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Tohorā Nō Aotearoa - New Zealand Southern Right Whale Auckland Islands Expedition Report, with Genotype Matching to 1995-2009 Catalogue

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TOHORĀ NŌ AOTEAROA - NEW ZEALAND SOUTHERN RIGHT WHALE AUCKLAND ISLANDS EXPEDITION REPORT, WITH GENOTYPE MATCHING TO 1995-2009 CATALOGUE

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ABSTRACT

In August 2020, an 18 day expedition to the Auckland Islands Maungahuka in the New Zealand sub-Antarctic aboard the yacht *Evohe* undertook the first of two field seasons to investigate the recovery and foraging ecology of Tohorā nō Aotearoa - New Zealand southern right whales (SRW, *Eubalaena australis*). This is the continuation of genetic monitoring work on Aotearoa New Zealand SRW initiated by the University of Auckland in 1995 that covered the austral winters of 1995-1998 and 2006-2009. The eight-person research team collected 220 skin biopsy samples, 21 of which are linked to individual whales with photogrammetry measurements (i.e., length, width), deployed six satellite tags, and undertook drone surveys in the Port Ross area. The expedition found a relative increase in the proportion of cow-calf pairs in the area compared with previous years. This is likely due to the COVID-19-related delay in our survey, meaning the trip coincided with the previously described peak abundance of cow-calf pairs, and missed the peak abundance of adult whales seen earlier in the season. Regardless, the importance of Port Ross to cow-calf pairs, the demographic class of SRWs most vulnerable to human disturbance, highlights the need for continued conservation and management of the region. Of the 220 skin biopsy samples, 210 provided genotypes that passed quality control and represented 178 unique individual whales. Of these 179, 21 had been seen previously in the Auckland Islands, 1 in Campbell Island, 1 in mainland New Zealand, and 1 potential match to New South Wales, Australia. There were 16 females recaptured across surveys in the Auckland Islands, two of which were seen as females with calves in all three decadal surveys. This work forms the basis of a planned research programme that includes close kin mark recapture, stable isotope, and satellite tagging to investigate the foraging ecology of NZ SRW.

INTRODUCTION

Tohorā nō Aotearoa - New Zealand (NZ) southern right whales (SRW, *Eubalaena australis*) have recovered from as few as 40 whales to an estimated 2000 whales in 2009, prompting a revision and improvement in their New Zealand threat status to *At Risk – Recovering* (Baker et al., 2019; Carroll et al., 2013; Jackson et al., 2016). Almost all of our knowledge of these whales is based on genetic monitoring work used to assess stock identity, abundance, growth rate and recolonisation around mainland NZ (Figure 1) (Carroll et al., 2015, 2011, 2016, 2014). However, SRWs across the species' range are a sentinel species for climate change, with strong correlations between environmental conditions at their high latitude feeding grounds and reproductive success and recovery of winter breeding grounds (Harcourt, van der Hoop, Kraus, & Carroll, 2019; Leaper et al., 2006; Seyboth et al., 2016). The need to understand these linkages has become increasingly important over the past decade, as most SRW populations around the world have experienced a decline in reproductive success or mass mortality events (Rowntree et al., 2013; Vermeulen, Wilkinson, & Van den Berg, 2020). Effective management in an era of climate change requires critical missing information on where SRWs forage throughout their range.

The 2020 Auckland Islands expedition was the first of two planned to collect data and deploy satellite tags to assess two key knowledge gaps: 1) population recovery and 2) foraging ecology. The first will be done using close kin mark recapture to understand population recovery (Bravington, Skaug, & Anderson, 2016). This technique is an extension of mark recapture methods based on assessment of kin relationships through genetic analysis (Bravington, Grewe, & Davies, 2016). In addition, a combination of stable isotope analysis and satellite telemetry will be used to identify and understand foraging ground linkages (Valenzuela, Rowntree, Sironi, & Seger, 2018; Zerbini et al., 2018). These two questions will be linked by undertaking photogrammetry (i.e., estimates of length, width and mass: Christiansen et al., 2020) on whales for which we have skin biopsy samples. Specifically, we will investigate the relationship between individual whale health, foraging ecology and demographics using photogrammetry measurements linked to genetics, ageing and isotopes of individual whales.

Objectives
The objectives of this study are:

1. Determine the current abundance and population growth rate for SRW, 10 years since the last estimate, using close kin mark recapture through genetic monitoring;
2. Determine local and long-range movement patterns of SRW from the Auckland Islands using satellite tracking data;
3. Reveal and compare foraging habits of SRW that winter in both the Auckland Islands and mainland NZusing stable isotope analysis;
4. Investigate the relationship between individual whale health, foraging ecology and demographics using photogrammetry measurements linked to genetics, ageing and isotopes of individual whales;
5. Continue to inform decision making around potential threats and recommend management actions to protect the species in both their well-studied socialising and nursery areas and newly identified but still poorly known foraging areas.

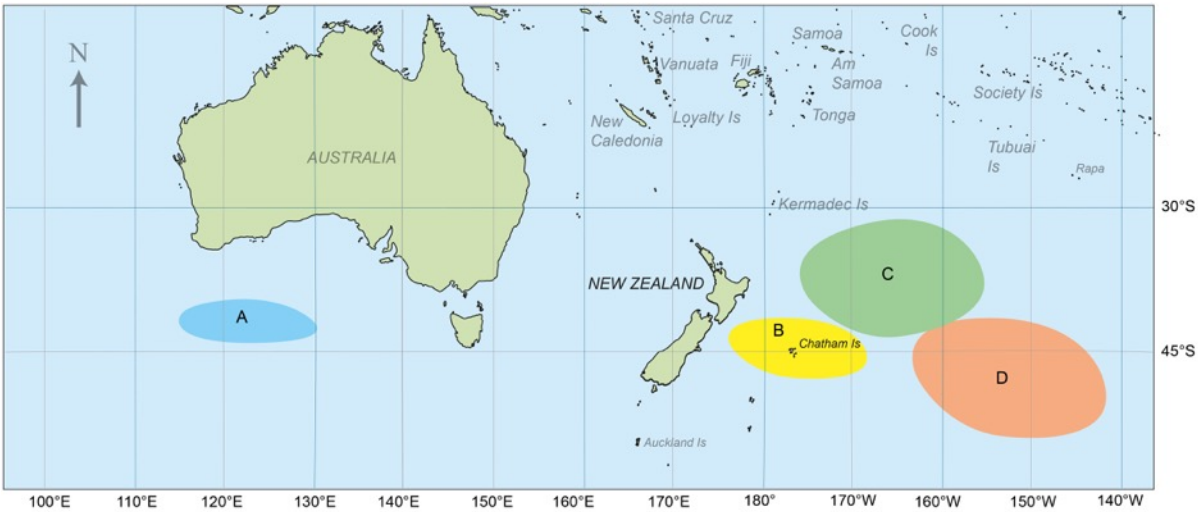

Figure 1: Map showing the Auckland Island and mainland New Zealand with foraging areas suggested by satellite tracking data (A) and historical whaling areas (B-D).

METHODS

Survey design
Fieldwork was conducted in Port Ross, Auckland Islands, (50°32’ S, 166°15’E) from 1 to 18 August 2020. A team of eight researchers travelled and lived aboard the *SV Evohe*, a 26 m motor sailor based in Dunedin, skippered by Steve Kafka. The team was led by Emma Carroll (University of Auckland, UOA) and comprised Simon Childerhouse (Cawthron Institute), Rochelle Constantine (UOA), Esther Stuck (UOA), Leena Riekkola (UOA), Ros Cole (DOC), Bill Morris (NZ Geographic) and Richard Robinson (Depth and NZ Geographic). The survey was conducted under Marine Mammal Permit 84845-MAR, Research in a Marine Reserve Permit 87513-MAR and University of Auckland Animal Ethics approved protocol 002072 issued to Emma Carroll.

Biopsy and photo-identification
Two small rigid-hulled inflatable vessels (4.3-5.2 m) were used to collect photo-identification (photo-ID) images and skin biopsy samples as was done in previous surveys (Carroll et al., 2013; Patenaude, Baker, & Gales, 1998). The skin biopsy samples were collected using small, stainless steel biopsy darts deployed from a crossbow or a modified veterinary capture device (Krützen et al., 2002; Lambertsen, 1987).

Microsatellite genotyping and comparison to southern right whale genotype catalogues
DNA was extracted using standard phenol-chloroform methods modified for small tissue samples (Sambrook et al. 1989). Genotyping at the 17 microsatellite markers used in previous global studies of SRW was done using previously published methodology (Carroll et al., 2019). Four samples and one blank in each 96 well tray were used as allelic ladders and to detect contamination, respectively.

The 2020 genotypes were compared with several other published datasets to identify matches: Auckland Islands (13 microsatellite markers; Carroll et al., 2013), Campbell Island (13 microsatellite markers; Torres et al., 2017), Mainland NZ (13 microsatellite markers; Carroll et al., 2014), and the Australian genotype catalogue (17 microsatellite markers; Carroll et al., 2015). Matching was done using CERVUS (version x) and matches with up to 3 mismatching loci were investigated to account for genotyping error. Exact matches, or those where dropout was identified after a match, were considered confirmed matches. Potential matches were identified as those genotypes that matched at 7 or more loci, but mismatched at 1-2 loci.

Drone surveys and photogrammetry
Aerial photogrammetry methods (Christiansen et al., 2020, 2018) were used to measure the body size and shape of SRWs using a DJI Inspire 1 Pro quadcopter drone with a 25 mm f1.8 lens. We also tested the efficacy of a DJI Mavic Pro2 drone for collecting comparable photogrammetry data.

Satellite tagging
We also deployed six SPOT6 tags using a modified version of the Air Rocket Transmitter System system (Heide-Jørgensen et al., 2001), methods and results of which are discussed in Riekkola et al. (2021).

RESULTS

Survey results

There was a total of 194 encounters, with an average encounter duration of 7 min (SD = 6 min, range 1 - 36 min). Of the 194 encounters (Figure 2; Table 1), 62% (122 encounters) occurred in inner Port Ross, most of which were in Laurie Harbour (39) or Terror and Erebus Coves (41). The remaining 38% (72) of encounters occurred in the outer Port Ross, particularly in Sandy Bay (22) and around Rose Island (15; Figure 3). This season, more encounters involved at least one cow-calf pair (64%) compared with previous survey years of 2006 to 2009 (Table 1). This is despite having comparable or less time in the inner Port Ross area, thought to be a key area for cows and calves (Rayment, Davidson, Dawson, Slooten, & Webster, 2012), than in previous years.

Table 1: Summary of encounter and biopsy data collected during the 1998, 2008, 2009 and 2020 Auckland Islands southern right whale surveys.

Year	Demographic composition		Locations		Biopsies			
	Cow-calf pairs	Groups without calves	Inner Port Ross	Outer Port Ross	Adults	Cows	Calves	Total
1998	27%	73%	58%	52%	80%	17%	3%	159
2008	49%	51%	89%	11%	49%	41%	10%	204
2009	36%	67%	64%	36%	70%	26%	4%	254
2020	64%	36%	62%	38%	37%	42%	21%	220

Biopsy and photo-identification
All photo-ID images, including the 50 unique IDs linked to biopsy samples, have been shared with the curator of the New Zealand southern right whale photo-ID catalogue (Dr W. Rayment, University of Otago). A total of 220 biopsy samples were collected, of which 147 had skin subsampled for stable isotope analyses, and sufficient blubber for hormone (12 samples) and gene expression analyses (21 samples). The breakdown of the demographic class of these samples is shown in Table 1.

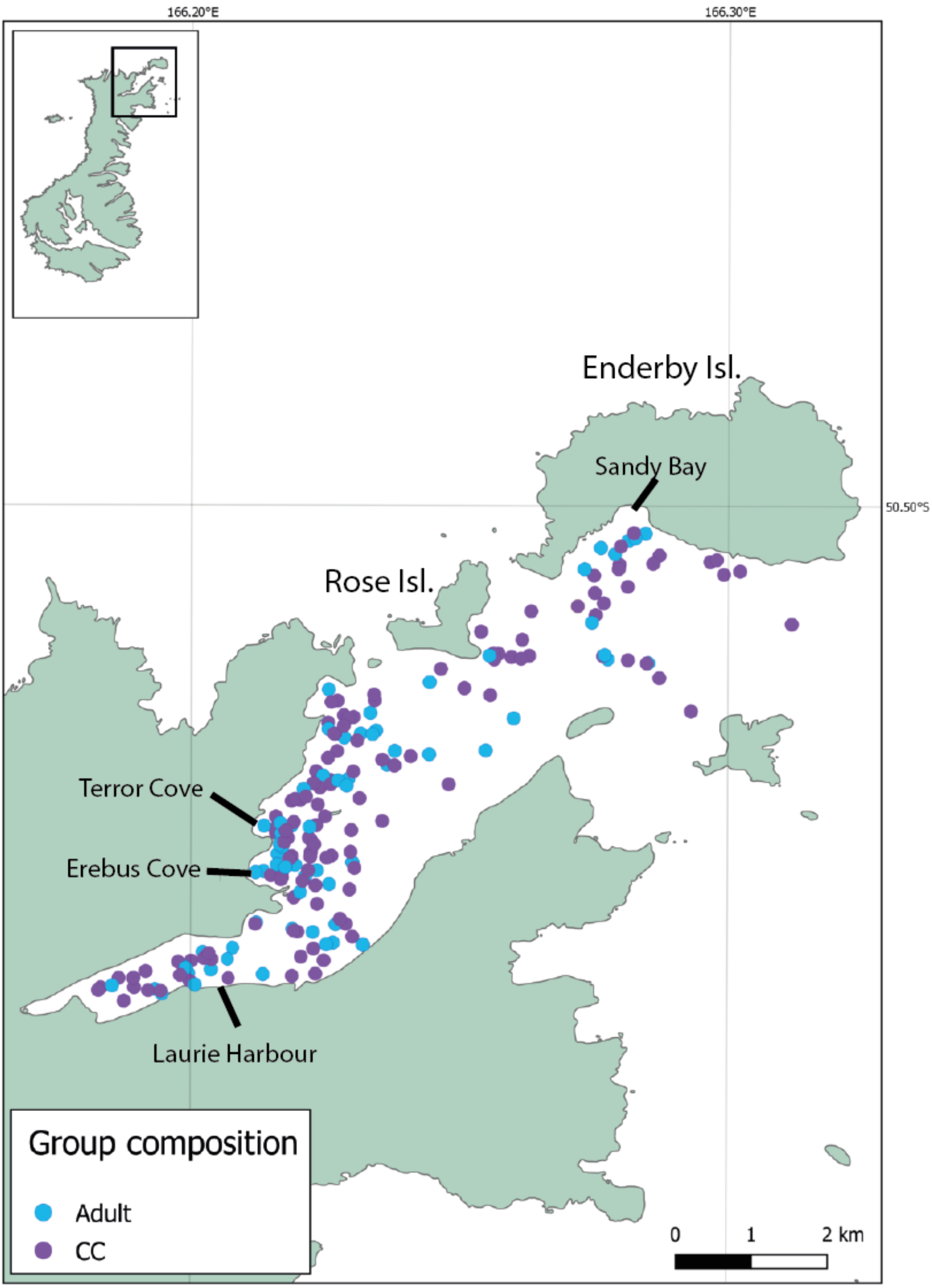

Figure 2: Positions of group encounters, coloured by group composition, and those comprising only adult whales shown in blue and those with cow calf (CC) pairs shown in purple.

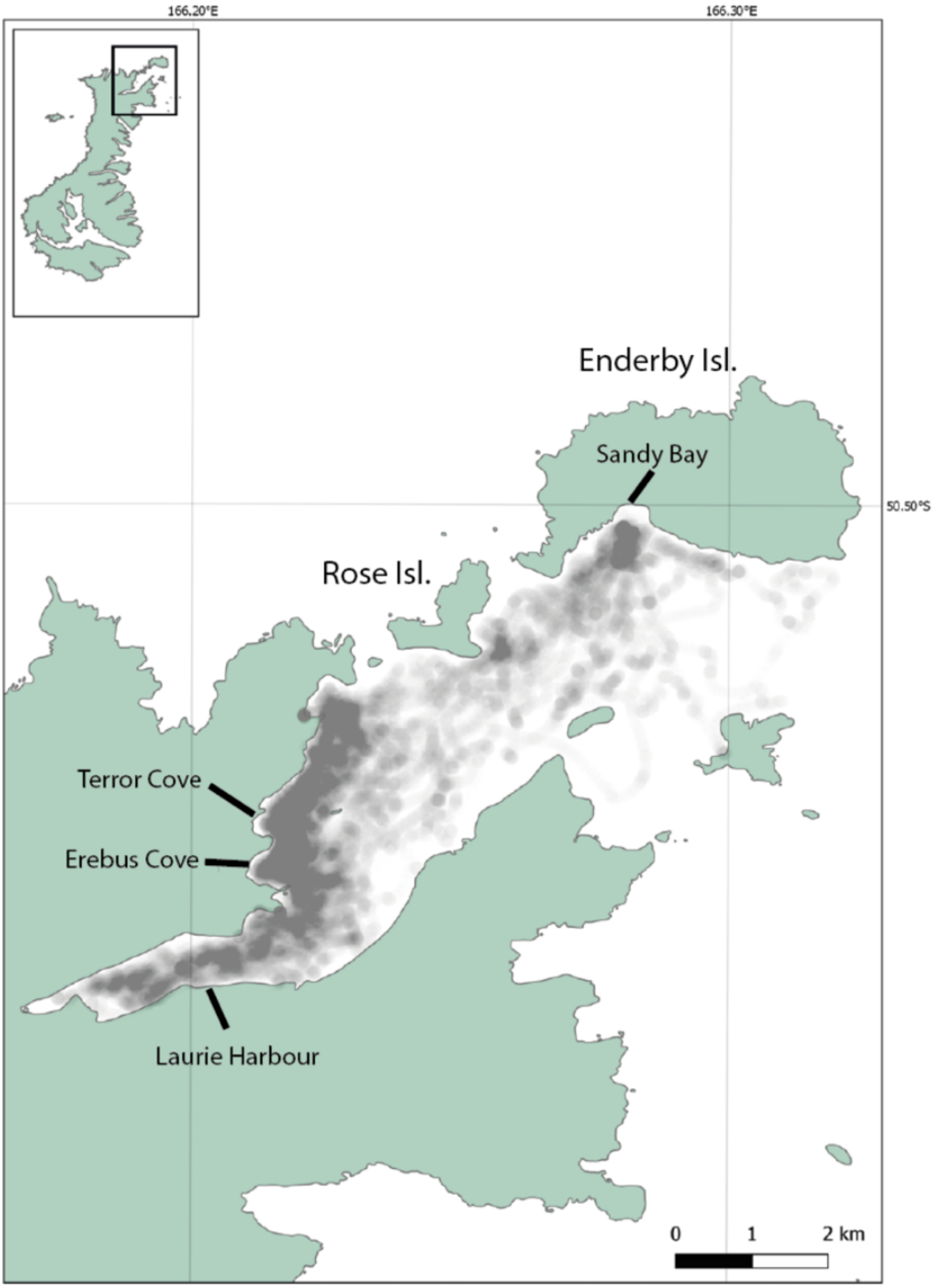

Figure 3: Relative survey effort, with increasing effort shown by darker shading.

Genotype catalogue comparisons
Of the 220 skin biopsy samples, 210 produced genotypes that passed quality control (QC) with an average of 16 loci (SD = 3.5) for each sample. Comparison within year indicated that 178 unique whales had been sampled, including 41 calves. Of the 137 non-calf whales available for comparison to the existing DNA catalogues, we identified 21 matches back to the Auckland Islands 1995-2009 catalogue: of these 18 are confirmed and 3 are considered potential matches[1] (Tables 2 and 3 and Figure 4). Of these, five were males, two of which were first sampled as calves in 2007 and 2009, respectively.

Of the 16 females:

- eight were cows with calves both in 2020 and the previous capture occasion, including 2 who were seen as cows with calves in all three decades of survey (Table 3)
- five were cows with calves in 2020 but unaccompanied adults on the previous capture occasion
- two were unaccompanied adults in 2020 and previous capture occasion
- one was a cow with a calf in 2020 but a calf itself in 2009

There was also 1 match back to the Campbell Islands (male), and 1 to mainland New Zealand (female, seen as a cow in mainland in 2009). In addition, one potential match to a calf sampled in New South Wales, Australia (matched at 14 loci; one allele mismatch at two loci that could be dropout), in 2010, was also sampled as a cow in the Auckland Islands in 2020. These results are summarised in Table 2, with details of the year of capture of those seen in 2020.

Table 2: Regional comparison datasets and matches to the Auckland Islands 2020 field expedition. Shown are sample sizes (N_{sample}), number of genotypes passing quality control ($N_{genotype}$) and unique genotypes (N_{unique}) from each study, as well as sex and demographic class of whales in each regional dataset. Potential matches shown by *.

Year	Region	N_{sample}	$N_{genotype}$	N_{unique}	Adult M/F/U	Calf M/F/U	Matches	Citation
2020	Auckland Islands	220	210	178	43/92/2	18/22/1	-	This study
1995-2009	Auckland Islands	1188	1089	888	314/388/8	34/32/0 **	18 (3*)	Carroll et al. 2013
1994-2015	Australia	94	78	77	34/40/3***	-	1*	Carroll et al. 2015
2003-2010	Mainland New Zealand	64	54	47	25/22/0***	-	1	Carroll et al. 2014
2014	Campbell Island	24	23	21	11/10/0	0/0/0	1	Torres et al. 2016

**calves were also recaptured as adults, therefore numbers do not add to 888

*** calves were not separated out in this analysis.

[1] Additional lab work is underway to investigate the true identity of these potential matches, which have identical matches at 9-14 loci but mismatch at 1-2 loci, before final confirmation.

Table 3: Capture histories of whales sampled in the Auckland Islands in 2020 that were also seen in previous genetic monitoring survey years. This table is inclusive of the 3 potential matches, thus the total individuals is 21.

Sex	1995	1996	1997	1998	2006	2007	2008	2009	2020
F					x				1
M						x			2
F						x			1
F							x		5
M								x	2
F								x	6
F					x			x	1
F	x					x			1
M						x	x	x	1
F		x					x		1

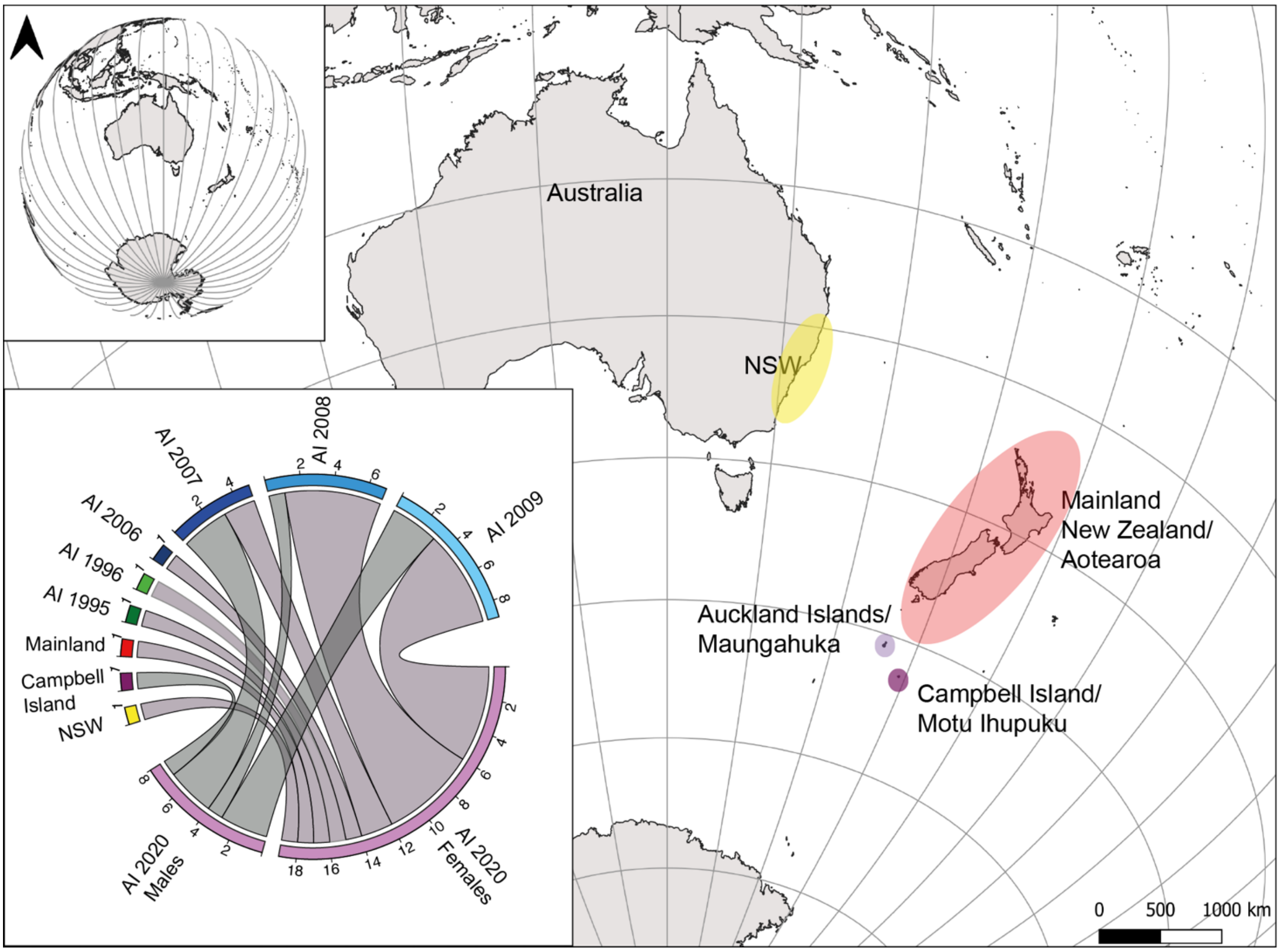

Figure 4: Graphical of DNA profile matches from the Auckland Islands 2020 survey (AI 2020) to previous survey years and to other regional DNA profile catalogues. Numbers shown are number of individuals found in AI 2020 that were also found in the datasets indicated.

Photogrammetry and linked data collection
Photogrammetry and biopsy sampling was conducted on 21 individual whales. Of these, three were cows for which we also have the calf sampled. The photogrammetry data will be analysed together with data collected in 2021. Drone survey data is also be assessed, although we can confirm that the composition of whales north of Enderby Island was qualitatively similar to that seen in Port Ross.

DISCUSSION

Port Ross remains the most important calving ground for SRW in NZ
Port Ross, Auckland Islands, is recognised as the key breeding and calving ground for SRWs in NZ waters, with all demographic classes present (Carroll et al., 2013; Patenaude et al., 1998; Rayment et al., 2012). This importance contributes to the Auckland Islands being listed as a marine reserve, marine mammal sanctuary (established in 1993), and an IUCN Important Marine Mammal Area (IMMA, established in 2020).

One finding of our preliminary analysis was the predominance of cow-calf pairs across all areas of Port Ross (Figure 1). This increase in the relative proportion of cow-calf pairs encountered from previous years could be reflective of the expedition being later in the season. We were two to three weeks later than previous surveys due to COVID-19-related delays. Indeed, Patenaude (2002) found that although the arrival time of cow-calf pairs and adult whales did not vary, peak abundance of the different groups did. Non-cow-calf abundance peaked in mid-July while cow-calf pairs peaked approximately three weeks later. Alternatively, habitat use patterns may have changed over time, however, additional data are required to differentiate between these hypotheses. A longer field season, commencing earlier than 2020 is planned for 2021 to investigate this issue.

Furthermore, our encounter data did not just show that the cow-calf pairs were only limited to the inner Port Ross area, traditionally thought of as their core habitat (Patenaude, 2002; Rayment et al., 2012), as we also found them in the outer areas such as Rose Island. This could be related to the physical development of calves, such that their mothers move them outside the nursery areas later in the season as they grow larger and more robust.

Overall, the results clearly highlight the importance of Port Ross to cow calf-pairs, as found in previous surveys. Controlled vessel approach experiments have clearly documented that cows with calves are the most sensitive demographic classes to disturbance (Lundquist, 2007). Research undertaken in Port Ross showed that cow-calf pairs started reacting to boat approaches from up to 1 km away (Barrett, 2000). All future coastal management plans for Port Ross should explicitly consider the negative impact of boat traffic on SRW cow-calf pairs, an issue that will be exacerbated by the increasing number of whales.

Genotype matching confirms philopatry of SRW to Auckland Islands
Genotype comparisons revealed that up to 23 of 137 non-calf (17%) whales sampled in 2020 had been captured before in NZ or Australia. While four matches need to be confirmed with additional genotypic data, the recaptures highlight that both males and females return to the Auckland Islands wintering ground. The recapture of three calves from the Auckland Islands, 11-13 years after their year of birth, further confirms the natal philopatry to this region (Carroll et al., 2016). The sex bias in recapture rates (1:3.2 males: females) likely partly reflects the bias in the 2020 sample (1:2.4 males:females), and also potentially the increased residence time and therefore capture probability of females with calves. The match of one male between Campbell Island and Auckland Islands is in line with the previous photo-ID matches between Campbell and other NZ habitat and the within-season movement of a satellite tagged whale from Auckland Island to Campbell Island in 2020 (Torres et al., 2017). Genetic data from 2020 and previous surveys will be compared with historical data to investigate changes in genetic diversity over time (Remedios, Smith, Allen, & Carroll, 2021).

Observations of gull - SRW interactions
This season, we noticed that the red bill gulls/tarāpunga (*Larus novaehollandiae*) were often seen in close association with the SRWs, especially calves (Figure 5). The gulls appeared to be following the whales and diving for material at the surface of the water in the whale's wake, landing on the whales, and in some circumstances pecking at their backs or on the whales' head. We interpret this as the gulls eating sloughed whale skin or cyamids from the water's surface or feeding directly on these while standing on the whale itself. The gulls were observed to elicit a strong startle-type reaction from the whales on more than one occasion.

Figure 5: Images of gull-SRW interactions, with gull landing on cow (above) and calf (below) in the same encounter. Photographs: University of Auckland southern right whale/tohorā research team 2020.

Gull feeding on whales has been documented at Península Valdés, Argentina leading to injuries on the back of SRW calves (Sironi et al., 2018). None of the whales we saw, or undertook photogrammetry on, had any lesions or any evidence of Península Valdés type interactions. However, it was the first time any of the researchers on the expedition or the Captain or crew of the *SV Evohe* had observed such behaviour in observations spanning more than 20 years. Given the significance of this issue to SRWs elsewhere, further monitoring of this interaction will be undertaken in 2021 fieldwork to assess the potential frequency and impact of this seabird behaviour.

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