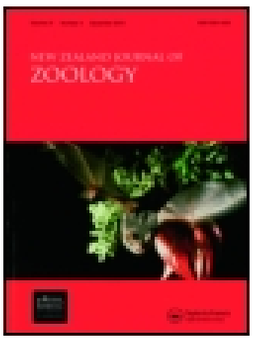

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Distribution and breeding of New Zealand sea lions *Phocarctos hookeri* on Campbell Island

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Abstract Campbell Island is the only major breeding site for the New Zealand sea lion *Phocarctos hookeri* outside the Auckland Islands. Minimum pup production was estimated at 78 for the 1997/98 breeding season, compared with the only previous estimate of 122 from 1991/92, and represents less than 5% of the total pup production for the species. Sea lions at Campbell Island have a widespread distribution, clumped at the coast and scattered inland. Local concentrations of sea lions were seen at Davis Point, Sandy Bay and both Northeast and Southeast Harbours. Isolated individuals were found up to 1.5 km inland and at altitudes up to 250 m. Breeding females at Campbell Island are generally solitary and give birth inland, in contrast to the highly gregarious colonies seen on the coasts of the Auckland Islands. In some years a small breeding colony forms on the coast, often at Davis point, but its location is variable. Overall, the present distribution and abundance of sea lions on Campbell Island does not appear to differ considerably from previous reports stretching back as far as the 1950s. Line transects proved inappropriate for estimating sea lion density, due to a low encounter rate and poor visibility in dense vegetation. Future work could include surveys for pups, which aggregate on the coast during March or April.

Keywords *Phocarctos hookeri*; Subantarctic; sea lion; New Zealand; Campbell Island; survey; breeding; distribution; pup; colony; solitary; historical

INTRODUCTION

The breeding distribution of the New Zealand sea lion, *Phocarctos hookeri*, is centred on the New Zealand Subantarctic Islands. Over 95% of pups are born at four colonies in the Auckland Islands (Gales & Fletcher 1999). The only other significant breeding population is on Campbell Island (Gales 1995). Occasional births have been recorded at the Snares (Crawley & Cameron 1972), Stewart Island (Childerhouse & Gales 1998) and Otago Peninsula (McConkey 1997; Heinrich 1998). There are regular haul-out sites on the Snares (Crawley & Cameron 1972), Stewart Island (Wilson 1979), South Otago (McConkey 1997; Heinrich 1998), Otago Peninsula (McConkey 1997) and to a lesser extent Macquarie Island (Gales 1995). The total population was estimated at 12 500 (95% C.I. 11 183 to 14 000) individuals for the 1995/96 austral summer (Gales & Fletcher 1999).

In the decade 1987 to 1997 an average of 78 individuals a year have been caught incidentally in the squid trawl fishery established on the Auckland Island shelf in the 1970s (Manly & Walshe 1999). The impacts of this bycatch on the New Zealand sea lion population are unknown, due to a lack of knowledge of their basic life history parameters. This bycatch is presently managed by calculating a catch limit of sea lions, the Maximum Allowable Level of Fishing Related Mortality (MALFIRM), which

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restricts bycatch to a theoretically sustainable level, and requires closure of the Auckland Island squid fishery should the MALFIRM trigger point be reached (Manly & Walshe 1999).

The Campbell Island group (52°33′S, 169°09′E) is situated 660 km south of the New Zealand mainland and comprises one large main island and several smaller islands, with a total land area estimated at 11 331 hectares (Anon 1983). Campbell Island is covered with dense vegetation forming distinct plant communities (Meurk et al. 1994), which include tussock meadows (*Poa* spp.), dwarf forest (*Dracophyllum* spp. and *Coprosma* spp.) and herb fields. The terrain is steep and much of the coastline is inaccessible to sea lions due to sheer cliffs.

Historic records of sea lions at Campbell Island

The pre-exploitation population size of sea lions at Campbell Island is unknown (Gales 1995). After Campbell Island was discovered in 1810, fur seals and sea lions were hunted to very low numbers, mainly for their skins (McNab 1907; Thomson 1912; Warneke 1982). Few records of the early sealing period at Campbell Island remain, but the industry as a whole, which was based primarily on fur seals, had declined to an unprofitable level by the 1830s (Kerr 1976).

During Musgrave's visit to Campbell Island in 1863, "sea lions, or other species of the phocidae were exceedingly rare", with only five sea lions caught during a one month period (Musgrave 1866; Raynal 1885). However, numerous sealing, whaling, scientific and government expeditions visited Campbell Island from the 1870s to early 1900s, and reported that sea lions were numerous and widely distributed over the island (Filhol 1885; Reischek 1889; Joyce 1894; Waite 1909; Thomson 1912). Possible breeding groups were sighted at Northeast Harbour, Perseverance Harbour and Northwest Bay (Filhol 1885). From 1909 to 1916 a whaling station was based at Northwest Bay, where sea lions were regularly killed for dog food (Timms 1978). When the whalers first arrived, Sandy Bay was "alive with sea lions", but few were left by the time of their departure (Timms 1978).

Since the 1940s estimates of the number of sea lions at Campbell Island have varied from "many hundred" male sea lions in 1947 (Bailey & Sorensen 1962), to 78 from a single days count in 1975 (Russ 1980) and between 120 and 200 in 1987/88 (Moore & Moffat 1990). Females were always fewer than males, but seem to have increased from "less than 20" in 1947 (Bailey & Sorensen 1962) and 50 in 1979 (Falla et al. 1979), to between 70 and 150 in 1997/88 (Moore & Moffat 1990). Male sea lions, particularly immature males, make up the majority of reported sightings. Bailey & Sorensen (1962) noted that between 1941 and 1958 the main sea lion concentrations were in Northwest Bay and Northeast Harbour, but animals were also regularly seen in Perseverance Harbour and in haul-outs around the coast. During the 1970s and 1980s the largest concentrations of male sea lions were recorded at Northwest Bay (Russ 1980; Taylor & Sadleir 1985; Moore & Moffat 1990). Northeast Harbour and Southeast Harbour were also regularly used as haul-out locations (Russ 1980; Moore & Moffat 1990).

Taylor & Sadleir (1985) reported that about 30 pups were born on Campbell Island during the 1984/85 breeding season. Moore & Moffat (1990) reported a minimum of 51 pups for 1987/88, mainly in Capstan Cove, Northwest Bay, and Tucker Cove (see Fig. 1). During the 1991/92 breeding season, 98 pups were tagged on Campbell Island and 24 dead untagged pups were counted, giving a minimum estimate of pup production of 122 (M. Fraser pers.comm.). Fraser's study was undertaken on an opportunistic basis, and pups were tagged and encountered all across the island. Cawthorn (1993) estimated the total pup production at Campbell Island to be 150 for the 1992/93 breeding season.

The aim of our study was to investigate the abundance, distribution and pup production of New Zealand sea lions on Campbell Island during the 1997/98 breeding season. Strip transects and direct counts were used to assess the distribution of adult animals. Pup production, distribution and mortality were assessed using strip transects, mark recapture techniques and direct counts.

METHODS

This study was carried out on Campbell Island between 5 January and 17 February 1998. Before arriving on the island, we conducted a literature review and interviews with people who had spent time on Campbell Island. From this research, locations reportedly used by sea lions were identified and ranked by the number seen in each location. Surveys were then conducted in these locations, in sequence from the highest to the lowest expected abundance of sea lions. After surveying, each location was classified as a breeding colony (aggregation including pups, with breeding behaviour

observed e.g., harems, mating, births, etc.) or a haul-out (aggregation with sea lions regularly present). Haul-outs were classified as main haul-outs when there were regularly large numbers (e.g., more than 20) of sea lions present. Work on the survey was prematurely halted on 29 January because of health concerns raised by an unexpected mass mortality event of sea lions on the Auckland Islands (Baker 1998). At this point, the work program was modified to collect information on the impact of the mass mortality event on the Campbell Island sea lion population. As a result the planned survey of the island was not completed.

Assessment of density and distribution

We tried using trip transect methodology to estimate sea lion density and distribution across the island (Buckland et al. 1993). Direct counts were utilised at specific locations on the coast (listed in Table 1) where sea lions were known to haul-out. Incidental encounters with sea lions were also recorded. Sea lions were classified into five sex and age categories: adult, sub adult, and juvenile males (McConkey 1997), adult females and pups. Individuals that could not be accurately sexed (genitalia not observed) were classed as unknown. These were mostly young adults, since it is often difficult to distinguish between the sexes until secondary sexual characteristics develop. Pups were identified from their distinctive natal pelage (Walker & Ling 1981).

For strip transects, pairs of observers followed parallel paths simultaneously while maintaining a constant distance between each other. Although the distance between observers remained constant within transect lines, it varied between transects as sighting conditions were different in different types of terrain and vegetation. Distance between observers was generally between 20 m and 40 m. The start point of each transect was selected randomly within each site, and where possible, the direction was chosen to include altitudinal variation to reduce bias from possible altitudinal trends in sea lion distribution. The start and end points of each pair of transects were recorded using a handheld GPS unit (Garmin, GPS 38). During these ground searches we tried to cover as much ground as possible including a variety of terrain and habitat types.

Pup tagging

Where possible, all pups encountered were sexed by direct observation of genitalia and tagged on each front flipper using red Allflex button tags (Allflex, Palmerston North, New Zealand) carrying an individual laser etched 5 digit code e.g., A0001. Plugs of tissue obtained from the female part of each tag were stored individually in vials of 10% alcohol for later genetic analysis. Weight and standard length (Scheffer 1967) were measured and recorded. The location of each pup was recorded using GPS, and also information about companion animals and the characteristics of its location. To aid resightings of tagged pups, each pup was marked both on the crown of the head and on the back with stock marker paint (Donaghys Super Sprayline Stock Marker) before release. Pups removed from their mothers or companions were released back with them or as close to them as possible. Not all pups encountered were tagged as some could not be caught (e.g., they were in the water), were injured, or were reported by other researchers on Campbell Island not equipped with tagging gear.

Pup production and mortality

Estimates of pup production and mortality were to be obtained from a combination of inland strip transects, coastal direct counts, and mark recapture techniques. A mark-recapture experiment was undertaken at Davis Point, the only breeding colony on Campbell Island, and the only site with large numbers of pups present. Two days were spent tagging pups at Davis Point, and a third day conducting recaptures. Chapman's modification of the Lincoln/Petersen estimator (Seber 1982) was used to estimate pup production at Davis Point. Incidental encounters of pups around the island were also recorded. Pup mortality was assessed by direct counts of bodies found. Dead pups were marked with stock marker to avoid recounting. The total estimate for pup production on Campbell Island was calculated by adding the number of pups tagged, the number of dead pups, and the minimum number of untagged pups seen at different locations.

RESULTS

Assessment of density and distribution

Altogether, 100 strip transects (50 pairs) were completed (Fig. 1). Sightings of sea lions were low along most transects, totalling 28 adults and 4 pups. The majority of sightings were around Northeast Harbour, where 19 males were recorded. In addition to transects, direct counts of sea lions were undertaken and any incidental encounters were also recorded. Table 1 shows a summary of count and incidental sea lion sightings. We logged over 1800

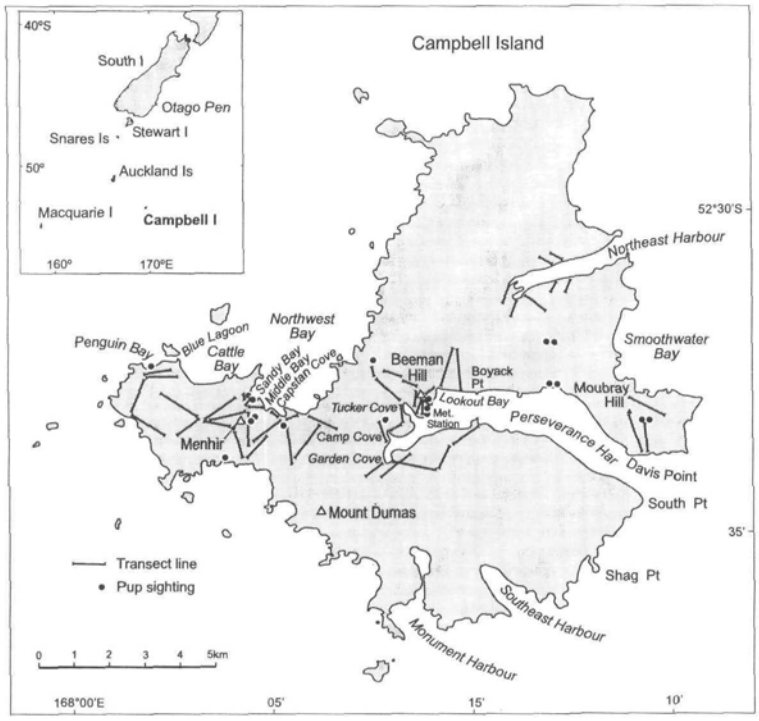

Fig. 1 Campbell Island showing location of transects and approximate locations of pups found.

sea lion encounters from transect lines, direct counts and incidental encounters, of which only 14 were with animals previously tagged on the Auckland Islands. As few sea lions were individually identifiable, the total number of encounters may include repeated sightings of some individuals. Eight dead sea lions excluding pups (3 females, 4 adult males, 1 juvenile male) were seen at different locations, but were not included in the counts.

Sea lions were found up to 1.5 km inland at altitudes of up to 250 m. They were found in a variety of vegetation and habitat types, including tussock meadows, dwarf forest, herbfields and coastal sward. In many places around the coastline there were well worn tracks up into the bush, used regularly by sea lions and penguins. Most male sea lions encountered inland were either solitary or in small groups. Females were rarely encountered away from Davis Point (n = 42) and were generally solitary (45%) or accompanied by a pup (5%), an adult male (12%), pup and adult male (12%) or others (26%). Small groups of males were seen along the coast, but were very variable in location and number.

The only site classified as a breeding colony was Davis Point, where all age and sex classes were present. Main haul-out sites that were regularly used by sea lions during this study include Northwest Bay, Perserverance Harbour, Northeast Harbour, and Southeast Harbour. Commonly used haul-out sites within Northwest Bay included Sandy Bay, Capstan Cove and Middle Bay, and within Perserverance Harbour included Tucker Cove, Camp Cove, Lookout Bay, and the Meteorological Station (Fig. 1). The most commonly used haul-outs included an area of sandy beach, while the less commonly used haul-outs consisted of bedrock with a mud layer, cobbles or raised bedrock platforms like Davis Point, with *Dracophyllum* scrub and tussock grasses on the shore.

Conditions along many of the transects were inappropriate for strip transect methodology. Much of the terrain was rugged and covered in dense vegetation, making sighting distances and the transect lengths very variable. Visibility from the transect line (half strip width) varied from 20 m to less than 1 m. This, coupled with the very low sea lion encounter rate, did not satisfy the assumptions of the method (Buckland et al. 1993), which was therefore judged unsuitable for calculating sea lion density on Campbell Island. Due to these difficulties with estimating abundance from transect surveys we have not attempted to estimate a total adult abundance estimate for Campbell Island.

Pup production and mortality

Thirty eight pups were tagged with the tag numbers A0001 to A0038 (21 male, 17 female) between 10 and 22 January, and an additional 16 untagged pups were sighted. Only four pups were located along the transects. Males were significantly heavier (t-test; df = 36, $P < 0.01$) and longer (t-test; df = 36, $P < 0.001$) than females (Table 2). Twenty seven pups were tagged at Davis Point, and 11 were tagged at other locations, which included three sites where two pups were found together. Eleven of the 16 untagged pups encountered were in areas surveyed before January 29, representing 17% of all live pups seen.

Mark-recapture calculations at Davis Point indicated a mean of 30 live pups (95% CI 27–33), while the mean estimate derived from direct counts was 16 (95% CI 10–22). The mean of direct counts does not accurately reflect pup numbers, as there was some movement between the beach at Davis Point and the scrub behind it, where it was difficult to find and count pups. We found 24 freshly dead pups when we first arrived at Davis Point, but no subsequent pup mortality was observed. The majority of dead pups were found in bog holes, but the causes of death could not be determined, as all the carcasses seen were reduced to skin and bone. This count suggests a mortality rate of approximately 44% at the Davis Point colony. About 40% of all sea lion pups tagged at Davis Point had blisters and/or abrasions on the soles of both front and hind flippers.

Table 1 Number of counts, mean number of individuals per count, and age structure of New Zealand sea lions by location, Campbell Island, January 1998.

	Counts				Mean number of sea lions counted by class					
Area	No. counts	Mean number individuals	Range	SD	Adult male	Sub-adult male	Juvenile male	Cow	Pup	Unknown
Perseverance										
Tuckers Cove	10	2	1–3	0.7	1	<1	<1	–	–	–
Camp Cove	4	4	1–5	1.9	2	<1	<1	1	<1	–
Met Station	8	8	3–16	4.2	3	2	2	2	<1	
Beeman Hill	3	3	1–5	1.7	2	<1	<1	<1	–	<1
Garden Cove	3	2	2–3	0.6	1	–	–	1		–
Lookout Bay	5	2	1–3	0.9	1	<1	<1	<1	–	
Boyack Point	1	2	–	–	1	–	–	1	–	–
North West Bay										
Capstan Cove	7	2	1–4	1.4	<1	<1	1	<1	–	–
Middle Bay	6	5	2–11	3.2	3	<1	2	1	–	
Sandy Bay	9	76	19–146	46.0	26	32	9	2	<1	–
Menhir	1	4	–		1	–	–	1	2	
Mount Dumas	1	5	–	–	–	1		2	2	
Cattle Bay	1	1	–	–	–		1	–	–	–
Blue Lagoon	3	9	6–13	3.8	7	2	–	–		–
Penguin Bay	1	4	–	–	1	–	1	1	1	
Moulbray										
Davis Point	4	25	10–41	16.5	2	1	<1	9	13	–
Smoothwater Bay	1	1	–	–	–	–	1	–	–	
West of Davis Point	1	3	–	–		–	–	1	2	–
North East Harbour										
Head of Harbour	2	9	5–13	5.7	7	1	1	1	–	–
North Side	1	27		–	14	5	6	2	–	–
South Side	1	4		–	2	1		–	–	1
South East Harbour										
Beach	3	24	16–38	12.2	5	7	8	4	–	–
East Side	–	–	–	–	–	–	–		–	–
West Side	1	6	–	–	1	1	3	1	–	–
Shag Point	1	1	–	–		–		1	–	–
Monument Harbour	1	6	–	–	2	2		1	–	1

Three of these otherwise healthy looking pups had great difficulties in walking on their flippers. A female pup at Davis Point had a compound fracture to its pectoral flipper and was not tagged (considered unmarked). No dead pups were seen elsewhere on the island. Our minimum estimate of pup production for Davis Point is 54 (30 live and 24 dead).

As for adults, strip transects were an inappropriate technique for estimating pup density and abundance. Instead we made a minimum estimate of total pup production on the island in the 1997/98 breeding season, which came to 78 (38 tagged pups, 24 dead pups and 16 untagged pups seen at different locations around the island).

DISCUSSION

Strip transect techniques were inappropriate for estimating density and abundance of sea lions on Campbell Island. The rugged nature of the terrain, the dense vegetation that covers much of the island, and the low sighting rate meant that we could not meet the assumptions of the method. However, our surveys did provide some useful data. Low sighting rates of sea lions on the transects indicated that sea lions were scarce inland, with a clumped distribution on the coast. Although large tracts of the island were not covered, representative parts of most areas previously reported as inland sea lion habitat were surveyed, and very few sea lions were found. Cliffs along much of the Campbell Island coastline allow limited access inland for sea lions, which makes it unlikely that there were many sea lions in the inaccessible areas that were not surveyed. Counts at different sites were conducted over a six week period, and during this time individuals could easily have moved between sites and could have been counted more than once, so it is not possible to estimate the total adult population on the island. In addition, the proportion of adult and juvenile sea lions foraging at sea, and therefore not available for counting, was unknown.

The minimum estimate of 78 pups produced in the 1997/98 season is lower than the 122 reported for Campbell Island from 1991/92 (Gales & Fletcher 1999). The 1991/92 estimate was based on opportunistic encounters from March to May, later than the more systematic surveys reported in this paper. Although the 1997/98 survey was not completed, the methods used to calculate both estimates were similar. However it is still not possible to draw any real conclusion other than that there has probably been no large change (i.e., an order of magnitude) in pup numbers over this time. Had our survey work not been halted prematurely due the mass mortality event, we would have achieved increased coverage of the island, and our estimate would probably have been higher. Pups comprise the only complete portion of the population that is accessible and confined to the island. They therefore could be used as an index of population size and health on Campbell Island, as is done at the Auckland Islands. It would be very difficult to generate a robust estimate of numbers of all other age classes for the island, and this may not be particularly useful in itself.

Pups were widely dispersed over much of the island. They were found along the coast, inland at varying altitudes (sea level up to 250 m) and in a variety of vegetation types. The low sighting distances, dense vegetation and mobility of sea lion pups made it difficult to locate them, so it was not surprising to find untagged pups in areas we thought to have been thoroughly searched. We doubt if this source of error could ever be eliminated, but increased effort could reduce it. We suggest that a better estimate of pup production for the island might be obtained by catching and tagging pups later in the year, about March or April. At this time, pups born inland come down to the coast, form small groups and are more visible (Moore & Moffat 1990). This would still provide only a minimum estimate, as any live or dead pups still located away from the coast would not be included. Inland surveys of areas known to be used by pups could still be conducted, along with coastal surveys to reduce errors introduced by observers missing some of the inland pups.

All of the dead pups found were at Davis Point.

Table 2 New Zealand sea lion pup measurements, Campbell Island, January 1998.

		Weight (kg)		Length (cm)	
	No.	Mean (S.D.)	Range	Mean (S.D.)	Range
Female	17	11.6 (1.7)	9.0–14.8	77.8 (5.2)	68.5–87.6
Male	21	13.7 (2.4)	9.8–20.0	84.6 (4.9)	71.2–93.6

It is likely that most of these pups died when trapped in holes and succumbing to either starvation, exhaustion, suffocation, or a combination of these. Similar pup deaths have been reported from Dundas and Enderby Islands in the Auckland Islands (Gales 1995). It is also common for sea birds such as skuas (*Catharacta* spp.) and giant petrels (*Macronectes* spp.), to scavenge dead pups and drag the carcasses about, and the remains may accumulate in any low points such as holes around the colony. The very high mortality rate seen at Davis Point does not appear to be typical of Campbell Island, as no dead pups where found elsewhere. However, it is much harder to find dead pups in the vegetation.

It is unclear if the mortality event described on the Auckland Islands (Baker 1998) contributed to the pup mortality at Campbell. Adults showing similar symptoms were seen at Campbell Island, so the causal agent(s), were probably also present there. However, the sores and abrasions seen on the flippers of some pups at Davis Point were not described as symptoms at the Auckland Islands. These could have been caused by the rough and contaminated terrain (i.e., a raised rock platform covered with peat holes, mud and faeces, and stagnant pools) on which these pups lived. Although similar conditions are found on Dundas Island, such injuries have not been reported previously.

Northwest Bay, particularly Sandy Bay, was the most common haul-out location identified in this study, and has been reported as a main haul-out in previous studies (Bailey & Sorensen 1962; Russ 1980; Moore & Moffat 1990). Perseverance, Northeast and Southeast Harbours were also frequently used. Within each of these areas, individual sea lions were often aggregated into small groups, but others were scattered widely around the coast and into the vegetation inland. Of the three sandy beaches at Campbell, the largest, Sandy Bay was the most popular haul-out location, and similar numbers of sea lions have hauled out there for the last 50 years (Bailey & Sorensen 1962). The general distribution of sea lions on Campbell Island does not appear to have changed significantly since the 1950s, as previous reports identify the same main haul-outs as were found in this study (Waite 1909; Bailey & Sorensen 1962; Moore & Moffat 1990). Although we were not able to calculate an absolute adult abundance estimate for Campbell Island, there does not appear to have been a large change in numbers reported in this study compared with earlier studies (Bailey & Sorensen 1962; Russ 1980; Moore & Moffat 1990).

Males were frequently found around the coast in small groups of mixed aged classes, and were not regularly encountered inland. Adult males were the most common category encountered on Campbell, especially in Sandy Bay. Adult females were seldom encountered, with one exception. Davis Point was the only location where pups, cows and bulls were found together, constituting a small breeding colony. Records in the journal at Moubray Hut nearby indicate that the use of Davis Point as a colony is sporadic, varying from year to year. Small sporadic breeding colonies have appeared at other locations around the island (P. Moore pers.comm.). It is unclear why the breeding colonies, as seen at Davis Point, are not permanent. Possible reasons may include food limitations, limit of historic breeding range, or lack of space, but there is little information to distinguish between these ideas. In contrast, breeding at the Auckland Islands is definitely colonial, with males and females of all ages congregating at four main sites around the islands (Gales & Fletcher 1999). In January 1999, during searches on Enderby Island, six solitary females with newborn pups were observed away from the main colonies suggesting that they had given birth there (S.Childerhouse pers.obs.). Although there have been no systematic searches of the main Auckland Island, there appears to be very few females breeding outside the colonies.

By contrast, breeding on Campbell Island is primarily non colonial, again with the possible exception of Davis Point. Campbell Island has a much smaller sea lion population than the Auckland Islands, but it is not clear why they do not form cohesive colonies, preferring to breed away from the coast in small groups. One possible explanation is that on the Auckland Islands, breeding females in small groups tend to suffer higher levels of harassment from males than they do in colonies with large numbers of females, so perhaps the females on Campbell Island seek more isolated breeding sites to avoid harassment. However, colonial breeding in pinnipeds is thought to offer advantages (e.g., higher reproductive success) over solitary breeding, as females are protected by a dominant male from harassment by subordinate males (Bartholomew 1970; Campagna et al. 1992). Perhaps the females at Campbell Island lack a "critical mass" for forming a colony, at which point they would start to gain some advantage from colonial over solitary breeding. A similar pattern was seen when a single female at Otago that gave birth away from the predominantly male haul-out sites (McConkey 1997). It is also possible that, as commercial sealing concentrating

on large colonies reduced sea lions to very low numbers on Campbell Island, the present population stems from ancestors who showed a preference for non colonial breeding.

Campbell Island is the southern limit of the New Zealand sea lion's breeding range and represents the only significant breeding site outside the Auckland Islands. Until more permanent breeding colonies are established, the New Zealand sea lion will retain IUCN classification as "vulnerable", as it has fewer than five established breeding sites (Reijnders et al. 1993). The 1997/98 mortality event, during which over half the pups born at the Auckland Islands died (Baker 1998), further underscores the vulnerability this species, and emphasises the importance of research on the small outlying populations in the New Zealand sea lion's range.

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