, one Operator's counts were removed from the mark-recapture estimate due to significantly high variance (based on analysis of variance and Tukey HSD tests) (Appendix 2). Raw data are presented in Appendix 1.

5.1.2 Round-the-island Survey

Table 4. Summary of pup production estimates for Enderby Island (excluding Sandy Bay), for 2021/22, including live pup estimates derived from direct counts, the maximum number of dead pups counted per day, and the adjusted estimate according to the day of the count as presented in Table 1.

Method	Date	Number of counts (observers)	Start/end time	Live pup estimate ± 1SE	Max. total dead pups	Adjusted live and dead pup estimate ± 1SE
Direct count	**10/1/22**	**1 (5)**	**9:50/14:38**	**1**	**0**	**NA**

A circumnavigation of Enderby Island, using the Albatross and Enderby Island tracks, was completed on 10 January 2022, to estimate if any pup births occurred outside of Sandy Bay. A female and pup were found with a small number of sub-adult males at the south end of East Bay. This is assumed to be the first pup born at this location since monitoring commenced in 1994/95. Raw data are presented in Appendix 1.

No pups were observed at Pebble Point ("Southeast Point"), marking ten years since breeding activity was last recorded at this location.

5.1.3 Dundas Island

Table 5. Summary of pup production estimates for Dundas Island, for 2021/22, including live pup estimates using mean direct counts, the maximum number of dead pups counted, and the adjusted estimate according to the day of the count as presented in Table 1.

Method	Date	Number of counts (observers)	Start/end time	Live estimate ± 1SE	Max dead	Adjusted estimate ± 1SE
Mean direct count	**7/1/22**	**6 (3)**	**14:51/15:36**	**1201 ± 49**	**31**	**1339 ± 53.3**

Due to time limitations, a mark-recapture experiment was not attempted on Dundas Island. Landing conditions were sub-optimal for getting onto the island, with the team having to wait c. 4 hours for calmer conditions before approaching from the north-eastern side. Due to these time limitations, three team members undertook two complete direct counts each, yielding a mean of 1201 live pups. With the dead pups added and the adjustment applied to account for pups yet to be born, this figure increased to 1339 ± 53 pups. The number of dead pups is likely underestimated, as only one dead pup count was undertaken. Raw data are presented in Appendix 1.

Dundas Island is relatively flat, and the opportunity to use a fixed-wing unmanned aerial vehicle (UAV, hereafter referred to as a drone), potentially utilising aerial photography, LiDAR (light detection and ranging) and photogrammetry to detect, count and measure sea lions of all age classes should be investigated, to complement the use of existing methods (direct counts of live and dead pups, mark-recapture, measurement of pups, tagging and resights). This would be particularly advantageous when sea conditions or time restrictions limit the use of traditional methods and numbers of replicate counts, as drone-assisted counts might improve accuracy and precision. Aerial photography was successfully tested as an alternate method to ground counts in 2012 and 2013 (Baker et al. 2012, 2013). However, using a helicopter in the subantarctic can be logistically difficult in terms of timing, weather, health and safety, and availability. Improvements to drone technology in the last decade have increased their capability to detect, count, and measure marine mammals (e.g., Fiori et al. 2017), and therefore the opportunity to use drone-aided abundance surveys, whether launched from a boat, or from a launch on Enderby Island, should be revisited, as an opportunity to complement, but not replace, existing ground counting methods.

5.1.4 Figure of Eight Island

Table 6. Summary of pup production estimates for Figure of Eight Island, for 2021/22, including live pup estimates using direct counts, the maximum number of dead pups counted, and the adjusted estimate according to the day of the count as presented in Table 1.

Method	Date	Number of counts (observers)	Start/end time	Live estimate ± 1SE	Max dead	Adjusted estimate ± 1SE
Direct count	**8/1/22**	**1 (5)**	**11:25/12:12**	**52**	**7**	**64**

A single team count was undertaken opportunistically on Figure of Eight Island on 8 January 2022, yielding a count of 52 live pups and seven dead pups. This estimate was adjusted to a total of 64 pups using the information presented in Table 2. Raw data are presented in Appendix 1.

Multiple female-pup contact calls were heard in the vicinity of Camp Cove and Musgrave Harbour on 8 January 2022, with females responding to mimicked pup calls while *Evohe* was anchored at these locations. It is probable that pups would be old enough to be moved from Figure of Eight Island (c. 10km) by 8 January, however it is also conceivable that several females birthed pups outside this breeding colony.

5.2 Pup production totals

5.2.1 Auckland Islands pup production totals, 2021/22

Table 7. Pup production summary for direct counts and mark-recaptures undertaken across the Auckland Islands from 6 to 10 January 2022. Adjusted estimates include the total number of dead pups counted.

Island	Method	Date	Number of counts (observers)	Live pup estimate ± 1SE	Max dead on day of counts	Live plus dead pup adjusted estimate ± 1SE
Sandy Bay, Enderby	Mean mark-recapture	6-7 Jan	21 (4)	320 ± 5.6	5	355 ± 6.1
Round-the island survey, Enderby	Direct count	10 Jan	1 (5)	1	0	1
Dundas	Mean direct count	7 Jan	6 (3)	1201 ± 49.0	31	1339 ± 53.3
Figure of Eight	Direct count	8 Jan	1 (5)	52	7	64
Total				**1574 ± 49.4**	**43**	**1759 ± 53.6**

Table 8. Range of total pup production estimates calculated based on direct counts and mark-recapture undertaken across the Auckland Islands from 6 to 10 January 2022.

Pup production estimate method	Live plus dead pup estimate ± 1SE ('Minimum estimate')	Live plus dead pup adjusted estimate ± 1SE ('Adjusted estimate')
Mark-recapture (Sandy Bay Enderby Island) + Direct counts (Dundas, Figure of Eight, East Bay Enderby Island)	1617 ± 49.4	1759 ± 53.6

Mark-recapture has a high degree of accuracy, and therefore the mark-recapture estimate for Sandy Bay, Enderby Island, was taken as being more accurate than the mean direct counts that were contemporaneously undertaken. The mark-recapture

estimate was summed with all other direct counts undertaken to determine an overall pup production estimate for the Auckland Islands (Table 7). Both the 'minimum estimate' and the 'adjusted estimate' for each method and location were summed in the same fashion (Table 8).

Total pup production for the Auckland Islands was estimated at **1759 ± 53.6 pups**, which includes an adjustment to account for pups yet to be born, and 43 pups sighted dead at the time that direct counts and mark-recapture were conducted. This figure is c. 8.1 % higher than the minimum estimate indicated in Table 8.

Without adjustment to offset the early date of the counts, the minimum estimate for pup production (1617 ± 49.4) is just above the Auckland Islands TMP threshold of 1575 pups (DOC and MPI 2017).

5.2.2 Auckland Islands pup production totals, 1994/95 to 2021/22

Pup production estimates for each of the breeding colonies follow a stable trend over the TMP reporting period from 2017/18 to 2021/22 (Figures 2-5), with only Enderby Island showing a slight increase in pup production since 2017. Figure 8 indicates total Auckland Islands pup production from 1994/95 to 2021/22.

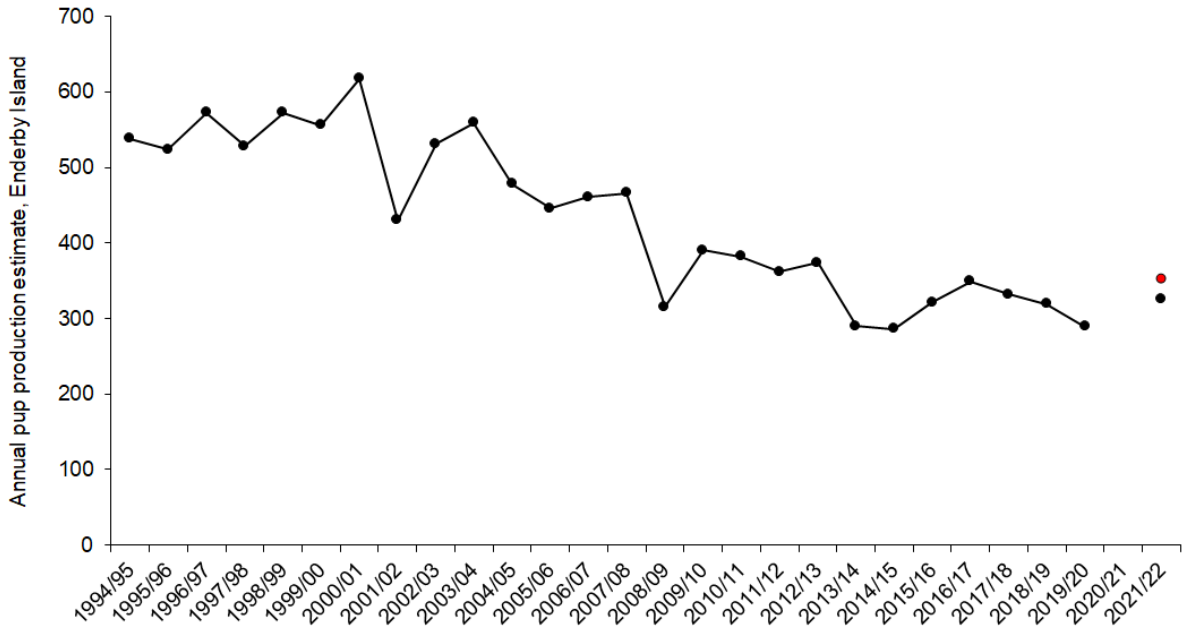

Figure 2. Enderby Island pup production estimates, 1994/95 to 2021/22. Two estimates are presented for 2021/22: (a) minimum estimate, based on direct counts and mark-recapture (black), and (b) adjusted estimate, based on direct counts and mark-recapture (red).

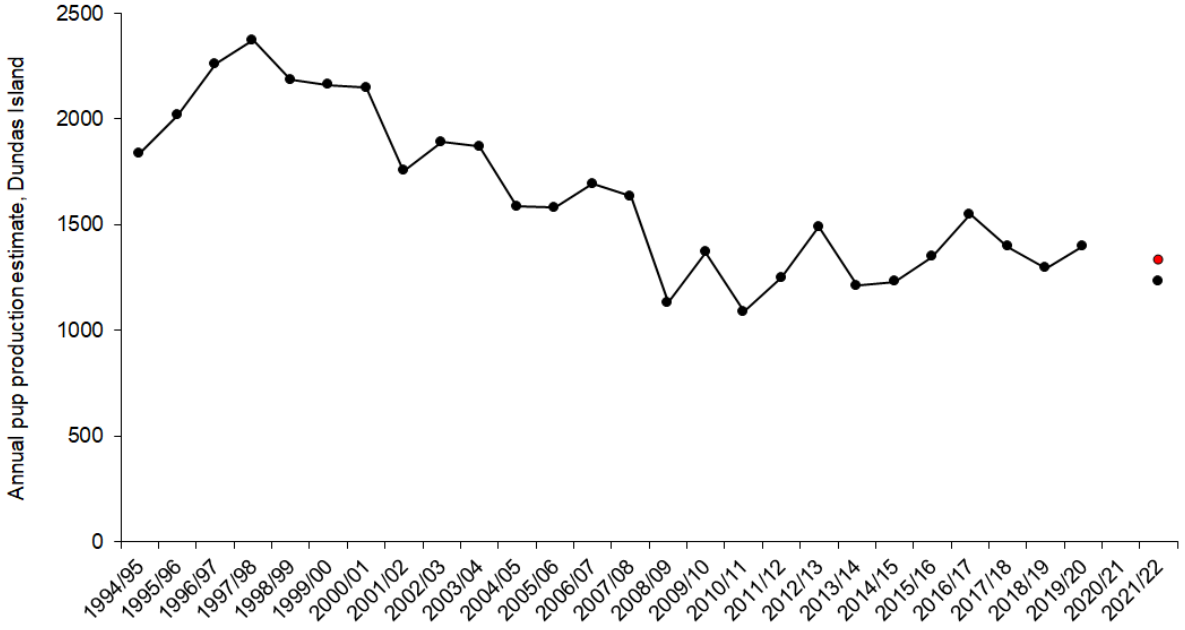

Figure 3. Dundas Island pup production estimates, 1994/95 to 2021/22. Two estimates are presented for 2021/22: (a) minimum estimate, based on direct counts and mark-recapture (black), and (b) adjusted estimate, based on direct counts and mark-recapture (red).

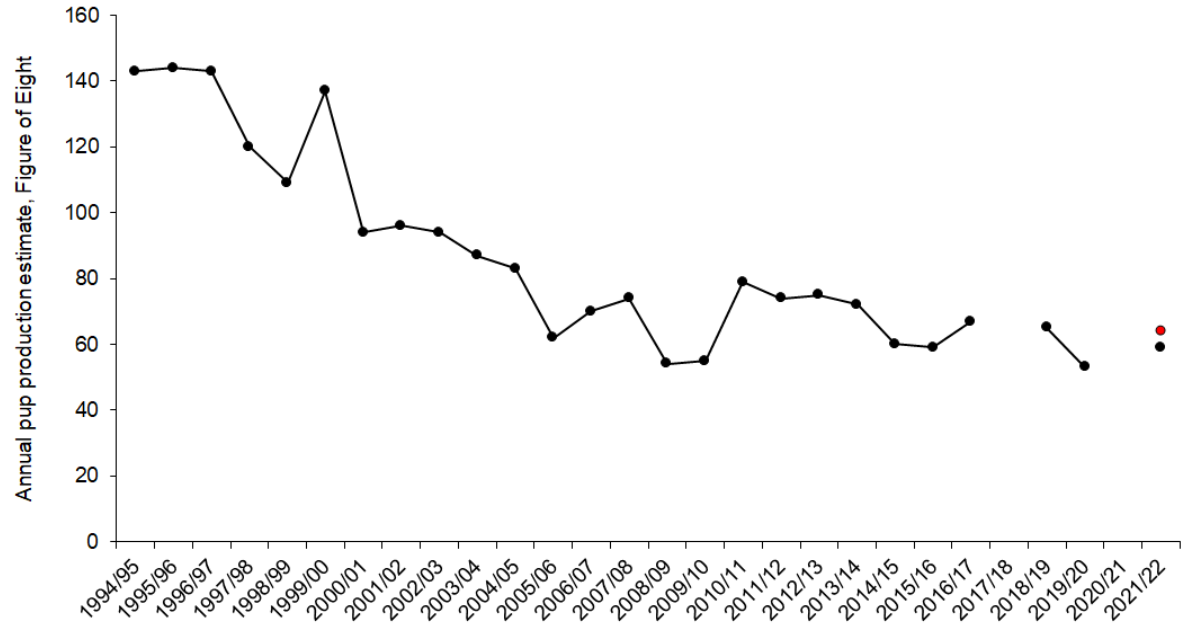

Figure 4. Figure of Eight Island pup production estimates, 1994/95 to 2021/22. Two estimates are presented for 2021/22: (a) minimum estimate, based on direct counts and mark-recapture (black), and (b) adjusted estimate, based on direct counts and mark-recapture (red).

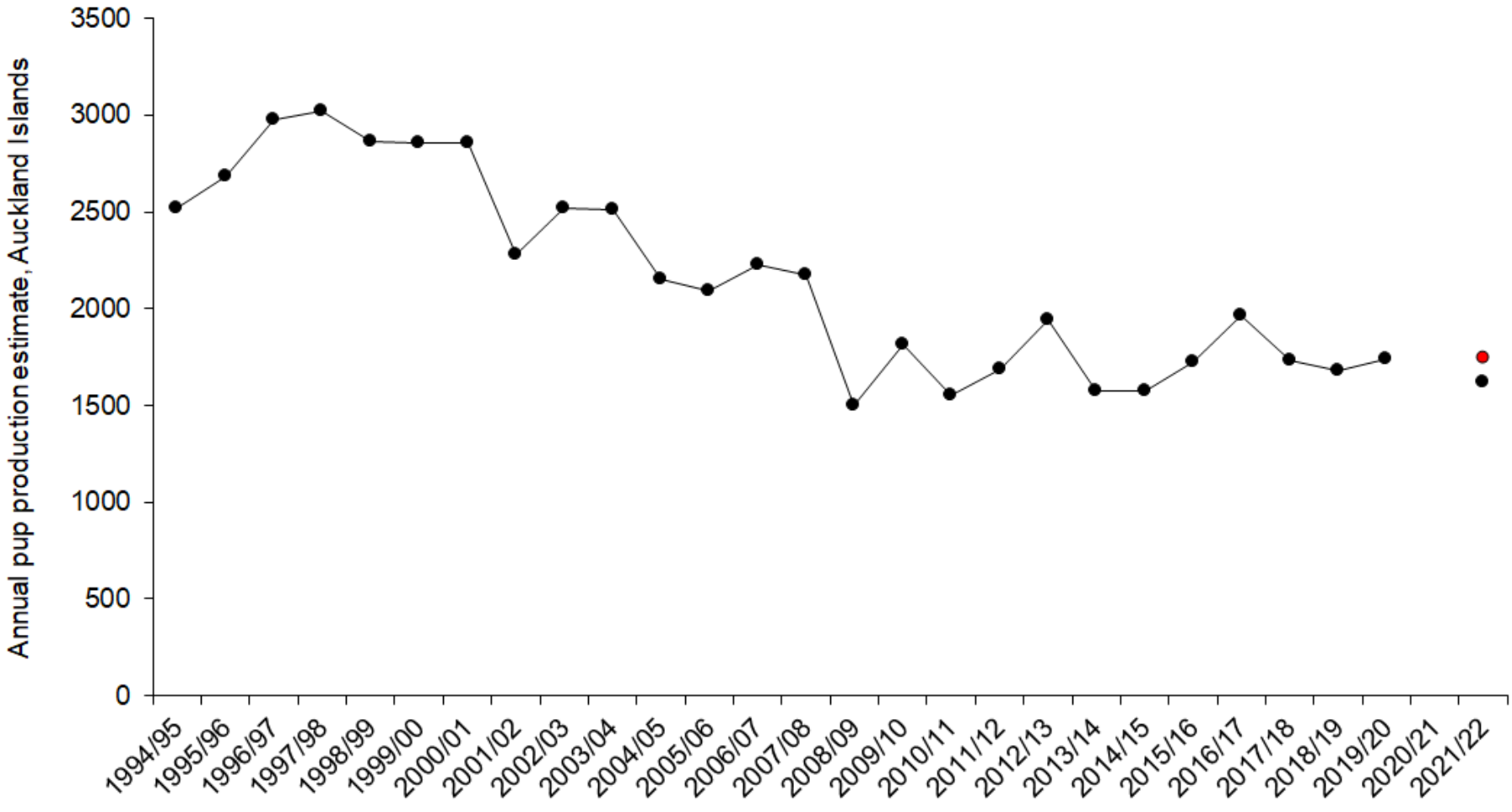

Figure 5. Total annual pup production estimates for New Zealand sea lions on the Auckland Islands, from 1994/95 to 2021/22. No estimates of pup production were obtained in 2020/21 due to the cancellation of the field season for CSP and TMP work. Two estimates are presented for 2021/22: (a) minimum estimate, based on direct counts and mark-recapture (black), and (b) adjusted estimate, based on direct counts and mark-recapture (red).

5.3 Trial of biodegradable canvas pup caps

To determine the visibility and retention of an alternative material to PVC caps, 31 circular canvas (100% biodegradable cotton) caps were glued to the dorsum of a subset of pups that received a PVC head cap (27.2 %), using a thin layer of cyanoacrylate glue (Loctite® 454™, Henkel AG, Düsseldorf, Germany) on 6 January 2022.

Figure 6. White 5cm diameter PVC caps applied to the head of New Zealand sea lion pups for mark-recapture (left), and white 5cm biodegradable canvas caps applied to the dorsum for trial (right, in yellow box), three days after both caps were applied to pups (9 January 2022).

Results are qualitative:

- The canvas dorsum caps were monitored from 6 to 10 January, and none were observed to be lost in this short observation period, possibly due to the higher absorption of glue into the canvas at the time of application.
- The immediate result was that the white canvas caps absorbed the glue more readily than PVC caps, which resulted in a slight yellow discolouration to the visible part of the material.
- When applied to the dorsum, the white canvas caps were discoloured further from wetting and rolling in the surrounding environment, however the caps were still visible three days after application (Figure 6).

These observations suggest that canvas caps have a high short-term retention (c. 4 days) suitable for undertaking mark-recapture experiments. Canvas caps might appear less obtrusive to tourists over time when compared to PVC caps because they are not bright white. The use of other biodegradable products, for example, using beeswax to cure the canvas prior to cutting the caps, might assist with reducing discolouration of the biodegradable caps in the short term. For longer-term (2-3 week) application on the dorsum, particularly where unique identification marks are required for behavioural

monitoring or Ivermectin dosing status, PVC caps might still be appropriate to use if they can be safely removed during pup tagging.

5.4 Direct counts by age class

Direct counts were undertaken for all age classes of animals at Sandy Bay, Enderby Island on 6 January, and for adult females also on 9 January 2022 (Table 9). Raw data are presented in Appendix 1. Direct counts of live and dead pups were undertaken at Enderby, Dundas, and Figure of Eight Islands as per Section 5.1.

Table 9. Direct counts of sub-adult and adult age classes at Sandy Bay, Enderby Island, on 6 & 9 January 2022.

	Adult males	Sub-adult males	Females
Mean ± 1SE	103 ± 2	34 ± 2	213 ± 6
Range	96 – 108	29 – 40	190 – 258
Dead	0	0	2

5.5 Opportunistic resighting events

5.5.1 Flipper tags

Opportunistic resightings of flipper tags at Sandy Bay, Enderby Island, were undertaken using a Canon digital SLR camera with a telephoto lens. Apparent tag colour, tag shape, left or right side, and tag number or partial number were recorded at the time, and photographs of tags were later investigated to determine if light/colour adjustments improved positive identification events (Figures 7 – 9). Tagged animal behaviours and pup status were not recorded for tagged individual sea lions. A total of 48 individuals with unique tags were resighted (28 females and 20 males).

The resighting effort undertaken to positively identify tags was opportunistic and was conducted over two days but significantly less effort was expended (< 4h total for 2 observers) than structured daily tag resighting effort required for the full TMP monitoring programme (> 4h for 2 observers per day for c. 5-6 weeks). Daily tag resightings by a minimum of two people per day over December and January are still

the best method for obtaining identity information for population models and should be prioritised to assess changes in female survival and fecundity to meet the site-specific measures of success outlined in the TMP.

Complementing tag resighting information with daily peripheral transponder detection sweeps are recommended, as many individuals are dual marked with flipper tags and transponders. Transponders stay in place for life, and have a high level of detection, so long as the observer can get close to the animal. Transponder reading of females would be suited to the harem break-up period in the second half of January when animals are more accessible. This proposed increase in transponder monitoring effort will increase positive identification of marked individuals and will allow for the determination the proportions of animals with 'failed flipper tags' for adjustment of population estimates.

5.5.2 Transponders

No effort was made to scan any sea lions for implanted transponders.

5.5.3 Brands

No branded animals were seen at any location.

Figure 7. An example of a 5cm white PVC pup cap on the crown of a New Zealand sea lion pup, used for mark-recapture. The female sea lion is tagged with a Dalton JumboTag that is no longer readable as the black etched alpha-numeric ID has worn off.

Figure 8. Tag resightings for marked individuals require positive identification of either flipper tags, brands, or implanted transponders. This tag, a Dalton PrimaTag 'tropicana' (green or blue face with a yellow back and post), was printed on the incorrect side, but the black etched writing is clearly visible.

Figure 9. A Dalton PrimaTag on a sub-adult male sea lion, with the black etched writing clearly visible.

6 Acknowledgements

We thank field team members Simon Childerhouse, Annie Pagé, and Andy Hirschberg for their contribution to this work. In addition, we thank Katie Clemens-Seely, Kris Ramm, Laura Boren, and Sharon Trainor from DOC, who assisted with all aspects of trip planning and logistics. Thanks to Te Rūnanga o Ngāi Tahu and Fisheries New Zealand for supporting the continuation of this research in partnership with the Department of Conservation. Thanks are extended to Janice Kevern and Louise Porter for undertaking quarantine inspections of equipment pre-departure. Special thanks are extended to Steve Kafka and the crew of the *Evohe* for safe passage and transfers between sites. Funding for this trip was provided by a Conservation Services Programme levy. The 2015/16 and 2016/17 data used for standardised comparison of pup counts were provided by Simon Childerhouse and collected by Chris Muller and Sarah Michael.

7 References

Baker B, Jensz K, and Chilvers BL (2012). Aerial survey of New Zealand sea lions – Auckland Islands 2011/12. Report prepared for the Ministry of Agriculture and Forestry, Deepwater Group, and the Department of Conservation. Latitude 42 Environmental Consultants Pty. Ltd., Kettering, Tasmania, Australia. 12p.

Baker B, Jensz K, and Chilvers BL (2013). Aerial survey of New Zealand sea lions – Auckland Islands 2012/13. Report prepared for the Department of Conservation. Latitude 42 Environmental Consultants Pty. Ltd., Kettering, Tasmania, Australia. 10p.

Boren L (2020). New Zealand sea lion and fur seal pup tagging and sampling SOP. Department of Conservation Standard Operating Procedure DOCCM-5993453 Version 32. Department of Conservation, Wellington, New Zealand. 38p.

Chapman DG (1952). Inverse, multiple, and sequential sample censuses. Biometric 8: 286-306.

Chilvers BL, Robertson BC, Wilkinson IS, and Duignan PJ (2007). Growth and survival of New Zealand sea lions, *Phocarctos hookeri*: birth to 3 months. Polar Biology 30 (4): 459-469.

Chilvers BL (2012). Research to assess the demographic parameters of New Zealand sea lions, Auckland Islands 2011/12. Final Research Report. Conservation Services

Programme report, contract number Pop 2011/01. Department of Conservation, Wellington, New Zealand. 11p.

Chilvers BL, and Meyer S (2017). Conservation needs for the endangered New Zealand sea lion *Phocarctos hookeri*. Aquatic Conservation: Marine and Freshwater Ecosystems 27: 846-855.

Department of Conservation (2021). Conservation Services Programme Annual Plan 2021/22. Department of Conservation, Wellington, New Zealand. 68p.

Department of Conservation and Ministry for Primary Industries (2017). New Zealand sea lion/rāpoka Threat Management Plan. Department of Conservation and Ministry for Primary Industries, Wellington, New Zealand. 19p.

Fiori L, Doshi A, Martinez E, Orams MB, and Bollard-Breen B (2017). The use of unmanned aerial systems in marine mammal research. Remote Sensing 9, 543; doi:10.3390/rs9060543

Manno K, Young M, and Boren L (2021). New Zealand sea lion fieldwork protocols: Auckland Islands, 2021/22 – 2022/23. Department of Conservation DOC-6855381 Version 5. Department of Conservation, Dunedin, New Zealand. 25p.

Melidonis M, and Childerhouse S (2020). New Zealand sea lion (rāpoka) monitoring on the Auckland Islands for the 2019/20 season: Field Research Report. Prepared for the Department of Conservation, Wellington, New Zealand. 23p.

Michael SA, Hayman DTS, Gray R, Zhang J, Rogers L, and Roe WD (2019). Pup mortality in New Zealand sea lions (*Phocarctos hookeri*) at Enderby Island, Auckland Islands, 2013-18. PLoS One 14: e0225461. doi: 10.1371/journal.pone.0225461.

Michael SA, Hayman DTS, Gray R, and Roe WD (2021). Risk factors for New Zealand sea lion (*Phocarctos hookeri*) pup mortality: Ivermectin improves survival for conservation management. Frontiers in Marine Science 8:680678. doi: 10.3389/fmars.2021.680678.

Roberts J (2015). Review of threats to the recovery of NZ sea lions and other otariid species. Report prepared by NIWA for the Department of Conservation, Wellington. 142p.

Roberts J, and Doonan I (2016). Quantitative Risk Assessment of Threats to New Zealand Sea Lions. New Zealand Aquatic Environment and Biodiversity Report No. 166. Ministry for Primary Industries, Wellington, New Zealand. 111p.

Young M, and Manno K (2021). Modifications to NZSL and fur seal pup tagging SOP. Department of Conservation Internal Memo DOC-6812820 Version 2. Department of Conservation, Dunedin, New Zealand. 4p.

8 Appendices

Appendix 1: Raw data for all counts

Appendix 2: Analysis of mark-recapture variance

8.1 Appendix 1: Raw data for all counts

Table A1. Direct counts of all age classes of New Zealand sea lions, Sandy Bay, Enderby Island, 6-10 January 2022. (NA=not counted)

Date	Adult males	Subadult males	Live females	Dead females	Live pups	Dead pups	Start	End	Observer
6/1/22	NA	NA	190	2	287	3	12:10	12:30	1
6/1/22	104	33	NA	NA	NA	NA	12:35	12:50	1
6/1/22	NA	NA	197	2	286	3	12:50	13:00	1
6/1/22	NA	NA	191	2	284	3	13:05	13:23	1
6/1/22	106	29	NA	NA	NA	NA	12:11	12:27	2
6/1/22	NA	NA	213	2	258	3	12:43	12:51	2
6/1/22	NA	NA	NA	NA	267	NA	13:06	13:16	2
6/1/22	NA	NA	192	NA	300	NA	12:10	12:30	3
6/1/22	96	40	NA	NA	NA	NA	12:35	12:50	3
6/1/22	NA	NA	200	NA	283	NA	12:50	13:00	3
6/1/22	NA	NA	199	NA	306	NA	13:10	13:30	3
6/1/22	NA	NA	218	NA	256	NA	12:30	12:41	4
6/1/22	NA	NA	220	NA	292	NA	12:55	13:03	4
6/1/22	NA	NA	NA	NA	325	NA	13:06	13:16	4
6/1/22	97	30	NA	NA	NA	NA	12:13	12:29	5
6/1/22	105	37	NA	NA	NA	NA	12:33	12:40	5
6/1/22	108	32	NA	NA	NA	NA	12:40	12:48	5
6/1/22	NA	NA	201	NA	NA	NA	12:54	12:59	5
6/1/22	NA	NA	200	NA	NA	NA	12:59	13:02	5
6/1/22	NA	NA	199	NA	NA	NA	12:48	12:54	5
6/1/22	NA	NA	NA	NA	299	NA	13:02	13:08	5
6/1/22	NA	NA	NA	NA	295	NA	13:08	13:16	5
6/1/22	NA	NA	NA	2	292	5	13:16	13:23	5
9/1/22	NA	NA	NA	NA	315	NA	15:30	15:40	3
9/1/22	NA	NA	NA	NA	287	NA	15:40	15:45	3
9/1/22	NA	NA	NA	NA	291	NA	15:45	15:50	3
9/1/22	NA	NA	234	NA	NA	NA	15:50	16:00	3
9/1/22	NA	NA	NA	NA	328	NA	15:30	15:40	4
9/1/22	NA	NA	NA	NA	297	NA	15:40	15:45	4
9/1/22	NA	NA	NA	NA	307	NA	15:45	15:50	4
9/1/22	NA	NA	256	NA	NA	NA	15:50	16:00	4
9/1/22	NA	NA	245	NA	NA	NA	16:00	16:06	4
9/1/22	NA	NA	258	NA	NA	NA	16:07	16:12	4
9/1/22	NA	NA	NA	NA	295	NA	15:22	15:48	5
9/1/22	NA	NA	NA	NA	297	NA	15:48	16:05	5
9/1/22	NA	NA	NA	NA	301	NA	16:05	16:13	5
9/1/22	NA	NA	NA	NA	NA	3	16:13	16:32	5
10/1/22	NA	NA	NA	NA	278	NA	9:40	9:50	1
10/1/22	NA	NA	NA	NA	299	NA	14:40	14:50	1
10/1/22	NA	NA	NA	NA	309	NA	9:40	9:50	2
10/1/22	NA	NA	NA	NA	299	NA	14:40	14:50	2
10/1/22	NA	NA	NA	NA	302	NA	9:40	9:50	3
10/1/22	NA	NA	NA	NA	312	NA	14:40	14:50	3
10/1/22	NA	NA	NA	NA	270	NA	9:40	9:50	4
10/1/22	NA	NA	NA	NA	324	NA	14:40	14:51	4
10/1/22	NA	NA	NA	NA	306	NA	09:40	09:54	5
10/1/22	NA	NA	NA	NA	307	NA	14:38	14:51	5

Table A2. Direct counts of live and dead pups, Dundas Island, 7 January 2022.

Date	Adult males	Subadult males	Live females	Dead females	Live pups	Dead pups	Start	End	Observer
7/1/22	NA	NA	NA	NA	1138	NA	14:51	15:15	5
7/1/22	NA	NA	NA	NA	1214	NA	15:15	15:36	5
7/1/22	NA	NA	NA	NA	990	NA	14:51	15:15	2
7/1/22	NA	NA	NA	NA	1282	31	15:15	15:33	2
7/1/22	NA	NA	NA	NA	1275	NA	14:51	15:15	4
7/1/22	NA	NA	NA	NA	1308	NA	15:15	15:33	4

Table A3. Direct counts of live and dead pups, Figure of Eight Island, 9 January 2022.

Date	Adult males	Subadult males	Live females	Dead females	Live pups	Dead pups	Start	End	Observer
8/1/22	NA	NA	NA	NA	52	7	11:25	12:12	1-5

Table A4. Direct counts of live and dead pups, Enderby Island, excluding Sandy Bay, 10 January 2022.

Date	Adult males	Subadult males	Live females	Dead females	Live pups	Dead pups	Start	End	Observer
10/1/22	NA	NA	NA	NA	1	0	09:50	14:38	1-5

Table A5. Mark-recapture resightings, Sandy Bay, Enderby Island, 6-7 January 2022.

Date	Capped	Uncapped	Start	End	Observer
06/01/22	67	140	NA	NA	3
06/01/22	81	146	NA	NA	3
06/01/22	65	134	NA	NA	3
07/01/22	68	140	07:25	07:34	3
07/01/22	57	134	07:36	07:45	3
07/01/22	64	120	07:49	07:57	3
07/01/22	70	118	07:57	08:05	3
06/01/22	88	193	20:20	20:35	4
06/01/22	84	155	20:50	20:57	4
07/01/22	63	174	07:37	07:45	4
07/01/22	66	145	07:49	07:57	4
07/01/22	67	155	08:00	08:06	4
06/01/22	72	99	20:34	20:48	2
07/01/22	62	93	07:25	07:34	2
07/01/22	44	87	07:37	07:45	2
07/01/22	47	84	07:49	07:55	2
07/01/22	60	96	07:57	08:05	2
06/01/22	77	136	20:34	20:38	1
06/01/22	80	148	20:40	20:58	1
07/01/22	71	121	07:25	07:34	1
07/01/22	66	136	07:36	07:45	1
07/01/22	76	121	07:49	07:57	1
07/01/22	91	157	07:57	08:05	1
06/01/22	73	128	20:34	20:38	5
06/01/22	72	123	20:40	20:48	5
06/01/22	70	135	20:50	20:57	5

8.1 Appendix 2: Analysis of mark-recapture variance

Table A5. Summary of mark-recapture pup production estimates for Sandy Bay, Enderby Island, on 6 and 7 January 2022. Based on analysis of variance, there was no significant difference between counts undertaken on these dates ($F(1,24) = 0.558$, $p = 0.462$).

Method	Date	Number of counts (observers)	Start/end time*	Live estimate ± 1SE	Max dead
Mean mark-recapture estimate ('eye-in')	6/1/22	11 (5)	20:21/20:58	324 ± 7.8	5
Mean mark-recapture estimate (count day)	7/1/22	15 (4)	7:25/8:05	334 ± 14.2	5

Table A6. Mean mark-recapture estimates per observer, for Sandy Bay, Enderby Island, averaged across 6 and 7 January 2022. Analysis of variance indicated a significant difference between Observers ($F(4, 21) = 5.641$, $p < 0.003$), with a Tukey HSD post-hoc test indicating that Observer 4 was significantly different ($p = < 0.05$) to Observers 1, 2 and 5.

Method	Number of counts	Live estimate ± 1SE	Retention in final mark-recapture estimate
Mean mark-recapture estimate – Observer 1	6	316 ± 9.5	Retained
Mean mark-recapture estimate – Observer 2	5	300 ± 19.0	Retained
Mean mark-recapture estimate – Observer 3	7	339 ± 10.1	Retained
Mean mark-recapture estimate – Observer 4	5	371 ± 26.2	Removed
Mean mark recapture estimate – Observer 5	3	318 ± 11.5	Retained

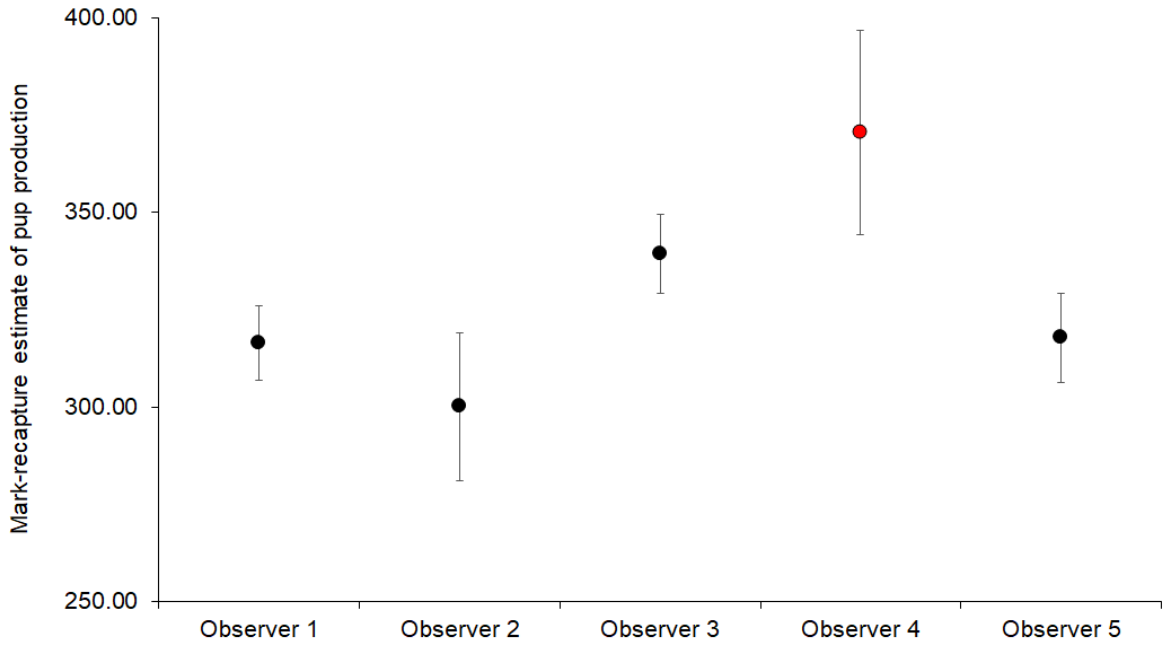

Figure A7. Mean mark-recapture estimates per observer ± 1SE, for Sandy Bay, Enderby Island, averaged across 6 and 7 January 2022. Based on analysis of variance and Tukey HSD tests, the estimates for Observer 4 (red) were removed from the mean presented in Table 3.