

## **Aerial survey of New Zealand sea lions – Auckland Islands 2011/12**



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**Ministry of Agriculture & Forestry,**  
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# Aerial Survey of New Zealand Sea Lions at the Auckland Islands 2011/12

## 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. 2010a) and Geshke and Chilvers (2009) found it to be the world's rarest sea lion. 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. Over the last decade there has been a considerable decline in pup production at the Auckland Islands (Chilvers 2010). This decrease in pup production is thought to be aggravated by a combination of incidental bycatch from commercial fishing activity and disease events.

There are four pupping sites at the Auckland Islands; 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) (Chilvers 2010).

Chilvers (2010) reports on three annual surveys (2007/08, 2008/09, 2009/10) of the Auckland Island area with one of the objectives to collect data to allow quantification and estimation of NZ sea lion pup production. NZ sea lion pup production at S.E. Point 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 estimate. 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. This work builds on surveys of NZ sea lions at the Auckland Islands since 1998 (Gales & Fletcher 1999; Chilvers et al. 2007) which has allowed estimates of annual sea lion pup production from 1998 to 2010.

In January 2012 we undertook a survey to estimate New Zealand sea lion pup production at the Auckland Islands for the 2011/12 breeding season using an alternative method to previous surveys, thus reducing the need to access restricted sites where the sea lion colonies occur and minimising disturbance to the colonies. We used aerial photography to count sea lion pups and establish an archival set of photographs that could potentially be used for future trend analysis. It was our intention that the techniques and protocols developed for this work be clearly documented, thus permitting replication in future years to determine trends in population change.

Specifically, we were tasked to:

1. estimate the New Zealand sea lion pup production at the Auckland Islands using aerial survey methods;
2. provide a detailed comparison of the pup production estimate obtained by aerial survey with ground counts undertaken by the research team led by Louise Chilvers, including the identification, and where possible quantification, of factors influencing any difference in estimate; and
3. make recommendations for future methods for robust, cost-effective estimates of New Zealand sea lion pup production at the Auckland Islands; and

In order to verify counts from aerial photographs with ground truthing, we attempted to carry out the aerial photography at the same time as a ground team collected information on

marked animals and conducted counts, to gain some level of understanding of the number of pups present in pup piles, and the proportion of pups that weren't visible from the photographs.

The aerial survey platform deployed for this project was also used to provide archived aerial photographs of Disappointment Island suitable for estimating the number of white-capped albatross nesting on the island (not discussed further in this report).

## 2. Methods

### *Field Work*

We chartered a helicopter from Southern Lakes Helicopters to conduct a photographic survey of sea lions at two of four sites used by this species at the Auckland Islands: Sandy Bay on Enderby Island, and Dundas Island. The other two sites — Figure of Eight Island and South East Point were not investigated because the first of these is not suitable to aerial survey as pupping occurs under forest canopy, and the latter site now contains very few sea lions. Permit conditions stipulated that we could undertake our work between 10-20 January and prior to leaving New Zealand we examined weather forecasts to select a weather window that predicted clear flying conditions to ensure the best quality photographs. The aircraft we used was a AS350-B3 Squirrel helicopter, piloted by Chris Green, and we flew from Invercargill to Enderby Island on 11 January 2012. On board was Barry Baker (photographer and project coordinator), John Barkla (additional photographer), Peter McClelland (Department of Conservation Invercargill) and another passenger. We based ourselves at the DOC research station on Enderby Island for a period of four days and undertook flights each day to photograph the sea lion colonies on Enderby and Dundas Islands. After completing our assignment, we returned to Invercargill on 15 January 2012.

Flights had been timed to coincide with the time when pupping had finished but before pups have left colonies, and within a few days of when ground counts were undertaken by others. At this time pups were approximately three weeks old and clearly distinguishable from adults in photographs. Flights were conducted each day between 10-15 January 2012 and carried out in varying weather conditions, ranging from fine and clear with no wind, to wet and windy with low cloud. The aircraft was flown from the starboard side, requiring the photographers to be seated on the port side. We took photographs through an open door using standard 35mm photographic gear; a Nikon D300 camera with Nikon 70 to 200mm F2.8 zoom lens, and a Canon EOS-1D Mark IV with a Canon 500mm F4 L IS USM telephoto lens. The zoom lens was set on 200mm and used to document entire colonies, while the 500mm lens was used to obtain detailed photography of sea lion pup piles. Shutter speeds were kept to  $>1/1000$ s to avoid camera shake. The focal length of the zoom lens was not adjusted within each pass sequence over a site to assist in subsequent data analysis.

Our approach was to leave the Enderby Research station and fly slowly along Sandy Bay and South East Point of Enderby Island, and then to fly to Dundas Island. Multiple traverses were made of each site to produce a complete series of overlapping images which could be used to compile a collage of all surfaces of sites where sea lions occur (**Figures 1 and 2**), and to ascertain appropriate flight heights and perspectives to minimise disturbance to sea lions. Consistent with DOC permit requirements, flight heights to photograph sea lions were kept at a minimum elevation of 150 m, parallel to the coast and about 150 m horizontal distance from the tide line, but we also tested flight heights of 350m (1000 feet) and 500m (1500 feet) directly overhead, carefully observing the behaviour of animals on the ground. Photographs were taken as raw or fine scale JPEG digital files of minimum 9MB size, although file size was determined automatically by the camera, subject to the complexity of

the information being recorded. In all cases photography was carried out between 09.00 and 15.00hours.



**Figure 1. Sandy Bay, Enderby Island showing extent of New Zealand sea lion colony**



**Figure 2. Dundas Island. New Zealand sea lions principally pup and mate on the sandy beach in the foreground. As the breeding season advances, females and pups move into the vegetation and can be found throughout the island.**

The full flight path and elevations were recorded using a GPS receiver and subsequently downloaded and archived along with the photographs. The entire set of photographs was subsequently replicated to ensure that adequate back-up sets were available for storage in

at least three different locations. A full collection of photographs and details of the flight path have been submitted to the Department of Conservation for archiving.

#### *Counting protocol for aerial photos*

We used protocols previously developed for aerial censuses of albatross colonies (Arata et al. 2003; Robertson et al. 2007; Baker et al. 2011) and fur seals (Baker et al. 2010). Photographic montages of all sea lion colonies were constructed from overlapping photographs using the image editing software package ADOBE PHOTOSHOP (<http://www.adobe.com/>). Counts of all pups and other sea lions on each montage were then made by magnifying the image to view sea lions and using the paintbrush tool in PHOTOSHOP to mark each animal with a coloured circle as they were counted (**Figure 3**). To assist with counting we used a hand held click counter. Once all sea lion pups had been counted on a photo-montage, the file was saved to provide an archival record of the count.

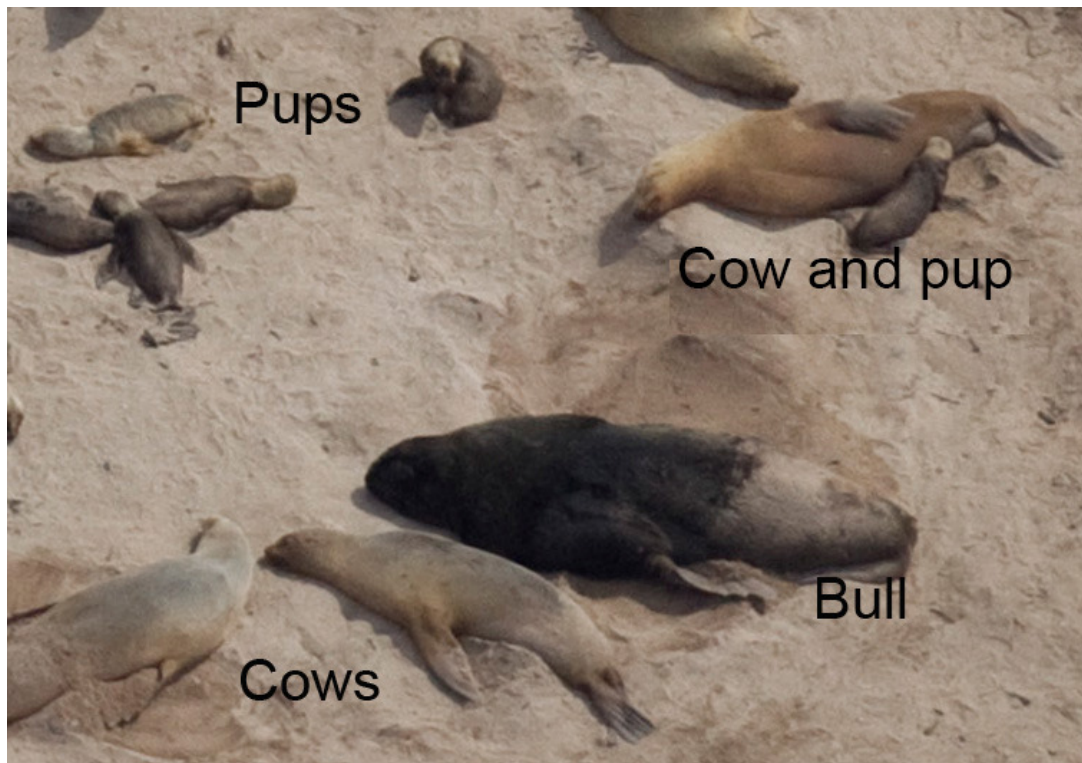


**Figure 3.** Photomontage of New Zealand sea lion colonies before (left) and after (right) counting. The yellow circles are animals identified as pups.

Detecting sea lions from aerial photos was a function of both the quality of the photos and the terrain encountered. Sea lion pups were easily detected on the sandy beaches preferred for pupping (**Figures 1 and 2**), but were less visible when they moved into the adjoining grass areas. Poorer quality photographs were usually characterised by low contrast between the sea lions and substrate, reducing the ability to determine the age class of animals. The age classes of interest were pups and non-pups. **Pups** were typically small and dark, with a lighter area on the head; **adult females (cows)** were larger and pale with a streamlined shape, while **adult males (bulls)** were larger again and darker than females, and had thick necks and a distinctive shape that was different to other age classes (**Figure 4**).

Counts of photo montages were undertaken by one observer only. To estimate counter variability associated with miscounting and misidentifying objects such as logs and rocks as sea lions, we undertook multiple counts of 15 photographs using three observers. These count data were statistically modelled by Poisson regression, a special case of a Generalised Linear Model (McCullagh and Nelder, 1989), with observer and area as fixed effects. After allowing for both mean observer and mean area differences, there was no evidence to suggest that our model and data were incompatible, based upon regression

diagnostics and model checking. There was also no evidence of a difference between observers and hence an observer bias. Thus we present raw counts only and assume the standard deviation is estimated as the square root of the count, a property of the Poisson model.



**Figure 4:** Age classes of New Zealand sea lions

#### *Photographic file management*

All photographs have been submitted to the DeepWater Group, the Ministry of Agriculture and Forestry, and the Department of Conservation. Photos were provided in one directory (*NZ Sea lions 2012*) with three sub-directories (*Original photos*, *Stitched images*, and *Counted images*). The following information is provided to assist others that may wish to access the photos at some stage in the future.

Extensive photo information is superimposed on all digital images taken with the Nikon D300 and Canon EOS-1D Mark IV cameras. This includes information on the time and date the photo was taken, the camera and lens used, image quality and size, shooting data (aperture, shutter speed, ISO, exposure correction), and geographic position (latitude and longitude) data where a GPS was connected to the camera. These data can be accessed when the photographic file is opened using Adobe Photoshop or other photographic software, and can be invaluable when analysing photos, building photo montages, or for archival purposes.

Original photographs were saved in the camera with a file name consisting of a prefix 'GBB\_' followed by a four-digit number and a three-letter extension 'jpg' or 'NEF' that signified the type of file was either JPEG or raw format, respectively. The initial file number sequence was set to 0001, enabling 9999 photos to be taken before the numbering would be automatically re-set. This was sufficient to ensure each photograph taken during the survey had a unique sequential number. At the completion of field work all files were downloaded to a computer and stored in a separate folder '*Original Photos 2012*', with each photographer's images

stored in a sub-directory bearing the photographer's name (*Barry* or *John*). Some photos were renamed to indicate the colony number and name, and the start and end point of each photographic run for each colony. The original four-digit number was retained in any subsequent renaming of files to permit easy tracking of work flows from the original photos to the stitching and development of photomontages, through to counting of images. File numbering protocols may be best explained in Table 1.

**Table 1. File numbering protocols for aerial photographs of sea lion colonies on the Auckland Islands taken with Nikon cameras.**

File Name/Number	Process	Explanation
GBB_1880.NEF	Original photo	Camera generated file name with unique sequential number.
GBB_1880_Sandy Bay, Enderby 1000ft Run 1 Start.jpg	File renamed	Some original photos renamed to indicate name of colony and start and end point for the each photographic run at the site. Files stored in directory <b><i>Original Images</i></b>
Sandy Bay 11 Jan_1(1881-1890).jpg	Photo montage	Photos GBB_1881 to GBB_1890 have been copied and stitched to create a photomontage of the site. Photomontage files stored in directory <b><i>Stitched Images</i></b>
Sandy Bay 11 Jan_1(1881-1890)_count.jpg	Counted image	Stitched image Sandy Bay 11 Jan_1(1881-1890).jpg has been duplicated and counted. Duplicate files showing the sea lions identified and counted stored in directory <b><i>Counted Images</i></b>

### *Ground counts*

Ground truthing of aerial counts was carried to quantify the proportion of sea lions that may be missed from the aerial counts, and to enable the development of correction factors that can be applied to aerial counts to ensure appropriate comparisons could be made with an existing long-term data set for the Auckland Islands (Chilvers 2012). Direct counts were carried out each day on Enderby Island by three people that walked the Sandy Bay Beach once with hand tally counters and counted all pups located. In addition, mark-recapture experiments were carried out on 16 January on Enderby Island, and on 21 January on Dundas Island (Chilvers 2012). Pups were marked with circular, 5 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 40% of previous pup production estimates at Sandy Bay (148 pups marked) and 30% at Dundas Island (380 pups marked). Marking was spread as evenly as possible through the breeding area (based on pup density and distribution). Most discs were shed a few days to weeks after the experiment. Recaptures involved three observers moving systematically through the entire sea lion pupping area counting pups, with each observer conducting 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. Results of each recapture were used to calculate a modified Petersen estimate (Chapman 1952; Seber 1982) of pup production.

Numbers of pups known to have died up to the date of the M-R estimate were then added to produce a figure for total pup production (Chilvers et al. 2007; Chilvers 2012). All pups that died during the breeding season from Sandy Bay were counted and removed on a daily basis, which resulted in the accurate assessment of numbers of dead pups from this site. Such pups would obviously not be available for detection from aerial counts. For Dundas Island, dead pup numbers were estimated by counting all visible pup carcasses the day of pup production estimate. Carcasses were counted by up to four observers systematically covering the islands at the same time calling out and identifying carcasses, so as not to overlap observer search areas, with one observer using a hand counter to tally the total carcass count (Chilvers 2012).

### 3. Results

#### *Photography*

We were able to photograph both the Sandy Bay and Dundas Island colonies on 11, 12 and 14 January, but low cloud to almost down to sea level prohibited this on 13 January. Trials indicated that the best images of sea lions were taken at an elevation of 1000 feet directly over a colony using 200mm focal length extension. This permitted a practical compromise between providing adequate photographic detail without the need to take an excessive number of photographs to ensure complete documentation of each colony during a photographic run. It was extremely difficult to document entire colonies with the 500mm lens unless the helicopter maintained a hover for a minute or so. This was not always possible with the strong tail winds we encountered on a couple of days. Even when the helicopter was moving slowly, it was difficult to photograph colonies systematically with the 500mm lens because the photographer became 'lost in the viewfinder'. For this reason, the 500mm lens was used to specifically focus on piles of sea lion pups. There was no detectable impact on sea lions when the helicopter was flown directly over colonies at 1000 feet or higher.

The quality of the photos taken was generally excellent. On one day (14 January) however, photos taken by both photographers and on all photographic runs were consistently soft in focus, although still of a fairly high standard. We are unable to explain why this occurred, but it could be related to different levels of vibration in the helicopter because of the weather conditions at the time, or perhaps the prevailing light conditions. Certainly at the time we were not aware of anything unusual in the operations of our photographic equipment or the helicopter.

We attempted to determine the presence of dead pups from the photographs, but this was not possible.

#### *Aerial counts*

Aerial counts for both Sandy Bay and Dundas Island on 11, 12 and 14 January 2012 are provided in Table 2. For Sandy Bay we estimate that there were 358 (95% CI 320 – 396), 353 (315-391) and 293 (259 – 339) pups on the 11, 12 and 14 January, respectively. These estimates are based on photographs taken with the 200mm focal length lens. When photographs of pup piles taken with the 500mm focal length lens are incorporated in the analysis, the estimate for 14 January is 304 (269 – 339) pups.

For Dundas Island we estimate that there were 1,269 (1,198 – 1,340), 1,207 (1,138-1,276) and 1,222 (1,152 – 1,292) pups on the 11, 12 and 14 January, respectively.



### Ground counts

The mark-recapture experiment undertaken on 16 January for Sandy Bay estimated  $343 \pm 9$  pups. There were 18 dead pups at that date giving a total pup production of  $361 \pm 9$ . (Table 2; Chilvers 2012).

The mark recapture estimate at Dundas Island was completed on 21st of January. The mark-recapture estimated 1189 live pups  $\pm 13$  and 59 dead pups were counted giving a total estimate of  $1248 \pm 13$  pups on the island (Table 2; Chilvers 2012).

**Table 2.** Comparison between Petersen estimates of sea lion pups at the Sandy Bay and Dundas Island colonies and counts derived from analysis of aerial photographs of the same sites. For Sandy Bay the comparison is made between aerial counts and live pups only, as dead pups were removed from the colony each day, which did not happen at Dundas Island.

Area Date	Ground count	Aerial Count	Lens focal length	Difference between aerial count & MR estimate		Comments
			mm	#	%	
<b>Sandy Bay</b>						
11-Jan	337	358	200	15	4%	Fine weather, sunshine, low wind. All pups on beach
12-Jan	341	353	200	10	3%	Weather fine but overcast, rained at 5.00 pm. All pups on beach
14-Jan	340	293	200	-50	-15%	Overcast, passing showers but clearing. Photo quality not good. 70 females up on sward but all pups on beach.
		304	500	-39	-11%	
<b>16-Jan</b>	<b>343</b>					<b>MR 343 + 18 dead = 361 <math>\pm</math> 9</b>
<b>Dundas Island.</b>						
11-Jan	-	1269	200	21	2%	
12-Jan	-	1207	200	-41	-3%	
14-Jan	-	1222	200	-26	-2%	
<b>21-Jan</b>	<b>1,248</b>					<b>M-R 1,189 + 59 dead = 1,248 <math>\pm</math> 13</b>

### Comparison of Aerial and Ground counts

With the exception of one day, the aerial and mark-recapture counts were highly correlated and varied by less than 4% at any one time (Table 2). For one day, 14 January, the difference between the aerial and ground count was 15%, or 11% if photos of pup piles taken with the 500 mm lens are included in the analysis (Table 2).

## 4. Discussion

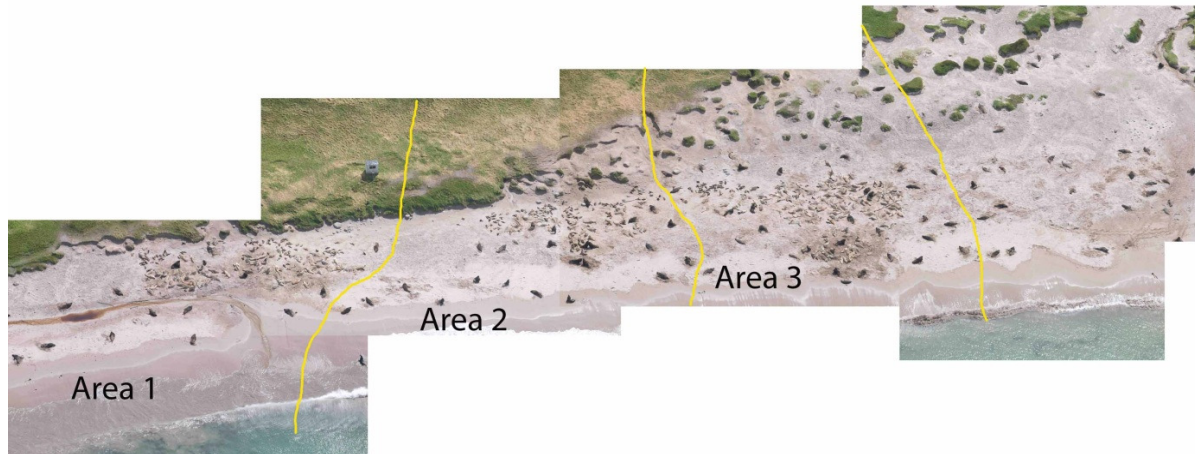
The use of aerial photography appears to have great potential to provide robust, cost-effective estimates of New Zealand sea lion pup production at the major pupping sites in the Auckland Islands, with all but one estimate falling within 4% of the estimate derived by mark-recapture methods.

More work is desirable to understand the reason for the disparity between the Sandy Bay ground count and the one low aerial estimate, but the only plausible explanation would appear to be that pups were missed because they were hidden deep in pup piles. It is clear from the ground count undertaken on that day that all pups at Sandy Bay were still on the beach and had not moved on to the grass sward adjoining the beach, where they may have been more easily missed because of poor contrast. We had thought that by using photographs taken directly overhead the potential for underestimating pups in piles would have been greatly reduced, as the pups do not appear to be more than two or three pups high at the most (**Figure 5**). Certainly, the use of multiple counters and analysis of four separate photographic runs taken on the beach that day provided remarkably consistent results.



**Figure 5.** A pile of New Zealand sea lion pups on Sandy Bay Beach.

An appropriate way to deal with this problem would be to accept that aerial counts need to be undertaken on more than one day to achieve a count that can be incorporated into the existing longitudinal dataset with confidence. Pups and pup piles are not static and large piles that may present counting difficulties on one day are likely to break up over a day or two, as indicated in **Figure 6**. Sea lion pups were concentrated in 3 areas (Areas 1, 2 and 3) over the four days we were present. While numbers of pups were reasonably consistent in Areas 1 and 3, there was a substantial difference between the number counted on 11 January (131) and that counted on 14 January (70). If photographs were taken over three or four days, as happened in this study, it is likely that at least one aerial count taken during that period would be comparable to a mark-recapture estimate. Certainly, the maximum counts obtained during this study were within 3 and 2% of the mark-recapture estimates for Sandy Bay and Dundas Island, respectively.



**Figure 6.** Sandy Bay, Enderby Island, showing areas where sea lion pups were concentrated over four days from 11 to 14 January 2012. While numbers of pups were reasonably consistent in Areas 1 (117 & 109) and 3 (110 & 114), there was a substantial difference between the number counted in Area 2 on 11 January (131) and that counted on 14 January (70).

Further consideration needs to be given to the issue of considering dead pups in aerial counts relative to existing mark-recapture data that includes these in pup production estimates. We were unable to distinguish dead pups in our photos, although it is likely most dead pups would have been accounted for in the Dundas aerial counts. If further aerial counts are to be undertaken, it would be useful to mark the location of a number of dead pups at various places on Sandy Bay, preferably of varying times since death, and examine photographs to ascertain just how visible these are in aerial photos.

It is also important that future aerial surveys are timed to occur as close as possible to the dates historically used for the mark-recapture estimates, to ensure their usefulness in building on the considerable longitudinal data set that exists for the Auckland Island sea lion population and enabling effective monitoring of population trend.

It should also be entirely feasible to conduct aerial surveys of the South East Point colony on Enderby Island too. There are currently very few pups produced there — only one this year — although there used to be up to 140+ in historical times and it is an area that could be easily checked and photographed annually.

As part of other work in the Auckland Islands we took the opportunity to overfly Figure of Eight Island on 12 January. This confirmed earlier advice that this site is unsuited to aerial counting of the sea lion pups born on that site. However, the presence of a helicopter in the Auckland Islands would provide the opportunity to land a survey team on the island to quickly conduct a ground count if necessary.

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