Draft Final Report

Research to assess the demographic parameters and at sea distribution of New Zealand sea lions, Auckland Islands

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Dr. B. Louise Chilvers

Aquatic & Threats Unit, Department of Conservation

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Abstract

The New Zealand sea lion (NZ sea lion), *Phocarctos hookeri*, is New Zealand's only endemic pinniped. It is classified as Nationally Critical and is estimated to be the world's rarest sea lion. This report summaries three annual surveys (2007-08, 2008-09, 2009-10) of the Auckland Island area with the objective to collect data to allow quantification and estimation of demographic parameters of NZ sea lions and the at-sea distribution of juvenile NZ sea lions from the Auckland Islands.

The pup production estimates for the Auckland Islands NZ sea lion population declined by 18.4% during the three year period with the most significant change recorded being a 31% decrease in pup production at the Auckland Islands between 2007-08 and 2008-09.

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 three field seasons 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.

The at sea distribution of both male and female juvenile NZ sea lions from the Sandy Bay breeding site were investigated during the three seasons. Fifteen females aged two and three years of age and 11 males aged between two and five years of age were captured and satellite tags were attached for between 2 and 71 days. Overall, the majority of juvenile NZ sea lions (those four years old and less) showed foraging distributions close to the Auckland Islands on the Auckland Island shelf, predominantly in the North and North-east areas of the shelf. There was significant overlap between juvenile NZ sea lion foraging locations and arrow squid (*Nototodarus sloanii*) 6T fisheries activities which is likely to result in fisheries/juvenile sea lion interactions and deaths, as does occur. For Sandy Bay juvenile NZ sea lions, there was little overlap of foraging locations with scampi or other fisheries activities around the Auckland Island area.

Keywords: New Zealand sea lions, *Phocarctos hookeri*, distribution, population, fishing bycatch, satellite telemetry, demographics, Auckland Islands

1. Introduction

The New Zealand sea lion (NZ sea lion), *Phocarctos hookeri*, is New Zealand's only endemic pinniped. It is classified as Nationally Critical (Baker et al. 2010) and a population estimate based on the results from this study found it to be the world's rarest sea lion (Geshke and Chilvers 2009). Based on the 2010 pup production estimates from the Auckland Islands and the pup production estimates from 2008 from Campbell Island (Maloney et al. 2009), 76% of all NZ sea lions pups born are born at the Auckland Islands. Between 1997/98 and 2005/06 pup production of NZ sea lions at the Auckland Islands decreased by 31% (Chilvers et al. 2007). This decrease in pup production is thought to be aggravated by a combination of incidental by-catch from commercial fishing activity and disease events. This work continues annual surveys of the Auckland Island breeding sites of the New Zealand sea lions (see http://www.doc.govt.nz/mcs). The project's objectives were to:

1) collect data to allow quantification and estimation of: i) NZ sea lion pup production; ii) survival of previously marked NZ sea lions; iii) and reproduction by known age female NZ sea lions;
2) maintain and update the NZ sea lion database and make available field data for relevant modelling work; and
3) characterise the at-sea distribution of juvenile NZ sea lions and analyse the distribution in a fisheries context.

Fieldwork was carried out between December and February each year 2007-08 to 2009-10, corresponding with the NZ sea lion breeding season.

2. Methods

There are two pupping areas (Northern Auckland Islands and Figure of Eight Island) made up of four pupping sites at the Auckland Islands (Figure 1). The four pupping sites, Sandy Bay (50°30'S, 166°17'E) and South East Point (SEP, 50°30'S, 166°19'E) on Enderby Island, Dundas Island (50°35'S, 166°19'E) and Figure of Eight Island (50°46'S, 166°01'E) were monitored each season.

2.1 Collect data to allow the estimation of demographic parameters and update NZ sea lion sighting database

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. unpublished data). Between 1999 to 2003 pups were also injected with individually identifiable passive integrated transponders (PIT, Trovan, Ltd., Douglas, United Kingdom).

Presence and breeding status of marked animals at breeding areas

Daily tag resightings were conducted at Sandy Bay and SEP between early December to at least the 14th February each season. Daily resighting takes 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. A minimum of three days of resighting were undertaken at Dundas Island each season. Resightings consist of the date and place of sighting, the animals tag number, colour and shape, the number of tags, in which flippers, and how many flipper seen, PIT presence (therefore alphanumerical series) or not, animal sex and breeding status or behaviour. PIT tag presence checking is undertaken throughout the season, although there is a higher likelihood of getting access to more animals after mid-January, because until then the animals in the harem are packed so tight, with large territorial males defending areas, that many animals can not be accessed. All animals, whether they have tags or not (unless very young, as animals have not been PIT tagged since 2003) are checked for PIT tags by passing the PIT reader over the hind end of a preferably sleeping or otherwise distracted animal.

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

Presence of any marked animals and breeding status data were collected opportunistically from other sites outside the breeding sites around the Auckland Islands (Kekeno, Ross Harbour area and North Harbour on the main Auckland Island and Rose Island) when researchers were travelling near the areas. At least half a day every season was spent searching the entire area of Rose Island. Kekeno was visited twice each season. North Harbour was visited for 1 to 2 hours in February 2008 and 2010. Ross Harbour was cruised by boat looking for sea lion marks (and radio tracking for VHF tagged juveniles) at least one day each season with landings occurring when marks or tracked animals were found.

Update NZ sea lion sighting database

All sighting field data were verified and entered into the NZ sea lion database and each year's data extracted and made available for relevant modelling work. Verification of data was conducted during the season and specifically at the end of the season when all data was 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 are still identified as having only one flipper tag seen additional effort is made to try and determine true tag number while the team is still in the field) colour and tag number matches checked, previous and original tag information entered where necessary for adult females, and ensuring class, tag year, age, tag location and status is entered for all animals. Details of the database are provided in Appendix 1.

2.2 NZ sea lions pup production

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 as consistent with previous methodology (Gales & Fletcher 1999; Chilvers et al. 2007).

Direct counts

Direct counts were conducted at SEP using daily surveys (from approximately December 4th to at least January 15th each year) during the breeding season. 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 daily counts recorded of the number of live pups and

any dead pups since the previous count. Pup production was based on the daily count 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 two to three people around the entire island made on a single day on the 9th or 10th of January annually. Live and dead pups were counted separately. Means of live and dead pups were calculated separately. The total standard error was calculated by determining the standard deviation of the total counts (alive and dead) from the mean total and divided by the square root of the sample size.

Mark-recapture experiments

A single M-R experiment was conducted each year at Sandy Bay on the 15th and 16th January and at Dundas Island on the 20th and 21st January. The mark-recapture study was timed to occur when pupping had ceased, but before the pups had started to disperse from their natal birth beach (Gales & Fletcher 1999; Chilvers et al. 2007). The best time for counts was estimated from pup production curves described from Sandy Bay and Dundas Island (Gales & Fletcher 1999). The date of maximum pup numbers at Sandy Bay (approximately the 10th of January) changes by only one or two days between years (Wilkinson et al. 2003; Chilvers et al. 2006a). 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). The number of pups marked was approximately 30-50% of previous pup production estimate (Sandy Bay 2008 197 marked pups, 2009 150 marked pups, 2010 148 marked, Dundas Island 2008 400 marked pups, 2009 396 marked pups, 2010 387 marked pups, note the number of marked pups at Sandy Bay decreased between 2008 and 2009 because of the severe drop in pup numbers that was apparent in that year). 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 a few weeks after the experiment. Recaptures involved three observers moving systematically through the entire sea lion pupping area counting pups, with each observer conducting 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. This greater probability of viewing marked caps could have 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. All recapture operations were conducted on the day following the marking operation to allow time for even mixing of marked and unmarked individuals.

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

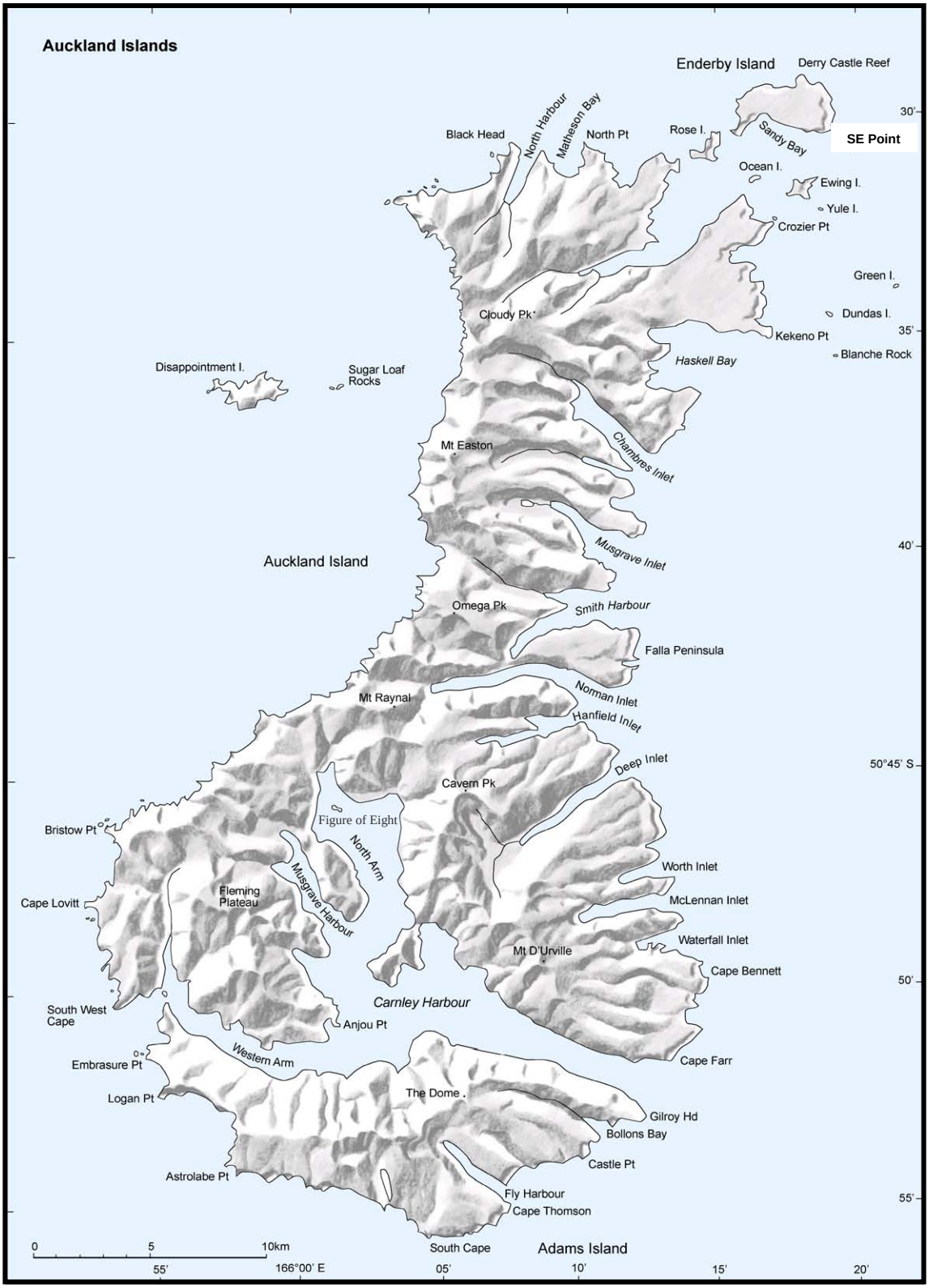

Figure 1: The Auckland Islands showing areas where sea lions were sighted: Figure of Eight, Dundas, Enderby, Ewing, Rose and Auckland Islands.

The standard error (SE), 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).
The standard error for the total Auckland Island pup production estimate is calculated as:

$$SE_{Total} = \sqrt{SE_{SandyBay}{}^2 + SE_{Dundas}{}^2} + SE_{Fig8}{}^2$$

The SE for pup estimates from 02/03 to 06/07 were also recalculated using these equations. The assumptions for the M-R model were: (1) all pups were born by 15 and 21 January at Sandy Bay and Dundas island respectively; (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 the following day; (5) mortality was negligible and assumed to be zero in the time between marking and recapturing; and (6) pups were not yet swimming and females had not started to move their pups away from the island (no emigration or immigration to the study area).

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 (Gales & Fletcher 1999; Chilvers et al. 2007). All pups that died during the breeding season from Sandy Bay and SEP were counted and removed on a daily basis for autopsy, which resulted in the accurate assessment of numbers of dead pups from these two sites. For Dundas 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 total carcase count.

The accuracy of mark-recapture estimates at Sandy Bay were assessed 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. This procedure was carried out to determine the accuracy of the mark-recapture procedure for NZ sea lions.

2.3 Characterise the at-sea distribution of juvenile NZ sea lions and analyse in a fisheries context.

Capture and deployment.

Captures of juvenile NZ sea lions were undertaken at Sandy Bay. Satellite-linked platform transmitting terminals (PTTs) (Telonics 300 mW ST6, potted in epoxy, 130 × 35 × 15 mm, 175 g; Telonics) and VHF transmitters (70 mm × 30 mm × 15 mm, Sirtrack, Havelock North, New Zealand) were attached to both male and female juvenile NZ sea lions between the ages of 2 and 5 years of age. Over the three years an even spread of animals from each age and sex class was attempted to be captured. Therefore animals identified to be the age and sex wanted in each year were approached while asleep and restrained by placing a net over the head; as the animals moved away and into the net their movements became restricted by its tapering shape. At the end of the net a small reinforced opening held the animal's muzzle, closing the mouth but leaving the nostrils clear (Gales & Mattlin 1997, Costa & Gales 2000). Netted animals were physically restrained by two people and anaesthetized using an isoflourane (2 to 5%) oxygen mix delivered by a mask from a portable vaporizing system (Gales & Mattlin 1997). From initial netting until the mask was in position took approximately 3 to 5 min, and

animals were anaesthetized for less than 30 min. Once stable, the sea lions were weighed (200 kg capacity spring scale ±0.5 kg, Salter Housewares) and length (noise to tail) and girth (circumference under flipper pits) measured before instruments were attached. Prior to deployment, each instrument was glued to a piece of neoprene material cut to the same size as the unit's base. This neoprene base was then glued to the dorsal pelage just below the shoulder blades of the sea lion using 2-part epoxy glue. Once the PTT and VHF units were adequately attached to the sea lion (8 to 10 min after glue application) the flow of anaesthetic was stopped and the animal was allowed to recover. Each animal was observed after restraint until they were fully conscious and had returned to the group or location where captured.

Most animals with transmitting tags were recaptured in the same manner before the end of the field season to retrieve tags. However, as juveniles are not restricted to returning to dependant pups ashore – like lactating females are (Chilvers et al. 2006a, 2006b), nine animals did not return within the season to the breeding site so tags were lost. The use of transmitting tags meant data from these tags was still collected remotely. Tags were removed by horizontally cutting through the neoprene leaving neoprene on the tag and on the animal. This neoprene would be moulted off within a month during the animals' natural moult. All animals were positively identified in the next year or following season and showed no marks or damage in the area where tags were deployed.

Data analysis

The at sea locations of juvenile NZ sea lions were calculated for each sea lion by reference to three satellites and were assigned to one of six classes by Argos on the basis of their accuracy. The accuracy of locations provided by Argos is classified as follows: class 3 accurate to 150m, class 2 accurate to 350m, class 1 to accurate to 1km, class 0 accurate to $\geq$ 1 km and classes A and B have limited accuracy assigned. Only the four most accurate classes (0, 1, 2, 3) were included in these analyses (as in Boyd et al. 1998, Bonadonna et al. 2000, Chilvers et al. 2005). The fisheries operational locations data were supplied by the Research Data Management section of the Ministry of Fisheries, New Zealand. Request rep-log 7138 supplied data which allowed the representation of all start locations for trawl shoots (all targets) undertaken each season within the area of the Auckland Islands part of the SQU6T fisheries management area.

The distribution of satellite locations of juvenile NZ sea lions were plotted in ArcGIS (Appendix 2), and all animal's locations summed within each square of a grid which was overlaid on the Auckland Island area in GIS, with each square having 10km x 10 km sides. Similarly the intensity of each fishery operation was mapped by summing all start tow locations undertaken within each 10km x10km square. Analyses were conducted separately for fishing effort targeting squid, scampi and other targets. The overlap between juvenile NZ sea lion satellite locations and fisheries operations was then quantified within each 10 x 10 km area by multiplying the number of sea lion sightings by the number of tows started within the area. The product was used to derive a relative interaction scale of 1 (<50, low interaction), 2 (50-99), 3-4 (100-149, medium interaction), 5-6 (150-300) and 7 (>300, high interaction), as used in Figure 3b. This provides a quantified estimate of the spatial distribution of juvenile NZ sea lion-fishery operation interactions, assuming that the risk of interaction is proportional to the extent of overlap of NZ sea lion distribution and commercial fishing operational distribution at any location. Hence areas where sea lions forage, but no fishing occurs or vice versa, have a zero interaction rate. As such, the expected level of interaction will be highest in regions with high NZ sea lion foraging and high commercial fishing effort.

3. Results

3.1 Sea lion counts and resights

There was no sign of breeding and very few animals were sighted at Kekeno, Ross Harbour area or North Harbour on the main Auckland Island or Rose Island. There were three, 11 and five tagged animals resighted each year at Kekeno and three, three and two tagged animals resighted at Rose Island each year respectively. Total number of animals at each sight was not recorded. Two groups of researchers studying Albatross were located on Adams Island and in the Western Arm of Carnley Harbour during all three summer seasons (G. Elliot, K. Walker, D. Thompson pers. comm.). Reports from these areas yielded no tag resights and no sign of breeding in any of these areas. These researchers were in these area for over 6 weeks of season. See Figure 1 for locations.

Sea lion (non-pup) counts at Figure of Eight Island were 48 females and 43 males on the 10th of January 2008, 26 females and 17 males on the 9th of January 2009 and 39 females and 16 males on the 10th of January 2010.

There were 6092, 5396 and 7154 field sightings of previously tagged, branded and/or passive integrated transponder (PIT) tagged animals collected and recorded each year respectively. The NZ sea lion database has had the three field seasons 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. This data has been made available for analyses of demographic parameters (e.g. MacKenzie 2010).

3.2 Pup production estimate

Estimates of pup production were calculated for each breeding site in the Auckland Islands using data collected between 10 January and 21 January each year (Tables 1 and 2, Figure 2a, b, c, d, & e). Mark recapture methods were used to estimate pup production from Sandy Bay and Dundas Island, while Figure of Eight Island and South East Point areas were estimated using direct counts. All estimates reported here are mean estimates (± standard error).

Each year on the 16th of January, a mark-recapture estimate at Sandy Bay was undertaken (Table 1; Figure 2b, Appendix 3). In 2008, 417 pups were tagged on the 17th of January at Sandy Bay. In 2009, 301 pups were tagged on the 17th of January on Sandy Bay. In 2010, 364 pups were tagged on the 17th of January at Sandy Bay. Comparison between M-R estimates and absolute pup numbers tagged on Sandy Bay showed an average difference of less than 2% of total pup production. This supports the use M-R methods to accurately estimate pup production on Dundas Island.

The mark recapture estimate at Dundas Island was completed on 21st January each year (Table 1; Figure 2c). Each year approximately 400 pups were tagged annually on Dundas Islands, 300 female and 100 male pups (Appendix 3).

Direct counts from Figure of Eight Island were made on the 9th or 10th January each year (Table 1; Figure 2d, Appendix 3). Direct counts were also conducted on the 15th of January each year at South East Point (Table 1, Figure 2e).

The estimate of pup production from the Auckland Islands was 2.2% lower between 2006/07 and 2007/08, 31% lower between 2007/08 and 2008/09 and increased 20.8% between 2008/09 and 2009/10, however the 2009/10 estimate is still 18.4% lower that the 2006/07 estimate (Figure 2a).

Pup mortality during the first 4 weeks of the 2007/08 season from all studied locations was 7% as of the 16th January (Table 2). Pup mortality at Sandy bay was 5% at the same date and was 14% by 15th Feb 2008. Pup mortality during the first 4 weeks of the 2008/09 season from all studied locations was 6% (Table 2). Pup mortality at Sandy Bay was 4% at 16th

January and was 12% by 15th Feb 2009. Pup mortality during the first 4 weeks of the 2009/10 season from all studied locations was 10% (Table 2). Pup mortality at Sandy bay was 5% at 16th January and was 15% by 18th Feb 2008.

Figure 2a. Annual pup production for the Auckland Islands 1998/99 to 2009/10.

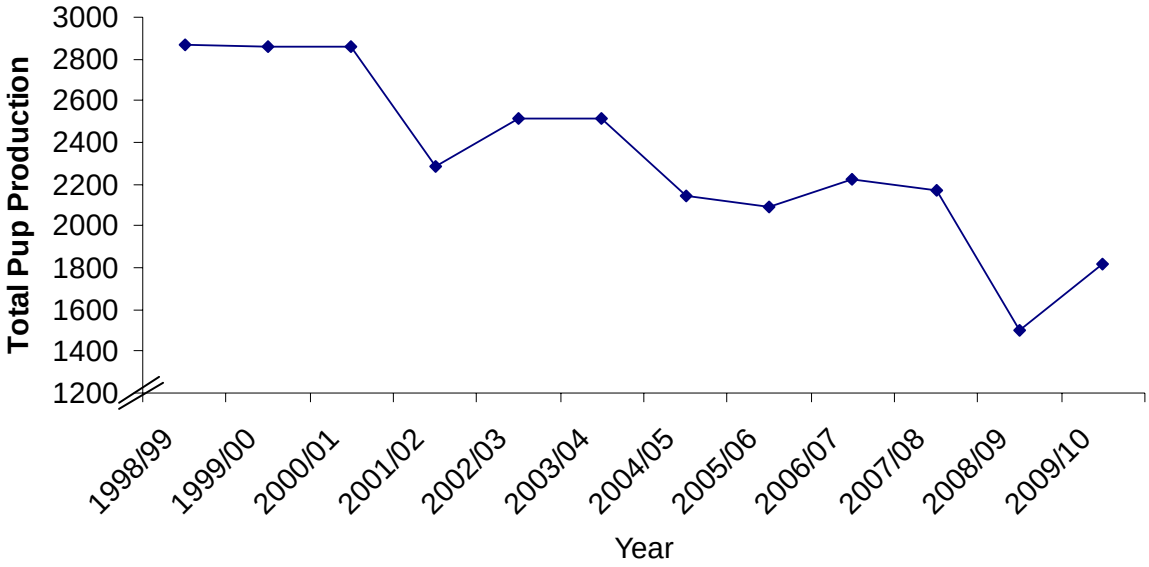

Figure 2b. Annual pup production for Sandy Bay, Enderby Island 1999 to 2010.

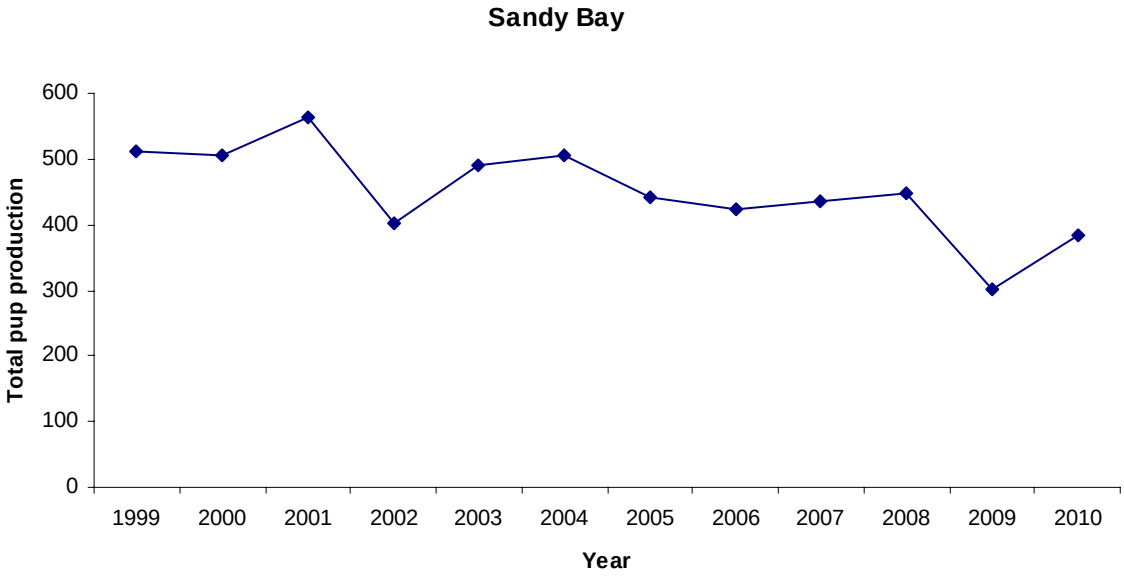

Figure 2c. Annual pup production for Dundas Island 1999 to 2010.

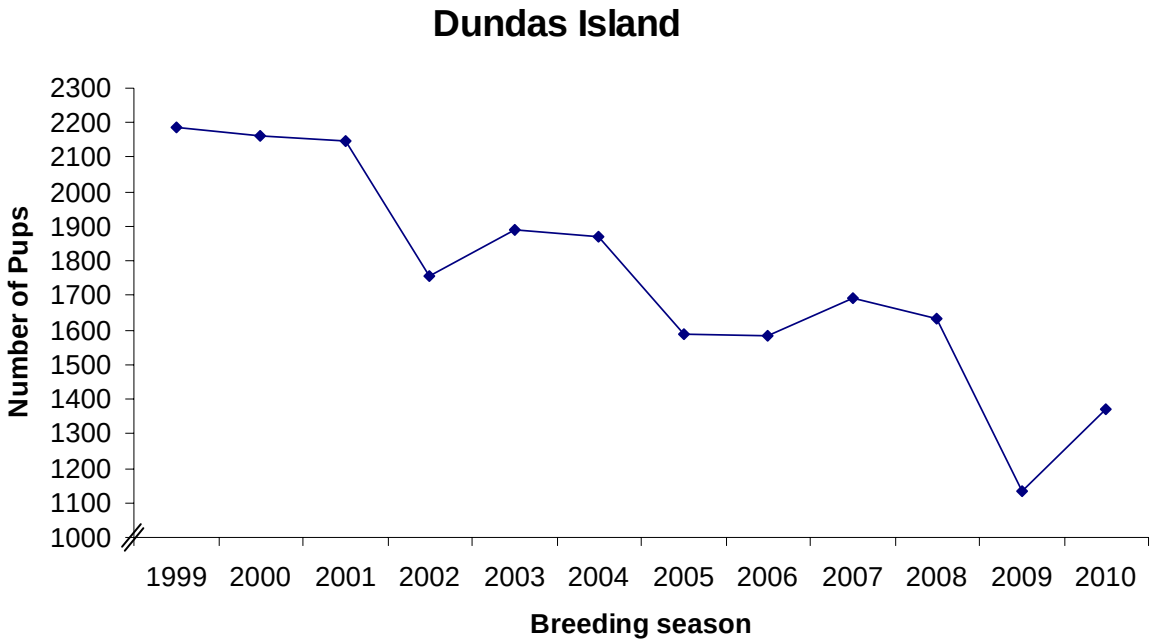

Figure 2d. Annual pup production for Figure of Eight Island 1999 to 2010.

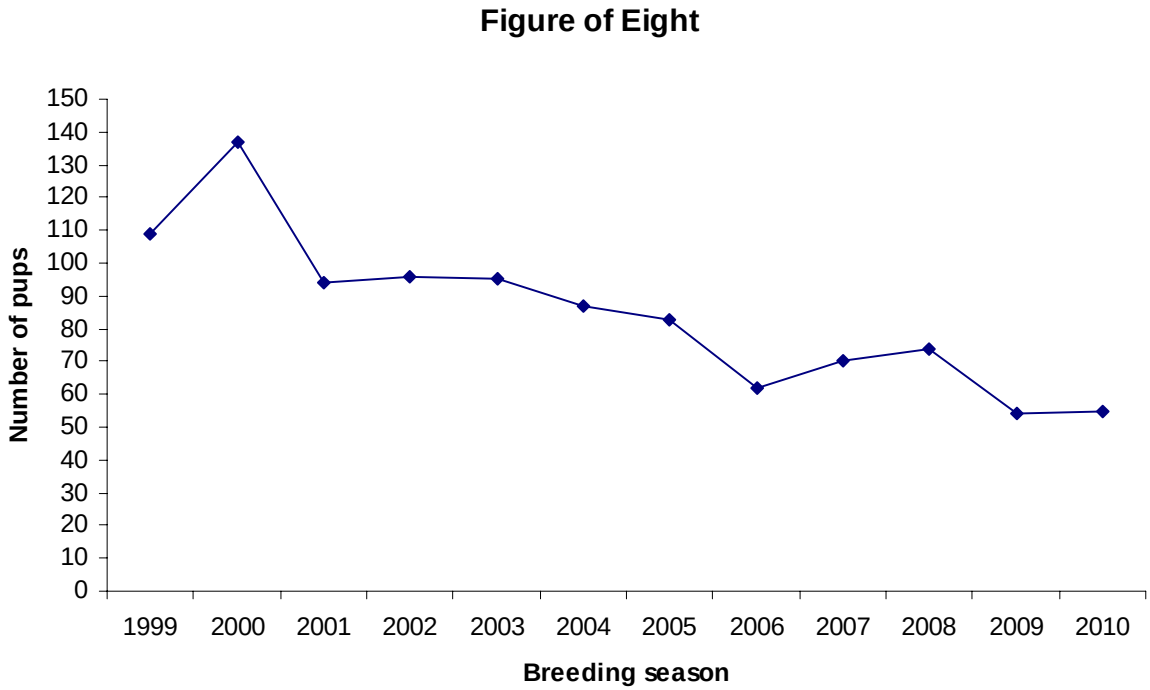

Figure 2e. Annual pup production for South East Point, Enderby Island 1999 to 2010.

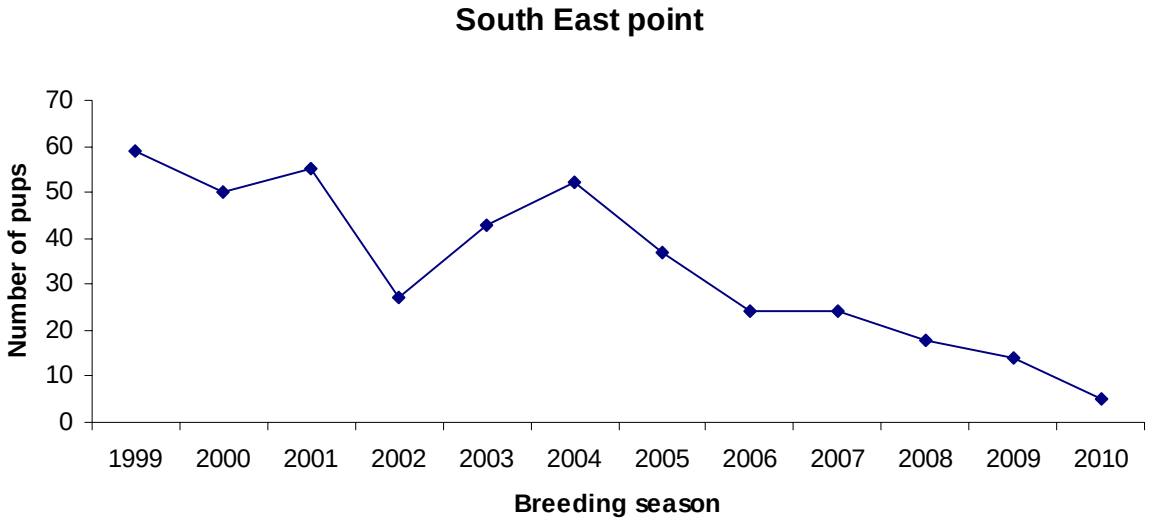

Table 1: Pup production estimates for Auckland Islands.

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 ± 4	473	40	2186 ± 90	1957	229	109	100	9	59	42	17
99/00	506 ± 10	482	24	2163 ± 33	2039	124	137	131	6	50	37	13
00/01	562 ± 5	527	35	2148 ± 57	1802	346	94	92	2	55	47	8
01/02	403 ± 4	320	83	1756 ± 23	1395	361	96	90	6	27	21	6
02/03	489 ± 4	408	80	1891 ± 38*	1555	336	95 ± 1	89	5	43	26	17
03/04	507 ± 4	473	34	1869 ± 40*	1749	120	87 ± 1	86	1	52	39	13
04/05	441 ± 10*	411	30	1587 ± 32	1513	74	83 ± 7	79	4	37	31	6
05/06	422 ± 3	383	39	1581 ± 31	1349	232	62 ± 2	55	7	24	20	4
06/07	437 ± 5	414	23	1693 ± 37	1587	106	70 ± 4	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**	**1369 ± 35**	**1218**	**151**	**55 ± 1**	**48**	**7**	**5**	**1**	**4**

* S.E. differs from that published in Chilvers *et al.* 2007 due to different S.E. equation used.

Table 2: Total pup production (± standard error) 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 ± 33	2572	295	-5.1%	10%	8%	9%
99/00	2856 ± 43	2689	167	-0.4%	6%	5%	11%
00/01	2859 ± 24	2468	391	0.1%	14%	6%	10%
01/02	2282 ± 34	1826	456	-20.2%	20%	21%	33%
02/03	2518 ± 38*	2078	438	10.3%	17%	16%	21%
03/04	2515 ± 40	2347	168	-0.001%	7%	8%	15%
04/05	2148 ± 34*	2034	114	- 14.6%	5%	7%	12%
05/06	2089 ± 30*	1807	282	- 2.8%	14%	9%	16%
06/07	2224 ± 38	2087	137	6.4%	6%	5%	16%
07/08	**2175 ± 44**	**2022**	**153**	**-2.2%**	**7%**	**5%**	**14%**
08/09	**1501 ± 16**	**1410**	**91**	**- 31.0%**	**6%**	**4%**	**12%**
09/10	**1814 ± 36**	**1631**	**183**	**+20.8%**	**10%**	**5%**	**15%**

* The standard error (SE) differs from those published in Chilvers *et al.* 2007 due to use of different SE equation. In all cases the SE is smaller using new equation. 98/99 to 01/02 not recalculated and S.E. from Chilvers *et al.* 2007 presented.

3.3 Characterise the at-sea distribution of juvenile NZ sea lions and analyse in a fisheries context

The distribution of the satellite locations of juvenile NZ sea lions around the Auckland Islands during January and February 2008, 2009 and 2010 are given in Figure 3 (Individual plots given in Appendix 2). Together there were over 6600 satellite locations collected from 26 animals made up of 15 females of age two and three years and 11 males aged from two to five years (Table 3).

The scale used to quantify fishing effort in Figures 3, 4a & 5a is 1-10 tows per 10 x 10 km area (Low-light grey), 11-20 tows, 21-30 tows (Med-medium grey), 31-40 tows, and 40+ tows (High-black)).

The spatial distribution of fishing operations (trawl start locations per 10 x 10 km area) for tows targeting arrow squid for each season (1 July to 30 June, with most fishing effort in the months of February to May) is shown in Figure 4a. The estimated spatial overlap between juvenile NZ sea lions and the distribution of fishing operations targetting arrow squid around the Auckland Islands is given in Figure 4b. There were a total of 1241, 1231 & 1733 tows targeting squid for the 2008, 2009 and 2010 seasons, respectively. Figure 4b represents the expected spatial distribution of juvenile NZ sea lion-fishery operation interactions, assuming 1) satellite locations represent foraging locations for juvenile NZ sea lions (as seen for female NZ sea lions, Chilvers et al. 2006b) and 2) that the risk of interaction is proportional to the extent of overlap of NZ sea lion distribution and commercial fishing operational distribution at any location, over the entire season. Hence areas where sea lions forage, but no fishing occurs or vice versa, have a zero risk of interaction. As such, the expected level of interaction will be highest in regions with high NZ sea lion foraging and high commercial fishing effort.

The scale for Figure 4b is a relative scale of 1(Low interaction - light grey), 2, 3-4 (Medium interaction – medium grey), 5-6, and 7(High interaction - black).

Table 3. Dates, tag number, satellite tag identification, sex, age, weight, length, girth, number of days deployed and number of satellite locations used from 26 juvenile sea lions captured January 2008-2010.

Date	Tag	Satellite tag id	Sex	Age	Weight kg	Length cm	Girth cm	Days	Number of satellite locations
14/01/2008	4121	49094	M	5	103.5	180	108	14	215
14/01/2008	5051	49095	M	4	134.5	184	126	49	366
14/01/2008	5093	54757	M	4	83.0	164	100	2	7
14/01/2008	3727	54760	M	5	102.0	177	106	16	309
17/01/2008	6130	76964	F	3	68.0	153	87	17	248
18/01/2008	5857	76966	F	3	71.0	141	92	14	183
24/01/2008	5863	54756	F	3	68.0	152	89	2	26
25/01/2008	6463	67259	F	2	73.5	146	91	31	322
25/01/2008	5913	54761	F	3	68.0	156	95	11	217
26/01/2008	6059	54759	F	3	84.5	154	96	4	39
11/01/2009	4907	1757	M	5	117.0	184	107	14	138
15/01/2009	7458	49093	F	2	57.0	140	90	13	105
15/01/2009	6363	76964	F	3	79.0	165	98	10	135
19/01/2009	6485	67260	M	3	85.0	159	98	12	208
19/01/2009	7610	76965	F	2	54.0	140	84	25	316
20/01/2009	6214	54760	M	3	81.0	160	104	13	139
20/01/2009	6218	54761	M	3	76.0	155	92	38	570
20/01/2009	6536	76963	F	3	70.0	157	93	19	235
25/01/2009	7445	89574	F	2	53.0	138	83	9	149
25/01/2009	8023	49094	F	2	54.0	135	84	17	206
15/01/2010	7199	76963	F	3	78.5	154	107	16	209
15/01/2010	7458	98814	F	3	73.0	153	98	16	222
24/01/2010	7584	76965	F	3	68.0	152	100	7	143
28/01/2010	5752	54760	M	5	150.0	209	125	31	569
28/01/2010	7260	76964	M	3	89.0	157	111	12	247
30/01/2010	8179	49094	M	2	77.5	156	91	71	1157

The spatial distribution of tows targeting scampi and tows targeting other stocks are given in Figures 5a and 5b, respectively, for each season 2008, 2009 and 2010 (July to June each season). There were 1297, 1169 and 1441 tows targeting scampi and 319, 159 and 80 tows targeting other stocks each season 2008-2010, respectively. Circles indicate the only areas where overlap with juvenile NZ sea lion satellite locations occur. For the two animals that foraged beyond the Auckland Island shelf no wider analysis of fisheries overlap was conducted.

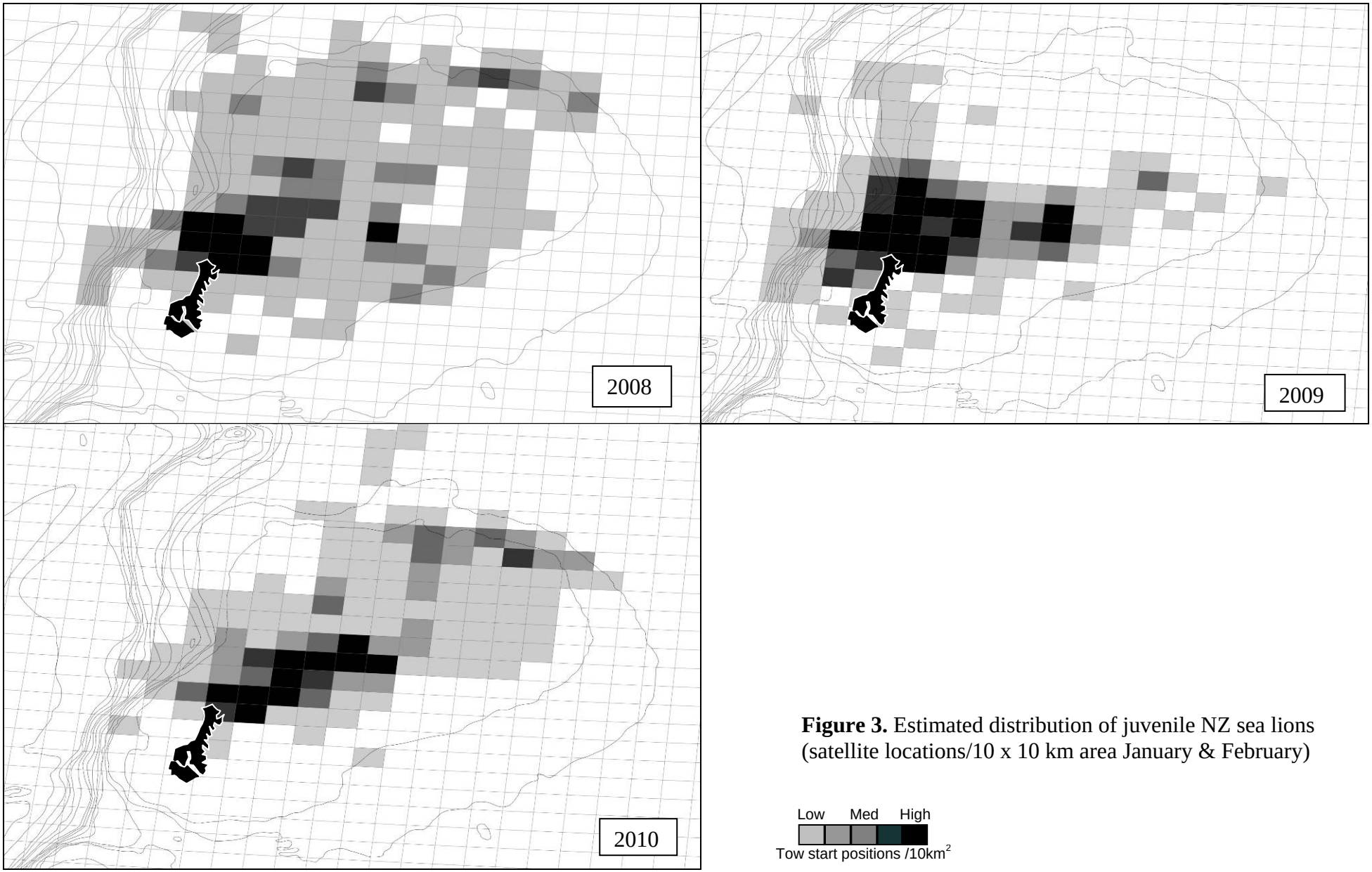

Figure 3. Estimated distribution of juvenile NZ sea lions (satellite locations/10 x 10 km area January & February)

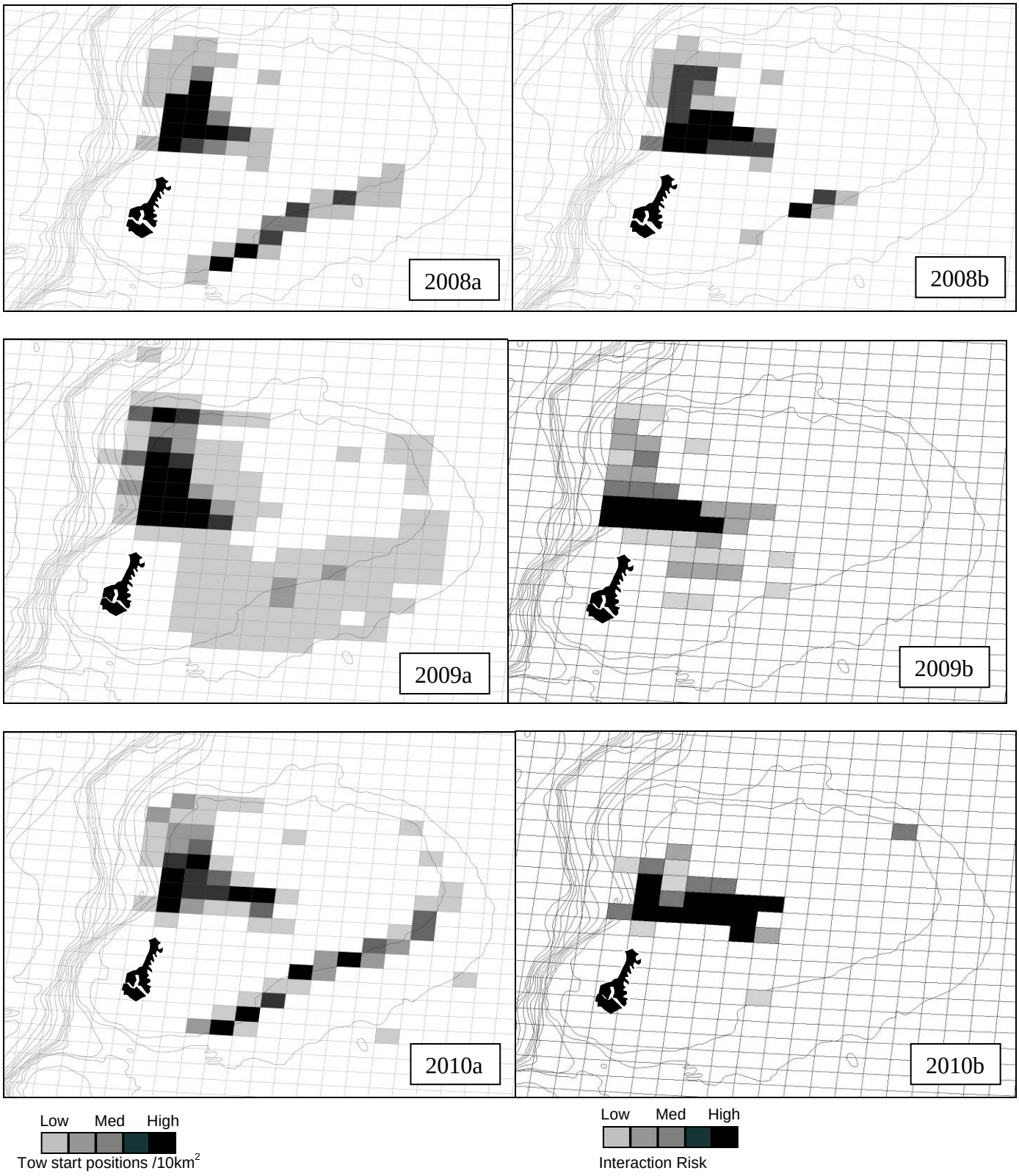

Figure 4. a) The distribution of fishing effort in the 6T squid trawl fishery (tow start positions/10 x 10 km area, February to June ot close of fishery 2008-2010) in the Auckland Islands 6T area (Scale 1-10 locations or tows per area (Low), 11- 20, 21-30 (Med), 31-40, 40+ (High)). b) The estimated interaction rate between juvenile NZ sea lion distribution and fishing activities for each year are presented in 3b (Scale 1 (Low), 2, 3-4 (Med), 5-6, 7 (High)).

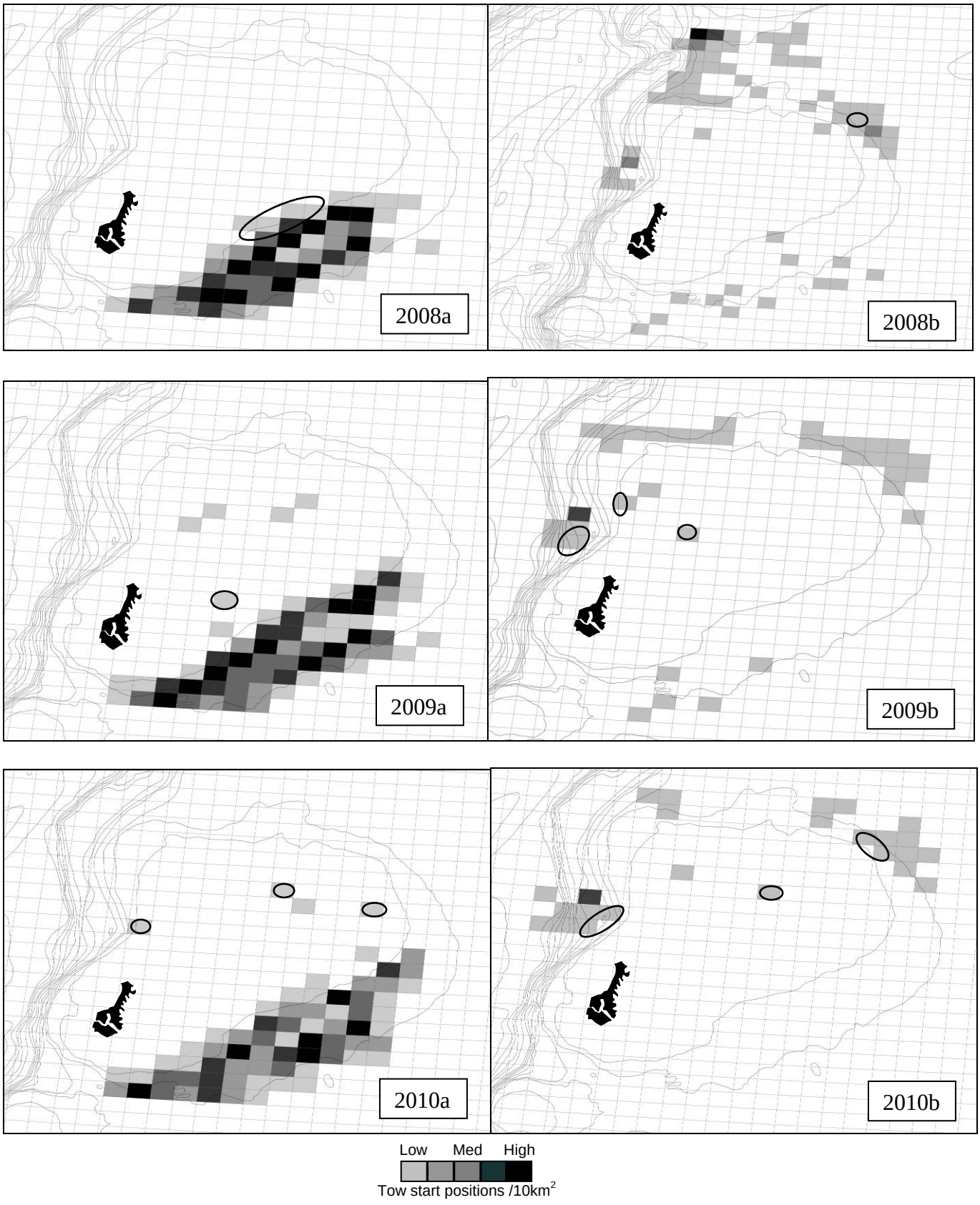

Figure 5. a) The spatial distribution of scampi fisheries (October to June each season) and b) all other tows recorded in other fisheries for each season 2008, 2009, 2010 in the Auckland Islands 6T area (Scale 1-10 locations or tows per area (Low), 11- 20, 21-30 (Med), 31-40, 40+ (High)). Circles indicate the only areas where overlap with juvenile NZ sea lion satellite locations occur.

Discussion

The New Zealand sea lion is New Zealands' only endemic pinniped. It is classified as Nationally Critical under the NZ threat classification system because the significant decline in pup production extrapolates to be well over a 70% decline per three generations which is the threshold for a species to be listed as Nationally Critical (Baker et al. 2010) and is estimated to be the world's rarest sea lion. This research shows the pup production at the Auckland Islands overall continued to decline from the previous 2006 estimate, with a massive drop recorded in 2009 (Figure 2).

Pup production and early mortality

For pinnipeds, estimates of pup production are the best index of relative population status and when combined with other population parameters provide the best estimate of overall population size and trends (Berkson & DeMaster 1985). Pups represent an estimate for the number of reproductive females within a population, they are relatively easy to handle and represent good experimental animals for M-R experiments to estimate abundance (Gales & Fletcher 1999). In the three years of this research the pup production estimate for the Auckland islands has decreased by 18.4% and between 1999 and 2010 the overall pup production of the Auckland Islands has decreased by 37%. During the three years of this research early pup mortality averaged 8% overall in the first month and for Sandy Bay averaged 5% at one month and 14% at the end of the season. These early mortality rates are normal compared with averages over the last 12 years of 10%, 8% and 15% respectively. The consistent yearly monitoring of annual pup production at the Auckland Islands is essential for monitoring this declining Nationally Critical species.

Juvenile at sea distribution

Overall, the majority of juvenile NZ sea lions (those four years old and less) showed foraging distributions close to the Auckland Islands on the Auckland Island shelf, predominantly in the North and North-east areas of the shelf (Figure 3, Appendix 2). There was significant overlap between juvenile NZ sea lion foraging locations and squid 6T fisheries activities (Figure 4b) which, as does occur, is likely to result in fisheries-juvenile sea lion interactions and deaths of sea lions. There was little overlap of juvenile NZ sea lion foraging locations with scampi or other fisheries activities around the Auckland Island area (Figures 5a & b). However, juveniles from other, more southerly, breeding sites at the Auckland Islands were not tracked and it is not known to what extent they may overlap with the different fisheries operating in the area.

Similar to adult female NZ sea lion foraging studies (Chilvers et al. 2005; Chilvers 2008, Chilvers 2009), the distribution of the juvenile NZ sea lions shown here indicate that the current 12-nautical-mile (22-km) marine protected area (MPA) surrounding the Auckland Islands would only protect the entire foraging area of two juvenile female NZ sea lions tracked from Enderby Island, exposing the other 77% of animals tracked to fisheries activities interactions and potential bycatch death.

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Appendix 1

Headings in NZSL database and metadata

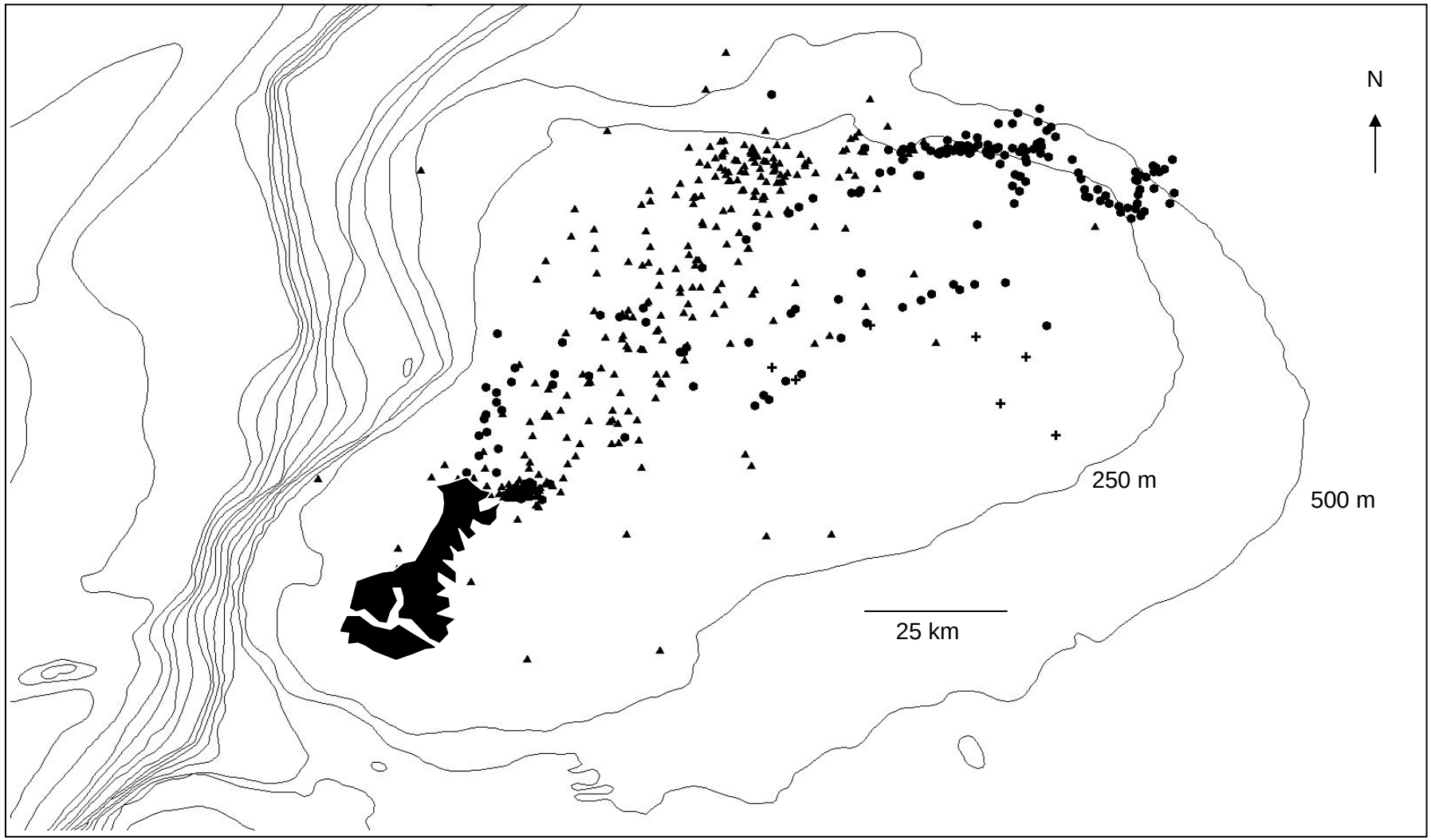
Current Tag	Colour	Tag Shape	Brand	Chip	Sex	N Of Tags	Original Tag	Previous Tag	Date	Season Of Resight	Location	Island	Class	Nature	Tag Year	Age	Tag Location	Status	Behaviour Comments	Pup Tag	Pup Tag Colour	Sight Status

DESCRIPTION OF FIELDS

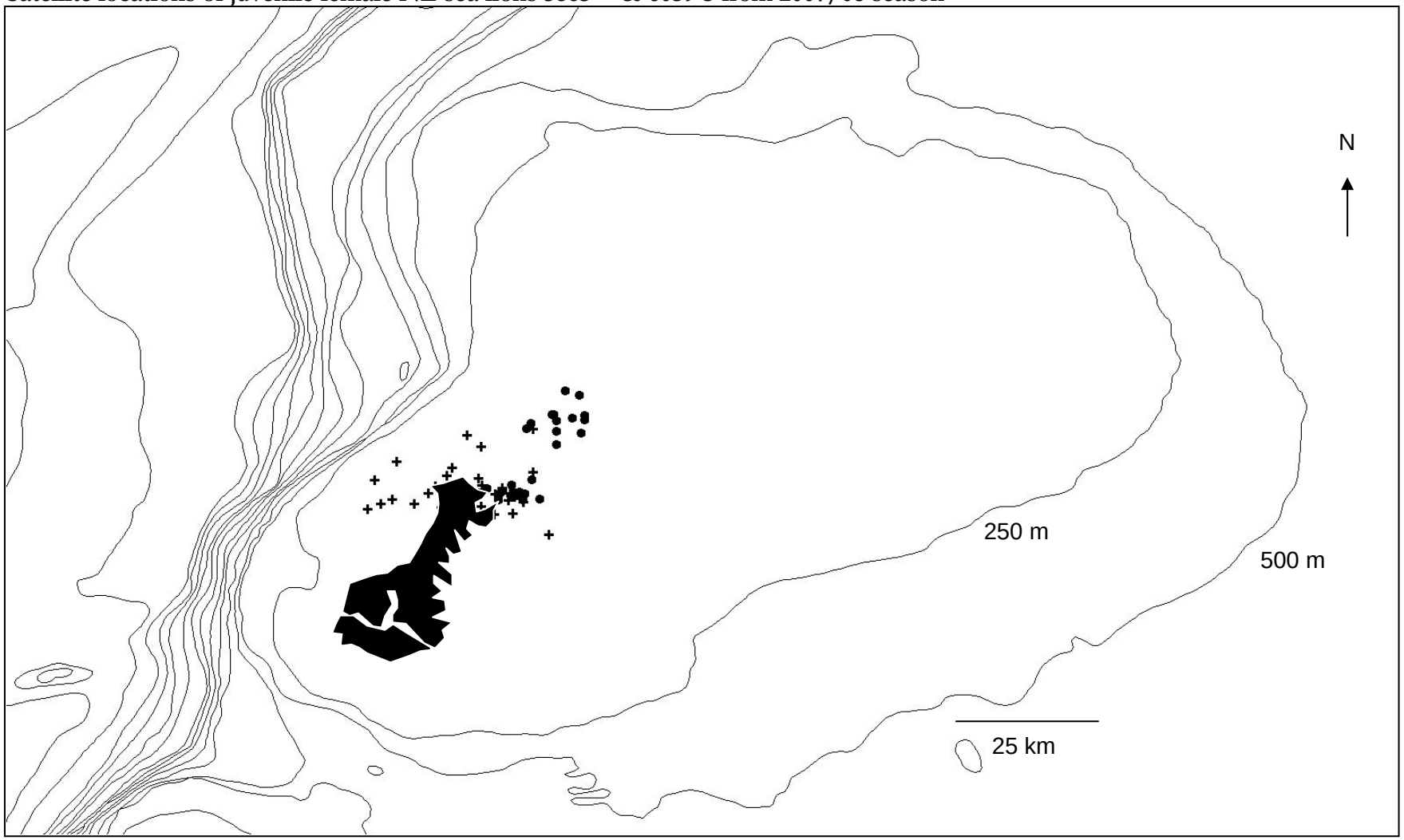
Current Tag - This is the **current** identification of the individual
Colour - In addition to a unique number, tags are also colour coded
Tag shape – Either R = Round shaped or C = Coffin shaped
Brand - Refers to the presence or absence of a brand on a specific sea lion
Chip - Refers to the presence or absence of a Passive Integrated Transponder (PIT or CHIP tag) in a specific sea lion
Sex - M (Male), F (Female) or U (Unknown)
N of tag - The number of tags recorded on a specific sea lion, which flippers the tags were in and which flippers were sighted
Original Tag – Refers to the tag number a sea lion was originally tagged with as a pup
Previous Tag – Refers to any tag that is not a sea lion current or original tag
Date - This field records the date on which a marked animal was resighted
Season of Resight - Season in which resights were made expressed as a year. Years run from November to October each year.
Location – The location at which the animal was sighted
Island- The island on which the resight location is found
Class - Provides details on the age class of the individual
Nature - The type of resight record in the database i.e. animal tagged, resighted or chip read
Tag Year - This field identifies the year in which animals were tagged for the first time
Age - The age of the animal in years determined as the difference between the year of resighting and the year of tagging if tagged as a pup
Tag Location - The location at which the animal was originally tagged, as a pup, yearling or adult
Status - This field provides information about the animal, particularly reproductive status, in a numerical coded format
Behaviour Comments - Descriptive comments about the animal at the time of sighting
Pup tag – Tag number of pup which is added to database of female if that female is known to be the pups mother
Pup tag colour – Tag colour of pup which is added to database of female if that female is known to be the pups mother
Sight status – Confidence in sighting accuracy

Appendix 2

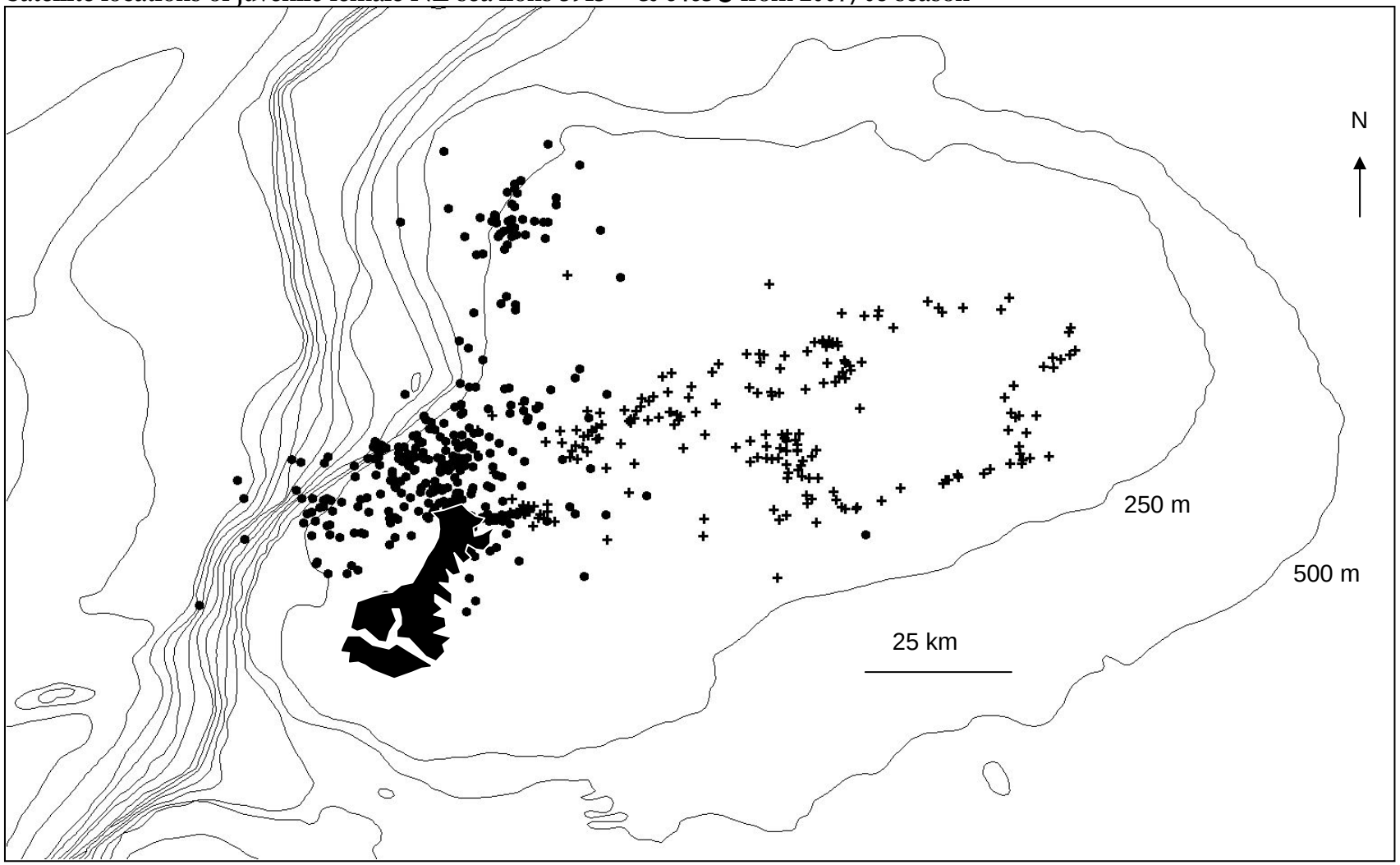
Satellite locations of juvenile male NZ sea lions 4121●, 5093 + and 3727▲ from 2007/08 season.



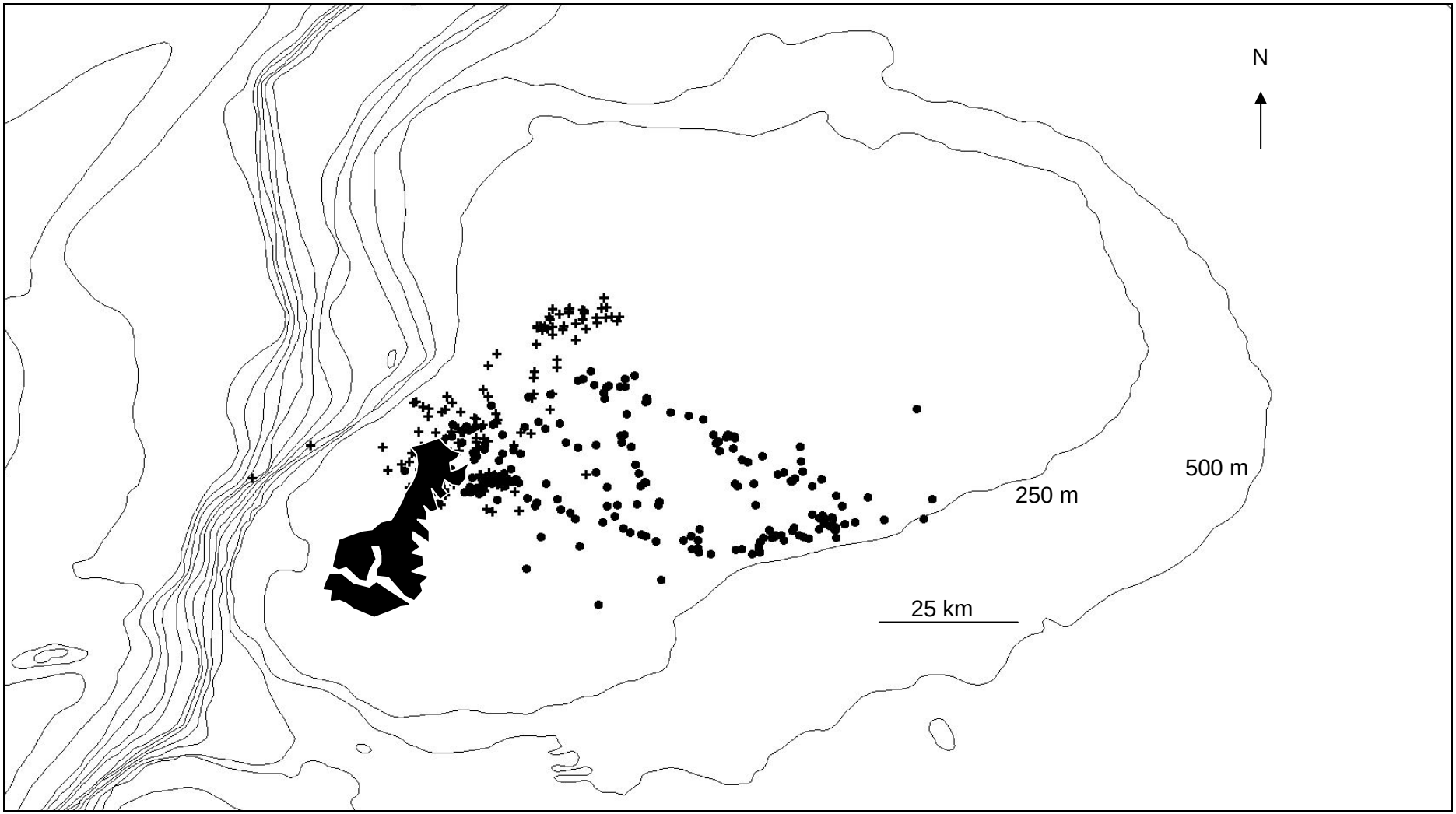
Satellite locations of juvenile female NZ sea lions 5863 + & 6059● from 2007/08 season



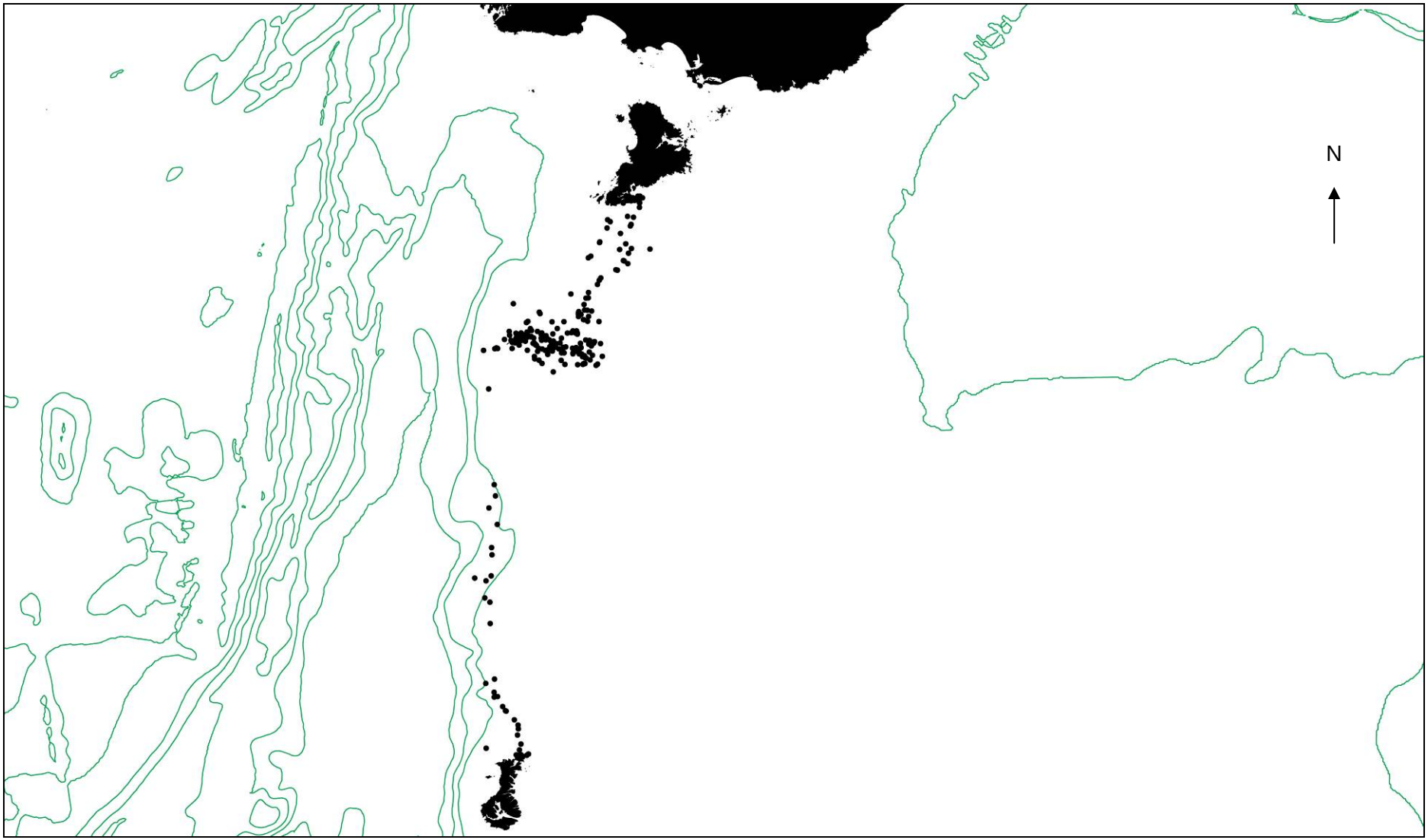
Satellite locations of juvenile female NZ sea lions 5913 + & 6463● from 2007/08 season



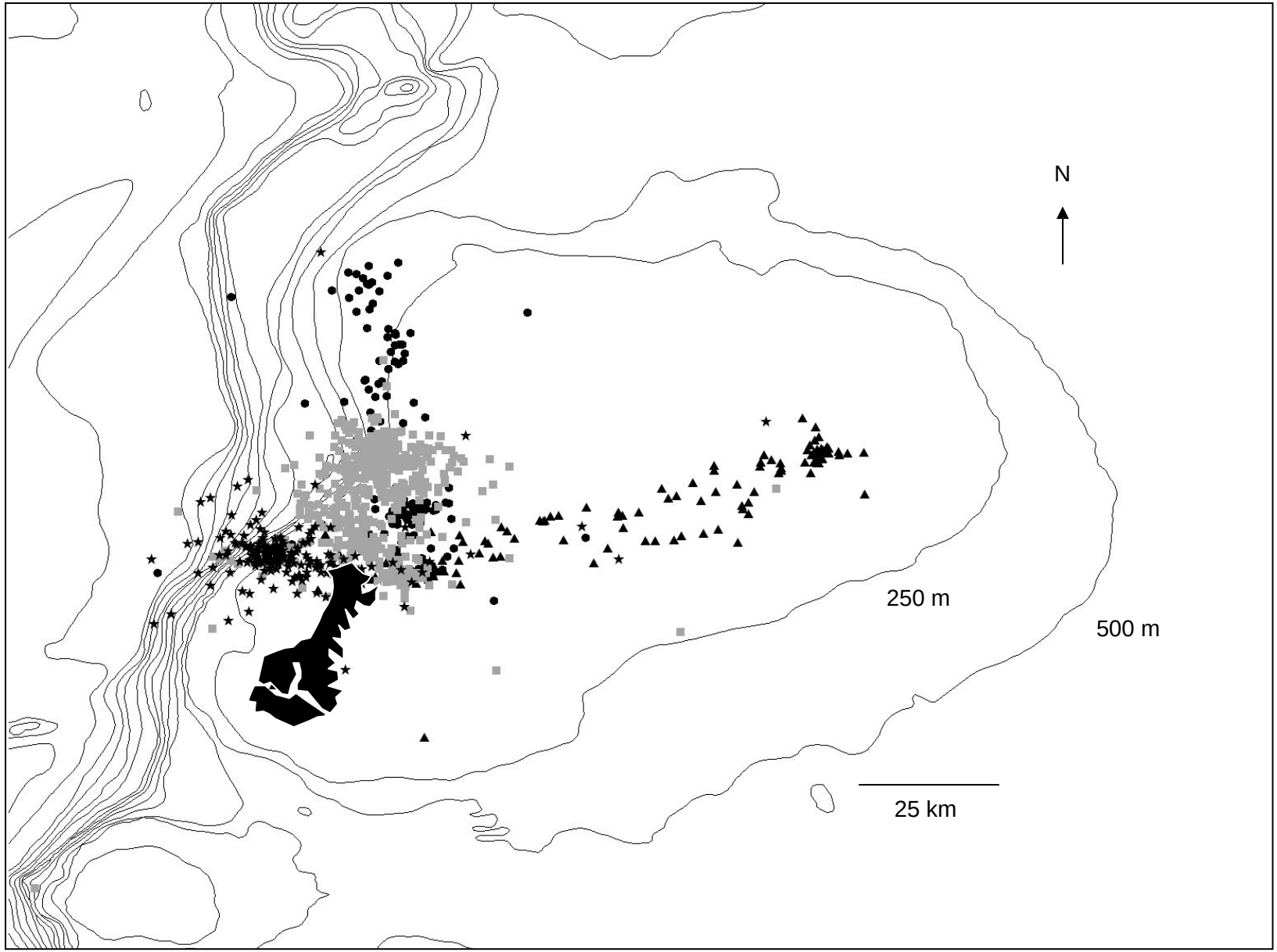
Satellite locations of juvenile female NZ sea lions 6130● & 5857 + from 2007/08 season



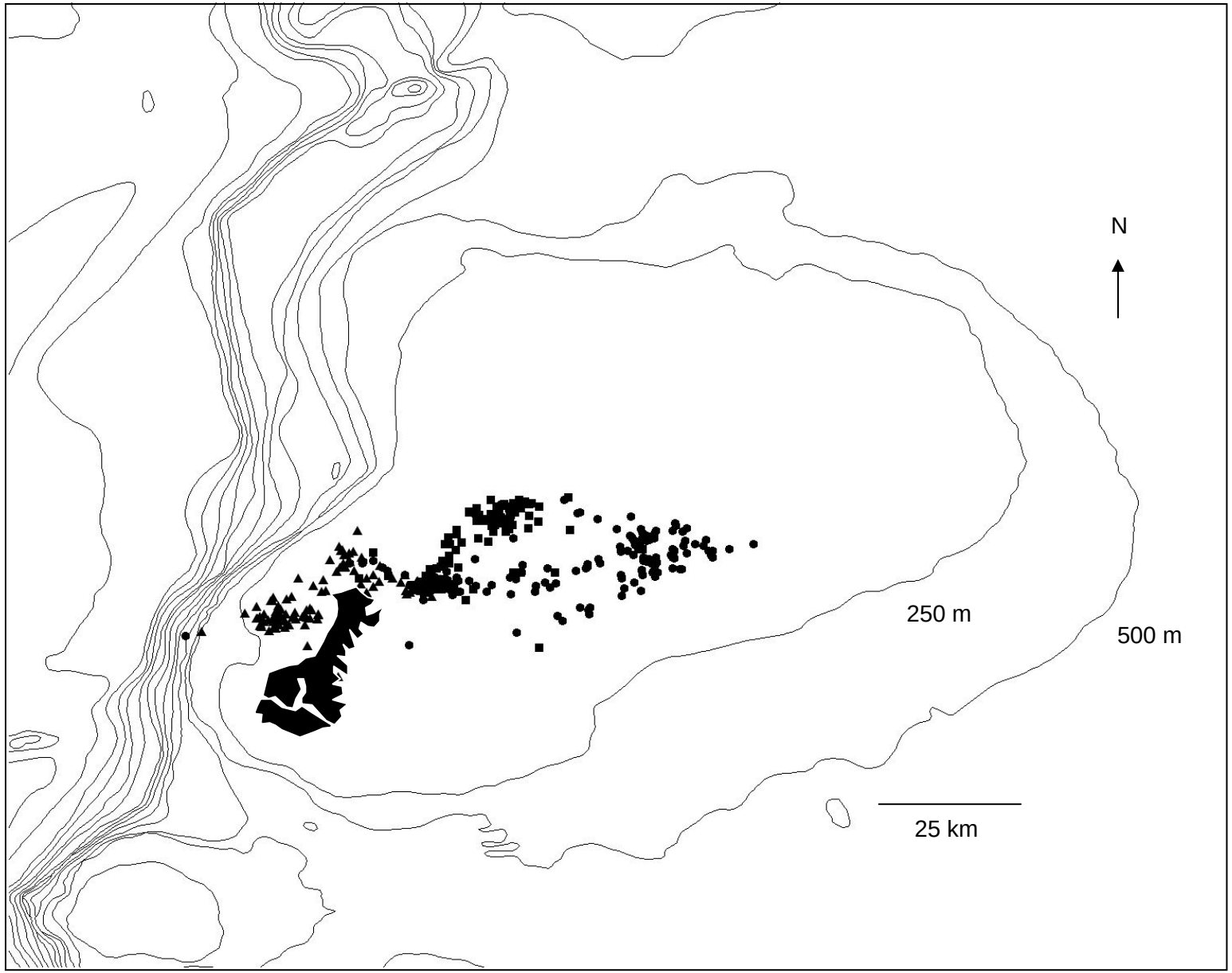
Satellite locations of juvenile male NZ sea lions 5051 from 2007/08 season



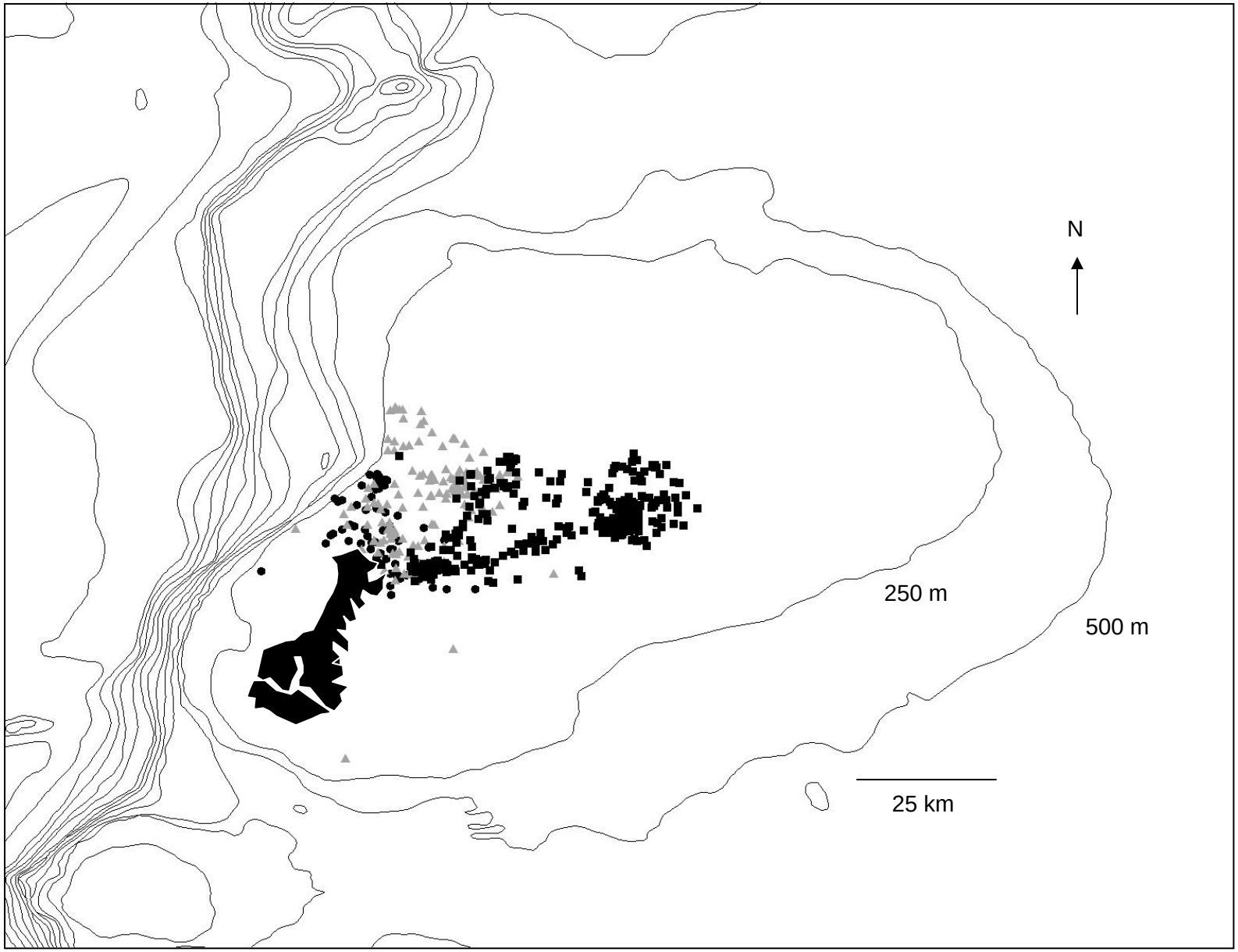
Satellite locations of juvenile male NZ sea lions 4907 ●, 6485★, 6214▲ & 6218■ from 2008/09 season



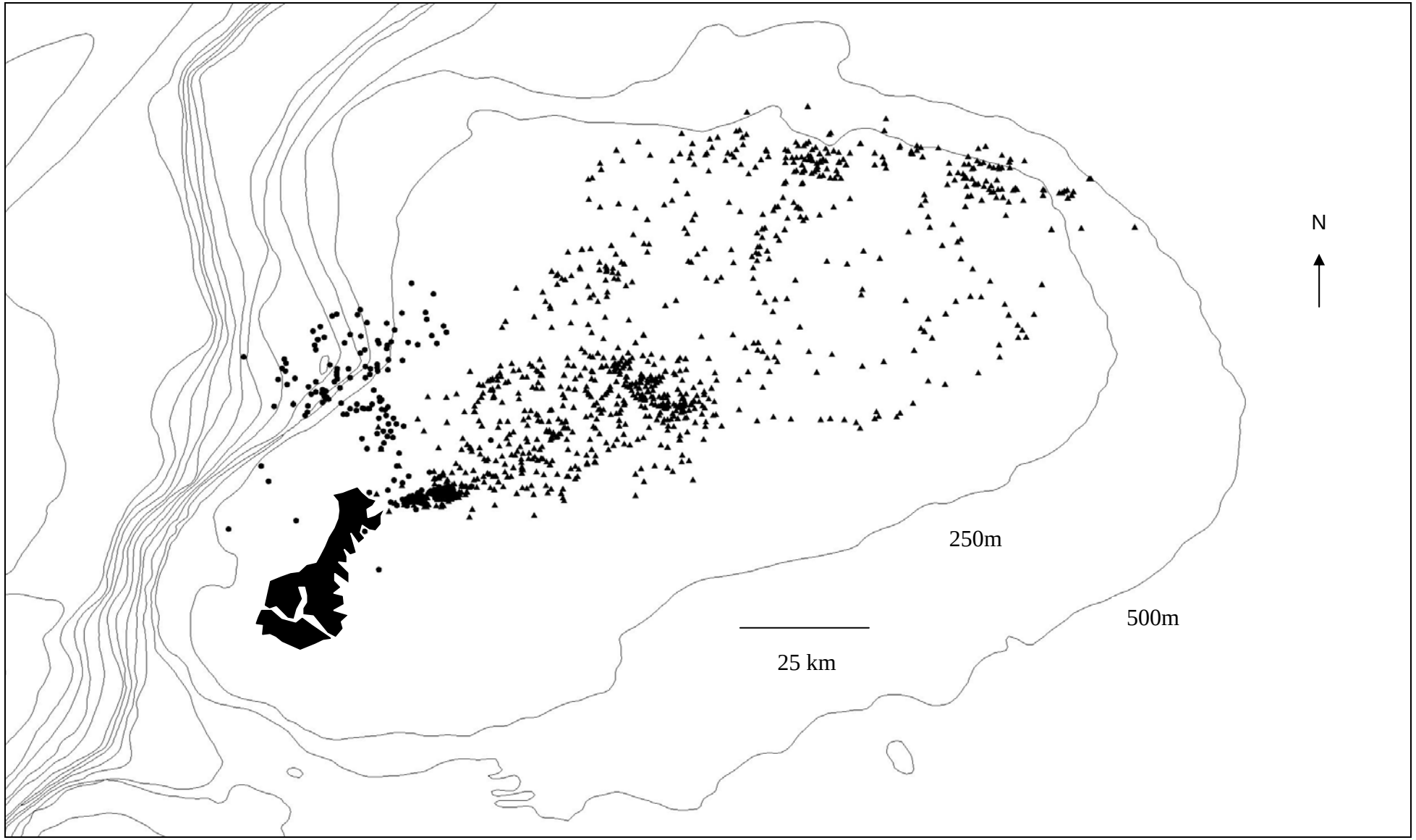
Satellite locations of juvenile female NZ sea lions 7445■, 8023● & 6363▲ from 2008/09 season



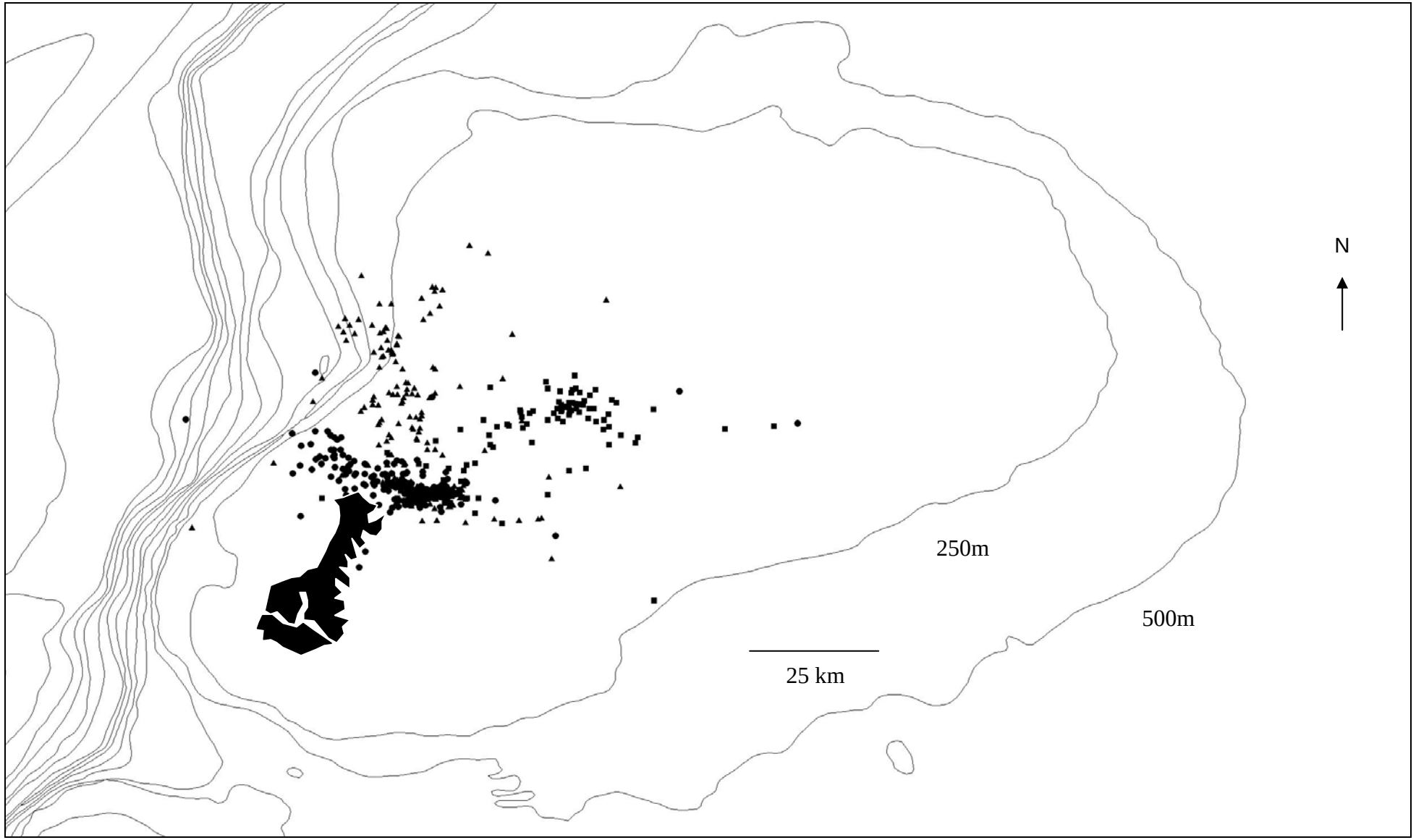
Satellite locations of juvenile female NZ sea lions 6536▲, 7458● & 7610■ from 2008/09 season.



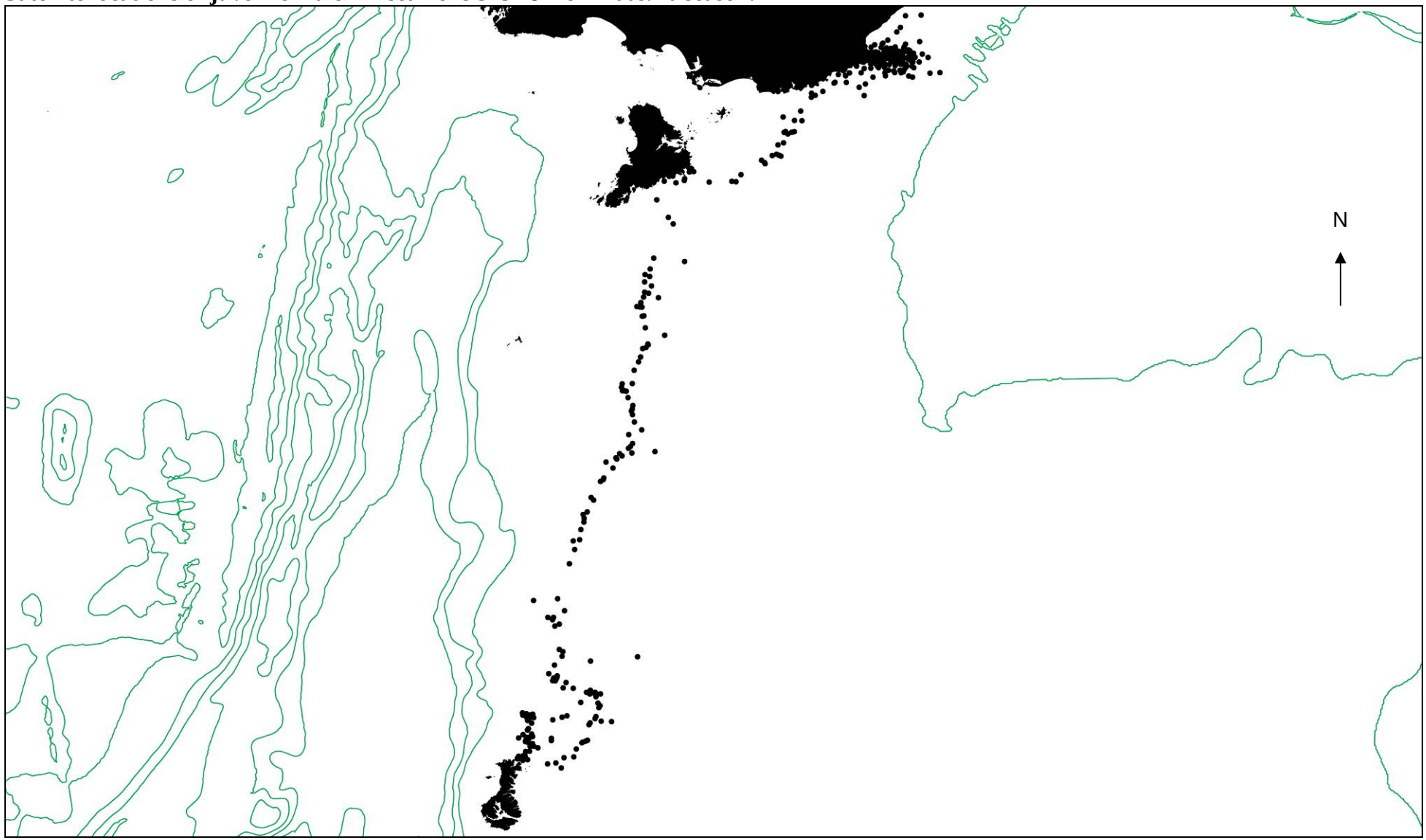
Satellite locations of juvenile male NZ sea lions 7260 ● and 8179 ▲ **from 2009/10 season.**



Satellite locations of juvenile male NZ sea lions 7458 ●, 7260 ▲ and 7199 ■ from 2009/10 season.



Satellite locations of juvenile male NZ sea lions 5752 ● **from 2009/10 season.**



Appendix 3

Raw mark-recapture values (for Sandy Bay and Dundas) and direct counts (for Figure of Eight) for the 2007/08 to 2009/10 seasons

	2007/08		2008/09		2009/10	
Sandy Bay	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked
Pups capped / marked	197		150		148	
Counter 1a	154	191	62	57	45	70
1b	132	150	62	59	50	73
1c	153	161	67	63	63	99
Counter 2a	144	157	70	67	62	85
2b	129	151	76	66	100	139
2c	137	172	82	78	66	81
Counter 3a	127	141	99	93	86	135
3b	152	177	88	78	97	156
3c	149	184	83	78	107	159
Dundas						
Pups capped / marked	400		396		387	
Counter 1a	228	581	163	284	127	238
1b	221	568	185	318	96	183
1c	227	565	186	336	72	175
Counter 2a	201	646	235	432	249	572
2b	216	713	248	419	227	552
2c	203	642	236	391	213	536
Counter 3a	141	362	230	323	181	359
3b	195	514	235	389	207	382
3c	183	475	251	432	167	332
Figure of Eight	Alive	Dead	Alive	Dead	Alive	Dead
Count 1	71	2	49	6	50	7
Count 2	73	2	48	6	46	7
Count 3	72		47		48	