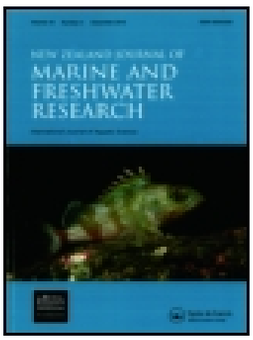

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Re-assessment of the status of southern elephant seals (*Mirounga leonina*) in New Zealand

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Abstract The history, distribution and numbers of southern elephant seals (*Mirounga leonina*) in New Zealand are reviewed. The small populations that breed on Campbell and Antipodes Islands, and the very few that occasionally pup on the New Zealand mainland, are part of the larger Macquarie Island stock. A comparison of recent and earlier counts has revealed a 97% reduction in the breeding population at Campbell Island since 1947. There has been a decline in the number and size of breeding harems, and in pup production: from 191 pups in 1947 down to 5 in 1986. Little is known of the Antipodes Island population but, with 113 pups in 1978, this may now be the main breeding population in New Zealand. Breeding populations at Macquarie Island, and at many other locations throughout the subantarctic zone of the Indian and Pacific Oceans, have also recently declined. Reasons for these changes are unknown, but possible causal factors in the marine environment are discussed.

Keywords Southern elephant seal; *Mirounga leonina*; Phocidae; New Zealand region; Campbell Island; Antipodes Island; breeding status; population decline

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INTRODUCTION

Southern elephant seals (*Mirounga leonina* L.) are circumpolar in distribution, and haul out to breed near the southern tip of South America and on subantarctic islands of the Atlantic, Indian, and Pacific Oceans. Three distinct stocks are recognised, centred on South Georgia, Kerguelen, and Macquarie Islands (Lydekker 1909; Laws 1960). There is little interchange between these and each display phenotypic differences in size, growth, and onset of maturity (Laws 1979; Ling & Bryden 1981). The Macquarie Island stock includes the small populations breeding at Campbell and Antipodes Islands, as well as the few stragglers occasionally pupping on the New Zealand mainland and in Tasmania (Fig. 1).

Southern elephant seals feed mainly on fish, cephalopods, and small crustaceans (Gaskin 1972; Laws 1979), and their optimum habitat is in the region of the Polar Front (Antarctic Convergence) (Carrick & Ingham 1962b). The northern boundary of the seal's major breeding concentrations is nowadays at the Subantarctic Front (the northern limit of the Antarctic Convergence Zone: Heath 1985), although in historical times several thousand southern elephant seals bred north of the Subtropical Convergence at 40°S in Bass Strait (Warneke 1982). The Subantarctic Front is a circumpolar feature generally located near 50°S, but near New Zealand it is deflected south to lie along the continental slope of the Campbell Plateau (Fig. 1). The southern boundary of the elephant seal's main breeding range coincides with the spring limit of the pack ice (Laws 1960; Carrick & Ingham 1962a).

A recent United Nations FAO commentary on seals in the Australasian region (Warneke 1982) and the New Zealand Wildlife Research Liaison Group review (Cawthorn et al. 1985), have highlighted the lack of knowledge of, and research interest in, the changing status of southern elephant seals in the New Zealand area. As a consequence, these and other recent publications understandably contain outdated and misleading information. For example,

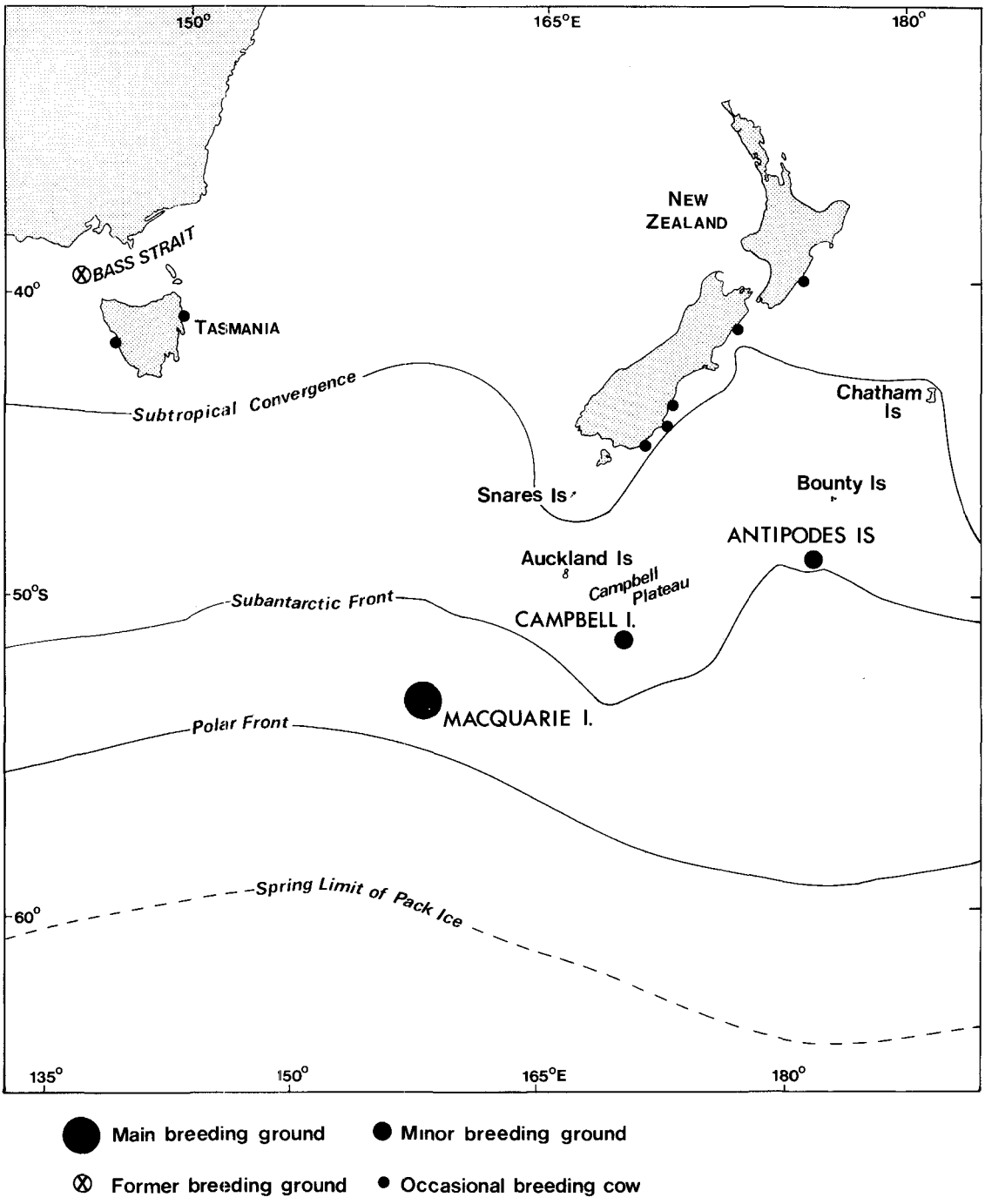

Fig. 1 The New Zealand region, showing southern elephant seal breeding grounds and oceanographic features.

the current management plan for Campbell Island Nature Reserve noted that numbers of southern elephant seals "are now increasing" (Department of Lands and Survey 1983).

For 2 decades there has been an appreciation among members of expeditions to Campbell Island (52°35'S, 169°10'E) that the population of elephant seals there was much smaller than that recorded by Sorensen (1950) in the late 1940s (RHT pers. obs. 1969 and 1970; Wilson & Gaze 1983), but no adequate census was carried out until 1984 and 1986 (present study). However, Bailey & Sorensen (1962) reported on counts of females and pups at some breeding sites in 1957 and 1958; Russ (1980) published counts of pups made between mid November and mid December 1975; R. Stewart (pers. comm.) counted pups at all breeding sites during the period September–November 1983; and casual, but often incomplete, counts of elephant seals have been included in some field reports of Campbell Island personnel (M. Cawthorn, pers. comm.).

No original observations have been published on the breeding status of southern elephant seals at Antipodes Island (49°42'S, 178°47'E) since the accounts of R. A. Falla (Anon. 1950) and Turbott (1951, 1952) on findings in early November 1950. However, unpublished reports have summarised the results of census counts in February 1969 and November 1978 (Taylor 1969, 1979).

The study presented here was motivated by the obvious lack of up-to-date documentation on the status of southern elephant seals in New Zealand.

PREVIOUS RECORDS

Despite a complete lack of early published records of southern elephant seals from Antipodes Island (Turbott 1952) and Campbell Island (Bailey & Sorensen 1962), these seals most probably frequented both islands and bred there at the time of their discovery in 1800 and 1810, respectively. As at King Island and other islands in Bass Strait (Warneke 1982) and at Macquarie Island (Cumpston 1968), elephant seals would have been severely exploited by the early sealers.

Sorensen (1950) postulated that elephant seals were exterminated on Campbell Island shortly after the island's discovery and for over a century thereafter there were only stragglers. The numbers at Campbell Island must have been small always, compared to Macquarie Island. During the 2 years after the discovery of the islands (in 1810) only 48 tuns of oil are known to have come from Campbell, compared with well over 265 tuns from Macquarie, and all sealing at Campbell was of very little commercial importance after 1813 (Kerr 1976). Scott (1882), who visited Macquarie Island in 1880 to study the flora and fauna, and who claimed a particular interest in southern elephant seals, stated that "they never, ... come as far north as either Campbell Island or the Auckland group". Although again common at Campbell Island by 1931 (Spence 1968), elephant seals were not reported as breeding there during the sheep farming era (1895 to 1931). However, they were breeding when Campbell Island was occupied in 1941 by members of the war-time "Cape Expedition" (Sorensen 1950).

At Antipodes Island, elephant seals possibly had a similar history, for although the island was often visited in search of shipwrecked sailors from 1865 until 1927, no elephant seals were ever reported by the many competent observers and biologists involved. The first record appears to be the mention of 6 near a landing place in February–March 1926 (Beck 1928). The U. S. Coastguard icebreaker *Northwind* found elephant seals "abundant" at Antipodes Island in March 1947 (Rear Admiral C. W. Thomas pers. comm.) and the first reports of breeding were in early November 1950 (Falla 1950; Turbott 1951).

Many authors (e.g., Laws 1960; Carrick & Ingham 1962a; Gaskin 1972; Gibb & Flux 1973; Erickson & Hofman 1974; Barrat & Mougin 1978; Owen 1984; McCann 1985; Daniel & Baker 1986) have indicated that southern elephant seals breed on the Auckland Islands group, but despite a wealth of early literature on the islands and many recent expeditions, no direct evidence of breeding has ever been published, or is known to us. Most of the above reports will have originated from the contention of Falla (1965) that elephant seals are regular visitors to the group "where breeding is presumed on Dundas Reef". R. A. Falla (pers. comm.) based his presumption on his finding on 28 October 1943, of 2 elephant seals, including a mature bull, ashore on Dundas Island and "a maze of wallows, ditches and pools of muddy fresh water" with "the appearance of having been frequented at some distant date by sea elephants".

More recent findings have not supported this conclusion. Wallows are mainly used during the moult by female and non-breeding male southern elephant seals (Carrick et al. 1962a; pers. obs.), and in no way indicate breeding. Dundas Island and all likely locations elsewhere in the group have been

inspected closely on several occasions since 1973, but no evidence of past or present breeding by elephant seals has been found (Falla et al. 1979; RHT pers. obs.; M. Cawthorn pers. comm.). Many wallows are still present on Dundas Island and on Figure of Eight Island, Auckland Islands, and are being formed and used by Hooker's sea lions (*Phocarctos hookeri*)—particularly pups and yearlings (M. Cawthorn pers. comm.; RHT pers. obs.). All evidence now indicates that it is most unlikely that elephant seals have bred, or even moulted in large numbers, at the Auckland Islands within historic times.

Southern elephant seal pups are occasionally born on the coasts of mainland New Zealand, including northern Wairarapa (Sorensen 1969), Kaikoura (Bowring & Stonehouse 1968; Sorensen 1969; Mills et al. 1977), near Oamaru (Grob 1985), at Karitane Beach near Dunedin in 1979 (A. Wright pers. comm.; Cawthorn 1981), and at Nugget Point in 1977, 1978, and 1982 (A. Wright pers. comm.). An incipient rookery exists at Nugget Point (Cawthorn et al. 1985; M. Cawthorn pers. comm.) and 1 or 2 cows have bred and pupped there frequently over the last 20 years.

There are 2 records in the past 30 years of southern elephant seals coming ashore to give birth in Tasmania (Davies 1961; Tyson 1977), close to their historical breeding grounds in western Bass Strait from where they were annihilated in the early 1800s (Warneke 1982). All known breeding grounds in the Australasian region are shown in Fig. 1.

Southern elephant seals have not been recorded breeding at the Snares or Chatham Islands, although stragglers of all age groups regularly visit these islands, as well as the Auckland Islands and the New Zealand mainland. On the rocky and barren Bounty Islands (Taylor 1982), which have no suitable hauling out ground, they neither breed nor occur as stragglers. We have been unable to find any early published reference of elephant seals breeding in numbers on the New Zealand mainland, or records of substantial amounts of elephant seal bone in material recovered from North or South Island archaeological sites. The reference in Cawthorn et al. (1985) to traditional breeding sites in "northern New Zealand" is incorrect (M. Cawthorn pers. comm.).

POPULATION ASSESSMENT

The breeding season

At Campbell Island, southern elephant seals begin their breeding season in August with the arrival of the mature bulls. Pregnant cows start to haul out in September and form into compact harem groups under the charge of dominant bulls. About 5 days after coming ashore the cows give birth to single pups. Most pups are born during the last week of September and the first half of October, and the maximum number of breeding cows is ashore on about 16 October (Sorensen 1950; Bailey & Sorensen 1962). The pups are weaned when approximately 3 weeks old, at about the time that their mothers mate before leaving for sea. Most harems are deserted by the middle of November when the last of the cows and the breeding bulls leave the island. Weaned pups remain near their birthplace for about 2 weeks and then gradually disperse to other beaches via inshore waters, although they do not start to leave for the open sea until they are 9–10 weeks old (Sorensen 1950; Carrick et al. 1962b; Lenglart & Bester 1982).

Yearling seals start hauling out for the annual moult from early November, before the final departure of the pups. Older submature animals come ashore to shed their coats in late November and December, mature cows in December and in January, and the mature bulls in late January and in February (Sorensen 1950).

Census methods

An accurate index of population size and breeding success can be obtained from repeated counts of breeding cows and pups produced in each harem from late September to early November. However, for about 2 weeks after the maximum number of breeding cows is ashore, a single count of cows, weaned pups, and dead pups can be combined for an effective estimate of total pup production (Van Aarde 1980; McCann 1985). Total counts of all pups on isolated islands such as Campbell and Antipodes are meaningful until mid November when the pups, by then often called "underyearlings" (Condy 1978), begin to depart for the open sea.

Care is needed late in the breeding season to avoid mis-identifying yearlings as pups. Fourteen-month-old moulting seals cannot be distinguished from weaned pups by their length, but only by colour and proportion (Carrick et al. 1962b). Newborn pups have long, dark fur which is shed about the time the pups are weaned to reveal a shorter, dense, silver-grey coat. The colour and "bloated" appearance of newly weaned pups distinguishes them from yearlings which start to haul out in early November. Yearlings have a yellow-tinged coat and are more streamlined. Once weaned, the pups start to use their fat reserves, and by the time they depart for sea their

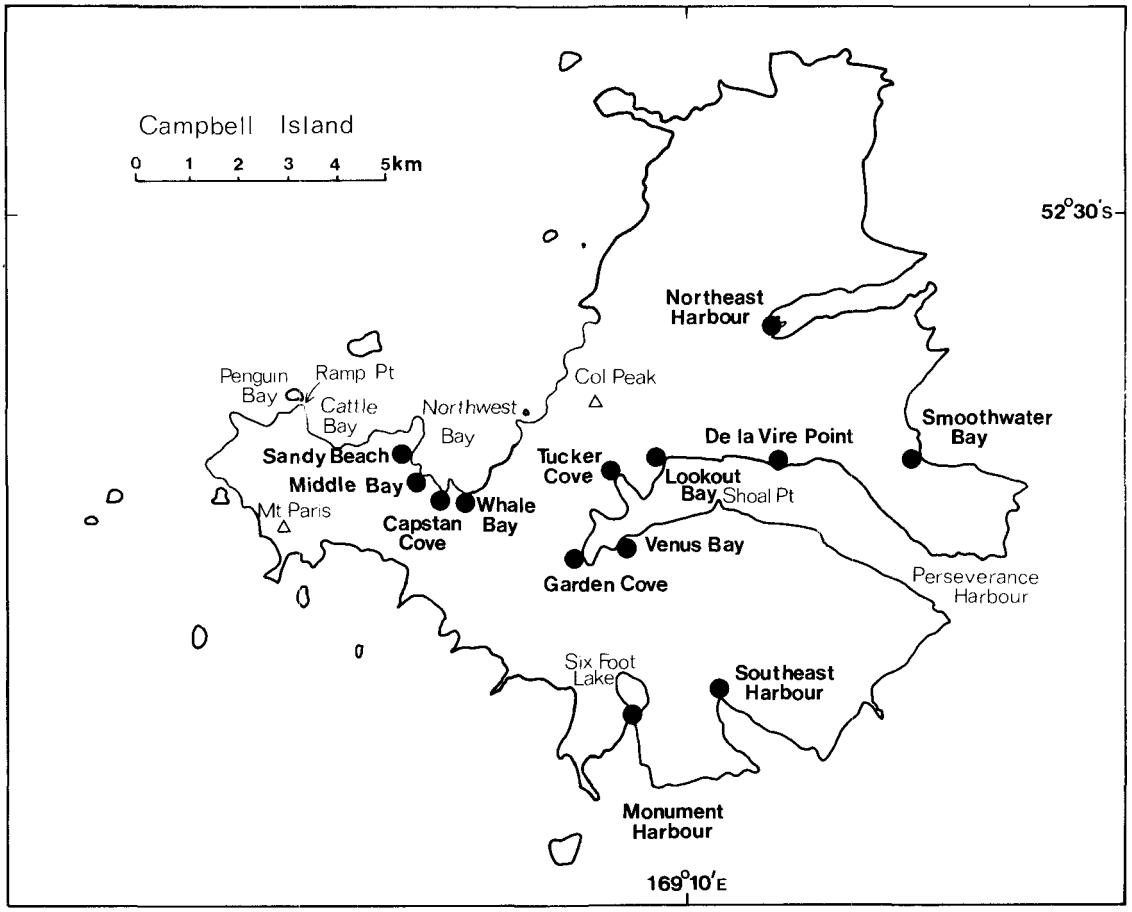

Fig. 2 Campbell Island, showing southern elephant seal breeding sites and other localities mentioned in the text.

body shape contrasts less markedly with that of yearlings.

During September, October, and early November in 1984 and 1986, all known elephant seal breeding sites on Campbell Island (Fig. 2) were visited by GAT. Elephant seals at each site were classified as bulls, breeding cows, or pups. Dead pups were also noted. Elsewhere, binoculars were used to scan likely shorelines for elephant seals.

In 1978, RHT used small boats to search for seals around the entire coastline of the Antipodes Islands, and a Royal New Zealand Navy Wasp helicopter was also used to check the many small coves along the rugged south and south-west coasts. Two censuses of elephant seal breeding sites (Fig. 3) were made, the first between 8 and 12 November and the second on 29 and 30 November. Elephant seals in harems were classified as bulls, cows, immatures, weaned pups, and total pups. Animals hauled out to rest or moult on other parts of the coast were also counted.

RESULTS

Campbell Island

Harem and haulout sites

The breeding sites on Campbell Island are typically sheltered gravel beaches backed by grass-covered flats or gentle slopes. Breeding since 1983 has been confined to Capstan Cove, Middle Bay, Monument Harbour, and to 3 sites in Perseverance Harbour: Tucker Cove, Venus Bay, and Garden Cove. The Monument Harbour breeding site is along the western shoreline of brackish Six Foot Lake.

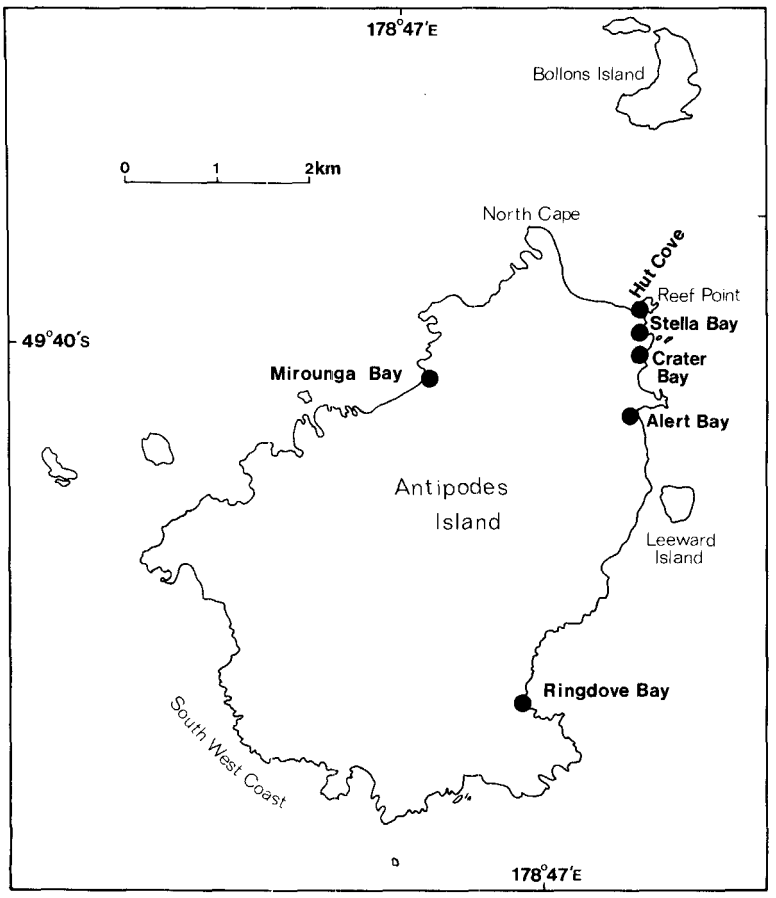

Fig. 3 Antipodes Islands, showing southern elephant seal breeding sites and other localities mentioned in the text.

Moulting elephant seals also haul out at these localities and at sites no longer used for breeding. These include sheltered gravel or boulder beaches such as at Ramp Point, the beach west of Col Peak, Lookout Bay, De la Vire Point, Shoal Point, Smoothwater Bay, Northeast Harbour, and the sandy beaches of Sandy Beach and Southeast Harbour. Elephant seals also come ashore for short periods on rugged boulder beaches on the south and west coasts (e.g., below Mt Paris, and at Penguin and Cattle Bays) but these exposed coasts are not used by moulting animals.

Census

Between 20 September and 3 November 1984, 11 breeding cows and 10 pups (1 of which died) were identified on Campbell Island. The largest harem group was in Capstan Cove where a large bull controlled 7 cows. 6 pups were born there between 30 September and 12 October 1984.

A similar census between 18 and 23 October 1986 revealed only 5 breeding cows. 5 pups were produced, 1 of which died before weaning. The largest harem was again in Capstan Cove, and comprised 2 cows.

These censuses now allow for some comparison of the present Campbell Island breeding population with that of the 1940s, 1950s, and 1970s. There have been major differences in the timing and completeness of previous counts. For instance, of the 5 censuses recorded by Sorensen (1950) for the years 1941, 1942, 1944, 1945, and 1947, only the last can be considered to be the result of an "accurate count of all the harems" during the optimum period for a census. However, Sorensen (1950) did consider that elephant seals were "very definitely increasing" at that time. In most years in the 1940s and 1950s certain harems were not counted, and others were visited before pupping was complete, with the result that pups, and to a lesser extent cows, were under-

represented in the tallies. In 1947 a number of cows (equal to the number of weaned and dead pups) had already departed for sea when the counts were carried out, and in 1945 and 1975 most dead pups would have been missed, as the counts were made late in the breeding season. These differences make it difficult to compare many of the early counts with each other and with recent results. However, the published counts from 1945, 1947, and 1957 are detailed enough to be able to make some allowance for these differences. To aid comparisons between years, the raw data have been interpreted to give an estimated figure for annual pup production (APP). For counts made before 21 October, estimates of APP are based on numbers of breeding cows, adjusted according to the relationship between census date and percentage of breeding cows ashore as found by McCann (1985) at South Georgia; for counts made later than 21 October, estimates of APP are based on totals of pups and dead pups found. Where dead pups were not counted they have been estimated as 5% of all pups produced (Sorensen 1950).

Table 1 gives the numbers of bulls, breeding cows, and pups counted, together with the estimated annual pup production, for each harem site censused during the years 1947, 1957, 1984, and 1986. Figure 4 shows the continuous decline in estimated pup production over the same period from 191 in 1947 down to 5 in 1986.

Similarly, the number of harems has decreased from 15 in 1945 and 1947 (Sorensen 1950) to 4 in 1984 and 1986; the average number of pups per harem has declined from 11.7 in 1945 and 12.7 in 1947 down to 2.7 in 1984, and 1.25 in 1986, and the maximum size of individual harems has also dropped from over 40 cows in 1947 down to 7 in 1984, and 2 in 1986.

Antipodes Island

Harem and haul out sites

All 6 southern elephant seal breeding sites found in November 1978 (Fig. 3) were on beaches of small, rounded boulders beneath steep cliffs. Most were on the relatively sheltered north-east coast of the main island. The breeding cows prefer protected positions near cave entrances and beneath overhanging cliffs at the heads of bays or coves.

Non-breeding elephant seals also haul out in these same general localities and at any of the other small boulder beaches that occur in bays, coves, and inside sea caves, on all coasts of the main island. As there is no level peaty ground near the shore the moulting seals cannot form wallows, but use areas covered in washed-up giant bull kelp (*Durvillea antarctica*). There are no beaches or sites suitable for either breeding or moulting on Bollons Island or any of the other small offshore islets.

Census

A census carried out at all breeding sites between 8 and 12 November 1978 located 12 bulls, 24 cows,

Table 1 Censuses of southern elephant seal bulls, cows, and pups at various breeding sites on Campbell Island in 1947 (Sorenson 1950), 1957 (Bailey & Sorenson 1962), 1984, and 1986. APP, annual pup production (corrected estimate). Names in brackets are those used by Sorensen (1950).

	1947				1957				1984				1986			
Location	Bulls	Cows	Pups	APP	Bulls	Cows	Pups	APP	Bulls	Cows	Pups	APP	Bulls	Cows	Pups	APP
Northeast Harbour (Penguin Harbour)	1	12	12	(12)	–	–	–	( )	0	0	0	(0)	0	0	0	(0)
Smoothwater Bay	1	3	13	(13)	–	–	–	( )	–	–	–	(0)	0	0	0	(0)
De la Vire Point	1	4	5	(5)	–	–	–	( )	0	0	0	(0)	0	0	0	(0)
Lookout Bay	2	11	11	(11)	3	9	4	(11)	0	0	0	(0)	0	0	0	(0)
Tucker Cove	0	0	0	(0)	1	3	1	(4)	0	0	0	(0)	1	1	1	(1)
Garden Cove	7	38	52	(52)	5	40	38	(44)	0	0	0	(0)	1	1	1	(1)
Venus Bay (Cove)	4	14	18	(18)	3	23	18	(25)	2	1	1	(1)	0	0	0	(0)
Southeast Harbour	2	2	21	(21)	–	–	–	( )	0	0	0	(0)	0	0	0	(0)
Monument Harbour	7	14	30	(30)	–	38	58	(58)	2	1	1	(1)	1	1	1	(1)
Sandy Beach (NW Beach)	2	2	2	(2)	1	2	1	(2)	0	0	0	(0)	1	0	0	(0)
Middle Bay	3	4	11	(11)	2	14	10	(17)	2	2	2	(2)	0	0	0	(0)
Capstan Cove (Windlass No. 2)	1	7	7	(7)	1	12	1	(15)	2	7	6	(7)	1	2	2	(2)
Whale Bay (Windlass No. 1)	1	4	9	(9)	–	–	–	( )	1	0	0	(0)	0	0	0	(0)
Total annual pup production				(191)				(176+)				(11)				(5)

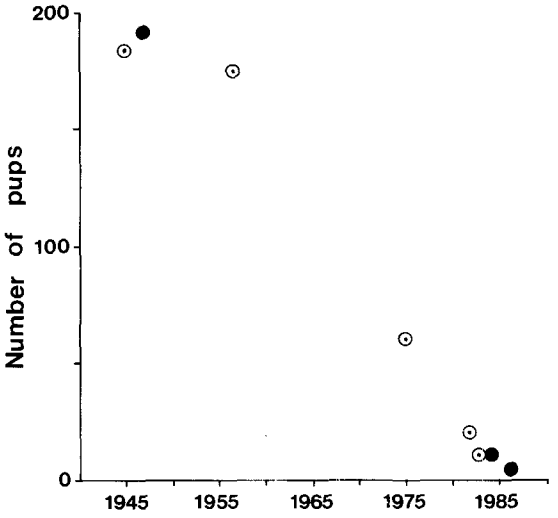

Fig. 4 Estimated numbers of southern elephant seal pups born at Campbell Island, 1945–86. Accurate censuses (●) were made in 1947 (Sorensen 1950), 1984, and 1986. Other values (○) are based on incomplete censuses (Sorensen 1950; Bailey & Sorensen 1962; M.W. Cawthorn pers. comm.); and on counts of pups in 1975 (Russ 1980) and 1983 (R. Stewart pers. comm.).

Table 2 Census of southern elephant seal bulls, cows, pups with cows, and weaned pups at various breeding sites on Antipodes Island in 1978. APP, annual pup production (corrected estimate).

Location	Date	Bulls	Cows	Pups with cows	Weaned pups	APP
Hut Cove	8 Nov	1	6	6	3	(10)
South Stella Bay	9 Nov	4	2	2	35	(39)
Crater Bay	9 Nov	3	4	2	31	(37)
Alert Bay	9 Nov	2	4	4	4	(8)
Ringdove Bay	9 Nov	1	2	2	0	(2)
Mirounga Bay	12 Nov	1	6	5	10	(17)
Totals:		12	24	21	83	(113)

and 104 pups—83 of which were already weaned (Table 2). Estimated pup production for the island after allowing for mortality was 113. At the same time an additional 17 bulls, and 13 immatures, were found elsewhere on the island. A re-survey of all parts of the coastline on 29 and 30 November revealed that only 68 of the pups were still ashore.

In early November 1950, Falla (1950) recorded southern elephant seals during a seal survey when "the whole of the east coast was carefully searched and a few points along the west coast were examined from the sea". He found "in all five large bulls, about twenty cows, and about the same number of pups". Falla (Anon. 1950) and Turbott (1951) also recorded that the harems were small, consisting of 4 or 5 cows, and included both newly born and last year's pups. By the second week of November it is usual for more than half of the pups to be weaned, and it is therefore surprising that the numbers of cows and pups recorded at harem sites by the 1950 party are about equal. It is likely that they underestimated the total number of pups present through misidentifying weaned pups as yearlings. Mr E. G. Turbott (pers. comm.) agrees that this is possible, as his field notes describe the unattended "last year's pups" seen in Alert Bay on 7 November 1950 as "quite small and furry".

There are not enough comparable data to be categorical about any trends in the Antipodes Island population between November 1950 and November 1978. However, from the total numbers of cows seen on equivalent dates—about 20 in the second week of November 1950 (Falla 1950), and 24 at the same time of year in 1978—and from the presence of similar numbers of occupied breeding sites on the north-east coast in both years, it appears that the breeding population remained about the same.

DISCUSSION

Population changes

It is now very clear that there has been a major reduction over the last 40 years, almost to the point of local extinction, in the number of southern elephant seals breeding at Campbell Island. The astonishing 97% decrease between 1947 and 1986 cannot be considered without reference to the Macquarie Island stock as a whole. It is unlikely that numbers breeding at the Antipodes Islands increased during the same period. Elephant seal pup production remained fairly constant there between 1950 and the most recent census in 1978. The 104 pups counted at Antipodes Island in November 1978 were far in excess of the 54 found on Campbell Island 3 years earlier (Russ 1980), and the Antipodes may now have the largest breeding population of elephant seals in New Zealand.

The numbers of elephant seals at Macquarie Island have decreased since the 1950s. The total population at that time has been variously estimated at 110 000 (Carrick & Ingham 1962b) and 135 000 (McCann 1985). In the early 1970s numbers were

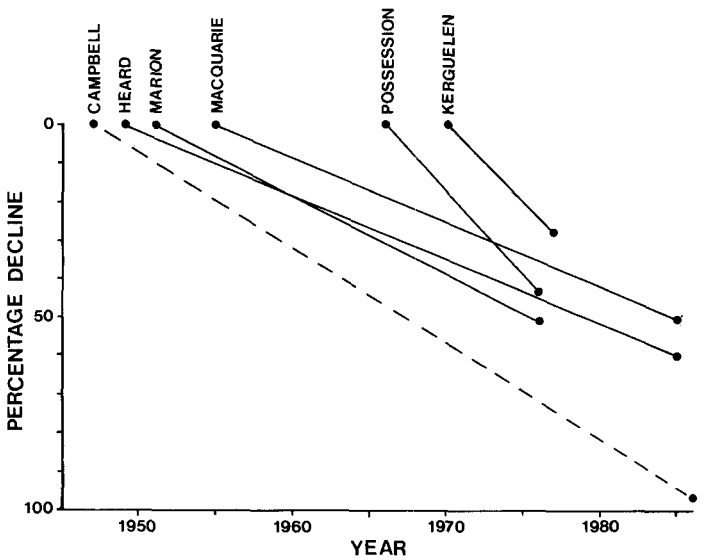

Fig. 5 Mean rates of population decline at Eastern Hemisphere breeding islands of the southern elephant seals. Note the relatively massive decline at the Campbell Island colony compared with the main Macquarie Island population.

said to be "stable and undisturbed" (Johnstone 1972), but more recently Fletcher & Shaughnessy (1984) concluded that not "anywhere near 110 000 elephant seals are to be found on the entire island today, and a serious census is long overdue". A census of elephant seals in 1985 and analysis of 21 previous counts confirmed a decrease over 36 years of between 45 and 55% in the number hauling out on the island (Hindell & Burton 1987).

The numbers of adult female seals moulting on Campbell Island during mid and late December 1986 were far in excess of the resident breeding population. Many of these may have come from Macquarie Island, as sightings at Campbell of animals branded at Macquarie indicate some movement of mature males and breeding females between the 2 islands (Nicholls 1970; Cawthorn et al. 1985; M. Cawthorn pers. comm.). The rapid emergence of a breeding population at Campbell Island, from none in the 1930s to peak numbers in the late 1940s, led Sorensen (1950) to postulate that this reflected an increase in the entire Macquarie Island stock, and that the elephant seals breeding at Campbell were an overflow from the Macquarie Island population. The apparent relationship between the subsequent decline at Macquarie Island and an even more dramatic decrease at Campbell Island supports Sorensen's "overflow" hypothesis.

Substantial declines in numbers of southern elephant seals have recently been reported from many other breeding grounds. Condy (1978) detected a 69.5% decline of the species on Marion Island between 1951 and 1976, and this continued at a reduced rate through to at least 1982 (Skinner & Van Aarde 1983). Van Aarde (1980) recognised a population decrease of 4.6% per year between 1970 and 1977 in the slowly fluctuating population at Kerguelen; Barrat & Mougin (1978) found a slightly steeper decline (5.7% per year) between 1966 and 1976 at Possession Island, Crozet Archipelago; and most recently, Burton (1986) has reported a 60% decrease in pup production at Heard Island over the last 36 years. These changes have occurred at both major and minor breeding grounds throughout the subantarctic zone of the Indian and South Pacific Oceans. Most seem to be in phase and to have sped up in recent years (Fig. 5). Many since 1970 are at rates varying from 4.6 to 8.0% per year (Skinner & Van Aarde 1983).

Elephant seal populations in the South Atlantic do not appear to be undergoing similar declines, apart from the suggestion of a "slight decrease" between 1955 and 1977 in the small population at Gough Island (Bester 1980). At South Georgia, where sealing ended in the 1950s, a recent island-wide census showed that the number of elephant seal pups produced in 1985 was almost the same (102 000), as the estimated number in 1951 (McCann & Rothery 1988).

Possible causes of decline

Condy (1984) considers that the common factors that may be affecting many southern elephant seal populations will be found at sea, perhaps well away

from the breeding grounds, and can best be investigated by a collaborative international effort. Such an approach is already underway in the South Indian Ocean (Bester & Jouventin 1984). Suggested explanations include: predation by killer whales (*Orcinus orca*) (Barrat & Mougin 1978; Condy 1978); competition with fur seals (*Arctocephalus* sp.) for local food resources (Condy 1978); changes in ocean temperatures and currents leading to altered availability of food (Burton 1986); and competition with humans for fish in winter feeding grounds (Condy 1978; Van Aarde 1980; Bester & Jouventin 1984; Burton 1986).

Barrat & Mougin (1978) hypothesised that predation on southern elephant seals by killer whales may have increased considerably after the decline of alternative prey in the form of baleen whales during the last 50 years, but very little is known on this aspect. Sorensen (1950) reported that many elephant seals hauled out on Campbell Island "with shocking wounds" which he thought were caused by killer whales, and in 1984–87 several elephant seals were seen at Campbell Island with extensive wounds on the body and head that could only have been inflicted by large predators, such as killer whales or white sharks (*Carcharodon carcharias*). Some predation on weaned elephant seal pups and yearlings by adult male Hooker's sea lions has been noted at Campbell Island (Wilson & Gaze 1983; Cawthorn et al. 1985), but this is unlikely to have affected elephant seal numbers there and, because of the limited range of Hookers sea lions, could not have caused the concurrent declines elsewhere.

Competition with expanding fur seal populations is unlikely to be significant in the Macquarie/Campbell Island region, where fur seals are still in relatively low numbers after the massive depredations of commercial sealing last century. The present level of fishing in the area around Campbell Island is low, and although it is an expanding trawl fishery for southern blue whiting (*Micromesistius australis*), hoki (*Macruronus novaezelandiae*), and ling (*Genypterus blacodes*), very little squid is harvested south of the Auckland Islands (King et al. 1985). Commercial fishing near New Zealand is, therefore, very unlikely to have affected the food supplies of southern elephant seals. Also, there has been no bycatch of these seals in trawl nets in New Zealand waters (M. Cawthorn pers. comm.), in contrast to the significant mortality of Hooker's sea lions caused by squid trawlers off the Auckland Islands (Owen 1984).

Mean monthly and annual surface air temperatures for Antarctica, the Southern Ocean, and the South Pacific Ocean (Jacka et al. 1984) show a rise since the mid 1960s at most of the antarctic and subantarctic island climate stations. Data from the South Indian Ocean area indicate that mean air temperatures at Kerguelen, and at other islands with long climatic records, have increased since the early 1960s. At Heard Island, glacial retreat has followed in the wake of a slight warming since the 1940s (Allison & Keage 1986). There is also evidence of recent climatic changes near Campbell Island. Salinger & Gunn (1975) and Salinger (1982) outline a warming in mean air temperatures (of 0.5°C since 1950) from stations in the New Zealand region (including Campbell Island) and cite changes in the frequency of snowstorms and air circulation patterns, and widespread glacier recession in the South Island, as supporting evidence.

This widespread trend of increasing air temperatures must be linked to the long-term warming of adjacent pelagic waters, already noted since 1930 in the sea-surface temperature anomaly for latitudes 30–50°S (Paltridge & Woodruff 1981).

Changes in ocean temperatures could affect the local availability of food for elephant seals and influence the survival of underyearlings. Little et al. (1987) argued that if food shortage was a major factor in the reduction of an elephant seal population, then it would be reflected in a reduced birth weight and growth rate of pups before weaning. After comparing growth data collected at Macquarie Island in 1956, 1965, 1984, and 1985, they concluded that the pups' pattern of growth has not altered significantly with time, and that this could support the view that there has not been a steady decline in the food available to pregnant cows. However, the reproductive strategy of the southern elephant seal means that the adult animals need not rely on food being abundant close to their breeding grounds. Both the cows and bulls fast from the time they arrive to pup and breed until after the young are independent. Thus, oceanographic changes close to a breeding island would have far less relevance to adult elephant seals than to other seals and marine birds that feed regularly while rearing their young.

It is possible that some of the environmental factors already mentioned have also contributed to the contemporary reductions in the populations of several seabird species breeding on Macquarie and Campbell Islands. Moors (1986) found a massive decline of rockhopper penguins (*Eudyptes chrysocome*) at Campbell Island over the last 40 years, and comparisons of photographs taken there by J. Sorensen in the 1940s with observations by

GAT between 1984 and 1986 indicate a very similar decline in the population of grey-headed mollymawks (*Diomedia chrysostoma*) and in some colonies of New Zealand black-browed mollymawks (*D. melanophris impavida*). However, although wandering albatrosses (*Diomedea exulans*) are currently decreasing at Macquarie Island, king penguins (*Aptenodytes patagonicus*) and royal penguins (*Eudyptes chrysolophus*) are increasing (Hindell & Burton 1987).

Considering the widespread nature of the decrease in elephant seal numbers throughout much of the Southern Hemisphere, we favour the suggestion that it is caused by a complex of ecological factors, including an altered availability of food in parts of the Southern Ocean due to shifts in oceanic temperatures and circulation patterns; and to increased predation on elephant seals brought about by these shifts and by the decline in whale populations. Newly independent pups (underyearlings) would be the age group most vulnerable to food shortages near the breeding grounds, and also to predation from killer whales or sharks.

Future research on southern elephant seals in New Zealand should include: regular censuses at all breeding sites at Campbell and Antipodes Islands and on the mainland; the individual marking of breeding bulls, cows, and pups to assess the amount of interchange between different sub-populations and the survival of different age groups, particularly weaned pups; study of food and the distribution of prey species; and study of the seasonal movements of elephant seals away from their breeding grounds.

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REFERENCES

Allison, I. F.; Keage, P. L. 1986: Recent changes in the glaciers of Heard Island. *Polar record 23*: 255–271.

Anonymous 1950: Party completed detailed survey of outlying islands. Interview with R. A. Falla. *Evening Star* Dunedin, 15 November.

Bailey, A. M.; Sorensen, J. H. 1962: Subantarctic Campbell Island. Proceedings, Denver Museum of Natural History, 10. 305 p.

Barrat, A. ; Mougin, J. L. 1978: L'elephant de mer *Mirounga leonina* de l'île de la Possession, archipel Crozet (46°25'S, 51°45'E). *Mammalia 42*: 143–173.

Beck, R. H. 1928: Beck's letters and journal, December 1923 - February 1928. Unpublished volume in Ornithology Library, American Museum of Natural History, New York.

Bester, M. N. 1980: The southern elephant seal *Mirounga leonina* at Gough Island. *South African journal of zoology 15*: 235–239.

Bester, M. N.; Jouventin, P. 1984: Rationale and Strategy for a collaborative research programme between SASCAR and TAAF on pinnipeds inhabiting South Indian Ocean islands (the Kerguelen Province). *South African journal of science 80*: 32–34.

Bowring, L. D.; Stonehouse. B. 1968: Birth of elephant seal (*Mirounga leonina*) in New Zealand. *New Zealand journal of marine and freshwater research 2*: 574–575.

Burton, H. 1986: A substantial decline in numbers of the southern elephant seal at Heard Island. *Tasmanian naturalist* July: 4–8.

Carrick, R.; Csordas, S. E.; Ingham, S. E.; Keith, K. 1962a: Studies of the southern elephant seal, *Mirounga leonina* (L). III. The annual cycle in relation to age and sex. *CSIRO wildlife research 7*: 119–160.

Carrick, R.; Csordas, S. E.; Ingham, S. E. 1962b: Studies on the southern elephant seal, *Mirounga leonina* (L). IV. Breeding and development. *CSIRO wildlife research 7*: 161–197.

Carrick, R.; Ingham, S. E. 1962a: Studies on the southern elephant seal, *Mirounga leonina* (L). I. Introduction to the series. *CSIRO wildlife research 7*: 89–101.

————1962b: Studies on the southern elephant seal, *Mirounga leonina* (L). V. Population dynamics and utilization. *CSIRO wildlife research 7*: 198–206.

Cawthorn, M. W. 1981: New Zealand's cetaceans and pinnipeds. *New Zealand veterinary journal 29*: 192–193.

Cawthorn, M. W.; Crawley, M. C.; Mattlin, R. H.; Wilson, G. J. 1985: Research on pinnipeds in New Zealand. WRLG review 7, Wildlife Research Liaison Group, Wellington. 29 p.

Condy, P. R. 1978: The distribution and abundance of southern elephant seals *Mirounga leonina* (Linn.) on the Prince Edward islands. *South African journal of antarctic research 8*: 42–48.

———1984: The population of southern elephant seal, *Mirounga leonina*, at Marion Island, 1973–1983. *South African journal of science 80*: 26–27.

Cumpston, J. S. 1968: Macquarie Island. Australian National Antarctic Research Expedition scientific reports, series A (1) publication no. 93. Melbourne, Antarctic Division, Department of External Affairs. 380 p.

Daniel, M.; Baker, A. 1986: Collins guide to the mammals of New Zealand. Auckland, Collins. 228 p.

Davies, J. L. 1961: Birth of an elephant seal on the Tasmanian coast. *Journal of mammalogy 42*: 113–114.

Department of Lands and Survey 1983: Management plan for the Campbell Islands Nature Reserve. Wellington, Department of Lands and Survey. 77 p.

Erickson, A. W.; Hofman, R. J. 1974: Antarctic seals. *In*: American Geographical Society, antarctic map folio series 18, antarctic mammals, pp. 4–13.

Falla, R. A. 1950: Unpublished. Letter to Secretary of Marine, 18 December 1950. New Zealand Marine Department files, New Zealand National Archives.

———1965: Birds and mammals of the subantarctic islands. *Proceedings of the New Zealand Ecology Society 12*: 63–68.

Falla, R. A.; Taylor, R. H.; Black, C. 1979: Survey of Dundas Island, Auckland Islands, with particular reference to Hooker's sea lion (*Phocarctos hookeri*). *New Zealand journal of zoology 6*: 347–355.

Fletcher, L.; Shaughnessy, P. 1984: The current status of seal populations at Macquarie Island. *Tasmanian naturalist* October: 10–13.

Gaskin, D. E. 1972: Whales, dolphins and seals with special reference to the New Zealand region. London, Heinemann. 200 p.

Gibb, J. A.; Flux, J. E. C. 1973: Mammals. *In*: Williams, G. R. *ed.*, The natural history of New Zealand, pp. 334–371. Wellington, Reed.

Grob, R. 1985: Seals on southern coasts creates interest. *Catch 12*: 18–19.

Heath, R. A. 1985: A review of the physical oceanography of the seas around New Zealand—1982. *New Zealand journal of marine and freshwater research 19*: 79–124.

Hindell, M. A.; Burton, H. R. 1987: Past and present status of the southern elephant seal (*Mirounga leonina*) at Macquarie Island. *Journal of zoology, London 213*: 365–380.

Jacka, T. H.; Christou, L.; Cook, B. J. 1984: A data bank of mean monthly and annual surface temperatures for Antarctica, the Southern Ocean and South Pacific Ocean. *ANARE research notes 22*.

Johnstone, G. W. 1972: A review of biological research by Australian National Antarctic Research Expeditions, 1947-71. *Polar record 16*: 519–532.

Kerr, I. S. 1976: Campbell Island. A History. Wellington, Reed. 182 p.

King, M. R.; Robertson, D. A.; McCormick, J.; Fisher, K. A. 1985: New Zealand deepwater trawl fishery statistics, 1978–80. *Fisheries Research Division occasional publication. Data series 19*.

Laws, R. M. 1960: The southern elephant seal (*Mirounga leonina* Linn.) at South Georgia. *Norsk hvalfangst-tidende 49*: 466–476; 520–542.

———1979: Southern elephant seal. *In*: Mammals in the seas: Pinniped species summaries and report on sirenians. *FAO fisheries series no. 5, vol. II*: 106–109.

Lenglart, P. Y.; Bester, M. N. 1982: Post-weaning dispersion of southern elephant seal *Mirounga leonina* underyearlings at Kerguelen. *Revue d'ecologie (terre et la vie) 36*: 175-186.

Ling, J. K.; Bryden, M. M. 1981: Southern elephant seal *Mirounga leonina* Linnaeus, 1758. *In*: Ridgway, S. H.; Harrison, R. J. *eds.*, Handbook of Marine Mammals, vol. 2: Seals. pp. 297–327. London, Academic Press.

Little, G. J.; Bryden, M. M.; Barnes, B. 1987: Growth from birth to 20 days in the elephant seal, *Mirounga leonina*, at Macquarie Island. *Australian journal of zoology 35*: 307–312.

Lydekker, R. 1909: On the skull characters in the southern sea-elephant. *Proceedings of the Zoological Society of London 1909*: 600–606.

McCann, T. S. 1985: Size, status and demography of southern elephant seal (*Mirounga leonina*) populations. *In*: Ling, J. K.; Bryden, M. M. *eds.*, Studies of sea mammals in south latitudes. pp. 1–17. Adelaide, South Australian Museum.

McCann, T. S.; Rothery, P. 1988: Population size and status of the southern elephant seal (*Mirounga leonina*) at South Georgia, 1951–1985. *Polar biology 8*: 305–309.

Mills, J. A.; Ryder, J. P.; Shaw, P. W.; McLay, R. 1977: Further birth records of elephant seals *Mirounga leonina* in New Zealand (Note). *New Zealand journal of marine and freshwater research 11*: 789–791.

Moors, P. J. 1986: Decline in numbers of rockhopper penguins at Campbell Island. *Polar record 23*: 69–73.

Nicholls, D. G. 1970: Dispersal and dispersion in relation to the birth site of the southern elephant seal, *Mirounga leonina* (L.), of Macquarie Island. *Mammalia 34*: 598–616.

Owen, S. J. 1984: The New Zealand sea lion—a problem of bycatch. *Forest and bird 15*: 34–35.

Paltridge, G.; Woodruff, S. 1981: Changes in global surface temperature from 1880 to 1977 derived from historical records of sea surface temperature. *Monthly weather review 109*: 2427–2434.

Russ, R. 1980: New Zealand sea lion, sea elephant, and fur seal census and habitat survey, Campbell Island group. *In*: Preliminary Reports of the Campbell Island Expedition 1975–76, pp. 124–125. Wellington, Department of Lands and Survey.

Salinger, M. J. 1982: On the suggestion of post-1950 warming over New Zealand. *New Zealand journal of science 25*: 77–86.

Salinger, M. J.; Gunn, J.M. 1975: Recent climatic warming around New Zealand. *Nature 256*: 396–398.

Scott, J. H. 1882: The fauna and flora of Macquarie Island. *Transactions of the New Zealand Institute 15*: 484–493.

Skinner, J. D.; Van Aarde, R. J. 1983: Observations on the trend of the breeding population of southern elephant seals, *Mirounga leonina*, at Marion Island. *Journal of applied ecology 20*: 707–712.

Sorensen, J. H. 1950: Elephant seals of Campbell Island. Cape Expedition series bulletin 6. Wellington, Department of Scientific and Industrial Research. 31 p.

————1951: Wildlife in the Subantarctic. Christchurch, Whitcombe & Tombs. 85 p.

————1969: New Zealand seals with special reference to the fur seal. Wellington, New Zealand Marine Department. *Fisheries technical report 39*. 35 p.

Spence, A. 1968: A story of the Campbell Islands. *Tussock Grasslands and Mountain Lands Institute review 15*: 63–75.

Taylor, R. H. 1969: Summary of studies carried out on Campbell and Antipodes Islands while with the University of Canterbury Antipodes Island Expedition, 1969. Unpublished DSIR Ecology Division file report.

————1979: Seals at the Bounty and Antipodes Islands. Unpublished DSIR Ecology Division file report.

————1982: New Zealand fur seals at the Bounty Islands. *New Zealand journal of marine and freshwater research 16*: 1–9.

Turbott, E. G. 1951: Antipodes penguins were not amused. *The weekly news*, January 24: 22.

————1952: Seals of the southern ocean. *In*: Simpson, F. A. *ed.*, The Antarctic today, pp. 195–215 Wellington, Reed.

Tyson, R. M. 1977: Birth of an elephant seal on Tasmania's east coast. *Victorian naturalist 94*: 212–213.

Van Aarde, R. J. 1980: Fluctuations in the population of southern elephant seals *Mirounga leonina* at Kerguelen Island. *South African journal of zoology 15*: 99–106.

Warneke, R. M. 1982: The distribution and abundance of seals in the Australasian region, with summaries of biology and current research. Small cetaceans, seals, sirenians and otters. *In*: Mammals in the seas. *FAO fisheries series no. 5, vol. IV*: 431–475.

Wilson, P. R.; Gaze, P. D. 1983: Report to Lands and Survey Department on a short visit to Campbell Island, 1–10 April 1983. Unpublished DSIR Ecology Division file report.