# Distribution, pup production and mortality of New Zealand sea lion (*Phocarctos hookeri*) on Campbell Island / Motu Ihupuku, 2008

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**Abstract:** Surveys were undertaken at Campbell Island / Motu Ihupuku during January and February 2008, to determine the distribution and pup production of New Zealand sea lions (NZ sea lion; *Phocarctos hookeri*). In addition, necropsies were performed at the main breeding site of Davis Point to determine the principal causes of early mortality for NZ sea lion pups. In total, 397 pups were tagged and 186 untagged pups were found dead, giving a minimum pup production of 583 pups and a one month of age mortality estimate of 40%. This represents a higher pup production than previous estimates from Campbell Island (although survey techniques are not comparable), and equates to 21% of the total pup production for NZ sea lions in the 2007/08 season. Early pup mortality was high (40%) at Campbell Island, with trauma, starvation, and drowning in rock pools and peat mires the major causes of death. Pups were concentrated in two colonial breeding sites: Davis Point on the north shore of Perseverance Harbour (76%) and a newly recorded breeding site (Paradise Point) on the southern shore of Perseverance Harbour (21%). Non-colonial breeding or single pups occurred around the southern parts of the island from sea level to 400 m; however, these only contributed 3% of the known pup production.

**Keywords:** Auckland Islands; Otariidae; pinniped

## Introduction

The New Zealand sea lion (NZ sea lion; *Phocarctos hookeri,* Gray, 1844) is New Zealand's only endemic pinniped, and one of the world's rarest otariids (fur seals and sea lions). Population size is estimated to be less than 12 000 animals, including approximately 5000 adults (Campbell et al. 2006). The breeding range of the NZ sea lion is one of the most restricted of any otariid, and is centred on the New Zealand subantarctic islands (between latitudes 48° and 53° S). Previous estimates suggest that 86% of all pups are born at the Auckland Islands, with the only other significant breeding population being at Campbell Island / Motu Ihupuku (hereafter referred to as Campbell Island), where 14% of pups are born (Chilvers et al. 2007a). Occasional births have also been recorded at the Snares Islands (Crawley & Cameron 1972), Stewart Island / Rakiura (Childerhouse & Gales 1998), Otago Peninsula (McConkey et al. 2002a, b) and the Catlins, eastern Southland (J. Fyfe, pers. comm.). NZ sea lions are classified as 'vulnerable' by the International Union for the Conservation of Nature (IUCN 2008) and 'threatened' under the New Zealand Threat Classification System (Hitchmough et al. 2007), based both on their small populations, which are in slow decline, and their low number of breeding sites and restricted distribution.

Campbell Island was discovered by Europeans in 1810, and both fur seals and sea lions were quickly reduced to low numbers by commercial sealing (McNab 1908; Warneke 1982). By 1830, sealing had declined to an unprofitable level and the industry collapsed (Kerr 1976), after which sea lion numbers on Campbell Island appear to have slowly increased into the late 19th century (Joyce 1894; Thompson 1912). Reports since the 1940s have documented a slow increase in the number of NZ sea lions on Campbell Island (Bailey & Sorenson 1962; Russ 1980; Moore & Moffat 1990; Cawthorn 1993; McNally et al. 2001; Childerhouse et al. 2005).

Population monitoring of the Campbell Island NZ sea lions has been infrequent, with early counts being opportunistic. Since earlier surveys used different methodologies, direct comparisons cannot be made between these counts. In addition, the belief that females gave birth in a non-colonial manner across a large part of the island made it difficult to make accurate population estimates. A non-colonial breeding pattern differs from the situation in the Auckland Islands, where the population breeds in a colonial fashion and has been monitored annually for the last 14 years (1994/95 to 2007/08), allowing accurate pup production estimates to be made (Chilvers et al. 2007a).

The main aims of the research reported in this paper were to: (1) estimate total pup production for the 2007/08 season; (2) estimate early pup mortality and investigate the causes of mortality; and (3) describe adult and pup distribution. Previous observations suggested there was minimal colonial breeding of NZ sea lions on Campbell Island (McNally et al. 2001; Childerhouse et al. 2005); however, no pup production study had been conducted during late December and early January, when colonial breeding usually occurs (Chilvers et al. 2007a). Therefore, the present research also aimed to improve on previous methodology (McNally et al. 2001; Childerhouse et al. 2005) by specifically conducting an intensive search of the breeding colony at Davis Point during the breeding season, before females and pups dispersed from the breeding area.

# Methods

The research was carried out on Campbell Island (52°33'S, 169°09' E; Fig. 1) between 4 January and 20 February 2008. The dates of the survey were chosen to be after most pups had been born but before females and pups started to disperse. At the Auckland Islands, Chilvers et al. (2007b) found the mean parturition date of NZ sea lions was 26–27 December with 70% of pups born 1 week either side of the mean. Campbell Island is steep and densely covered with tussock meadows (*Poa* spp.), dwarf forest/scrub (*Dracophyllum* spp. and *Coprosma* spp.), and herbfields. Much of the coastline is inaccessible to sea lions (or humans) because of sheer cliffs (McNally et al. 2001). Our study was timed to survey Campbell Island during January–February to estimate pup production, investigate early mortality, and determine the extent of colonial breeding. The survey was divided into two phases: phase one was undertaken at Davis Point only, from 4 to 20 January, while phase two, from 21 January to 20 February, covered the rest of the island and included a return trip to Davis Point.

During the first phase, direct counts, tagging and necropsies were undertaken at Davis Point (Fig. 1), the only known colonial breeding area on Campbell Island. Daily counts were made of adult and subadult males and females, and pups. Accessible pups were caught and tagged in both pectoral flippers with uniquely numbered white or yellow 'coffin'-shaped Dalton 'Jumbotags' (Dalton ID systems, Oxon RG9 5AA, UK). Adults and subadults seen with tags had their tag numbers recorded where possible. Animals were previously tagged at Campbell Island in 1998 (McNally et al. 2001) and 2003 (Childerhouse et al. 2005), and at the Auckland Islands annually since 1998/99 (Chilvers et al. 2007a). A cumulative daily count was made of dead pups, with fresh carcasses removed for necropsy where possible.

Necropsies were carried out on all recoverable pups that were recognised as having been dead for less than 3 days. This was not a representative group, as many pups that had died in peat mires often did not become visible until several days after death, when decomposition gasses floated them to the surface. Also, since the research was started after the midpoint of the pupping season, few necropsies were carried out on less than week old pups. Necropsies were carried out on the rocks close to the colony. Weights were estimated to the nearest 0.5 kg, and blubber depth measured by tape measure to the nearest 1 mm. As all samples had to be backpacked out of the site, weight constraints prevented routine tissue collection for histopathology from all necropies. However, any gross lesions were noted, and selected tissue samples from six pups were collected into 10% buffered formalin. In addition, swabs of apparent bacterial lesions were collected from 15 pups and saved in an algal transport medium before being transferred into liquid nitrogen upon return to the base camp at Beeman (Fig. 1). All tissues were then sent to Massey University, Palmerston North, New Zealand, for processing. Formalin-fixed tissues were processed routinely for histopathology, sectioned at 5 µm, and stained with haematoxylin and eosin. All samples in liquid nitrogen were cultured onto blood agar and MacConkey agar. Bacteria were then subcultured onto another blood agar plate to obtain pure cultures for identification.

During the second phase, from 21 January to 20 February, other areas of Campbell Island where NZ sea lions pups had previously been recorded were surveyed (McNally et al. 2001; Childerhouse et al. 2005). They included Perseverance Harbour from Boyack Point to Garden Cove, Southeast Harbour, Six Foot Lake, areas of Northwest Bay (Capstan Cove to Sandy Bay) and Penguin Bay (Fig. 1). In addition, the south side of Perseverance Harbour (approximately 2.5 km west across the harbour from Davis Point) was surveyed (and named Paradise Point) following reports of 'a large number of adult sea lions of both sexes on the south side of Perseverance Harbour in December 2007' (Alison Ballance, pers. comm.). Northeast Harbour and the northern part of the island were not visited, as extensive cliffs make access for sea lions difficult. A return visit was also made to Davis Point on 31 January.

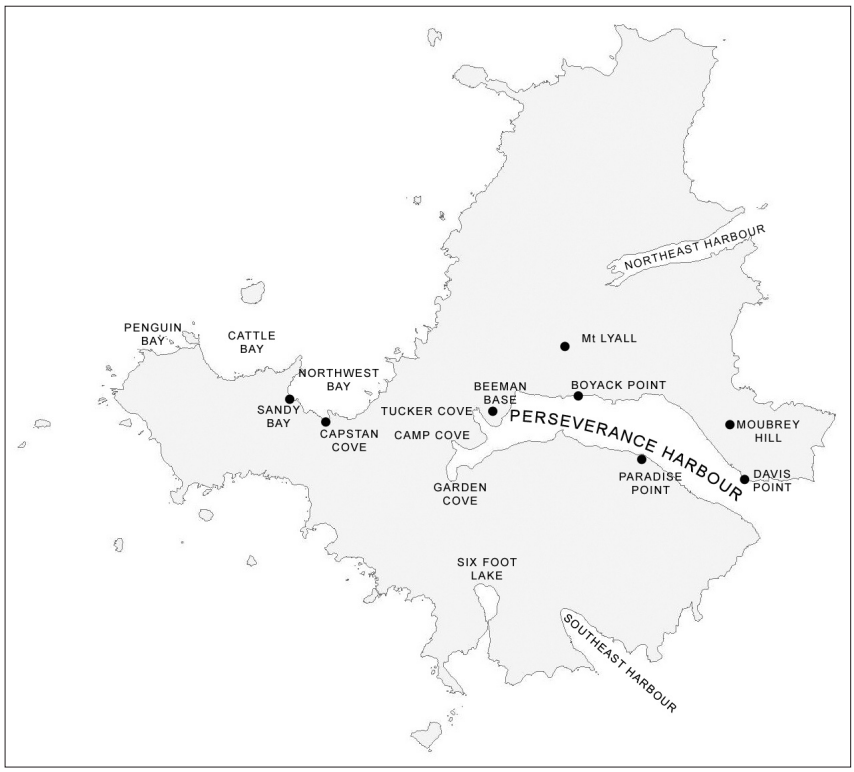



**Figure 1.** Campbell Island showing all locations of pup and tagged NZ sea lion sightings in January–February 2008.

Areas surveyed generally included the coastal strip up to 200 m from the shore. Sea lion tracks, streamways and forest on the banks of streams were also followed during surveys. Any tracks heading inland from the coast were followed as far as possible. These tracks are common across the island and generally head uphill, reaching altitudes of 200 m or more in some cases. The team members usually maintained visual contact with each other during searches (around 20 m apart), and would stay within voice contact when following sea lion tracks or in dense bush. Pups were also found occasionally near paths well away from the usual search areas close to the shore. A GPS unit (Garmin 12) was used to mark the location of any pup found, and where possible the pup was tagged with two coffin tags. Some pups with mothers could not be tagged at the time they were found, but when possible they were re-located on a later date and tagged when the mother was absent. No necropsies were attempted on dead pups found during this phase of the expedition. Where concentrations of adults were found, counts were made and any tagged individuals had their tag numbers recorded.

# Results

During the 2008 survey, 397 live pups were tagged and 186 dead pups were found untagged on Campbell Island, giving a minimum estimate of pup production of 583. The number of pups at each location is shown in Table 1, and locations are shown in Fig. 1. The sex ratio of pups tagged was 1:1.

The majority of pups were found at only two sites: Davis Point, with 442 pups (76% of known pup production; Fig. 2a), and Paradise Point, a newly identified breeding site on the south side of Perseverance Harbour, with 122 pups (21%; Fig. 2b). In addition, 19 pups (3%) from non-colonially breeding females were found. These latter pups were distributed around the island in habitats ranging from dense coastal *Dracophyllum* forest to herbfields and tussock at up to 400 m above sea level. Six of these non-colonial pups were found around the meteorological station at Beeman Base (Fig. 1). Seventeen animals that had been tagged prior to 2008 were sighted (13 males and 4 females). All four females had been tagged as pups on Campbell Island, whereas males had been tagged as pups on both Campbell Island (3) and the Auckland Islands (10).

**Table 1.** Pup numbers obtained by direct count at various locations around Campbell Island (see Fig. 1), 4 January to 20 February 2008.

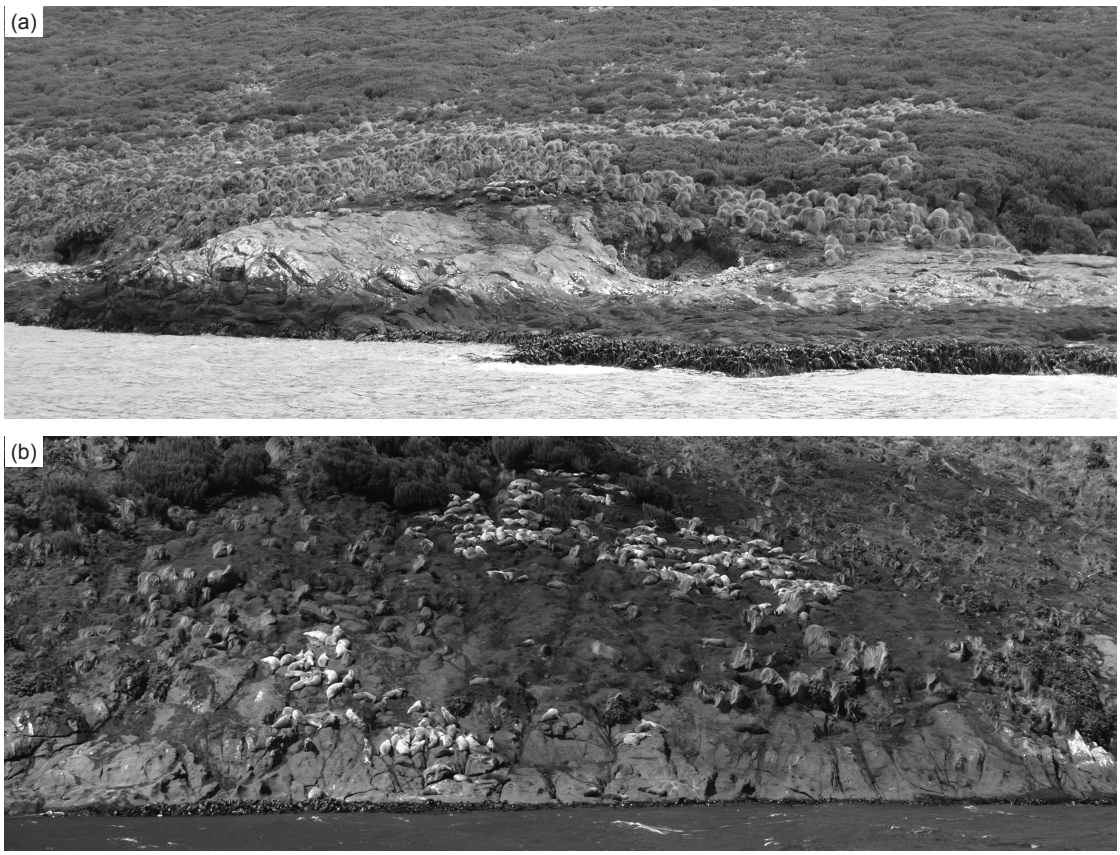
| Location | Number tagged | Dead* | Total |
|---|---|---|---|
| Davis Point | 290 | 152 | 442 |
| Paradise Point | 92 | 30 | 122 |
| Beeman Base | 6 | 0 | 6 |
| Northwest Bay | 3 | 1 | 4 |
| Mt Lyall | 2 | 0 | 2 |
| Southeast Harbour | 1 | 2 | 3 |
| Cattle Bay | 1 | 0 | 1 |
| Penguin Bay | 0 | 1 | 1 |
| Garden Cove | 1 | 0 | 1 |
| Moubray Hill | 1 | 0 | 1 |
| Total | 397 | 186 | 583 |

* Some tagged pups also died, but these were not included in the dead pups column, to avoid counting the same individual twice.

The cumulative dead pup count at the Davis Point colony was 196 on 31 January 2008, giving a mortality rate of 44%. Thirty-two dead pups were found at the smaller colony at Paradise Point during three visits between 28 January and 13 February, 26% of known pup production. This figure is likely to be an underestimate, due to the late arrival of researchers at this site and the fact that some carcasses are likely to have disappeared due to scavenging and weather or sea conditions. A further four dead pups were found elsewhere on the island. In total, 232 dead pups were counted on Campbell Island, giving a mortality estimate of 40% of pup production.

Forty-nine pups and one adult female were necropsied between 5 and 19 January 2008. As noted in the Methods necropsies could only be carried out on recoverable pups and these may not have been a representative group. The adult female had died as a result of a chronic suppurating infection in the neck, likely to have been caused by a bite wound from another NZ sea lion. The most commonly observed lesions in pup necropsies were the result of

**Figure 2.** New Zealand sea lion breeding habitat: (a) Davis Point, Campbell Island, (b) Paradise Point, Campbell Island, (c) Sandy Bay, Enderby Island, Auckland Islands. Photos: (a and b) Roving Tortoise Photography, (c) B.L. Chilvers.




trauma, malnutrition, bacterial infections and hookworm infection and many pups had several of these syndromes concurrently. Signs of trauma were present in 25 pups (50%) and included bite wounds, bruising of the head and chest, crushing, liver rupture, and suffocation. Only one of the necropsied pups had been trapped in a peat mire, although numerous highly decomposed bodies were found in mires (Fig. 3), and the research team prevented many deaths by extracting up to 10 pups daily from inescapable mires. Malnutrition (defined as having a blubber depth of 2 mm or less) was evident in 22 pups (44%). Fifteen pups (31%) had gross lesions associated with bacterial infections, including peritonitis, pneumonia, pericarditis, abscesses and joint infections. Culture of tissues from pups showed that 9 of 15 infections were due to *Streptococcus* sp. Various gram-negative rods were cultured from the remaining pups. No tissues grew *Klebsiella pneumoniae*, a bacterial infection known from the Auckland Islands (Wilkinson et al. 2006). No stillbirths or congenital anomalies were diagnosed. Hookworm larvae were seen grossly in the intestines of four pups, and four others had haemorrhagic enteritis, which is likely to be due to hookworm infection.

Microscopic examination of tissues was possible for six pups. In two of these pups, the tissues were too autolysed (degraded) for accurate analysis. Of the remaining four, two had haemorrhagic enteritis (likely due to hookworm infection), one had bacterial pneumonia and pleuritis, and one had multiple kidney cysts. The lesions were similar to those found in tissues from Enderby Island pups (Castinel et al. 2007).

A common non-lethal condition of necropsied pups was abrasion and ulceration of the carpal (front flipper) area, and also (but less frequently) of the hind flippers

**Figure 3.** Peat mire at Davis Point, Campbell Island, showing at least 14 dead, bloated sea lion pups that could not be necropsied to determine cause of death. Photo: A. Maloney.

around the tarsal and metatarsal areas. Also, swollen carpal joints with inflammation (red, swollen tissues around the joint and often cloudy joint fluid) were frequently present with or without concurrent ulcerations. These pathological conditions were almost certainly associated with the unusually abrasive substrate (basalt rock) at Davis Point, and are almost unknown at the Sandy Bay colony, Auckland Islands (A. Maloney, pers. obs.; Fig. 2a & c respectively).

# Discussion

This survey provided a pup production estimate for NZ sea lions at Campbell Island of 583, higher than the largest and most recent previous estimate ($n = 385$; Childerhouse et al. 2005). However, results are not directly comparable with previous estimates because for the first time research was undertaken at colonial breeding sites during the height of the breeding season, before the dispersal of adults and pups. This change in survey timing is likely to account for much of the increased pup production reported here. Our research also confirmed that the majority of NZ sea lion breeding is colonial at Campbell Island, and that a second colonial breeding site, which we named Paradise Point, was present on the south side of Perseverance Harbour. It may have been present but remained undiscovered at the time of the 2003 survey.

NZ sea lion pup production estimates for Campbell Island have shown an increasing trend over the last 20 years. Moore and Moffat (1990) reported a minimum of 51 pups for the 1987/88 season. During the 1991/92 season, 98 pups were tagged and 24 dead pups were counted, giving a minimum production of 122 (M. Fraser, unpubl. data). Cawthorn (1993) estimated total pup production to be 150 for the 1992/93 season and McNally et al. (2001) estimated a minimum pup production of 78, based on an incomplete survey in 1997/98. Before 2008, the most comprehensive survey was conducted in 2003 (Childerhouse et al. 2005) when a population of 385 was estimated using a mark-recapture model. The 2003 survey found that a significant proportion of pups, and therefore breeding sites, were non-colonial, but this may have been a consequence of the late timing of the survey.

Despite differences in methodology some evidence suggests there has been an increase in population size. This includes the observation that the area of bare rock at Davis Point is expanding, with tussocks being killed and eroding away close to the colony, and peat mires forming and trapping many pups (Fig. 3). Also, there is evidence that the colony at Paradise Point was established relatively recently, as it has formed on fellfield (herbs, grasses, sedges) covering steeply angled rock strata, where the vegetation has been completely destroyed, but where an almost continuous blanket of peat covers the rock (Fig. 2b). If the colony had been present at this site for many years, the peat would almost certainly have been eroded more, exposing bare rock, as seen at Davis Point (Fig. 2a). Supporting this idea, the 2003 expedition did not see the large eroded area at Paradise Point when travelling in a small boat around Perseverence Harbour as far out as Davis Point (S. Childerhouse, pers. comm.), yet in 2008 the erosion was very obvious when seen from the water (Fig. 2b).

True pup production is likely to be greater than our estimate of 583. Thus, dispersal of pups away from the vicinity of Paradise Point, and the likely disappearance of carcasses before the expedition's first visit on 28 January, likely resulted in an underestimate of pup production at that site. Future expeditions should visit the new Paradise Point colony in late December to early January to obtain a more accurate estimate.

The number of pups born away from the two colonies may also have been underestimated. The 2008 expedition discovered only 16 pups away from the colonies, some as far as 1.4 km from the shoreline and 400 m above sea level. Although some areas of the island were searched methodically for pups (see Methods), some pups were found incidentally near walking tracks and six were seen at Beeman Base (Fig. 1), the headquarters for the expedition, where a regular human presence increased the chances of pup detection. A better estimate of numbers of non-colonially bred pups could be obtained by including a March–April search period when non-colonial pups are more likely to have moved closer to the shoreline and be easier to detect. However, this would have to be done in conjunction with all colonial pups being tagged earlier in the year to ensure they can be distinguished from non-colonial pups.

Despite uncertainty about the numbers of non-colonial pups, it appears they only make up a minority of the total number born on Campbell Island. This challenges the conclusions of previous expeditions (McNally et al. 2001; Childerhouse et al. 2005), which suggested that the majority of pups are born away from the colonies. It is possible that previous human exploitation (sealing) selected for females that bred away from colonies. However, it may be that, if the population has grown, it has become more advantageous for females to breed colonially (Cassini & Fernández-Juricic 2003). Further expeditions will be needed to fully quantify NZ sea lion pup production on Campbell Island and provide trend data. We recommend that future studies search the two main colonies, Davis Point and Paradise Point, during the pupping period before dispersal from the colonies (mid-December to mid-January), which would also enable more accurate data on causes of mortality to be collected, as newborn pups would be included, and extending the research into March–April to allow better searches for pups born away from the colonies.

The pup mortality rate of 40% for Campbell Island is much higher than rates recorded at Sandy Bay on the

Auckland Islands, where mortality by late February typically varied from 9% to 16% in non-epidemic years (Chilvers et al. 2007a). The mortality rate at the Davis Point colony (44% by 31 January) was similar to the highest mortality recorded at Sandy Bay (42%) in the epidemic season of 1997/98. However, a high rate would appear to be 'normal' for Campbell Island, as the 2003 expedition recorded 36% pup mortality (Childerhouse et al. 2005) and the 1998 expedition recorded 44% (Mc Nally et al. 2001). This high mortality appears to be caused by several factors, particularly suboptimal breeding habitat for NZ sea lions, which usually prefer sandy beaches (Augé 2007; Fig. 2a, b, c). The Davis Point colony forms on a basalt platform with several large rock pools and part of it is backed by eroding tussocks, which form peat mires where young pups are trapped and die (Fig. 3).

Our survey in 2008 was the first year that necropsies of pups had been carried out on Campbell Island. These indicated that causes of mortality were similar at Davis Point as at Enderby and Dundas islands (Auckland Islands), although the prevalence of each cause differed (Results; Castinel et al. 2007). However, unlike the Enderby Island study, not all pups could be necropsied and it was not possible to accurately diagnose the cause of death in all cases. Nevertheless, trauma seemed to play a major role in pup mortality at Davis Point. The unyielding nature of the rock substrate may have been a cause of many deaths by trauma, and a majority are likely to have been caused by pups being crushed against the rock (which has few crevices where pups can hide; Fig. 2a) during fights between adult males. Injuries recorded as bite wounds were most likely inflicted by subadult males, as commonly observed at all NZ sea lion colonies (Chilvers et al. 2005).

Bacterial infections were found in 15 of 49 pups necropsied (31%), but the true prevalence of infection may have been higher than this, as tissue samples were not obtained from all pups. Regardless, this is a relatively high rate of bacterial infection compared with Sandy Bay in the Auckland Islands, where rates ranged from 6% to 24% in non-epidemic years (Castinel et al. 2007). At Sandy Bay, most recent bacterial infections have been caused by *Klebsiella pneumoniae* (Wilkinson et al. 2006; Castinel et al. 2007), a bacterium not found in the present study. This may indicate that either: (1) there is little transfer of bacterial infections between the Auckland Islands and Campbell Island sea lion groups, (2) environmental conditions differ between the two island groups, or (3) the organism is present at Davis Point but was not detected due to the small number of samples collected. *Klebsiella pneumoniae* has caused two mass mortality events at Enderby Island (Wilkinson et al. 2006; Castinel et al. 2007) and pups at Campbell Island could be highly susceptible if they are exposed to it in the future. Male sea lions are known to move between breeding areas, and could potentially spread infections. It is not known whether the mass mortality events on the Auckland Islands in 2001/02 and 2002/03 affected the Campbell Island population, and the absence of *Klebsiella pneumoniae* in samples taken on Campbell Island suggests they may not have done so.

Malnutrition was relatively common on Campbell Island, with 45% of necropsied pups affected and in 9 of the 22 malnourished pups no other gross pathology was found. However, it was impossible to ascertain whether malnutrition was the primary cause of death (with affected pups being more prone to trauma and infections), or a secondary condition (with sick pups being unable to feed). The overall rate of malnutrition (44%) was much higher than found on the Auckland Islands (Sandy Bay) where in January 2008 only 2 of 29 pups necropsied had blubber depth of less than 2 mm, indicating malnutrition (unpubl. data). The reasons for this are not clear, but contributing factors may include higher numbers of young inexperienced females as mothers, or a 'bad year' for prey abundance at Campbell Island.

Resightings of animals tagged in previous years confirmed the site fidelity of females, and the mobility of male NZ sea lions between the Auckland Islands and Campbell Island breeding areas, as all females resighted were tagged at Campbell Island, whereas males showed a mixture of Campbell Island and Auckland Islands tags.

In conclusion, the number of pups produced by NZ sea lions on Campbell Island appears to be increasing, despite high pup mortality, possible poor breeding habitat, and sparse data from past years. This contrasts with a trend for decreasing pup production on the Auckland Islands (Chilvers et al. 2007a). Reasons for both the decrease at the Auckland Islands and the apparent increases at Campbell Island are unclear. The only reason that can be ruled out is migration of females, because records from tagged animals show that female NZ sea lions have never migrated from the Auckland Islands to Campbell Island. NZ sea lions are known to be included in the by-catch of commercial fisheries around both Campbell Island and the Auckland Islands, although actual numbers have varied over time and between areas (Rowe 2008; Thompson & Abraham 2008, Ministry of Fisheries unpubl. report PRO2007/02). Both areas have also been impacted by mass mortality events (McNally 2001; Castinel et al. 2007). The disparate trends between the Campbell Island and Auckland Islands populations underscore the need for careful research and decision making to ensure effective management of this threatened, declining species.

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