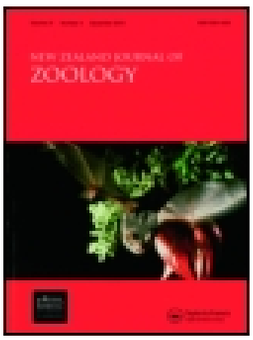

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Historical and modern distribution and abundance of the New Zealand sea lion *Phocarctos hookeri*

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Abstract This paper describes both the modern and the pristine distribution, breeding range, and relative abundance of the New Zealand sea lion (*Phocarctos hookeri*). Archaeological data and historical references were used to determine the pristine status of the sea lion, and its present status was determined from recent scientific studies and observations. The sea lion had a substantially more widespread distribution before the arrival of humans in New Zealand than it does today. The species used to range along the whole length of the coast, from the north of the North Island through to Stewart Island and the subantarctic islands. Although we have no direct estimate of pristine abundance, the present population size is clearly reduced. Subsistence and commercial killing of sea lions is the most likely cause of historical changes in distribution and abundance. Their pristine breeding range extended at least as far north as Nelson and may have extended to the North Island. The present breeding range is restricted to the Auckland Islands and Campbell Island. Within the last 10 years a few individuals have started to breed on mainland New Zealand and Stewart Island, which may reflect a slow recolonisation of earlier breeding grounds. Pup production at Sandy Bay, Enderby Island, has been stable for at least the last three decades, and no major changes in pup production at Dundas Island and Figure of Eight Island are apparent.

Keywords New Zealand sea lion; *Phocarctos hookeri*; historical trends; distribution; abundance

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INTRODUCTION

The endemic New Zealand sea lion, *Phocarctos hookeri* (also known as Hooker's sea lion), is one of the world's rarest pinnipeds, and has a highly localised distribution. Most of the population is found in the Auckland Islands although some animals disperse as far as the New Zealand mainland, Campbell Island, and occasionally Macquarie Island (Fig. 1). The most recent total population estimates, for the 1995/96 breeding season, suggest between 11 600 and 15 200 animals (95% C.I.) (Gales & Fletcher in prep.). Approximately 95% of all pups are produced

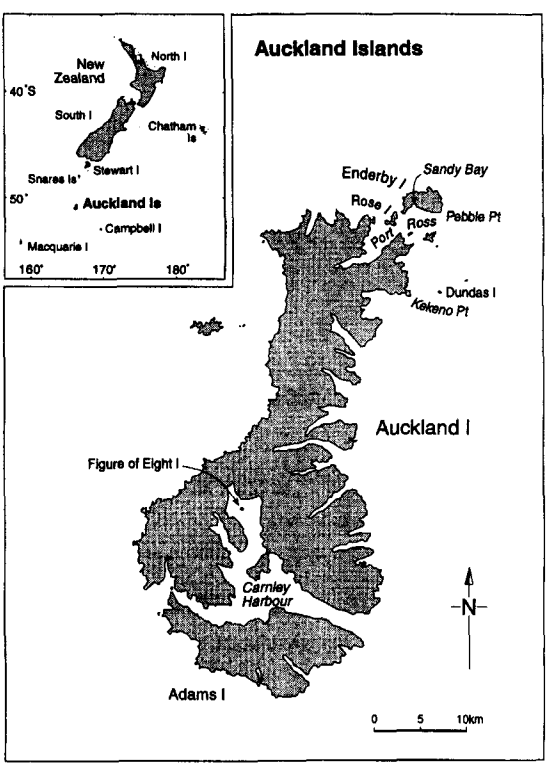

Fig. 1 Location of Auckland Islands and sea lion breeding sites.

at four colonies in the Auckland Islands. The largest, on Dundas Island, accounts for about 70% of total pup production; the other colonies are on Figure of Eight Island and on Enderby Island, at Sandy Bay, and Pebble Point (Gales & Fletcher in prep.).

During the 1970s a trawl fishery for arrow squid (*Nototodarus sloanii*) was established on the Auckland Island and Snares Island shelf. As the fishery developed, a bycatch of sea lions became apparent; this led to the establishment in 1982 of a 12 nautical mile fishing exclusion zone around the Auckland Islands (Baird 1996). Estimates of the sea lion bycatch have varied from year to year, but range from 17 to 140 for the years 1988–95 inclusive (Baird 1996). Doonan & Cawthorn (1984) modelled the impact of bycatch on the population using the reported bycatch figure of 123 sea lions in a single season, and concluded that if bycatch continued at that rate then the population would have declined by one-half after 64 years. Woodley & Lavigne (1993) constructed two models to investigate the impact of the bycatch on the sea lion population using life history parameters derived from two species with a similar estimated lifespan: the northern fur seal (*Callorhinus ursinus*) and Himalayan thar (*Hemitragus jemlahicus*). Both models, using a constant level of bycatch, predicted that the New Zealand sea lion would have a limited capacity for population increase.

In an attempt to limit the potential impact of the sea lion bycatch, a catch limit or Potential Biological Removal (PBR) of 63 sea lions was set in 1993 by the New Zealand Department of Conservation, on the basis of draft guidelines from the United States National Marine Fisheries Service. This number was used for the 1993–96 fishing seasons. In 1995 the estimated bycatch of sea lions exceeded the catch limit, but the fishery was not closed because a delay in processing the data resulted in the situation not being recognised until the season had finished for that year. In 1996 the fishery was closed early as the estimated bycatch again exceeded the PBR.

Recent changes in New Zealand legislation require the Department of Conservation to produce Population Management Plans for threatened fauna killed incidentally in fishing operations. The first of these plans, to be produced in 1998, is for the New Zealand sea lion. It is necessary to understand the current status of the sea lion in relation to pristine stocks, for managers to make informed decisions on sustainable levels of bycatch that will not limit the ability of this species to recover from previous exploitation.

The pristine abundance and distribution of the sea lion is unknown, but it is clear from various archaeological and sealing records that significant exploitation for food and skins took place. There has been little previously written about the New Zealand sea lion, but many parallels are evident with the New Zealand fur seal (*Arctocephalus forsteri*) and, where possible, we have discussed relevant fur seal examples. Although many of the records and much evidence of historical distribution and abundance are dispersed and occasionally ambiguous, they are nevertheless fairly numerous and potentially relevant. The purpose of this paper is to document and interpret this information with the aim of describing the pristine distribution, breeding range, and relative abundance of the New Zealand sea lion and to compare this with the current situation.

HISTORICAL RECORDS OF SEA LION

There is a wide variety of sources reporting information on sea lions. Much of this work is unpublished or is reported only in the "grey" literature. We have examined reports from personal diaries, vessel manifests, expedition reports, unpublished reports, published books, scientific reports and papers, and personal communications. Many of these make only brief reference to sea lions but, where possible, we have critically reviewed the information. We summarised the information under three main sections: pre-European, 19th century, and 20th century.

Pre-European

The remains of sea lions dated to pre-European times have been reported from at least 47 sites around New Zealand (Fig. 2). The combined records extend from North Cape to Stewart Island, with almost half occurring in the southern half of the South Island (Smith 1989). Fordyce (1988) summarised the records of fossil seals in New Zealand and found no specimen older than the Pleistocene (2–3 million years ago). A full list of recorded sites with sea lion remains, other than those reported by Smith (1985, appendix 3), are summarised in Table 1.

Smith (1989) provided a comprehensive summary of what is known of the past distribution and abundance of sea lions as determined from archaeological records. Smith reported 43 pre-European sites where sea lion remains have been found. No pup remains were reported, but numerous juveniles and several adult females were found. Most sites are Maori or Moriori middens, indicating that sea lions were used for food.

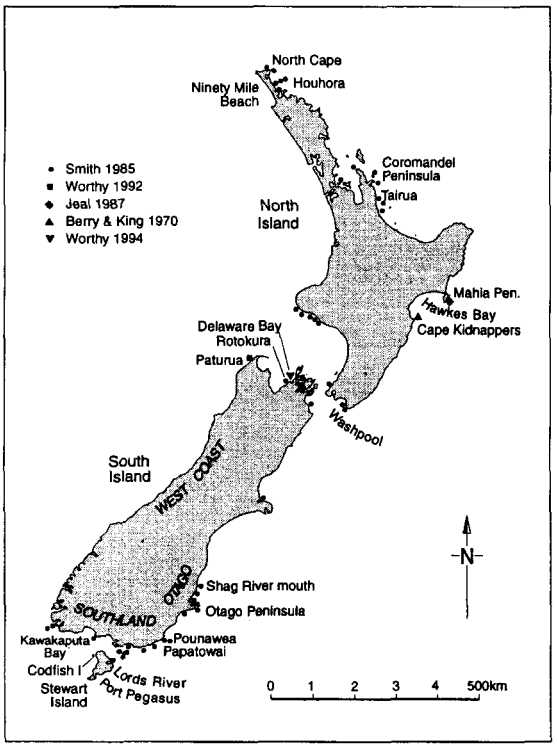

Fig. 2 Location of archaeological sites with sea lion remains.

McFadgen (1994) reported on the remains of sea lions from the Chatham Islands, again including bones from both adults and juveniles, but not from pups. Gastroliths, identified as being from sea lions, have also been recorded. Some of these remains were found in Moriori middens. The Moriori are reported to have hunted marine mammals, including sea lions, at Te Whakaru, the north-eastern tip of Chatham Island, before European discovery of the island (Richards 1982).

Fossil bones from sea lions have been found in caves in north-west Nelson (Worthy 1992). Radiocarbon dating of two bones has yielded ages of c. 10 000 and 3000 years, although other evidence suggests that this site was occupied by sea lions until several hundred years ago. Most of the bones appear to have been from males, as no females have been definitively identified. Sex determination from the bones was made on the basis of tooth and skull structure and skeletal dimensions.

The only pre-European records of pup remains on the New Zealand mainland are from Delaware Bay and Paturau in Nelson (Worthy 1994). Three remains recovered from Delaware Bay have been identified as young pups from skeletal and cranial measurements and dental characteristics. One of the pups was tentatively dated to the late Holocene on the basis of progradation of the site. At Paturau the fossil remains of several sea lions have been recovered (Worthy 1992), and re-examination of the material yielded

Table 1 Description of pre-European archaeological sites with sea lion remains.

Location of site	Description of site	Number and type of remains found	Reference
Cape Kidnappers, Hawke's Bay	Maori midden	Description of Berry (1928) specimen as 1 young male <1000 years old (Weston & Repenning 1973). Also remains of 1 young female	Berry & King (1970)
Mahia Peninsula	Maori midden	1 sea lion	Jeal (1987)
Chatham Islands	Sandy dunes and Moriori middens	Numerous bones from both adults and juveniles and of both sexes. Oldest bones dated at 2700 years old.	McFadgen (1994)
Tairua, Coromandel Peninsula	Maori midden	1 sea lion aged at maximum 700 years old	Smith (1978)
Palliser Bay	Maori midden	1 adult female and 1 juvenile male	Smith (1979)
Mainland New Zealand	Maori midden	42 sites with female remains at 5 sites	Smith (1989)
Shag River mouth, Otago	Maori midden	14 sea lions	Smith (1996)
Northwest Nelson	Limestone caves	6 subadult and adult male fossils up to 10 000 years old	Worthy (1992)
Delaware Bay, Nelson	Sandy beach dunes	1 adult and 3 pup fossils at least 5000 years old	Worthy (1994)

the remains of a pup (Worthy 1994). Worthy (1994) cites the finding of pups as strong evidence that sea lions bred in the Nelson area during the late Holocene. The remains of two young sea lions have been found at Hawke's Bay, probably in a midden, and the remains are <1000 years old (Berry & King 1970; Weston & Repenning 1973)

Remains tentatively identified as female have been recorded from Papatowai (12th century), Pounawea (12th century), Washpool (12th century), Rotokura (14th century), and Houhora (14th century), which may indicate breeding in these areas (Smith 1989) (Fig. 2). However, it is not possible to determine if these females were breeding at, or close to, the location where their remains were found.

19th century

Auckland Islands

Most of the records from this time are from Auckland Islands sealing expeditions. Many are anecdotal, but they do provide a picture of the exploitation of sea lions from this area. Taylor (1971) provides a good summary of the history of sealing in the Auckland Islands.

The Auckland Islands were discovered on 18 August 1806 by the vessel *Ocean*, commanded by Captain A. Bristow. In his log he says, "This place, I should suppose abounds with seals, and sorry am I that the time, and the lumbered state of my ship do not allow me to examine" (McNab 1907, p. 95). It soon became clear that there was an abundance of fur seals, and sealing began shortly thereafter. Sea lion (also known as hair seal) skins were not as highly valued as those of the fur seal, and so sea lions were not targeted initially. It is likely that sea lions were initially taken in small numbers, and it was not until fur seal stocks were severely depleted that sea lions were killed in larger numbers. One of the first records of a commercial sea lion take is from the vessel *Commerce*, which arrived in the summer of 1807/08 and found two teams of sealers already ashore (McNab 1907). Owing to heavy exploitation, catches declined, and by 1815 there was little sealing being carried out on the Aucklands (McLaren 1948).

In 1823 the vessel *Henry* visited the Aucklands and returned with 12 000 fur seal skins. The vessels *Wellington* and *Elizabeth and Mary* returned from hunting in the Aucklands and on Campbell Island early in 1825 with a total of 3670 sea lion skins (Cumpston 1968). Although most of the accounts are anecdotal, there is little doubt that the sea lion population at the Auckland Islands was depleted, and by about 1826 the southern sealing trade was virtually finished (McNab 1907).

Captain Benjamin Morrell (1832) visited the Auckland Islands in January 1830. When some of his crew spent 5 days circumnavigating the islands with the express purpose of discovering fur seals, they saw no fur seals and fewer than 20 sea lions. Morrell wrote "Although the Islands once abounded with numerous herds of fur and hair seals, the American and English seamen engaged in this business have made such clean work of it as scarcely to leave a breed – at all events, there was not one fur seal to be found on the 4th of January, 1830" (Morrell 1832, p. 363). January is the peak of the breeding season for both sea lion and fur seal and the breeding colonies, had they existed, should have been easily visible. The fact that no seals and few sea lions were seen at this time strongly suggests that there were few animals remaining of the former population. Morrell also visited The Snares islands and found no fur seals or sea lions.

Morrell's accounts have not always been found to be accurate and reliable. Best & Shaughnessy (1979) compared Morrell's account of a sealing voyage to Africa with that of an independent private journal of the same trip and found many discrepancies between the two descriptions. They suggest that Morrell frequently used "omission, elaboration, exaggeration or fictionisation" of events, possibly as they may have reflected poorly on his authority or competence (Best & Shaughnessy 1979, p. 15). There appears to be little to gain for Morrell in falsely reporting numbers of sea lions at the Auckland Islands, but his account cannot be relied upon to be completely accurate. However, it does seem likely that, with the large number of skins being taken from the subantarctic islands, both the fur seal and sea lion population would have been much reduced.

The vessel *Caroline* continued to make frequent sealing trips to the Aucklands and other islands, and landed 1000 fur seal skins in Sydney in 1833. It is not clear from which subantarctic island or islands these skins came, but they were a small fraction of the quantities that vessels had landed earlier in the century (Cumpston 1968). After 1830 a small number of sealers frequently visited the Aucklands but without much success (McLaren 1948).

In 1840, McCormick (1884) visited the Auckland Islands and spent several days in Port Ross. He made detailed accounts of the natural history of the area but made no mention of sea lions anywhere, although he landed several times at Sandy Bay on Enderby

Island during November and December, during what should have been the start of the breeding season. Sandy Bay is a very visible site, and it is unlikely that sea lions would have escaped observation had they been present.

The settlement of Hardwicke in Port Ross was founded in 1849, and the capture of sea lions was apparently an "exciting pastime in which they engaged whenever they could" (McLaren 1948, p. 52). After 3 years the settlement failed, and the buildings were dismantled and removed by departing settlers. This was due to the harsh environment, the lack of whales, and the few visits by whaling vessels (McLaren 1948). It seems likely that fur seals and sea lions were both in low numbers in the area at the time, as there is no reference to sealing as a source of either food or income in the records. However, Malone (1854) reported that in May 1852, when he arrived to help dismantle the settlement, at least 20 sea lions were shot by his crew in and around Port Ross.

Musgrave (1866) was shipwrecked on the Auckland Islands in 1864 and spent over a year there, subsisting on a diet of primarily seals and sea lions. During this time he reports a "great number of seals" and "hundreds of seals" in Carnley Harbour (Musgrave 1866, pp. 10, 16). Although species identification is not always clear (he refers to tiger seals, black seals, seals, and sea lions, often switching between the definitions), it is evident from his description that there were sea lions breeding on Figure of Eight Island. He wrote in his diary, "seeing 3 mobs of seals [sea lions from his description] asleep on the island, we landed. We found 30 to 40 in each mob, including many young calves" (Musgrave 1866, p. 28). A tally from his diary records the killing of 22 pups from Figure of Eight Island in one season, and many more are mentioned.

An expedition to the subantarctic reported that Rose Island and Enderby Island had "plenty" of sea lions ashore in 1864 (Anon. 1865, p. 4). In 1881 the first official steps were taken to close the remaining seal fisheries in New Zealand (Wilson 1893), although some poaching occurred into the 1890s (McGhie 1888; Joyce 1894). Captain Fairchild, who made numerous trips to the subantarctic islands, reported in 1890 that "The sea lion is numerous everywhere throughout the islands. There are millions of them on the islands at one time of year" (Cumpston 1968, p. 148). In 1893 sealing, for both fur seal and sea lion, was prohibited by law in New Zealand. There were still low levels of sealing up until this time, and it was believed that if sealing continued it might prevent sea lions and particularly fur seals from recovering (Cumpston 1968). Since 1893 some open seasons have been declared for fur seals, although sea lions have remained completely protected (Chapman 1893; Falla 1962).

The sea lion population at the Auckland Islands, although depleted in the early 19th century, showed signs of recovering by the end of that century. After returning from a trip to the subantarctic, Joyce (1894, p. 2) wrote that sea lions frequented the inlets and harbours of the eastern coastline, and were found "at nearly every point touched at among the Auckland Islands and also Campbell Island. At Rose Island ninety were counted on the beach or among the scrub and tussock."

Sea lions at other locations

The only record of sea lions on Campbell Island were from the 1815/16 season when at least 300 sea lions skins were taken from there (Warneke 1982).

During his trip to Stewart Island in 1826 and 1827, John Boultbee wrote in his diary that the local Maori annually killed "great quantities" of sea lions at Lord's River for the purposes of food, and also that sea lions bred there (Starke 1986, p. 105). This was apparently an important food resource, some of which the Maori preserved for future use, either smoked or in kelp bags (Begg & Begg 1979). Port Pegasus had numerous sea lions when visited by Thomas Shepherd in 1826, and he reported that they bred there (Howard 1940; Begg & Begg 1979). Boultbee found and killed a "young hair seal" at Kawakaputa Bay near Riverton (Begg & Begg 1979, p. 186).

Sir James Hector (1892, p. 257) reported that "About December they [sea lions] take up stations on the coast in warmer latitudes, such as the West Coast of New Zealand, and formerly used also to frequent the islands of Bass Strait and on the west coast of Tasmania. The breeding season is in January after which the males leave and the females remain until May." He described each male securing a harem of 10–20 females, which would suggest a reasonable-sized colony. He continues: "the mode of life of the hair seals has, however, been much altered since 1863, when I made my first observations, and I believe that the New Zealand hair seals have now become much more solitary, and that they will soon become extinct."

Sea lion tracks were reported in the extreme south of Stewart Island in 1874 by Thomson (1921, p. 75), but he had "not heard of one being seen for many a long day."

20th century

Waite (1909, p. 542) reported from his trip in 1907 that sea lions were "quite numerous" on The Snares, The Auckland Islands, and Campbell Island. Sea lions were present in the Aucklands year round, scattered mostly around the eastern coastline (Turbott 1952). Most of the records from this period are from the Auckland Islands, and we have compiled them into sections by geographical area, concluding with a summary of all population estimates for the species reported in the literature.

Enderby Island

Wilson (1907, p. 60) reported seeing "numerous sea lions" on the Auckland Islands when he visited in March 1904. In his diary he wrote that there were about 200 on the beach of Sandy Bay and that there were more animals in the scrub (Wilson 1966). He also saw two young sea lions that had been born the previous breeding season (Wilson 1907). This is the earliest record of sea lions breeding, since the population was depleted from sealing in the 19th century.

Coastwatchers were stationed on the Auckland Islands from 1941 and began to make observations of the sea lions. L. H. Pollock (1941) wrote in his diary on 4 September 1941 that Webling [a fellow officer] reported seals to be plentiful on Enderby Island.

Falla made intermittent observations of sea lion behaviour at Sandy Bay over the period 1942–79 and reported that the breeding population of about 1000 animals, and production of about 350–400 pups per annum, was stable over this whole period (Falla 1965, 1975; Falla et al. 1979).

Counts of pups during the breeding season at Sandy Bay have been collected most years (n = 19) since 1972 and estimates of pup production are shown in Table 2. Data from nine seasons spanning 1972/3–95/6 were used to determine whether the number of live pups was stable over this period (Best 1974; Gales & Fletcher in prep.; M. Cawthorn unpubl. data). We estimated a mean and standard error for the maximum number of pups in each season using the standard errors associated with the estimated dates of peak pupping (determined from the optimisation routine in Excel), calculated by parametric bootstrapping (Efron & Tibshirani 1993). We then used weighted regressions to test for a linear trend, defining each weight as the reciprocal of the square of the standard error of the estimate

Table 2 Estimates of pup production from Sandy Bay, Enderby Island.

Season	Date of estimate (d/m/y)	Estimated number of live pups	Estimated number of dead pups	Technique used in calculating the estimate	Source
1942–44	–	c. 350		anecdotal accounts	Falla (1965)
1965/66	22/1/66	407		single count	Taylor (1971)
1972/73	12/1/74	460		daily count	Best (1974)
1974/75	19/1/75	368		daily count	Cawthorn (1975)
1975/76	17/1/76	406		daily count	Cawthorn unpubl. data
1976/77	19/1/77	375		daily count	Cawthorn unpubl. data
1977/78	19/1/78	380		single count	Falla et al. (1979)
1979/80	26/1/80	180		daily count	Mitchell & Ensor (1986)
1980/81	18/1/81	375		daily count	Cawthorn unpubl. data
1981/82	17/1/82	450	41*	daily count	Cawthorn (1986a)
1982/83	–	–	142*	–	Cawthorn (1986b)
1983/84	14/1/84	400	30*	daily count	Cawthorn (1986c)
1984/85	18/1/86	446		daily count	Cawthorn unpubl. data
1985/86	4/1/86	358		daily count	Cawthorn unpubl. data
1986/87	12/1/87	415		daily count	Cawthorn unpubl. data
1989/90	12/1/90	379		daily count	Cawthorn unpubl. data
1990/91	14/1/91	376		daily count	Cawthorn unpubl. data
1991/92	11/1/92	436		daily count	Cawthorn unpubl. data
1992/93	9/1/93	408	16*	daily count	Cawthorn (1993)
1994/95	14/1/95	418	46	mark recapture experiment	Gales & Fletcher in prep.
1995/96	15/1/96	417	38	mark recapture experiment	Gales & Fletcher in prep.

*Minimum mortality estimate for the season.

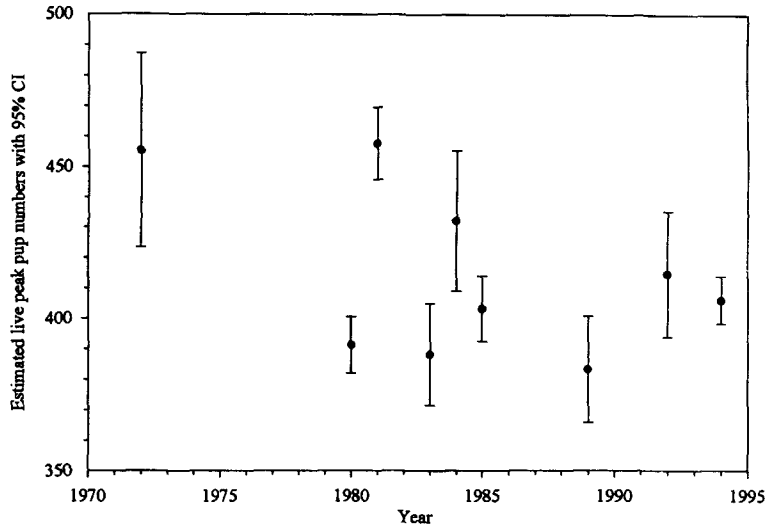

Fig. 3 Estimated maximum live pup numbers (with 95% CI) at Sandy Bay, Enderby Island, over nine seasons.

(Fig. 3). There was no evidence of any trend in live pup numbers in estimates from Sandy Bay over this period ($t_7 = -0.54$, $P = 0.6$), indicating stability over this period. Power analysis showed there to be an 83% chance of detecting a linear trend in live pup numbers of 1% per year (with $\alpha = 10\%$).

Estimates of live pup numbers from Pebble Point are: 16 pups in the 1981/82 season (Cawthorn 1986a); 25 pups in the 1992/93 season (Cawthorn 1993); and 59 (excluding 12 dead) and 49 (excluding 20 dead) for the 1994/95 and 1995/96 seasons, respectively (Gales & Fletcher in prep.). All were made by direct counts of pups.

Dundas Island

Estimates of pup production from Dundas Island are shown in Table 3. The first record of sea lions there was made in September 1941 when Dundas was reported by Webling to be "practically covered in them" (Pollock 1941).

The first record of a pup count on Dundas Island was on 25 January 1974 when over 1000 pups were counted (R. Russ pers. comm. to Falla et al. 1979). The colony, at this time, was estimated to be at least twice the size of that at Sandy Bay, that is, about 2000 animals (Best 1974). Falla et al. (1979) conducted a survey of Dundas Island on 21 January

Table 3 Estimates of maximum pup production from Dundas Island.

Season	Date of estimate (d/m/y)	Estimated number of live pups	Estimated number of dead pups	Technique used in calculating the estimate	Source
1972/73	25/1/73	1000+		single count	Falla et al. (1979)
1977/78	21/1/78	1680		single count	Falla et al. (1979)
1980/81	29/12/80	1050		single count	Cawthorn unpubl. data
1984/85	20/2/85	253		single count	Taylor & Sadlier (1985)
1985/86	19/1/86	1087		single count	Cawthorn unpubl. data
1986/87	20/1/87	1121		single count	Cawthorn unpubl. data
1990/91	12/2/91	973		single count	Cawthorn unpubl. data
1991/92	4/1/92	2369		single count	Cawthorn unpubl. data
1992/93	18/1/93	1804	66*	multiple counts on same day	Cawthorn (1993)
1994/95	20/1/95	1603	234*	mark recapture experiment	Gales & Fletcher in prep.
1995/96	20/1/96	1810	207*	mark recapture experiment	Gales & Fletcher in prep.

*Minimum mortality estimate for the season.

1978. Their total count of 2762 animals was later scaled up to 3550 after an estimate of the number of cows at sea at the time of counting was included. The maximum number of pups counted was 1680, but it was agreed that 1700 would still be a conservative estimate. Falla et al. believed that the population at Dundas was increasing, although they acknowledged that the evidence was sketchy.

Sea lions on Dundas Island were counted on 20 February 1985. A total of 253 pups was counted with many other sea lions seen on nearby Kekeno Beach (Taylor & Sadleir 1985).

Figure of Eight Island

Estimates of pup production on Figure of Eight Island are shown in Table 4.

Adams Island

Sea lions have also been reported on Adams Island in the Auckland Islands (Buckingham et al. 1991), and 42 animals were found near Lake Turbott on 12 November 1989. The group comprised 4 males with harems, 10 bachelor males, and 28 females. This is unlikely to have been a breeding group because it was observed too early in the season and was more likely part of the pre-breeding build-up. No pups have been reported from this site.

Campbell Island

Most of the reports from Campbell Island have been as a result of opportunistic surveys and encounters and not the result of detailed studies. The data reported therefore reflect a minimum count for most of the references mentioned. Bailey & Sorensen (1962) estimated that on Campbell Island at the end of 1947 there were no more than 20 females and many hundreds of males, the majority of them immature. The sea lions were mostly concentrated at Northwest Bay and Northeast Harbour although young pups had been seen all across the island. They also reported that there may have been a slight increase in the number of sea lions on Campbell Island between 1941 and 1958. Bailey & Sorensen (1962, p. 52) wrote of Campbell Island that "while of regular occurrence, the sea lion is not an abundant animal." Degerbol (1956, p. 205) reported seeing "only a few" sea lions in Perseverance Harbour in 1951.

Russ (1980) counted 78 animals on the island on 21 December 1975, with only a single female being seen. He reported that sea lions could be found all over the island but particularly at Perseverence and Northeast Harbours and Northwest Bay. Southeast and Monumental Harbours are also used as resting areas. During the 1991/92 breeding season, 98 pups were tagged on Campbell (M. Frazer pers. comm.), and the 24 dead untagged pups counted give a minimum production estimate of 122 pups. This study was undertaken on an opportunistic basis, and pups were tagged when encountered all across the island. Taylor & Sadleir (1985, p. 4) reported approximately 30 pups born on Campbell Island during the 1984/85 summer and that this "represents a continuing gradual increase of breeding animals there." Moore & Moffat (1990) reported that a minimum of 51 pups were born on Campbell in the summer of 1987/88, with most being seen in Capstan Cove, Northwest Bay, and Tucker Cove. Cawthorn (1993) estimated pup production to be 150 for the 1992/93 season.

Sea lions at other locations

Sea lions have been reported from The Snares islands, where small numbers breed (Falla 1948). Waite (1909) reported a single pup and female found

Table 4 Estimates of pup production for Figure of Eight Island.

Season	Date of estimate (d/m/y)	Estimated number of live pups	Estimated number of dead pups	Technique used in calculating the estimate	Source
1863/64	N/A	22+		tally of pups killed	Musgrave (1866)
1972/73	2/1/73	24		single count	Best (1974)
1980/81	29/12/80	38		single count	Cawthorn unpubl. data
1984/85	16/2/85	39	8*	single count	Taylor & Sadlier (1985)
1986/87	10/1/87	91		single count	Cawthorn unpubl. data
1989/90	15/1/90	104		single count	Cawthorn unpubl. data
1992/93	7/1/93	67		single count	Cawthorn (1993)
1994/95	11/1/95	123		single count	Gales & Fletcher in prep.
1995/96	24/1/96	113	31*	single count	Gales & Fletcher in prep.

*Minimum mortality estimate for the season.

at The Snares in 1907. Basaltic pebbles assumed to be sea lion gastroliths have also been found there (Fleming 1951). In a visit in the summer of 1970/71, a maximum of 47 animals were counted consisting of 36 males and 11 females (Crawley & Cameron 1972). Crawley & Cameron (1972) also reported the presence of two pups that were probably born on the islands in 1969 and 1971, respectively. Cawthorn (1993) estimated pup production for The Snares islands at 10 for the 1992/93 season. Gales & Fletcher (in prep.) reported that no sea lion pups have been reported born on The Snares islands for the past few years, despite frequent visits by scientific parties during the pupping season.

Male sea lions visit Macquarie Island, and some individuals stay for several years or return over several consecutive years (Gwynn 1953; Csordas 1963). Csordas (1963) noted that there was no evidence of sea lions breeding on Macquarie Island when it was discovered in 1810.

Stewart Island has been reported as a frequent haulout site for immature and subadult males during 1971 and 1974 (Wilson 1979); the maximum number of animals counted in a single day was 15. Lone males are reported to visit these shores during winter (Begg & Begg 1979). Fleming (1951) reported some animals, mostly immature, hauled out on the coast of Stewart Island and Southland, which he classified as a non-breeding overflow from the Auckland Island population.

The Otago coastline is now a regular haulout site for immature and subadult males (Hawke 1986, 1993; Beentjes 1989; McConkey 1994). A small number are resident for the whole year, with many remaining for several months before leaving (McConkey 1994). Some have returned over successive years (Beentjes 1989). Most of these sea lions leave early in the summer months and are not seen again until late March. These individuals may have been travelling to the subantarctic islands for the breeding season (Beentjes 1989). Hawke (1993) reported the first post-sealing record of a female on the New Zealand mainland. In 88 surveys conducted on the coast of Otago between 1984 and 1992, Hawke sighted 28 sea lions, four of which were female; at least two different females were individually identified.

McConkey (1994) estimated a population of about 20 animals for the Otago Peninsula in 1994. The number of resident individuals and maximum haulout numbers indicate a doubling of the population size over the last 10 years. The population is composed almost exclusively of males with only one or two females. Six sea lions have been reported killed by humans in the Catlins (four shot and two run over) in 1993 and 1994, from a population with an estimated size similar to that of Otago's. This population is also composed almost exclusively of males.

Single females have given birth on the Otago coast in the summers of 1992/93, 1993/94, and 1995/96 (McConkey 1994, and pers. comm.); at Butterfield Beach on Stewart Island in 1988/89 and 1991/92, and on Codfish Island in 1989/90 and 1995/96 (L. Chadderton pers. comm.).

Total population estimates

Estimates of total population size for New Zealand sea lion are shown in Table 5.

DISCUSSION

Archaeological evidence demonstrates that sea lions were once more widespread than they are today. Before the occupation of New Zealand by humans, sea lions ranged all along the coast from the far north of the North Island through to Stewart Island and the subantarctic islands to the south.

There are several potential biases arising from examination of archaeological records to infer distribution patterns of pinnipeds. First, archaeological research has a patchy distribution around the New Zealand coastline, and the reported location of sea lion bones and other remains is concentrated in areas of greatest effort. Selection of sites for excavations has usually not been based on an investigation of sea lion distribution, but rather on other criteria such as Maori history. For instance, there have been few systematic investigations of sites for marine mammal remains on the West Coast of the South Island (Smith 1989), although R. Hooker (pers. comm.) reported that no sea lion and only a few fur seal bones were found during a survey of 45 sites while investigating Maori occupation of the area. Consequently, the pattern of sea lion remains shown in Fig. 2 implies a widespread distribution but gives no clear clues as to areas of relative abundance. Second, the location of bones may or may not relate to the site where the animal was originally found and killed. Fortunately, this is unlikely to be a significant problem with large animals such as sea lions, because Maori traditionally dressed out the meat for transport and storage, leaving the bones *in situ* (Smith 1989).

A further potential bias is in the interpretation of

the significance of a find of bone material at a particular site. If remains are from only one animal, it is possible that the animal was beyond its normal range when killed and butchered. When bone remains from several animals are found (e.g., 8 at Houhora and 15 at Kaupokonui; Smith 1989) it is more likely that the find of bones is from within the normal range of sea lions. It is possible that sites where the remains of several sea lion have been found could reflect the accumulation of material over a long period of time, potentially several hundred years or longer. However, this seems unlikely given the range of coastline from which remains have been found and the number of sites that have yielded multiple remains.

The pre-European distribution of fur seal remains is similar to that of sea lions (Smith 1989). Abundance estimates from this time are not available for sea lions, but fur seals were estimated to number between 1.5 and 2 million animals before exploitation (Richards 1994). Remains of fur seals are recorded at 103 archaeological sites around New Zealand (Smith 1989), compared with 47 sites for sea lions. Sea lion and fur seal remains are often found in the same midden, the fur seals usually being more abundant than sea lions (e.g., the remains of 14 sea lions and 57 fur seals from a midden at Shag Mouth; Smith 1996). It is likely that fur seals have always been more abundant than sea lions (see Smith 1989; Reijnders et al. 1993), and so this bias is not surprising. Nevertheless, as the number of sites with sea lion remains is close to half that for fur seals, this index of abundance—although fairly crude—would suggest that the current sea lion population is significantly reduced in numbers as well as distribution. This seems likely if it is assumed that sea lions were not preferred as a food resource over fur seals.

Direct exploitation is the most likely cause of the decrease in distribution of sea lion with Moriori, Maori, and later Europeans all hunting them to some degree. The evidence suggests that there was opportunistic hunting of sea lions around the whole country, whereas regular, seasonal hunts were known to occur in at least two places—Lords River and Shag Mouth (Stark 1986; Smith 1996). All age classes were hunted, but juveniles and subadult males are represented in higher proportions than their incidence in the total population (Smith 1989). As juveniles and subadult males disperse more widely than other age/sex classes, this finding is not unexpected.

Smith (1985) stated that sea lions disappeared from the northern North Island by about AD 1500, and elsewhere they appear to have become scarce. Worthy (1992, p. 38) stated, "The implication is that

Table 5 Total population estimates for New Zealand sea lion.

Date of estimate	Total population estimate	Method used to calculate estimate	Reference
1974/75 season	3000	sum of counts at three main breeding colonies	Best (1974)
1974/75 season	3144[1]	sum of counts with estimation of other parameters	Cawthorn (1975)
1978/79 season	6000[2]	calculated from counts and estimates at breeding colonies	Falla et al. (1979)
1982	4000	based on reports of Best (1974) and G. J. Wilson pers. comm.	Warneke (1982)
1984	6655	sum of counts at breeding colonies and from aerial photographs	Doonan & Cawthorn (1984)
1984/85 season	6440–7300	method not described	Cawthorn (1986b)
1985	6500–7000	calculated from tagging and survey programmes	Cawthorn et al. (1985)
1992/93 season	14 083	modelled from counts of pup production	Cawthorn (1993)
1992/93 season	8587–15 393	modelled from counts of pup production	Gales (1995)
1994/95 season	10 900–14 300	modelled from mark recapture estimate of pup production	Gales & Fletcher in prep.
1995/96 season	11 600–15 200	modelled from mark recapture estimate of pup production	Gales & Fletcher in prep.

[1]Estimate for Auckland Islands only.
[2]Estimate excludes non-breeding males and juveniles.

there were resident populations in New Zealand and that hunting by Polynesians exterminated these. The remaining population was much reduced and its usual range extended only to southern New Zealand. Then nineteenth century hunting by sealers further reduced the population so that sea lions only survived on the inaccessible southern islands." The apparent disappearance of sea lion from the Chatham Islands occurs about the same time as European contact began (Smith 1989). The coincidence of European settlement and the disappearance of sea lions indicates that the sea lions were probably driven from the Chatham Islands by human predation.

Smith (1989) suggested that human disturbance may have caused the abandonment of some sea lion colonies. We feel that this is unlikely as, in our experience, sea lions appear to be tolerant of human disturbance, and, further, sea lions are now colonising sites with relatively high levels of disturbance (i.e., Otago Peninsula).

There is little evidence that environmental changes have affected the distribution the of sea lion. This partly reflects the fact that the habitat requirements of the New Zealand sea lion are unknown, but Smith (1989) suggested that as both the Australian sea lion (*Neophoca cinerea*) and the South American sea lion (*Otaria byronia*) inhabit lower latitudes (Vaz-Ferreira 1981; Gales et al. 1994), then it is possible that the New Zealand sea lion could as well.

Environmental factors have been suggested as a constraint on the distribution of breeding colonies of fur seal (Wilson 1974; Mattlin 1978). North of the present breeding limit, fur seals ashore may be disrupted by higher air temperatures and longer hours of sunshine, through effects such as heat stress. As a result, it is likely that fur seals would spend more time in the water cooling and less time ashore maintaining territory and bearing and suckling pups. It follows that sea lions may also be affected by heat stress, but to what extent is unknown.

Climate change has also been suggested as a possible explanation for the change in distribution of sea lions. Smith (1989) acknowledged that some climatic changes have occurred but that they are unlikely to account for a decline in sea lion range. The changes have been small (±0.7°C), and although there was a slightly warmer and more settled period between the 10th and 16th centuries it was followed by a minor deterioration between the 17th and 19th centuries (Leach & Leach 1979), which may in fact have favoured sea lions breeding at lower latitudes.

That sea lions used to breed on the mainland is indicated by the presence of pups and females in the archaeological record. Although female remains do not constitute direct evidence of breeding, temporal changes in their distribution are likely to reflect changes in distribution of breeding sites. Currently females breed throughout their known range, from Campbell Island in the south to Otago in the north. The fact that they breed at the northern limit of their present distribution suggests that their breeding range may be the same as their geographic range. The presence of female remains in Northland is therefore possible evidence for a more northern breeding range before the arrival of Europeans to New Zealand.

The relative lack of pup remains in the archaeological record could be interpreted as evidence against breeding on the mainland or Stewart Island. However, Worthy (1994) stated that the finding and identification of pup remains, particularly in dune deposits, is unlikely given that their small, porous bones are the least likely to remain intact. Furthermore, pup bones are unlikely to be found unless they are specifically looked for, as most investigations target the larger, well preserved bones. There have been no archaeological investigations carried out at either Lords River or Port Pegasus where sea lions were known to breed. Smith (1989) reported that only 28 fur seal pup remains have been recovered from sites across mainland New Zealand. This is an extremely small archaeological representation of the previously extensive breeding range and population size of the fur seal on the mainland. The same pattern appears to be true for the sea lion.

Berry & King (1970) reported the remains of two young sea lions from Hawke's Bay, and concluded that they either bred as far north as Hawke's Bay or close enough that the young animals could swim there. Without a more specific age determination for these specimens it is impossible to say whether they were, in fact, young pups and probably born there, or juveniles, which are known to disperse widely after weaning. However, juveniles have not been reported from this area recently and this would imply that their present range is reduced from former times.

The two clear references to breeding on Stewart Island in the 1820s, at Lords River and Port Pegasus (Howard 1940; Starke 1986), describe sea lions as "numerous" and in "great quantities." Hector (1892) referred to breeding on the West Coast of the South Island and made reference to the occurrence of New Zealand sea lions in Bass Strait and in Tasmania. This is likely to have been a misidentification of the Australian sea lion as there are no other records of

New Zealand sea lion reaching Australia. Notwithstanding this misidentification, it seems unlikely that an accomplished naturalist like Hector would have confused a sea lion with a fur seal and that consequently the breeding range of the sea lion did indeed extend up the West Coast of the South Island. The only subsequent records of breeding on the mainland have been recent ones (post 1988) involving seven pups born on Stewart Island, Codfish Island, and the Otago coastline. These are rare events and may reflect a slow recolonisation of past breeding sites rather than an expanding population that is colonising new areas.

Most of the records from the 19th century are accounts by sealers, and they provide only a rough estimation of sea lion abundance and distribution. Few records refer specifically to sea lions, as most are concerned with the more commercially valuable fur seal. The 3670 sea lion skins landed by the sealing vessels *Wellington* and *Elizabeth and Mary* in 1825 represent the only real quantitative reference available from this period. This actually reflects a larger number of sea lions killed, as pelts were often damaged during skinning and curing; these were not retained and hence were never reported (McNab 1907).

Given that fur seals and sea lions had been reduced to very low numbers around the New Zealand mainland and offshore islands by 1830, both species were faced with recovery from severe depletion—a long and slow process. Fur seals are now abundant and expanding around much of the South Island, and breeding colonies are establishing in the North Island. Fur seals commonly haulout, and are now seen throughout their pristine range, although at population levels estimated to be as low as 2% of pristine abundance (Richards 1994). This "early recovery phase" has not yet been observed for the sea lion.

Why has the apparent partial recovery of sea lion observed in the Auckland Islands in the latter half of the 19th century not continued through the 20th century? We offer no explanation in response to this question, but make the following observations. Throughout the Southern Hemisphere, fur seals are likely always to have been more abundant than the three sea lion species (Australian, South American, and New Zealand), and many fur seal populations, while still at a small fraction of their pristine abundance, are now rapidly increasing in size and recolonising their previous range (Reijnders et al. 1993). By comparison, the populations of all three southern sea lion species appear to be stable and showing no real increase in population size (Reijnders et al. 1993). Further work on the ecological differences between fur seals and sea lions towards understanding the mechanisms that facilitate population expansion is prudent for agencies responsible for protecting sea lion stocks. In particular, and given the current lack of such knowledge, it is important to maximise efforts to reduce anthropogenic factors that may limit the ability of pinniped populations to recover.

Many counts and estimates of the various breeding colonies in the Auckland Islands made in the latter part of the 20th century have been reported. The technique most used to estimate numbers, direct counts, is the easiest and most convenient and provides a good estimate of visible pups, but takes no account of pups hidden by terrain or other pups. This observational bias is likely to be inconsistent, and is impossible to correct for (Gales & Fletcher in prep.). There are also likely to be differences between years as personnel and conditions change. Despite these drawbacks, successive counts over the years are the only means available to monitor changes in sea lion numbers and especially pup production. At colonies such as Sandy Bay, where pups are fairly easily viewed from the sand bank behind the beach, these biases are likely to be minimised.

The time of year at which estimates are made has a strong influence on the outcome, as peak pup numbers in the colony occurs consistently in mid January (Gales & Fletcher in prep.). Estimates that are not made close to the date of peak pup production will not reflect the maximum for that year. Estimates of total pup production require the inclusion of mortality estimates with live pup numbers. Most of the past estimates are only of live pup numbers and do not include any estimate of mortality. Therefore, total pup production estimates are not available for most seasons.

Pup production is the best index of relative population status (Berkson & De Master 1985; Gales & Fletcher in prep.). There is no evidence of either an upward or downward trend in estimates from Sandy Bay over the last 20 years, indicating that the number of live pups has been stable over at least this period. There was a high likelihood of detecting any such trend. Of all the seasonal estimates used to investigate population trends, only the first in 1973/74 was made before the southern squid fishery became active. It is not known whether the impact of bycatch from this fishery has influenced later pup production estimates. Modelling by Doonan & Cawthorn (1984) and Woodley & Lavigne (1993) suggests that the population would have been affected by a high level

of bycatch. Other reports (e.g., Falla 1965, 1975) suggest that production may have been stable, at c. 350–400 pups at Sandy Bay, since the 1940s. Unfortunately there are no good long-term records from any of the other breeding colonies from which to compare the stability of pup production.

Six sea lions have been reported killed by humans in 1993 and 1994 in the Catlins from a population of approximately 20 males (McConkey 1994). If this mortality rate continues, it would severely threaten the viability of this population and would limit the possibility of the Catlins population increasing. With sea lions still rare on the mainland, even such localised human-induced mortality could affect the ability of sea lions to recolonise the mainland.

There have been several estimates of the total sea lion population size, employing a range of techniques. The most recent, with 95% confidence intervals, is between 11 600 and 15 200 (Gales & Fletcher in prep.) and is based on modelling from pup production estimates from the 1995/96 breeding season. This is the best estimate to have been derived for total sea lion population, and is similar to the figures previously calculated by Cawthorn (1993) and Gales (1995). The New Zealand sea lion is therefore currently one of the least abundant of any pinniped in the world.

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