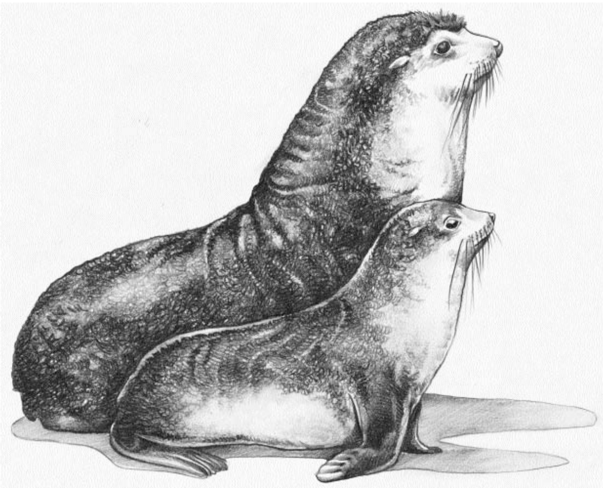
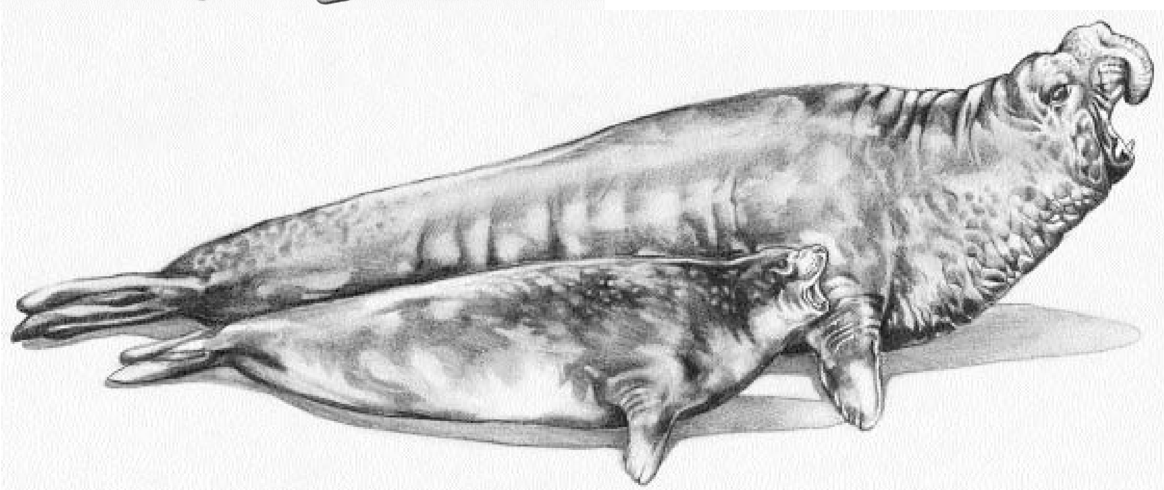
Biology, threats and conservation status of the SUB-ANTARCTIC FUR SEAL AND SOUTHERN ELEPHANT SEAL in Australian waters





Australian Government

Department of the Environment and Heritage

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The recovery plan linked to this paper is obtainable from:

www.deh.gov.au/biodiversity/threatened/recovery/seals

or:

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List of abbreviations

AAD	Australian Antarctic Division
AAT	Australian Antarctic Territory
ACW	Antarctic Circumpolar Wave
AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
ANARE	Australian National Antarctic Research Expedition
AMSA	Australian Maritime Safety Authority
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CCAS	Convention for the Conservation of Antarctic Seals
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department of the Environment and Heritage
DPIWE	Department of Primary Industries, Water and Environment
DTPHA	Department of Tourism, Parks, Heritage and the Arts
ENSO	El Niño Southern Oscillation
EEZ	Australian Exclusive Economic Zone
EPBC Act	*Environment Protection and Biodiversity Conservation Act* 1999
FRDC	Fisheries Research and Development Corporation
IUCN	International Union for the Conservation of Nature
IUU	Illegal, Unreported and Unregulated
HIMI	Heard Island and McDonald Island
MACC	Ministerial Advisory Committee on Co-operation
MARPOL	The International Convention for the Prevention of Pollution from Ships
MPA	Marine Protected Area
NSSG	National Seal Strategy Group
PCB	polychlorinatedbyphenyl
SAFAG	Sub-Antarctic Fisheries Stock Assessment Group
SETFIA	South East Trawl Fishery Industry Association
SED	Seal exclusion device
SCAR	Scientific Committee for Antarctic Research
TAC	Total Allowable Catch
TSSC	Threatened Species Scientific Committee

Summary

The subantarctic fur-seal *Arctocephalus tropicalis* and southern elephant seal *Mirounga leonine* are carnivorous marine mammals of the southern ocean. In Australian waters, both species breed and haul out mainly on Macquarie and Heard Islands, but individuals range widely and occasionally reach the beaches of Tasmania and the Australian mainland. Both species are listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EBPC Act). Both seal species survived a period of severe over-harvesting close to two centuries ago and populations are still recovering. The species now face potential new, less palpable, human-related threats.

The purpose of this document is to:

- Summarise knowledge on the biology of the species;
- Describe the distribution, abundance and habitat requirements of the species;
- Review the conservation status and identify threats to the species and their habitats; and
- Underpin the National Recovery Plan for the species.

This document does not recommend actions necessary for the recovery of the species. These issues are covered by a recovery plan for the species, which can be found at: www.deh.gov.au/biodiversity/threatened/recovery/seals.

Among the many potential threats to both seal populations are competition and interaction with legal and illegal fisheries, marine pollution of various kinds, including oil and non-biodegradable debris, climatic and oceanographic change, increased predation, disease outbreaks, and direct disturbance from tourism, research and ignorant interference. At present, none of these, with the possible exception of climatic and oceanographic change, appear to present a significant threat to populations of either the sub-Antarctic or southern elephant seal, however they pose real risks to some individuals.

Although trends can only be detected in the long-term, there is some evidence that southern elephant seal populations are no longer decreasing. The sub-Antarctic fur seal presents unique problems because of natural small population processes, which include hybridization and introgression, and the possibility that immigration may be maintaining the population. The species' future in Australia is uncertain and questions about its past status in the region cloud the issue.

In the Australian region, important breeding sites are Macquarie Island for the fur seal and Macquarie, Heard and potentially Maatsuyker Islands for the southern elephant seal. Both species are generally well protected on Macquarie and Heard Islands.

Part A: Species information

1. Species details: Sub-Antarctic fur seal

1.1 Description of species and taxonomy

The sub-Antarctic fur seal *Arctocephalus tropicalis* is a carnivorous marine mammal of the cold Southern Ocean. In Australian waters, it breeds, moults and hauls out mainly on Macquarie Island, but individuals range widely and occasionally reach the beaches of Tasmania and mainland Australia.

The fur seal belongs to the Order Carnivora and the family Otariidae, or 'eared' seals. The Otariids (i.e. fur seals and the sea lions) have a small external ear, large neck and typical carnivore dentition (bear-like). When swimming, their front flippers are the main source of propulsion. On land, they fold their hind limb forward and use all four limbs to walk with reasonable agility.

Within the region, the sub-Antarctic fur seal has three close congeners: the New Zealand fur seal *A. forsteri*, Antarctic fur seal *A. gazella* and the Australian fur seal *A. pusillus doriferus*. Like all fur seals, the sub-Antarctic fur seal has dense body fur beneath a sleek covering of guard hairs (Goldsworthy and Shaughnessy 1995; Goldsworthy *et al*. 1999). It is chocolate brown with a contrasting yellow face and chest and long white vibrissae (sensory whiskers). Sub-Antarctic fur seals are the smallest of the seals in Australian waters. Adult females reach approximately 100-140 cm and 30-55 kg, and are smaller than adult males, which reach approximately 150-200 cm head to tail and 95-165 kg. Adult females can also be distinguished from adult males as the latter have a thick mane, barrel chest, broad shoulders, darker brown dorsum (back) and richer, yellow ventrum (underparts). Pups are glossy-black with a dark chocolate brown belly. The species can be distinguished from other similar seals by its pale yellowish underparts contrasting darker upperparts, and also by the distinctive 'mo-hawk' crest of the adult males. Pups tend to be darker than those of other local species (Menkhorst and Knight 2001).

1.2 Population estimates at colonies

Although isolated births have been recorded on Heard Island since 1987 (Goldsworthy and Shaughnessy 1989a, b), the only established breeding colony in Australian territory is on Macquarie Island.

At Macquarie Island, some 200 000 fur seal skins were taken, and the colony was extirpated within roughly ten years of its discovery in 1810. (Ling 1999a; Cumpston 1968; Goldsworthy and Shaughnessy 1995). It is uncertain whether sub-Antarctic or Antarctic fur seals were being harvested (Shaughnessy and Fletcher 1987). In part, this is because the two species were not formally recognised as being separate until 1925 (Wood Jones 1925). Nevertheless, the timing of the harvest (during winter), suggests it was more likely that sub-Antarctic fur seals were being removed, since Antarctic fur seals are thought to desert the island during the winter months (Shaughnessy and Fletcher 1987).

Fur seals began to breed again on Macquarie Island in about 1955 (Shaughnessy and Goldsworthy 1993). By the mid 1990s, the Macquarie Island sub-Antarctic fur seal population was estimated at between 90 and 130 individuals, with a growth rate of 10% per anum; a slower recovery than experienced elsewhere (Goldsworthy and Shaughnessy 1995). However, this estimate is confounded by the extent of hybridization and back-crossing with Antarctic fur seals (see Section C2.11, Lancaster 2001). Recent DNA analysis has indicated that there are critically low numbers of pure sub-Antarctic fur seal stock in the population, with only 10 (4%) of 259 animals sampled being non-hybrid/backcrossed sub-Antarctic fur seals (Goldsworthy 2002).

World-wide, the sub-Antarctic fur seal is considered to be recovering following a period of widespread exploitation (see Table 1). The estimated world population is currently 277 000 - 356 000 individuals (Hofmeyr *et al*. 1997).

Table 1 Estimated size and trends of sub-Antarctic fur seal populations worldwide (from Hofmeyr *et al*. 1997)

Site	Pup numbers	Total population	Year of census	Mean annual increase	Reference
Macquarie Island	164[a]		1992/1993	13.3% (1954/1955–2000/2001)[a]	Shaughnessy (1993)
Heard Island	1	13	1987/1988		Goldsworthy & Shaughnessy (1989a)
Ile Amsterdam	>9638[b]		1992/1993	0.4% (1981/1982–1992/1993)[f]	Guinet *et al*. (1994)
Ile Saint Paul	365		1992/1993	23.8% (1984/1985–1992/1993)[f]	Guinet *et al*. (1994)
Ile de la Possession (Iles Crozet)	190		1990/1991	21.6% (1978–1991)[f]	Guinet *et al*. (1994)
Marion Island	10,137[c,d]	48,658[e]	1994/1995	1.8% (1988/1989–1994/1995)	Present study
Prince Edward Island	5,372[c,d]	25,786[e]	1988/1989	9.7% (1981/1982–1988/1989)	Wilkinson and Bester (1990)
Gough Island	>53,076[b,c,d]	200,000[e]	1988/1989	14.9% (1955–1977/1978)[f]	Bester (1987, 1990)
Tristan da Cunha	50	250	1993/1994		C. Glass (pers comm)
Nightingale and Inaccessible Islands (Tristan da Cunha Group)		600			Swales (1956)

[a] For populations of both *A. tropicalis* and *A. gazella* and hybrids including those with *A. forsteri* (Goldsworthy 2002)

[b] Extrapolation based on a proportion of the total populated area

[c] Corrected for observer undercount

[d] Corrected for pre-count mortality

[e] Estimated from pup total

[f] Recalculated from population values in publication

1.3 Social organization and breeding

Like all pinnipeds, the sub-Antarctic fur seal comes ashore to mate, give birth and nurse their young. The species is polygynous (i.e. the male mates with more than one female in a single breeding season), and gregarious, congregating annually at traditional breeding sites.

Beginning in November, adult males return to breeding sites to establish territories. The largest and most aggressive males compete vigorously for territories, which may contain 4-12 females (Goldsworthy *et al*. 1999). The number of males ashore at any one time increases through October and November. Females are gregarious and males discourage them from leaving the territory. Subordinate bulls and bachelors are forced to the fringes of colonies, but sometimes obtain mating opportunities.

From late November to February, female sub-Antarctic fur seals haul out to give birth to a single pup, with a peak in births at around 10-15 December (Goldsworthy and Shaughnessy 1995). Newborn pups are 65 cm long and weigh 4-5kg. Twins are rarely born (Bester and Kerley 1983). Females give birth one year after mating, and will mate again seven to 12 days after pups are born. Implantation is delayed for four months before a gestation period of eight months (Bester 1995).

Soon after mating, females leave the colony to feed at sea and will alternate between periods ashore nursing their pups and foraging trips. The length of trips will depend on colony location and feeding opportunities, but trips can extend for up to one month (e.g. at Amsterdam Island; Georges and Guinet 2000). On Macquarie Island, females with pups make short, nightly trips of around eight hours, interspersed with more extended foraging journeys averaging 3.8 days (Goldsworthy 1999a). During pup-raising, females spend 25% of their time in overnight foraging trips and 38% of their time ashore in either short (mean 0.5 day) or long (mean 1.7 day) bouts of pup attendance.

Milk is high-energy, containing about 39% fat, and sustains the pup through periods of maternal absence, although pups are sometimes able to obtain milk from other cows (Goldsworthy and Crowley 1999). Growth rates have been documented by Kerley (1985) and Bester and Van Jaarsveld (1997). The pups grow until about 220 days of age, before dropping some weight prior to weaning at about 280 (± 30) days. At around three months of age, pups moult from black into their adult pelage of a dark brown back and creamy yellow face and chest. Maternal investment in the form of milk is equal for male and female pups, even though as adults, females are smaller than males, implying a relatively greater metabolic cost of growth in female pups as is typical for other highly dimorphic species (Guinet *et al*. 1999; review in Trillmich 1996).

By mid-December, first-time breeders will have mated and left the colony (Goldsworthy and Shaughnessy 1995). Adults moult between March and May (King 1983).

1.4 Reproductive success

World-wide, at least 80 000 pups are born annually (Table 1; Hofemyr *et al*. 1997). On Macquarie Island, 25 pups were reportedly born during 1995 (Goldsworthy 1996), 19 during 1996 (to 22 cows; Goldsworthy *et al*. 1999) and 29 during 1999 (TSSC 2001a). However, these estimates are questionable given the possible extent of hybridization and backcrossing within the population, and a more conservative estimate is that less than ten purebred pups are born per annum on Macquarie Island (Goldsworthy 2002).

Cooler autumn sea surface temperatures (March-May) are associated with improved breeding success and pup growth, presumably because of increased prey abundance (Goldsworthy *et al*. 2001b).

1.5 Sexual maturity and life expectancy

Female sub Antarctic fur seals become sexually mature at 4-6 years of age (Bester 1995) and males at 4-8 years (Bester 1987). However, males do not usually secure a territory until they are over seven years of age, with an average of 10-11 years (Bester 1987, 1990). Individual females have lived to 23 years of age and males to over 18 years.

1.6 Mortality

Killer whales *Orcinus orca* are quite common around Macquarie Island (DPWH 1991) and are known to prey on sub Antarctic fur seal pups and adults, but little is known of mortality patterns. During the 1996-1997 summer on Macquarie Island, a visiting Hooker's sea lion *Phocarctos hookeri* was implicated in 64% of pup deaths, equivalent to 43% of the cohort from all fur seal species (Robinson *et al*. 1999).

Annual pup mortality at Macquarie Island has been reported to vary from 16% in 1994 to 64% in 1996, averaging 30% for pups of about three months of age (Goldsworthy 2002). This is high compared with other, higher density Antarctic fur seal populations, which have reported mortality rates of 3-6% (Doidge *et al*. 1984; Shaughnessy and Goldsworthy 1990).

1.7 Foraging and diet

The sub-Antarctic fur seal forages mainly at night on surface, mid-water and bottom dwelling fish, squid and octopus. The diet varies seasonally and according to location (eg, Bester and Laycock 1985). Rockhopper penguins *Eudyptes chrysocome* are summer fare at least on Amsterdam Island (Bonner 1981; King 1983). On Macquarie Island the sub-Antarctic fur seal apparently feeds almost solely on myctophid (lantern) fish, mostly *Electrona subaspera*, which migrate vertically, rising during the night where the seals often catch them at depths of 10-20 m, but occasionally at 80 m below the surface (Green *et al*. 1990; Shaughnessy and Goldsworthy 1993; Goldsworthy and Shaughnessy 1995; Goldsworthy *et al*. 1997; Robinson *et al*. 2002). Sub-Antarctic fur seals are known to forage at oceanographic frontal zones where food is expected to be most abundant. At Macquarie Island, lactating cows concentrated their foraging trips in two areas; 30 km and 100 km north of the island (Robinson 2002; Robinson *et al*. 2002). Shorter, overnight trips are usually within 10 km of the island.

Lactating cows are estimated to have nutritional needs 1.5-1.8 times those of non-lactating females (Costa 1991). Their lipid-rich milk supports rapid growth and storage of blubber as a source of energy to sustain pups while cows are on foraging trips. Pups may also drink sea (mariposia) and fresh water to lessen the physiological impact of fasting (Lea *et al*. 2002) even though they probably adopt a protein-sparing strategy as the fast progresses (as in Antarctic fur seal pups; Arnould *et al*. 2001).

1.8 Long-range movements

The sub-Antarctic fur seal is thought to be resident, but long movements of up to 3 000 km have been recorded from dispersing juveniles and adult males. Further, the individual fur seals recolonising Macquarie Island following sealing must have originated from islands in the South Indian Ocean, located some 5 500 km distant, possibly assisted from east-flowing circulation generated by the West Wind Drift (Goldsworthy and Shaughnessy 1995, Menkhorst 1995).

Lactating females can forage up to 530 km from their breeding colony (Goldsworthy 1999a; Robinson *et al*. 2002). Dispersing juveniles from Macquarie Island are thought to occasionally find their way to southern Australian beaches (Gales *et al*. 1992; also see section B1).

2. Species details: Southern elephant seal

2.1 Description of species and taxonomy

The southern elephant seal *Mirounga leonina* is a carnivorous marine mammal of the cold Southern Ocean. In Australian waters it breeds, moults and hauls out mainly on Macquarie and Heard Islands, but individuals range widely and occasionally reach the beaches of Tasmania and mainland Australia.

The southern elephant seal belongs to the 'true' seals, family Phocidae. The phocids are unable to 'walk' using their fore flippers. Rather, they move on their belly in a lunging, caterpillar-like motion. On land, their short forelimbs offer little support to the huge body and their backward projecting hind limbs are of little use for locomotion. In the water, they propel themselves by moving their hind flippers left and right. They lack an external ear, and have a streamlined neck and varied dentition.

The southern elephant seal has no congeners in the region, but other members of the family that enter Australian waters include the leopard seal *Hydrurga leptonyx* and crab-eater seal *Lobodon carcinophagus*.

The largest of the pinnipeds, the bulky male southern elephant seal reaches over 4 m from head to tail and can weigh almost 4 000 kg (Bryden 1995) although size can vary somewhat between localities. Adult males often have intensive scarring on the neck and carry a prominent erectile proboscis, or trunk, which gives the species its common name and adds resonance to the male's vocal challenges to other bulls. Females are much smaller than males, weighing as little as 10% of male weight (usually 200-260 cm and 250-350 kg). Females lack the intensive scarring and prominent proboscis of adult males. Females and young males have a robust body, large eyes and bulbous nostrils, giving them a pug-like appearance (Menkhorst and Knight 2001). On land both sexes are brown above, slightly paler below, and in water they appear uniformly dark grey. Pups are black. The species can be distinguished from other true seals in the region, as other species are paler or have spots or streaks which elephant seals lack.

2.2 Population estimates at colonies

In Australia, hunting of southern elephant seals for the oil in their blubber started in the late 1800s and continued until 1920 (Daly 1994; Ling 1999), by which time the population at Macquarie Island, originally estimated at 93 000-110 000 animals, had been reduced by 70%. After cessation of sealing, populations began to recover. At Macquarie Island, numbers had recovered by about 1913 (Hindell and Burton 1988a; Burton and van den Hoff 2002). Pyke (1999) reviews the history of sealing and its impact on populations at Heard Island. The species has not yet returned to King Island, Bass Strait, where the estimated population prior to sealing was 10 000-17 000 individuals (Micco 1971; Ling 1999b).

During the 1950's, southern elephant seal populations again declined significantly, almost across their entire range (Laws 1994). At Macquarie Island, the population declined by 59% from approximately 183 000 animals in 1949 (Hindell and Burton 1987), and the Heard Island population declined by 50% (Burton 1986). The Macquarie Island population continued to decrease from the late 1980s through the 1990s, at a rate of 0.8% annually (Bradshaw *et al*. 2002b). The cause of this decline is largely unknown.

In recent years, the Macquarie Island population has apparently ceased its decline (Figure 1; Table 2; McMahon *et al*. a in review). The Heard Island population also appears to have stabilised, although monitoring on Heard Island has been more erratic (Table 2; Hindell and Slip 1997; Slip and Burton 1999).

Southern elephant seals have been relatively uncommon in Tasmanian waters since sealers extirpated the breeding population there in the early 19th century. However, data collected over the last 25 years suggest there has been a partial recovery, with at least six pups born on Maatsuyker Island since 1975. Elephant seals of both sexes and varying age classes have been recorded at this location in most years (Nature Conservation Branch, DPIWE; Rosemary Gales pers. comm.).

In 2002, the species' global population was estimated at 740 000 individuals, an overall decrease of 20% since the 1950s. However, this figure represents stabilization, if not a recovery of about 11% since the 1990s (Table 2, from McMahon *et al*. a in review). The Australian populations represented 27% of the world population of southern elephant seals prior to 1970, but this proportion fell to 18 and 19% in the 1990s and 2001, respectively.

At the time of listing under the *Environment Protection and Biodiversity Act 1999* (EPBC ACT), it was estimated that if the decrease of the Australian populations of southern elephant seals continued the species would be extinct in Australian jurisdiction within 100 years (TSSC 2001b). However, recent modelling of trends in the female population is more optimistic, and predicts a low probability of extinction (McMahon *et al*. b in press). This modelling has employed a projected stochastic Leslie-matrix model, based on long-term demographic data, to examine how different life history parameters contributed to population declines. Results suggested that small changes in survival and fecundity could have dramatic effects on population growth rates. At Macquarie Island for example, a small change (circa 5%) in survival and fecundity rates resulted in a reversal of population trends, from decreasing to increasing. The life history parameters found to have the greatest impact on population growth were, in order of importance: (1) juvenile survival, (2) adult survival, (3) adult fecundity and (4) juvenile fecundity. Population viability analysis revealed that the probability of extinction of southern elephant seals at Macquarie Island was low, with an estimated mean time to extinction of 564 years (the minimum time to extinction was 307 years).

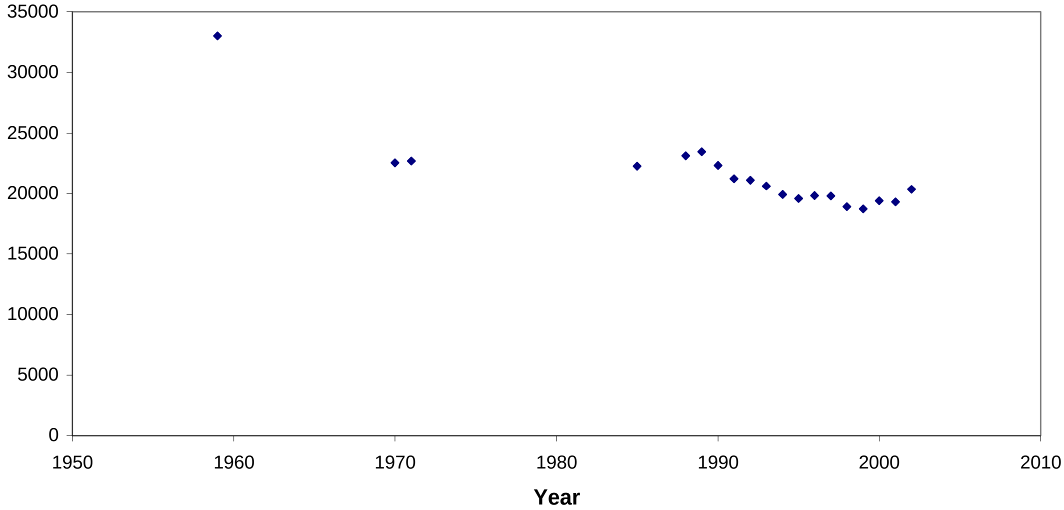


Figure 1 Annual census numbers of adult female southern elephant seals on Macquarie Island at the time of maximum haul-out, about October 15th (data from Harry Burton and Mark Hindell)

Table 2 The estimated population sizes of southern elephant seals worldwide in 2001 (from McMahon *et al*. in press). The pre-1970s estimates are from McCann (1985) and the estimates for the 1990s are from Laws (1994a)

Population	Sub-population	Estimated population size pre-1970s	1990s	2001	Reference	Trend since 1990s
South Georgia	South Georgia	350,000	357,000	397,054	Boyd *et al*. 1996	Stable
	South Orkney Is	350	20	20	Laws 1994b	Unknown
	South Shetland Is	1,050	2,300	2,300	Laws 1994b	Unknown
	Falkland Is	3,500	3,500	1,827	Galimberti and Boitani 1999	Stable
	Gough Is	350	105	63	Bester *et al*. 2001	Increase?
	Bouvet Is			308	Kirkman *et al*. 2001	
Kerguelen	Kerguelen Isles	157,500	143,500	153,237	Guinet *et al*. 1999	Stable
	Heard Is	80,500	40,355	61,933	Slip and Burton 1999	Stable?
	Marion Is	3,850	2,009	2,131	Bradshaw *et al*. 2002b	Decrease
	Prince Edward Is			782		Unknown
	Isles Crozet & Possession Is	10,500	2,023	1,995	Guinet *et al*. 1999	Stable
Macquarie	Macquarie Is	136,500	77,791	76,000	H. Burton pers. comm.	Decrease?
	Antipodes Is		400	249	Anon. 2001	Decrease
	Campbell Is	455	20	<10		Decrease
Peninsula Valdés	Peninsula Valdés	13,800	33,726	42,371	Lewis *et al*. 1998	Increase
World population		*757,900*	*663,531*	*739,498*		*Increase?*

2.3 Social organization and breeding

Like all pinnipeds, the southern elephant seal comes ashore to mate, give birth and nurse their young (Hindell 2002). The species is polygynous and gregarious, congregating annually at traditional breeding sites. The largest and most aggressive males compete vigorously for territories containing several adult females. Subordinate bulls and bachelors are forced to the fringes of colonies but sometimes obtain mating opportunities. Females give birth one year after mating, so that births take place on land prior to mating.

On Macquarie Island, the southern elephant seal breeds from September to early November (Hindell and Burton 1988b). Bulls begin to come ashore in late August to establish territories and are followed about a month later by pregnant females. The largest, most experienced males (about 2-3% of males each year) attempt to gather and control harems of up to 100 females, and spend much time defending cows from rival males. Assistant bulls may patrol sections of the largest harems.

Pups are born in September and October, usually within 10 days of cows coming ashore (Carrick *et al*. 1962). Typically, a single pup is born, but twins have been recorded (Bryden 1966) and accounted for 0.4% of births on Macquarie Island in 1999 (McMahon and Hindell 2003). Pups are about 1.3 m long at birth and on Macquarie Island males weigh about 42 kg and females 38 kg (McMahon *et al*. 1997). The cows remain on the beach to suckle their pups for 20 to 25 days (Little *et al*. 1987).

Up to five days before weaning their pup, but mostly within three days, the cows will mate. At weaning, cows abandon their pups and return to the sea. The new blastocyst goes through a free stage before implanting in about late February, for a gestation period of eight months.

The bulls often stay ashore longer than cows, sometimes up to 90 days. When ashore, males do not feed and may lose 40 % of their body weight, or about 12 kg per day.

Pups moult from a black natal fur to shorter, silver grey fur at 3-4 weeks during suckling. After weaning they fast for about seven weeks, then improve their aquatic skills in pools and shallows before heading to sea at 10 weeks of age. Pups vary enormously in their fat reserves, some being three times the weight of others.

After returning to sea, adults of both sexes spend a period feeding intensively to rebuild reserves, before coming ashore for 30-40 days in January-February for the moult. Some bulls moult on the Antarctic continent (van den Hoff *et al*. 2003 in press), however most seals return to their breeding colony, such as at Macquarie Island, where they lie in deep mud wallows, which become quite warm and appear to hasten moult so that the animals can spend minimal time ashore (Ling and Bryden 1981).

2.4 Reproductive success

At Heard Island, pup production is documented as having fell from 31 827 in 1949, to 13 111 during 1985 (Burton 1986). In 1992, pup production at Heard Island was estimated as 17 927 ± 455 (Slip and Burton 1999). At Macquarie Island, about 19 000 pups are estimated to be born per annum (Geof Copson pers. comm.).

Studies elsewhere indicate that per capita food supply is likely to be the main determinant of pupping success (Bradshaw *et al*. 2002b). Nevertheless, female age, weight and harem size also influence the reproductive success of individuals. Generally, the pups of older, heavier mothers will have a higher probability of survival, with these older females likely to be in larger harems (McMahon and Bradshaw in review).

2.5 Sexual maturity and life expectancy

Maturing at 4-6 years, cows usually live 10-13 years, but a few may live as long as 23 years (Ling and Bryden 1981; Hindell and Little 1988; Bryden 1995). Bulls become sexually mature at about six years but do not usually attempt to mate until they are about 10 years of age, and seldom garner a harem before they are 14. Males generally live for 20-25 years (Jones 1981; Ling and Bryden 1981).

2.6 Mortality

At Macquarie Island, the mortality of pre-weaning pups is reported at 4.6% for singletons, higher for the few twins (McMahon and Hindell 2003). Starvation, followed by trampling by bulls and inundation from heavy storms, has been identified as the main causes of mortality for unweaned pups (Carrick and Ingham 1962). Southern elephant seals of all ages are hunted by killer whales (Morrice *et al*. 2002) and occasionally leopard seals. On Macquarie Island, pups are killed occasionally by Hooker's sea lion (Johnstone pers comm. to Geof Copson 1977; Geof Copson pers. obs.) and sleeper sharks *Somniosus pacificus* may take some animals.

Most adult males that die at the island's breeding colony are bachelors that show no obvious signs of injury (Carrick and Ingham 1962). In the Vestfold Hills area of east Antarctica, trauma from deep lacerations made by other species has been identified as the primary cause of adult death (Tierney 1977).

The reduction in the size of the Macquarie Island population over the last half-century corresponds to a marked increase in mortality of juveniles, although the cause of mortality is unknown. The extent to which poor survivorship may have contributed to the population decrease is not yet fully understood, though recent modelling suggests that juvenile mortality is an important determinant of population persistence (Hindell 1991; McMahon *et al*. 1999; McMahon *et al*. b in press). Increased predation by killer whales has been suggested as a possible cause of southern elephant seal declines at Marion Island (Condy *et al*. 1978), but evidence is lacking both elsewhere and in Australian waters.

2.7 Foraging and diet

Near-shore nototheniid fish and deep-water squid are the southern elephant seal's main prey near breeding colonies, but elsewhere krill can be important (Green and Williams 1986; Rodhouse *et al*. 1992; Green and Burton 1993; Slip 1995; review by Burton and van den Hoff 2002; Best *et al*. 2003; van den Hoff 2003). Larger seals take a wider range of prey sizes (Slip 1995). Elephant seals from Heard Island consume more fish than those at Macquarie Island, especially benthic fish. Diet studies of seals at Heard Island found that 86% of southern elephant seal stomachs contained cephalopods and 66% contained fish (Slip 1995). For female elephant seals, diet appears to vary seasonally, with more fish consumed in winter when foraging around the Antarctic continental shelf, and more squid taken in summer when the animals forage pelagically (Bradshaw *et al*. 2003a).

There has been much research into the foraging activity of southern elephant seals (Hindell *et al*. 1991, 1999; Slip *et al*. 1991a, b; McConnell *et al*. 1992; Slip 1995b; Bell *et al*. 1997; Jonker and Bester 1998; Field *et al*. 2001; Bradshaw *et al*. 2002a, 2003a; van den Hoff *et al*. 2003 in press). The main foraging areas for juvenile seals from Macquarie Island are along the Antarctic Polar Front and in warmer sub-Antarctic waters to 50˚ S (van den Hoff *et al*. 2002). Most adults forage on or near Antarctica's continental shelf (Hindell *et al*. 1991; Slip *et al*. 1994b). Post-breeding females forage between the Antarctic Polar Front and Sub-Antarctic Polar Front 45% of the time, and in the Antarctic Circle 20% of the time (Hindell *et al*. in press). Juveniles and weaners from Macquarie Island range widely (811-3 258 km) and centre their activity on bathymetric features and oceanographic frontal systems, especially the Antarctic Polar Front (van den Hoff *et al*. 2002; McConnell *et al*. 2002). Newly weaned pups have been tracked on their first trip to sea from Macquarie Island, with most individuals moving to a region about 2000 km to the SE with one trip ending at the Chatham Islands. Other individuals move west, south and south-east, spend from two to 179 days at sea and travelled as far as 1 900 km from the island (McConnell *et al*. 2002).

The adult females typically dives to 300-600 m for durations of 20-22 minutes, however, individuals can dive to 1 700 m or deeper and can remain submerged for periods of more than one hour (Hindell *et al*. 1991, 2000; McConnell *et al*. 1992; Jonker and Bester 1994; Slip *et al*. 1991, 1994a). Only brief periods, usually of 2-3 minutes, are spent on the surface between dives. Juveniles make shallower, shorter dives than adults and heavier weaners will dive deeper and for longer periods than lighter animals, although weaner mass does not appear to affect foraging success (Hindell *et al*. 1999; Irvine *et al*. 2000).

The species hunts by day and night, diving deeper during the day. Southern elephant seals probably "sleep" below the surface for periods of up to 30 minutes or more. The physiological adaptations of the species for deep diving have been relatively well studied (Bryden 1988; Hindell *et al*. 1991, 1992; Slip 1994).

2.8 Long-range movements

When not based on land to breed or moult, the southern elephant seal leads a pelagic lifestyle, spread out, singly or in small groups, over a wide area of ocean, spending several months at a time at sea. The species tends to be philopatric, meaning they tend to return to the same colony each year.

The movements of southern elephant seals have been relatively well studied, through marking and re-sight programs and through the use of tracking devices (eg, Bester 1989; Slip *et al*. 1994b; McConnell *et al*. 2002; Jonker and Bester 1998; Hindell and McMahon 2000; van den Hoff 2001; Bradshaw *et al*. 2002a; van den Hoff *et al*. 2002, 2003). Individuals within each of the sub-populations share common foraging areas (Hindell *et al*. 1991; Jonker and Bester 1998; McConnell *et al*. 2002; McConnell and Fedak 1996; Slip *et al*. 1994b; van den Hoff *et al*. 2002) and these areas are particular to each population (McMahon *et al*. a in prep.).

The southern elephant seal tends to be philopatric, with pups returning to their natal territory to moult and breed (McMahon *et al*. 1999). However, individuals may disperse far, where they may intermix (eg, 5 200 km from Macquarie Island to Peter 1 Øy; Hindell and McMahon 2000). However, Southern Ocean animals are unlikely to interbreed with South Atlantic stocks, which are genetically distinct from the Macquarie Island population (Slade 1997; Slade *et al*. 1998).

Individual southern elephant seals haul out regularly on sub-Antarctic islands and parts of the Antarctic continent and appear to disperse randomly from these areas rather than in a mass migration (Bryden 1995). Adults and juveniles make at least two migratory trips of up to 2000 km each way to their feeding grounds, returning to breed and sometimes also to moult. Most of the seals tagged at Macquarie Island have been resighted within 1000 km of the island, mostly at Campbell Island, with older seals tending to travel furthest (van den Hoff 2001). Marked individuals have demonstrated that there is also considerable interchange between animals from the Heard-Kerguelen and Vestfold Hills region of the Antarctic (Burton 1985), and the Casey region (van den Hoff *et al*. 2003 in press). Southern elephant seals occasionally visit mainland Australia and Tasmania (Kirkwood *et al*. 1992; van den Hoff *et al*. 2002; also see Section B1). Each year in Tasmania an average of three elephant seals are reported. The age of these animals varies from 'under-yearling' and yearling animals (i.e. less than a year old and one year old respectively), to animals of 16 or more years of age (DPIWE; www.dpiwe.tas.gov.au).

Part B: Distribution and location

1. Distribution on land

Neither the sub-Antarctic fur seal nor the southern elephant seal is endemic to Australian waters. The Australian populations of both species haul out mainly at Macquarie and Heard Islands and breed there, but individuals range widely and occasionally reach the beaches of Tasmania and mainland Australia.

Macquarie Island is in the Southern Ocean, about half way between New Zealand and the Antarctic continent, approximately 1 500 km south, south east of Tasmania. The island itself is 34km long, up to 5km wide and 12 800 ha in area. Sub-Antarctic fur seal colonies are located at Secluded Beach and Goat Bay on North Head peninsula (Shaughnessy 1999). Southern elephant seals concentrate on the northern beaches although colonies are scattered around the island.

Situated in the southern Indian Ocean, on the Kerguelen Plateau, 4 100km southwest of the Australian continent and 1 500km north of Antarctica, Heard Island covers approximately 36 800ha. Large populations of southern elephant seal are found principally on the eastern spit area of the island.

Sub-Antarctic fur seal

The sub-Antarctic fur seal is distributed widely across the Southern Ocean and north of the Antarctic convergence (Figure 2). It breeds at traditional sites north of the Antarctic Convergence, in the South Atlantic, on Tristan da Cunha and Gough Islands, and in the South Indian Ocean, on Prince Edward, Marion, Amsterdam and St Paul Islands and Crozet Island. Some of these sites were recolonised quite recently. Since the early 1980s, the species has been recorded breeding on Macquarie Island; a major range extension eastwards of about 90˚ longitude. The species has been recorded breeding on Heard Island since the late 1980s (Goldsworthy and Shaughnessy 1989a,b; Shaughnessy 1992). Although isolated births have been recorded on Heard Island since 1987, perhaps representing the early stages of colonization (Goldsworthy and Shaughnessy 1989), no males have been sighted on Heard Island and the only Australian breeding colony for the species is at Macquarie Island.

Whether the apparent extension in the species range represents a return to old breeding colonies removed by sealers is uncertain as the species of fur seal harvested at Macquarie Island is unknown. Some have attributed the recent expansion to increasing abundance at existing sites, a roaming, pelagic lifestyle and assistance from east-flowing circulation generated by the West Wind Drift, with some dispersing animals even reaching southern Africa (Menkhorst 1995).

Since the mid-1980s, small, but increasing, numbers of individuals have hauled out along coastal southern Australia, from Kalbarri (27˚S) Western Australia, through South Australia, Tasmania and Victoria to Urunga, southern New South Wales (NSW, 30˚30˚S) (Gales *et al*. 1992; Warneke 1995a; Table 5). From 1986-1996, 41 animals have been recorded in Western Australia alone (Gales *et al*. 1992). In Tasmania, sub-Antarctic fur seals are very occasionally reported, up to two a year, most commonly in southern Tasmania, especially on Maatsuyker Island (Rosemary Gales pers. comm.). These stragglers are thought mostly to be juveniles that are dispersing post-weaning.

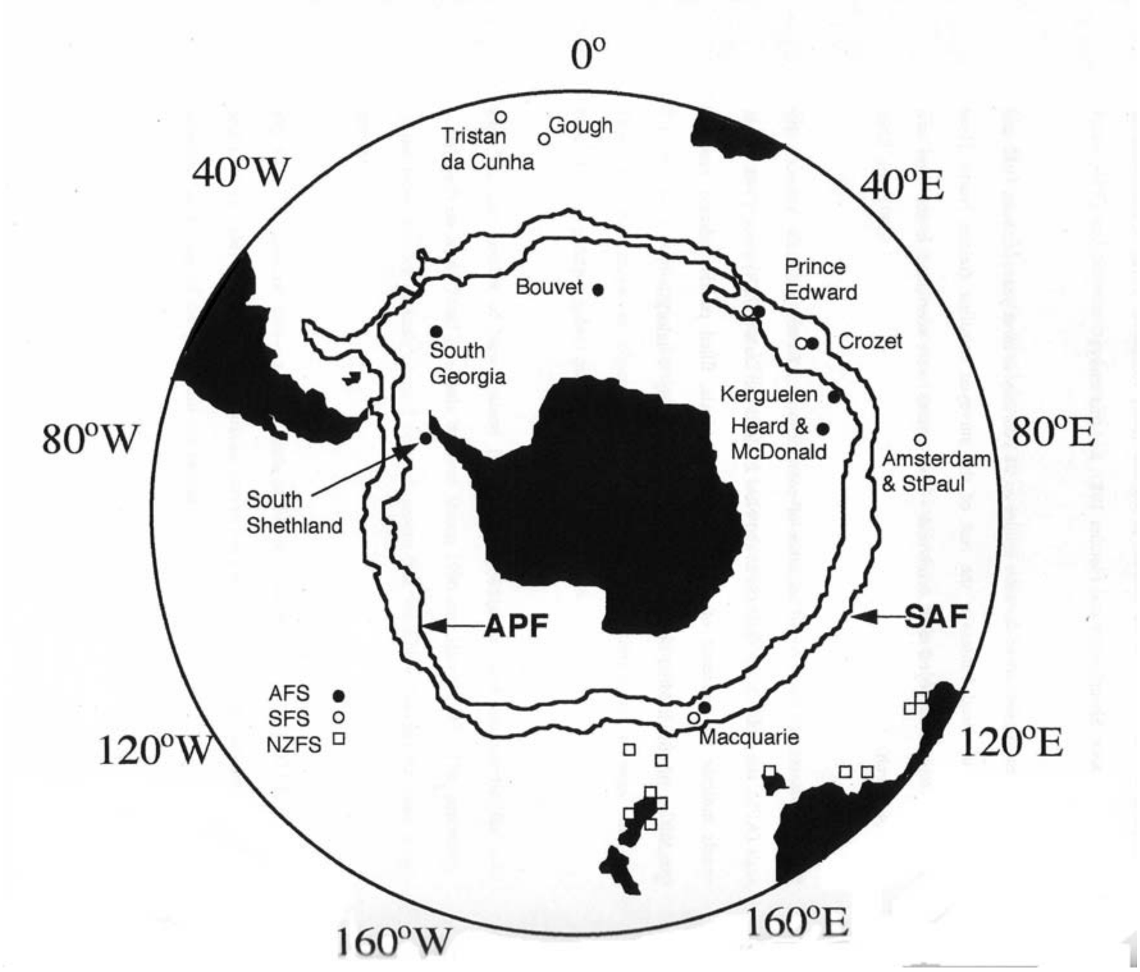


Figure 2 Distribution breeding colonies of sub-Antarctic fur seal (SFS), Antarctic fur seal (AFS) and New Zealand fur seal (NZFS). APF = Antarctic Polar Front; SAF = Sub-Antarctic Polar Front. A few Sub-Antarctic fur seals give birth on Heard Island (not shown)(Figure by Simon Goldsworthy)

Southern elephant seal

The distribution of the southern elephant seal is circumpolar, centred on the sub-Antarctic islands of the Southern Ocean, but there are scattered records from 16˚ N to 78˚ S and a gap across most of the Pacific (Bryden 1995)(Figure 3). The species breeds on the Argentine mainland at Tierra del Fuego and Punta Norte, on the Falklands, South Shetlands, South Orkneys, South Georgia, South Sandwich, Gough, Marion, Crozet and Kerguelen Islands, and the Australian islands of Macquarie, Heard and Campbell (King 1983; Laws 1984, 1994). Individuals often haul-out in the Antarctic but rarely give birth there. Over several years since the 1970s, single pups have infrequently been born at Peterson Island, Antarctica; the most southerly known breeding location (Murray 1981; McMahon and Campbell 2000).

Four, genetically distinct populations are recognised: Macquarie Island; Kerguelen in the South Indian Ocean; South Georgia in the Atlantic; and Peninsula Valdés in Argentina (Lento *et al*. 1997; Slade 1997; Hoelzel *et al*. 2001).

Until the very early 1800s, when sealers eradicated these colonies, the species also bred in Bass Strait, on Hunter, King and possibly New Years Islands (Micco 1971; Warneke 1982). Subfossil remains indicate that colonies were also formerly present on the northwest coast of Tasmania (Bryden 1995; Marsh *et al*. 1999). In the past 50 years, occasional births have occurred on beaches of Tasmania, Victoria, South Australia and Western Australia (Warneke 1995b; Mawson and Coughran 1999a) (Table 3).

Table 3 Records of birthing, of single pups, by southern elephant seals in Australia north of the sub-Antarctic

Tasmania	Maatsuyker Is	1977, 1998	DPIWE website
	near Dover	2000	Hindell & van den Hoff 2002
	main street, Strahan	1958	DPIWE website
	near St Helens	1977	DPIWE website
Victoria	near Gold Beach	1968	Warneke 1995b
	mouth of Elliott River	1994	Warneke 1995b
South Australia	Wright Bay	1986	Robinson and Dennis 1988
Western Australia	Wylie Bay*	1996	Mawson and Coughran 1999a
	Epineux Bay	1996	Mawson and Coughran 1999a

*pup died soon after birth

Between December and February, southern elephant seals haul out on land to moult at the breeding colonies. Occasional vagrants (mostly juveniles or moulting sub-adult males) find their way to the southern mainland from south-west Western Australia (see Table 4) to South Australia, Victoria and NSW, where they can go as far north as Sydney (King 1983; Pemberton and Skira 1989; Menkhorst and Knight 2001; van den Hoff 2001).

Southern elephant seals occur regularly at Maatsuyker Island and are sighted increasingly on the Tasmanian mainland. Between 1977 and 1989, 25 non-breeding elephant seals were recorded on mainland Tasmania (Pemberton and Skira 1989; Nature Conservation Branch, DPIWE unpubl data, Rosemary Gales pers. comm.). From 1990 to 2002, 37 non-breeding individuals were reported. Between 1998 and 2000, there appears to be a marked increase in sightings, with 24 elephant seals recorded.

Table 4 Numbers of sub-Antarctic fur seals and southern elephant seals encountered by Conservation and Land Management (CALM) staff 1980-1996 in Western Australia. Values in parentheses indicate the number of seals returned to the wild and the number that died (Mawson and Coughran 1999a and CALM website)

Year	**Sub-Antarctic fur-seal**	**Southern elephant seal**	**Year**	**Sub-Antarctic fur-seal**	**Southern elephant seal**
1980	0	0	1989	3 (1,2)	0
1981	0	0	1990	1 (0,1)	0
1982	0	0	1991	1 (0,1)	1 (1,0)
1983	0	0	1992	11 (1,10)	0
1984	0	0	1993	6 (4,2)	1 (0,1)
1985	0	0	1994	6 (3,3)	0
1986	1 (1,0)	0	1995	4 (2,2)	1 (1,0)
1987	3 (1,2)	0	1996	5 (3,2)	5 (4,1)
1988	4 (1,3)	0	*Total*	*45 (17,28)*	*8 (7,1)*

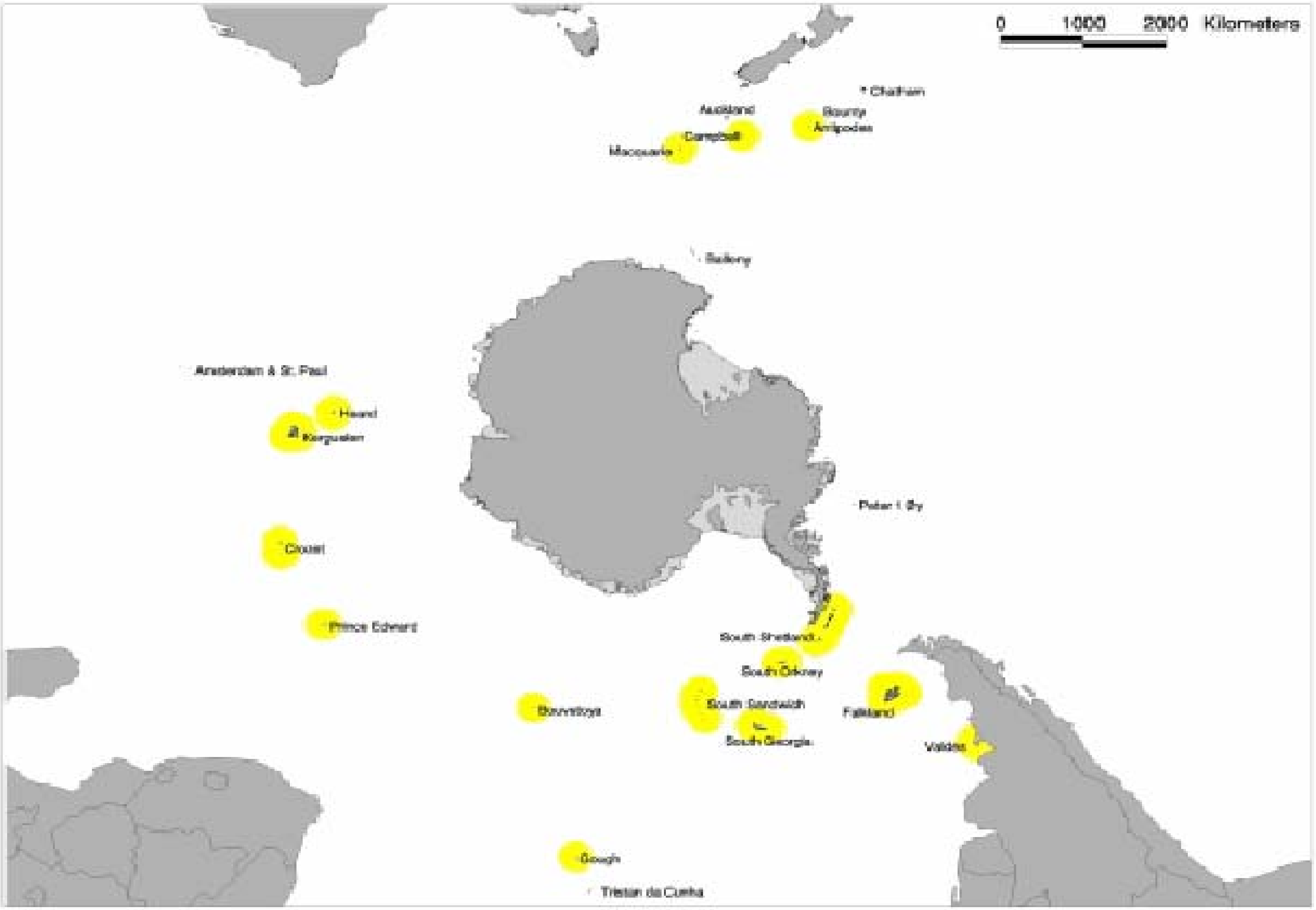


Figure 3 The circumpolar breeding distribution of the southern elephant seal in 2001 (McMahon *et al*. a in review)

2. Habitat requirements

Sub-Antarctic fur seal

The sub-Antarctic fur seal utilises rocky coastal habitat containing rock platforms and beaches with exposed boulders (Bester 1982; Goldsworthy and Shaughnessy 1995). At Macquarie Island, breeding animals are found on rocky shores, and non-breeders above the shore on the tussock slopes. Suitable terrestrial habitat on Macquarie Island can be found at Secluded Beach and Goat Bay on North Head Peninsula (Shaughnessy 1999). There is potential for animals to utilise other rocky beaches elsewhere on the island.

Important feeding habitat for the species includes the waters immediately surrounding Macquarie Island (Copson *et al*. 1994), where females occasionally feed while nursing. Two important feeding areas for lactating cows have been identified at 30 and 100 km north of Macquarie Island (Robinson *et al*. 2002).

In addition to being used for feeding, the waters adjacent to breeding colonies are also used by sub-Antarctic fur seals for access to land, respite and refuge. These waters may have importance for pups learning to swim and feed in the shallows, particularly since pups are nursed for up to 10 months.

Southern elephant seal

To breed or moult the southern elephant seal prefers sand or cobble stone beaches where it can easily come ashore. It often settles among *Poa* tussocks, but at more southerly locations lies on ice and snow. At Macquarie Island, moulting individuals lie in deep mud wallows (Ling and Bryden 1981).

The species breeds mainly on the northern part of Macquarie Island on the most extensive beach areas, near the Australian National Antarctic Research Expeditions (ANARE) Station. However, substantial numbers are also dotted around the entire island in other sand beach colonies. On Heard Island, the colonies are principally located on the eastern spit, often on beaches where there is short tussock grass *Poa cookie.*

The southern elephant seal formerly occupied several sites in western Bass Strait, including King Island, until the nineteenth century, and on the Tasmanian mainland. Should the population recover sufficiently, individuals may recolonise some of these sites.

Important feeding areas for the southern elephant seal at Macquarie Island are located south of the island in the Ross Sea, and coastal Antarctica south of 60˚ S (van den Hoff *et al*. 2002; Bradshaw *et al*. 2003). Southern elephant seals will also use the waters adjacent to breeding colonies for access to land, respite and refuge. These waters may have importance for elephant seal pups learning to swim and feed in the shallows.

Protection and management of habitat areas

The major Australian breeding colonies of both the sub-Antarctic fur seal and the southern elephant seal are secured within protected areas (Table 5), namely the Macquarie Island Nature Reserve and Heard Island Wilderness Reserve.

Macquarie Island and Heard (and McDonald) Islands (HIMI) were World Heritage listed in 1997. Macquarie Island was listed mainly on geological/geophysical grounds and, to a much lesser extent, its natural values. HIMI have been listed to protect distinctive benthic habitats, flora and fauna of the islands and foraging predators dependant on the region. The area is also listed on the Register of National Estate. At both islands, the properties nominated for inclusion on the World Heritage List comprise the main islands and several islets, offshore rocks and shoals, in addition to the surrounding waters to a distance of 12 nautical miles (approx. 22km). Further information about the World Heritage listing of Heard and McDonald Islands can be found at: http://www.deh.gov.au/heritage/worldheritage/index.html.

Macquarie Island is also fully protected under Tasmanian legislation and is on the National Heritage List, which invokes the EPBC Act. The island is a Tasmanian administered nature reserve. In 2000, a 16 million hectare Commonwealth Marine Park was declared, extending from three nautical miles out to 200 nautical miles in places, on the eastern side of Macquarie Island. The north-west portion of the Marine Park covers approximately half of the area most intensely foraged by sub-Antarctic fur seals (Robinson 2002). The waters surrounding breeding sites at Macquarie Island are the responsibility of Tasmania up to three nautical miles from the coast, and the Australian Government up to 200 nautical miles.

Table 5 Main breeding locations of the sub-Antarctic fur seal and southern elephant seal in Australian waters. Every few years pups are also born at Peterson Island, Antarctica

Colony	Latitude/longitude	Land classification	Land tenure/ Management authority
Macquarie Is	54˚ 29'-54˚ 47'S	Nature Reserve	Tasmanian DTPHA
	158˚ 47'-158˚ 58'E	Natural World Heritage Site	
Heard Is	53˚ 06'S	Nature Reserve	Commonwealth/
	7˚ 30'E	Natural World Heritage Site	Australian Antarctic Division
Maatsuyker Is	43˚ 39'S	Part of south-west Tasmania	Tasmanian DTPHA
	146˚ 16'E	World Heritage area	

In Australia, the islands on which breeding colonies occur (i.e. Macquarie and Heard Island), have been well described because of their World Heritage Listing (Commonwealth of Australia 1996a,b). The range of both species may change with time, for example, as seal populations expand, or species distribution shifts in response to climate change.

3. Important populations

In the Australian jurisdiction, the most important population of the sub-Antarctic fur seal is based at Macquarie Island. The island supports less than 1% of the world population. Extralimitally, Gough and Amsterdam Islands have the largest breeding colonies in the world.

Two major populations of southern elephant seal are in Australian territory, at Macquarie and Heard Islands (about 18-19 % of the world population), the third major concentration is outside Australia, at South Georgia.

The southern elephant seal (and perhaps the sub-Antarctic fur seal) has the potential to increase its current distribution and return to colonies it formerly utilised.

Part C: Conservation status and threats

1. Conservation status and legislative protection

Domestic measures

The sub-Antarctic fur seal is listed as nationally Vulnerable under the EPBC Act (section 178). In listing the species as Vulnerable, the Threatened Species Scientific Committee (TSSC) determined that the species met criterion four, because the estimated total number of mature individuals is extremely low (TSSC 2001a). In Tasmania, the species is listed as Endangered under the *Threatened Species Protection Act 1995.*

The southern elephant seal is also listed as nationally Vulnerable under the EPBC Act. In listing the specie as Vulnerable, the TSSC determined that the southern elephant seal met criterion one, because it has undergone, is suspected to have undergone or is likely to undergo in the immediate future, a substantial reduction in numbers. At the time of listing, there was evidence of a 1.2% annual reduction in numbers such that, should population decline continue, the species was considered likely to be extinct in Australian waters within 100 years (TSSC 2001b). The species also met criterion five because the probability of its extinction in the wild is at least 10% in the medium-term future. The southern elephant seal is listed as Endangered in Tasmania under the *Threatened Species Protection Act 1995* and as Rare in South Australia under the *National Parks and Reserve Management Act 2002* and *The Nature Conservation Act 2002*.

Currently, Australian Government responsibility extends 200 nautical miles offshore to the border of the Australian Exclusive Economic Zone (EEZ). Where these species occur in waters under Australian jurisdiction, State/Territory as well as Commonwealth legislation applies (see Appendices I-III). State legislation applies in waters up to three nautical miles offshore and on land at breeding, resting and moulting sites.

International measures

The sub-Antarctic fur seal is not considered to be globally threatened (International Union for the Conservation of Nature (IUCN) Red List of Threatened Species 2002; www.redlist.org). All major breeding colonies are protected, by Britain (Tristan da Cunha and Gough Is) and France (Amsterdam and St Paul Is).

The southern elephant seal is considered to be globally threatened (IUCN Red List of Threatened Species 2002). All major colonies of southern elephant seal are protected (Warneke 1995b). The killing or capture of elephant seals is prohibited by the Convention for the Conservation of Antarctic Seals (CCAS), which applies south of 60˚.

Both the sub-Antarctic fur seal (as *Arctocephalus* spp.) and southern elephant seal are listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Appendix II (1975), which includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilisation incompatible with their survival. More information on the CITES status of the species can be found at http://www.cites.org.

The Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) establishes a Commission to manage the marine living resources of the CCAMLR area for which it is responsible. The resources specifically exclude whales and seals, which are the subject of other conventions. For seals, this is the Convention for the Conservation of Antarctic Seals (1972) (CCAS). The CCAS was set up to protect all six species of seal found in the Antarctic, including the southern elephant seal, following concerns about a possible resumption of commercial sealing in the region. Commercial sealing has not been resumed in the Antarctic, and although the Convention remains in force its provisions have never been put to use. Additional information on CCAMLR and CCAS can be found at: http://www.ccamlr.org.

CCAMLR takes an active interest in the assessment of the impact of fisheries on non-target species such as seabirds and seals through the Working Group on Incidental Mortality Arising from Fishing, and seeks to develop mitigation measures where applicable. For seabirds, CCAMLR has been very active in promoting sustainable fisheries however seal interactions in sub-Antarctic fisheries have been relatively low to date, and have not necessitated active response. Australia is a signatory to CITES, CCAMLR and CCAS.

2. Identification of threats

Among the many potential threats to both seal populations are competition and interaction with fisheries, pollution and marine debris, climatic and ocean change, predation, disease, and direct disturbance from tourism, research or interference. With the possible exception of climatic and oceanographic change, whereas they pose real risks to some individuals, none of these factors appear to currently present a significant threat to populations of either the sub-Antarctic fur seals or southern elephant seal.

2.1 Legal fisheries

Background

Australia's main sub-Antarctic fishery is the HIMI Fishery, which is managed under the *HIMI Fishery Management Plan 2002* (AFMA 2001*)*. For environmental reasons, the Plan limits vessel numbers operating in this fishery to three. Currently, there are two trawl vessels operating in the fishery and a third longline vessel operating under a Scientific permit to trial seabird mitigation measures. When the fishery commenced in 1997, environmental standards over and above those required under CCAMLR were adopted in recognition of the conservation values of this remote fishing area (Anon. nd). These measures include, but are not limited to:

- carriage of two full-time observers;
- carriage of an operational vessel monitoring system;
- ensuring that there is not offal (waste products from fish processing) or unwanted dead fish discharged from the fishing boat; and
- giving aid to mammals and seabirds injured by fishing operations, and recording deaths.

The same range of conservation measures apply to other Australian fishing vessels operating in Antarctic and sub-Antarctic waters, namely at Macquarie Island and off the Australian Antarctic Territory (AAT) in CCAMLR statistical area 58.4.2.

The fishery at Macquarie Island is limited to a single trawl vessel targeting Patagonian toothfish (AFFA 2001; He and Furlani 2001). The Fishery commenced in 1994-95 and for the first two years established itself in the Aurora Trough. In 1996-97 the Northern Valley grounds were discovered. Fishing in this area was based on the presence of a transient stock, which is not currently present. In 1999, due to stock depletion, the Aurora Trough was closed to commercial fishing, however this stock is now thought to have recovered to commercial levels.

The Macquarie Island Fishery is relatively small in terms of legal fishing activity. In recent years, due to depleted fish stocks, less than one trip per year has been undertaken. The setting of a commercial catch limit for the Aurora Trough is not expected to dramatically increase the level of activity in the Fishery and the total allowable catch is expected to be taken in a single trip.

Interest by Australian fishers in CCAMLR New and Exploratory Fisheries has increased over recent years. This interest has come from the longline operators who are looking to fish off the AAT and other high seas areas within CCAMLR waters. Early in 2003, Australia's first longline vessel to fish in CCAMLR waters trialled seabird mitigation measures in Prydz Bay, Antarctica, in statistical area 58.4.2. This vessel is subject to the same environmental controls as the other vessels, including nil offal discharge.

Potential threats to seals from fisheries arise from:

- Direct interaction between seals and fishing operations, for example, seals can be entangled, hooked or shot because they interfere with fish behaviour, steal fish and baits from nets and damage nets (also see Section C2.3).
- Ecological impacts through depletion of prey on which the seals depend.
- Pollution from oil spills and other discharges and gear loss and discards. This is not dealt with further here because of the environmental standards required of these remote fisheries and the type of vessels permitted: vessels of "class" holding that comply with International Convention for the Prevention of Pollution from Ships (MARPOL) certified regulations specifically designed to minimise the risks of non-biodegradable material being discharged into the ocean. (Also see Sections C2.3, C2.4).

Direct interactions

Seals are attracted to fishing vessels and their nets, and where they interact with trawl fisheries, they can become incidental casualties, drowned in trawl nets or deliberately killed when trapped (Shaughnessy 1985; Shaughnessy and Davenport 1996; Tilzey 2001). In Australia, for the sub-Antarctic fur seal and southern elephant seal there are few examples of interactions with trawl fisheries (eg, Burton and van den Hoff 2002; van den Hoff *et al*. 2002).

The Australian Fisheries Management Authority (AFMA) actively monitors and reviews the seal bycatch by Australian vessels in Antarctic Fisheries, that is, those that operate in the main range of sub-Antarctic fur and southern elephant seals. Skippers are required to immediately report all interactions with seals. These reports include: the species, sex, location, weather and other conditions at the time of the incident, and action skippers are initiating to avoid similar incidents. Observers on board vessels are required to collect biological samples from deceased seals and record vital statistics. Gales (nd), provides a protocol for handling of samples from seal bycatch at HIMI.

AFMA's records for the Antarctic fisheries show that a total of 15 seal interactions have been recorded since 1997, of which 10 have resulted in the death of seals as a result of interaction with fishing gear (Table 6). There are no strong patterns emerging between reported seal incidents and other factors, such as time of year or number of seals around the vessels. This lack of correlation may present problems in the development of further seal bycatch mitigation. Environmental observations undertaken by observers onboard and reports made by skippers revealed no evidence of seal habituation to fishing vessels. During the 2003 longline trial in Prydz Bay, no seal interactions were reported. However, on the first observed longline trip to HIMI in June 2003, three southern elephant seals were caught within five days by a longline vessel. All three animals died as a result of these interactions and reports indicate there was no evidence of general elephant seal activity at the time of their capture. CCAMLR records also contain a report of a southern elephant seal caught in a trawl net on the Kerguelen Shelf in 1995 (Burton and van den Hoff 2002).

All observed incidents between seals and fisheries are reported to the Australian Government Department of the Environment and Heritage (DEH) and the Australian Antarctic Division (AAD). AFMA's Sub-Antarctic Fisheries Stock Assessment Group (SAFAG) regularly reviews incidents and mitigation measures. Management actions to formally address the seal bycatch issues in these fisheries are reflected in the Antarctic Fisheries Bycatch Action Plan (AFMA 2004). The impact of fishing on seals was also considered when the HIMI Fishery underwent a strategic assessment during 2002, as required under the EBPC Act. The Assessment Report: *Heard Island and McDonald Islands Fishery – December 2001* states:

> **"**Periodic assessments undertaken through SAFAG, based on observed number and reported interactions, indicate that these interactions are minimal and there are no immediate threats to seabird or mammal populations".

In response to this report, DEH's Sustainable Fisheries Section advised that they were "satisfied that all reasonable steps are being taken to avoid the capture of seals during fishing operations at HIMI". SAFAG considers that the current level of seal interactions with fishing vessels does not have a significant impact on seal populations. However, the recent death of three elephant seals in the developing longline HIMI fishery posits careful monitoring and assessment of that fishery. The strategic assessment recognised that AFMA is monitoring seal interactions and recommended that, 'In the event that seal interactions increase, AFMA should review existing mitigation measures and implement appropriate responses in a timely manner.' This, and other recommendations made in the strategic assessment will be reviewed during the next EPBC Act evaluation of the fishery in 2007.

Table 6 Summary of marine mammal interactions (deaths) with fishing vessels operating in Antarctic fisheries (AMFA Reported Seal Incidents at 12 June 2003). All interactions were with trawl gear, except the 2003 elephant seal deaths in longline gear. Macquarie Island Fishery (MIF); Heard Island and McDonald Island Fishery (HIMI)

Year	**Fishery**	**Interaction**
1997	HIMI	1 Antarctic fur seal*
	MIF	1 southern elephant seal*
1998	HIMI	2 Antarctic fur seal
1999	None reported	
2000	HIMI	1 Antarctic fur seal
2001	HIMI	5 Antarctic fur seal
2002	HIMI	1 southern elephant seal (juvenile); 2 Antarctic fur seal
2003	HIMI	2 Antarctic fur seal; 3 southern elephant seal

*in a state of decomposition when encountered

Occasionally, but perhaps increasingly, sub-Antarctic fur seals and southern elephant seals venture into waters where mainland fisheries operate, where they may be at greater risk. Kirkwood *et al*. (1992) summarised interactions between seals and fisheries in Tasmanian waters and noted the potential for entanglement in recreational gill nets off Tasmania. Southern elephant seals are rarely seen entangled, but in 1998 a juvenile died in an aquaculture perimeter net near Dover, Tasmania (AAD record cited in Burton and van Hoff 2002) and another became entangled and drowned in a net at a salmon farm in southern Tasmania (Kemper *et al*. 2003). Antarctic fur seals also routinely drown in aquaculture nets in Tasmania (Kemper *et al*. 2003).

There are no reported interactions between Commonwealth managed fisheries operating off the mainland of Australia and southern elephant seals and sub-Antarctic fur seals (Joanna Fisher, AFMA, pers. comm.). However, seals are infrequently recorded to species level. Some believe the South East Trawl Fishery incidentally catches an average 720 seals each year, 490 of which do not survive (Anon. 2003). AFMA is working with industry to trial seal exclusion devices (SEDs) and develop fishing strategies to avoid interactions. To this end, the South East Trawl Fisheries Industry Association (SETFIA) has recently developed a code of practice ("Seal Code of Conduct") designed to assist operators in minimising interactions with Australian and New Zealand fur seals, including information on how to handle and deal with captured or entangled seals. In addition, the industry initiated and undertook three years of research (now in its fourth year) on two vessels operating in the winter Blue Grenadier Fishery off the east coast of Tasmania, trialling the use of various SEDs and other mitigation methods and supporting radio-tracking of seals to gather information on foraging routes and locations.

Competition

It has been suggested that depletion of marine resources by commercial fisheries may have been responsible for the decrease of Indian Ocean elephant seal populations (Pascal 1986; van Aarde 1980; Wilkinson and Bester 1988). Ecological interaction between seals and fisheries can be through direct competition for the same fish stocks or through indirect trophic interactions. Competition is notoriously difficult to measure but several studies indicate that, at present, competition by fisheries is unlikely to be important to either the sub-Antarctic fur seal or southern elephant seal (Goldsworthy *et al*. 2001; Slip *et al*. 1994b; AAD 1997; van den Hoff *et al*. 2002; Hindell *et al*. 2003a; van den Hoff 2003; McMahon *et al*. a in review).

Toothfish is the principal species targeted by fisheries at Macquarie Island and off the AAT in CCAMLR statistical area 58.4.2. The only other fish species currently targeted by Australian fishers in these waters is mackerel icefish in the HIMI Fishery (AFFA 2001). The Australian Fisheries and Development Corporation (FRDC) funded a study of the diet of the harvested Patagonian toothfish at Macquarie Island (Goldsworthy *et al*. 2002), which overlaps with that of the southern elephant seal (19%) and, to a lesser extent, the sub-Antarctic fur seal (Goldsworthy *et al*. 2001). A possible implication of the fishery may therefore be the removal of one of the competitors of seals from the system. However, Van den Hoff (2003) found evidence of greater dietary separation, than expected between juvenile southern elephant seals and toothfish. Each species was found to focus on a different size class of squid, further reducing potential for competition.

Southern elephant seals forage widely in Antarctic waters, spending a significant amount of time in the CCAMLR management area and Australia's Antarctic EEZ, where the legal commercial fisheries catch is presently relatively small compared with the volume of fish consumed by the seals. Further, there appears to be little overlap between the main foraging areas of seals and concentrations of fishing activity (Slip *et al*. 1994b; AAD 1997; van den Hoff *et al*. 2002; Hindell *et al*. 2003a). In addition, southern elephant seal populations at South Georgia and Kerguelen, where fisheries are relatively intensive, are stable, whereas in the southern Pacific, where commercial fishing activity is comparatively low, seal populations have declined (Hindell *et al*. 2003a; McMahon *et al*. a in press).

The bycatch of legal fisheries is low and the impact of this catch on the diet of seals is considered negligible (AFFA 2001). While the diets of the seals do not include toothfish, AFMA recognises that mackerel icefish are important prey (AFFA 2001). This is taken into account annually when setting the total allowable catch limit for icefish, which ensures that the spawning biomass remains at or above 75% of its pre-exploitation median level to cater for predators. The Fisheries Stock Assessment Group meets regularly so that responses to negative changes in stock are timely. Further, a review of studies of southern elephant seal stomach contents reported that mackerel icefish constituted less than 5% of prey items (Burton and van den Hoff 2002), although this is likely to vary seasonally and regionally.

AFMA has identified the need for fisheries to take a systematic approach to identifying the relative risks of different fisheries to the ecological sustainability of the marine environment. As a result, ecological risk assessments are being undertaken by CSIRO in relation to target, byproduct, bycatch and broader ecological impacts for each fishery.

The development of new fisheries that target the main prey species of seals is of potential concern (eg, Goldsworthy *et al*. 2001) but improbable at present. For example, Burton and van den Hoff (2002) found harvested commercial squid species in the stomachs of southern elephant seal. However, the capital costs involved, combined with the current market price for squid make it unlikely that a remote squid fishery would be viable (Viki O'Brien pers. comm.).

Marine Protected Areas

Further protection is provided to seals through the Marine Protected Areas (MPAs) established at HIMI and Macquarie islands under Australian Government legislation. At Macquarie Island, the MPA has resulted in the area east of the Island being closed to fishing. Waters within three nautical miles of Macquarie Island are managed under Tasmanian State jurisdiction and are closed to fishing. The main fishing ground, Aurora Trough, does not overlap with the known foraging grounds for seals, however, the Northern Valley area of the fishery does.

At HIMI, vessels are not permitted to legally fish within 13 nautical miles of the Islands and in a number of other large areas within the Australian Fishing Zone (AFZ, AFFA 2001). In 2002 the HIMI Marine Reserve was declared under the EPBC Act. The Reserve includes the World Heritage listed islands themselves and the Territorial Sea plus a marine protected area extending in parts to the 200 nautical mile EEZ boundary. Classified as an IUCN Category 1a Strict Nature Reserve, it is mainly concerned with benthic values and one of the purposes for declaring the reserve was to protect marine areas used by land-based marine predators for local foraging activities. The proposed management plan will exclude most human activity in the region. The plan will recognise that 'long term commercial fishing is the main potential threat to the conservation values of the HIMI region. The management provisions for legal fishing in the region include a range of mitigating measures to minimise these threats. These include precautionary catch limits for both target and bycatch species that take account of predator-prey relationships, independent observers on all voyages, collection and analysis of a wide range of catch data and samples, restrictions on gear to minimise non-target species interactions, and ongoing research on the ecological viability of commercial fish stocks and impacts on the surrounding ecosystem' (AAD website http://www.aad.gov.au/).

Summary

- At present, there is low potential for sub-Antarctic fur seals and southern elephant seals to interact with fisheries, either directly or through ecological competition for the same resource. There have been few reported interactions between these seals and fishing gear in Australian waters, but the establishment and diversification of fisheries in the sub-Antarctic and Antarctic fishing zones may increase the chance of interaction.
- However, the deaths of three elephant seals during the first observed longline operation at HIMI highlight the need for continued observer coverage.

- Operational interactions between seals and fisheries are well informed in sub-Antarctic fisheries but biological interactions are not as well understood. Operational interactions in other areas/fisheries are not well known.
- As seal populations recover, the likelihood of interaction with mainland fisheries will increase.

2.2 Illegal, Unregulated and Unreported fishing

Background

Typically, longline Illegal, Unregulated and Unreported (IUU) fishing activity occurs in CCAMLR Divisions and extends into at least some of the AFZ (AFFA 2001). Commercial fisheries of a number of other countries have operated for some time in the Kerguelen region to the north of the HIMI EEZ. The northern and central parts of the Kerguelen-Heard Plateau have been the principal target of illegal longline fishing for Patagonian toothfish. The zone to the east and north east of HIMI is the main area where illegal fishers have taken toothfish (by longlining rather than trawling) from the HIMI EEZ. There was some evidence of a reduction in activity in 1997 and 1998, perhaps due to increased surveillance or a drop in price from oversupply (AFFA 2001). Regardless, CCAMLR agreed to a range of measures to combat IUU fishing including automated satellite-based vessel monitoring systems for legal vessels and a catch certification scheme for importation of fish to markets of CCAMLR parties.

Australia's estimate for IUU fishing for the period 1 July 2001 to 30 June 2002 covers the CCAMLR statistical area 58.5.2, which is essentially the AFZ around Heard and McDonald Islands. The estimated catch was 2 500 tonnes of toothfish, or 89% of the legal Total Annual Catch (TAC) of 2 815 tonnes set for the Australian EEZ around Heard and McDonald Island. Little, if any, IUU fishing takes place at Macquarie Island (John Davis pers. comm.).

IUU fishing is a serious problem for seabird bycatch, fish stocks and legal fisheries. However, because most illegal fishing occurs in sub-Antarctic waters, a low level of interaction between IUU vessels and the southern elephant seal is expected. There is little spatial overlap in distribution between the largely Antarctic-based seals and the area of illegal fishing activity. The IUU fishermen use the demersal longline method which is believed by AFMA to have little if any potential for interaction with the seals that inhabit the area (John Davis, AFMA, pers. comm.).

Summary

- At present there appears to be some potential for interaction between southern elephant seals and IUU fisheries but virtually no potential for interaction with the sub-Antarctic fur seal.
- Based on recent events, it is evident that there are fatal interactions between elephant seals and longline vessels in sub-Antarctic waters, although the extent of the interactions in the IUU (or other unobserved fisheries) is unknown.

2.3 Interaction with human-generated non-biodegradable debris

Background

Man-made debris that is cast or lost overboard from vessels, or blown or washed out to sea from land is an increasingly widespread international problem to many marine animals (Shomura and Yoshida 1985; Fowler 1987; Laist 1987; Jones 1994; Eriksson and Burton 2001). Such material includes trawl nets, packing straps, monofilament nets and lines, nylon rope, six-pack yokes and plastic bags (Pemberton *et al*. 1992; Prendergast and Johnson 1996; Shaughnessy 1999). Much of this material degrades slowly and can be carried far. Seals may play with marine debris, haul out to try to rest on it, or try to remove trapped prey items before themselves becoming entangled (Laist 1987). There are many ways in which seals can be harmed by debris, including:

- Fishing hooks and squid jigs with attached material can become embedded in flesh and cut into the animal as it grows;
- Nets, lines and rings can loop around a seals' neck, flipper, mouth or teeth and drown the animal, catch on something later or slowly strangle constrict a seal's growth; or
- Seals can swallow plastic bags and other debris, which can cause blockages and death (Cawthorn 1985).

Entanglement has been strongly implicated in the decline of at least one northern fur seal population (Fowler 1987) and is considered a threat to southern populations (eg, Hofmeyr and Bester 2002; Hofmeyr *et al*. 2002). Studies of Australian seal populations indicate 0.2-2% of seals at colonies are entangled in debris (Gales 1990; Pemberton *et al*. 1992; Shaughnessy 1999), with more males than females affected (Prendergast and Johnson 1996). However, seals may die at sea following entanglement or ingestion, suggesting that this low percentage may underestimate the extent of the problem (Shaughnessy 1999). Elsewhere, research shows that almost twice as many males as female Cape fur seals *Arctocephalus pusillus* were entangled in man-made debris (monofilament line, trawl net, rope, wire, Shaughnessy 1980; Croxall *et al*. 1990).

Few entanglements of sub-Antarctic fur seals have been observed (Goldsworthy 1991) (Table 7). At Heard Island, several Antarctic fur seals have been seen entangled in stranded fishing debris and other artefacts (Slip and Burton 1991).

Table 7 Fur seal entanglements recorded at Macquarie Island since 1993: JM juvenile male; J juvenile; SAM subadult male; AM adult male; T sub-Antarctic fur seal; G Antarctic fur seal; NZ New Zealand fur seal (table supplied by Simon Goldsworthy)

Season	Date	Species	Age class	Material	
02/03	20-Dec-02	T	JM	5mm green trawl net	
	20-Jan-03	T	JM	5mm green trawl net	
	9-Feb-03	NZ/T?	J	5mm green trawl net	
99/00	22-Jan-00	F	SAM	Packing tape	
98/99	19-Feb-99	T	J	Trawl net	
	20-Feb-99	F	J	green trawl net	
	28-Apr-99	F	J	green trawl net	not captured
	12-Mar-99	G	J	packing tape	
97/98	27-Apr-98	T	J	netting	not captured
94/95	17-Dec-95	T	J	white monofilament	
	26-Apr-95	G	J	green rope	not captured
93/94	6-Mar-94	T	J	netting	
	16-Jan-94	F	AM	rope	

AFMA has documented fishing gear lost by Australian vessels since they commenced fishing operations in the Antarctic. These vessels have been required to carry two observers on all trips. Environmental standards include strict limitations on the use of plastic packaging bands and prohibition on the disposal of plastic waste at sea (CCAMLR Conservation Measure 25-01 1996, Regulation of the Use an Disposal of Plastic packaging Bands on Fishing Vessels; AFFA 2001). Nonetheless, considerable amounts of plastic, hooks and nets are lost (Table 8), usually due to hooking on the rough sea floor. The contribution of IUU fisheries to marine debris is unknown but might be expected to be greater than that from the legal industry.

Table 8 Reported gear loss in the Antarctic Fishery 2001-May 2003 (AFMA Summary Table of Gear Loss, 14 May 2003)

2001	HIMI	2 floats plus netting; 37 plastic floats; 5 hardhats; 1 life raft and cradle; 1 nylon strop; 1 codend/lengthener; 1 port stern roller; 1 bobbin, 1 trawl door.
2002	HIMI	2 trawl nets; 7 plastic floats; 1 aft port side bulwark roller; 2 trawls, rock hopper rigs, monitors and 2 trawl doors that were subsequently retrieved.
2003	CCAMLR 58.4.2	3060 hooks, backbone, downline and steel anchor; red buoys; 900 hooks and mainline; 750 hooks and mainline; 1000 hooks and mainline,

downline, floats and anchor; 1 light beacon.

Human-generated debris reaches remote islands such as Macquarie and Heard as flotsam (Slip and Burton 1990, 1991). A review of the total number of plastic items found on these islands over a decade found that the percentage of fisheries related netting and plastic ropes increased but other material, such as plastic bands/straps, did not. The study also found that the timing of wash-up on the beaches corresponded with the activity periods of the fisheries (Slip and Burton 1990, 1991; Eriksson and Burton 2001).

A considerable number of hooks and other gear are lost in the Antarctic Fishery (Table 8). A longline hook was removed from the nose of a southern elephant seal at Macquarie Island and it was surmised that this resulted from an interaction with a longliner operating around the Campbell Plateau or to the south of New Zealand (McMahon *et al*. 2000b; Burton and van den Hoff 2002).

Goldsworthy *et al*. (1997) reported plastic fragments in fur seals scats from Macquarie Island and Eriksson and Burton (2003) studied 164 plastic particles up to 4 mm long in 45 fur seal scats and identified them as the remains of flotsam ingested by the fish on which the seals had fed. Their impact on the seals is unknown.

Injury and fatality caused by the ingestion and entanglement of wildlife in marine debris is currently being considered by the TSSC for listing under the EPBC Act as a Key Threatening Process.

Summary

- Entanglement in oceanic debris is a known problem that kills individuals of many seal species, but it is of unknown impact on populations of Australian sub-Antarctic fur seal and southern elephant seal.
- With reports of southern elephant seals visiting Tasmania and the mainland continuing to increase, the number of entanglements might be expected to rise.

2.4 Oil spills and other pollutants

Background

Even though remote from major shipping lanes, at both Heard and Macquarie Islands there is potential for oil spills by fisheries, commercial, tourist and resupply vessels. At Macquarie Island, there was a serious oil spill after the wreck of the *Nella Dan* in 1987 on the beach at Buckles Bay. On this occasion, oil drifted out to sea (Anon. 1988). In 1998, a fire in the engine-room of the *Aurora Australis*, soon after it left Macquarie Island, resulted in spillage of 12 000 litres of fuel-oil. In addition, vessels that visit Macquarie Island each summer to re-supply the station present a potential hazard. The ships are close to southern elephant seal colonies and pump large quantities of fuel ashore near colonies of fur seals on North Head Peninsula. The seals are concentrated in just a few places, increasing their vulnerability.

By contrast, at Heard Island, there are few visits by vessels and seal colonies are scattered around much of the coastline. Nevertheless, with increased fisheries activity near both Macquarie and Heard Island the potential for accident spills has no doubt increased.

Oil spills elsewhere in Australian waters have threatened seal colonies. For example, the incident involving the *Sank Harvest* in Western Australia, resulted in seal pups being temporarily removed and cleaned while rocks were cleared of oil (Gales 1991). Fur seals have also been threatened by oil spills in nearby New Zealand (Anon. 1991).

The Australian Maritime Safety Authority (AMSA) manages Australia's National Plan to Combat Pollution of the Seas by Oil, by coordinating, funding and supporting the actions of industry, State, Territory and Commonwealth governments (Gray 1991; AMSA 1993; Gilbert 1996). In Commonwealth waters, AMSA has prime responsibility for oil spill response, whereas in State waters, the relevant State authority is responsible. However, the National Plan makes no provision for marine mammals, responsibility for which is delegated to the States by default. A draft National Oiled Wildlife Response Plan was completed in September 2002 and includes an appendix on seals. AMSA produces briefing information for the public called: *Rescuing Oiled Wildlife – What You Can Do*, and has distributed oiled wildlife response kits to key mainland centres.

St Aubin (1990) reviewed information worldwide on interactions between oil spills and seals and concluded that, although large-scale mortality has not occurred, seals are nevertheless vulnerable. This is particularly so where seals must emerge through oil to reach colonies where surrounding inlets and foreshores may also be contaminated. Oil can foul the fur of seals, which can interfere with mobility and buoyancy, and lead to decreased hunting efficiency, increased risk of predation, and drowning in pups. Fur seals are more vulnerable than southern elephant seals because oil is likely to adhere to their longer fur. Pups may be more exposed to oil because of their habit of waiting and playing along the rocky shoreline. Oiling can compromise insulation and even lead to abandonment of pups because the pup's odour, used by the mother to locate it, is masked by the oil. Ingestion may also be a problem, particularly through the mother attempting to clean an oiled pup. Oil, especially light oil, attacks exposed sensitive tissues of the eyes, mouth, respiratory surfaces, anal and urogenital orifices, and can result in corneal abrasions, conjunctivitis and ulcers and accumulations of hydrocarbons in tissues and organs.

Other pollutants that have the potential to adversely affect seals, either directly or through the food chain, include heavy metals such as copper and zinc, which could cause problems if mobilised during periods of illness or starvation (Holden 1978). Organochlorines and polychlorinated biphenyls (PCBs) are persistent and lipophilic (i.e. have an affinity for lipids). They can therefore accumulate in the plentiful fatty tissue of pinnipeds (Riseborough 1978). High concentrations of organochlorines have been associated with premature births and other reproductive abnormalities (DeLong *et al*. 1973); suppression of immune function (Ross *et al*. 1997; Duinker *et al*. 1979; Reijnders 1986); and pathological changes in bony tissue and reproductive organs (Bergman *et al*. 1992; Olsson *et al*. 1992, 1994). PCB levels have been correlated with pathological change to the uterus (Helle *et al*. 1976). The general global trends is towards a decrease in the level of organochlorines and PCBs being used, and although these persistent compounds can disperse far from their site of application, the relative isolation of Macquarie and Heard Islands and the seals' foraging grounds gives some protection against these pollutants (Iwata *et al*. 1993). These compounds do not appear to be significant threats to Antarctic and sub-Antarctic populations at present (O'Shea 1999; Burton and van den Hoff 2002; Evans 2003).

MARPOL is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It covers pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage. State Parties must accept two annexes; one on oil, the other on bulk noxious substances. Other annexes in the convention are voluntary. More information on MARPOL can be found at (http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258).

Summary

- With greater sea traffic, oil spills are an increasing hazard to seal colonies worldwide. Macquarie and Heard Islands are relatively isolated from this threat. Nevertheless, fishing, visiting tourist, research and supply vessels may pose a risk of oil spillage.

2.5 Increasing tourism

Background

The natural and wilderness values of Heard and Macquarie Island offer the potential for economic value through tourism. Such tourism is ship-based, which brings with it the risk of spread of alien species and pathogens between islands, and other, limited environmental impacts through such things as logistical operations, waste disposal and walking tracks.

The Macquarie Island Nature Reserve Management Plan (2003 in prep.) states: 'The risk of accidental introduction of alien species, particularly pathogens, is the greatest threat from tourism, as well as disturbance to wildlife and the environment in general. These risks must be kept to a minimum and that is achieved through educational material, quarantine measures, limiting the time allowed in the reserve, the number of sites visited, the frequency of visits, and limiting the number of visitors, their group sizes, their activities and monitoring sites. Tourism at Macquarie Island has so far been very successful in balancing the risks with the benefits.' The same could be said of the risks and management arrangements at Heard Island.

On Macquarie Island, temporary localized influxes of over 100 people may occur for a few days when resupply or tourist ships visit the island (DPWH 1991), and increasing tourism has been identified as a potential threat to the seals (Shaughnessy 1999). In recent decades, increased human activity on Macquarie Island, both through tourist visits and the maintenance of the ANARE station, has had limited environmental impacts through, for example, logistical operations, waste disposal, and the creation and use of walking tracks and field huts. The Tasmanian Parks and Wildlife Service (now Department of Tourism, Parks, Heritage and the Arts; DTPHA) and the Australian Antarctic Division (AAD) have established management procedures to deal with these concerns (DPWH 1991). The Macquarie Island Nature Reserve Management Plan (DPWH 1991), prepared in accordance with the requirements of the *Tasmanian National Parks and Wildlife Act 1970*, does not refer to either seal species specifically but aims to provide maximum protection for the natural assets of the reserve.

A new plan of management is currently being developed (DPIWE 2003). Consistent with the previous plan, tourism is limited to the carrying capacity of the island and its wildlife (also see section A7). Guidelines for tourism operations are given, based on the *National Parks and Reserved Land Regulations 1999*. Visitors must be ship-based and may only visit two small sites, on the Isthmus and at Sandy Bay, and in the presence of management staff from the Tasmanian Department of Primary Industries, Water and Environment (DPIWE), or authorised volunteers. Facilities such as walkways and viewing platforms may be provided to protect the reserve. Tourists do not visit the fur-seal breeding areas. The Parks and Wildlife Service of Tasmania have set a maximum figure of 750 tourists per year, but since this limit was introduced in 1990-1991, it has only been reached on one occasion. Tourists are taken ashore to view southern elephant seals at specified locations and under supervision. At present, tourists do not visit the fur-seal breeding colonies on Macquarie Island and visits do not coincide with the elephant seal breeding season.

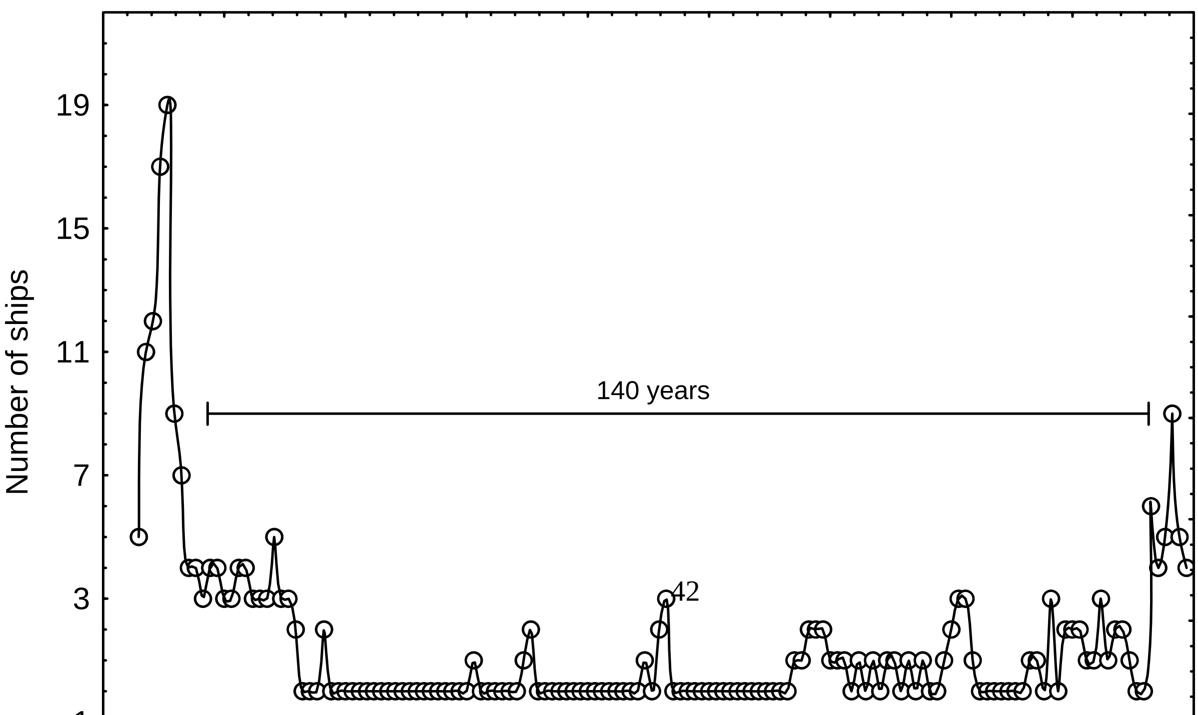
The number of visits by ANARE expeditioners to the fur-seal breeding colonies is regulated, and access by researchers working on the fur-seals is managed by a permit system. Additional information on management arrangements can be found at: (http://www.worldheritagesite.org/sites/site629; and http://www.wcmc.org.uk/protected_areas/data/wh/macquari.html).

Historically, few tourist visits have been made to Heard Island due to geographical and climatic difficulties. Since 1855, there have been visits from 240 ships (see Figure 4, Chown 2003), but in recent years there has been a marked increase. Between 1860-1880 there were about 150 visits to the Island by sealing ships. From 1880-1950, post-sealing, about 20 visits to the island occurred, and between 1950-2000 there have been 60 visits to the island. The ANARE station, built in 1947, has been dismantled. In the past decade, 12 fisheries vessels (and defence vessels); six tourist ships, two yachts and 10 AAD vessels are known to have stopped at the island (all except defence land). In particular, in 2000, several research and survey vessels were sent to the island and another concentrated scientific visit is planned for 2005 or 2006. Numbers of people ashore is generally low, but AAD related activity deployed as many as 58 visitors a day in 1992 and again in 1997.

The Heard Island Wilderness Reserve Management Plan (AAD 1996) outlines protective measures that prohibit entry to the island without a permit and preclude activities, which would be potentially harmful to the natural environment. However, the island is visited infrequently and there is no permanent habitation (http://www.wcmc.org.uk:80/protected_areas/data/wh/himi.html).

Thus, even though there is some increase, at present tourist ships visit Heard Island less than once a year on average. Any increase in tourism activities would most likely be concentrated ashore and within the territorial sea and be subject to conditions imposed by the Heard Island Wilderness Reserve Management Plan, which was instituted in February 1996 and is currently being redrafted (AAD 1996). The plan outlines the protective measures that are in force which prohibit entry to the island without a permit and proscribe activities that would be potentially harmful to the natural and cultural environment. Landing is allowed at only two sites, Atlas Cove and The Spit, although nearly all landings take place at the former. Disease and the introduction of non-indigenous species are seen as the main threat to the relatively pristine environment and the new plan aims to minimise this risk with strict quarantine measures.

Figure 4 Number of ships visiting Heard Island annually since 1895 (Chown 2003)



Summary

- Wilderness areas, high latitude ecotourism and seal watching are increasingly popular tourist attractions.
- At Macquarie Island, there is potential for increased visitation to the reserve, but the management and timing of visits currently affords protection to the seals.
- At Heard Island, tourism occurs at a low level but is largely unmonitored.

2.6 Research impacts

Background

The Macquarie Island Nature Reserve Management Plan (DPWH 1991) notes that: 'The impacts of tourism are negligible compared to the impacts of year round occupation of the island to support scientific, monitoring, conservation and management personnel and programs.'

The same could be said for the potential for disturbance of seals. Disturbance can lead to trampling and desertion of pups and injuries to older seals. Disturbance can be particularly harmful during the breeding season, when pups can be trampled, lost or move to the sea before they are old enough. Adults can also be injured in the crush, and adult males may have to fight to return to their territories (Shaughnessy 1999). Reported impacts include: males trampling pups during charges at human intruders (Galimberti *et al*. 2000; Le Boeuf and Briggs 1977), pups separating from mothers (Galimberti *et al*. 2000; Le Boeuf and Briggs 1977), interruption to suckling, resulting in lighter weaning mass (Bryden 1968) and increased pup mortality (McMahon *et al*. 2000a).

Nevertheless, a study of the weaning mass of southern elephant seal pups on Macquarie Island could detect no difference between two beaches, one with high human presence in the form of an adjacent research station, staff and vehicles, and the other remote from human activity (Engelhard 2002). In this study, lactating females spent more time alert in the presence of human activity but soon returned to normal after people departed the vicinity of the harem. Heavy-lift helicopter operations over two days on the isthmus of the island, adjacent to the elephant seal colony, elicited little discernable reaction (Englelhard *et al*. 2001b). Nor was there evidence from physiological indicators that the handling for research of elephant seal mothers and pups caused measurable stress (Engelhard *et al*. 2002 a, b).

In general, it is believed that southern elephant seals are reasonably robust to human activity near their colonies and elsewhere (Wilkinson and Bester 1988; Burton and van den Hoff 2002), but situations vary and the seal's welfare should always be a high priority.

There has been significant concern over the marking for research of southern elephant seals. Marking seals individually yields information not attainable from broader research, for example, movement and foraging patterns, and demographic data including mortality patterns, survivorship, life expectancy and age at maturity. Several methods of marking seals have been used in Australia, many of which have been applied to pups. These include:

- Plastic tags applied to a web in the hind flipper (southern elephant seal) or the trailing edge of the fore-flipper (sub-Antarctic fur seal);
- Transponder chips, which are embedded sub-dermally and have potential application, are being used for Macquarie Island fur seals, but are not useful for southern elephant seals (eg, Galimberti *et al*. 2000);
- Archival or satellite tags (eg, Bradshaw et al. 2002b; Goldsworthy *et al*. 1997; Robinson *et al*. 2002); and

- Freeze branding and hot iron branding of southern elephant seals (Ingham 1981). Cryo-branding has been found to be unsuccessful because it does not produce readable results in subsequent years (McMahon *et al*. a in prep).

On Macquarie Island since 1993, about 14000 southern elephant seal pups have been hot-iron branded with an individual code to enable long-term life-history studies (e.g., McMahon *et al.* a in prep; van den Hoff in prep). Large numbers of seals were also branded in the 1950s and 1960s for similar life-history studies (Carrick and Ingham 1960; Carrick and Ingham 1962; Carrick *et al.* 1962). The Commonwealth Environment Minister stopped this practice in March 2000 because of serious concerns over animal welfare. Researchers have discontinued the marking of seals in this way and generally the amount of research involving seals on the island is decreasing, but branded seals will persist in the population for some time and they are a valuable source of demographic information.

Research is now moving to less invasive marking techniques. One of the most common and useful techniques is the use of data loggers (time depth recorders – TDRs) and satellite linked transmitters (PTTs), which provide information about the seal's location and behaviour while at sea. Concern has been expressed that the attachment of these devices causes injury and could contribute to population decline.

The current tracking program at Macquarie Island has been operating since 1999 and uses 210g TDRs, and 450g PTTs, which weigh less than 0.08% of the average body weight of females (Mark Hindell pers. comm.). A maximum of 25 seals at a time are carrying TDRs, representing <0.03% of the total population. After some initial problems with attachment in the first year of the study, when three seals developed superficial abrasions under the TDRs, attachment no longer causes injuries, and no long-term health problems have been detected.

A working group of stakeholders has begun to develop an agreed protocol for tag attachment and removal for southern elephant seals (Nick Gales and Mark Hindell pers. comm.). The group has suggested that: 'To minimise impacts on individuals the smallest equipment packages currently available should be used, and the amount of glue minimised. The size of both TDRs and PTTs has decreased significantly over the last decade and these are now less than half the size of the early models. Gluing techniques have also improved and it is now known that smaller amounts of glue reduce the incidence of abrasion, and applying cold seawater to the almost-hardened glue reduces the heat produced by the glue during setting. Units are removed, to enable data to be downloaded, by cutting the hair to which it is attached, without breaking the seal's skin.'

At present, stomach lavaging is the most common means of dietary research for southern elephant seals (Ferreirier and Bester 1999). This technique is quite invasive and the development of fatty acid analysis as a replacement is showing promise (Best *et al.* 2003; Bradshaw *et al.* 2003). A range of other, more sophisticated techniques is available, for example, DNA and microscopic analysis of scats, although their efficacy remains largely unknown.

Researchers in the sub-Antarctic (and Antarctic) report their tagging effort to the Antarctic Pinniped Tagging and Marking Database, maintained under the Scientific Committee for Antarctic Research (SCAR) Group of Specialists on Seals (by Dr John Bengtson, National Marine Mammal Laboratory, Seattle, USA), but reporting is not mandatory.

The new Macquarie Island Nature Reserve Management Plan (DPIWE 2003) states that: 'Due to the high conservation status and values of the reserve, as well as the vulnerability of the flora, fauna and soils, access to the reserve will be strictly controlled. All visits to the reserve, whether they are for scientific, management, educational tourism or emergency purposes, must be conducted in a manner that minimises accidental introductions, adverse environmental impacts and wildlife disturbance.'

The new plan aims to encourage research and data-collecting programmes providing that they have no long-term detrimental effects and: 'All scientific research, monitoring, conservation and management activities involving threatened species must clearly demonstrate significant contribution to the long term conservation, management and protection of those species and must meet the current guidelines for threatened species research.'

For long-term programs, the Secretary and the Director may require interim reporting of research results where these results are important for ongoing conservation management programs, particularly of threatened species.' Permits are to be issued for 12 months, then reviewed, and regular reporting is required.

Proposals to carry out scientific research programs in the Macquarie Island Nature Reserve are considered by several committees, including the Macquarie Island Research Advisory Group of the DTPHA and DPIWE, AAD, and other organisations.

The Plan allows for a services zone, Zone A, for buildings, facilities and scientific equipment necessary to carry out approved scientific data collecting and management programs. Zone A also provides the main living, working and logistic support facilities for visitors working in the reserve. The beach areas in this zone are the principal resting and moulting areas for elephant seals (and many breeding birds). Access to Zone A for resupply and logistic purposes may be across any of the beaches adjacent to the zone provided that disturbance to seals and breeding birds is kept to an absolute minimum. This is crucial during the breeding season when researcher presence on the island is at its highest.

Research on seals on Heard Island is subject to the *Heard and McDonald Islands Act 1953* and the *Environment Protection and Management Ordinance 1987*. Advice on the avoidance of disturbance to seals can be found in the AAD's Operations Manual. Under their interim guidelines for Heard Island it is prohibited to collect samples except for *bona fide* scientific reasons. There have been few opportunities for research on the island. However, if plans by AAD go ahead, there will be increased research activity on Heard Island and less on Macquarie Island.

Summary

- Responsible research is vital to the understanding of seal population ecology and the identification and management of significant threats.
- Seal research projects need to have clearly defined objectives that contribute to long-term conservation, management and protection. They need to describe methodology, numbers of animals likely to be directly affected, duration of the program, reporting outcomes and links to other programs.
- There is some concern over intrusive research involving pup handling and marking because of the risk of direct impacts of disturbance and of impacts of marking.

2.7 Direct human interference away from the main breeding colonies

Background

As increasing numbers of southern elephant and sub-Antarctic fur seal venture north beyond the sub-Antarctic to reach Tasmania and mainland Australia, the potential for interactions with humans also increases. The management of 'stranded' pinnipeds is often well publicized and there is strong public empathy for them, but to the inexperienced, seals may appear to be sick and in need of assistance when they are not.

Though seals are generally considered to be robust in their interactions with humans, undesirable incidents occur. For example, in Tasmania, southern elephant seals have been persecuted when they have not been under protective surveillance (Rosemary Gales pers. comm.). Reports include incidents of a seal being clubbed Bruny Island in 2002, another two being shot on

Maatsuyker Island in the 1990s and another, near Strahan, being euthanased unnecessarily (Burton and van den Hoff 2002). Fur seals are sometimes also shot (eg., 'Dead seals were shot', Daily Telegraph September 5, 2002), in some cases, it is claimed, by mainland fishery personnel.

Mawson and Coughran (1999b) reported on the occurrence of sick, injured and dead pinnipeds and the success of any applied management in Western Australia from 1980-1996. A total of 244 pinnipeds of six species were recorded sick, injured or dead, of which 179 (73.4%) were dead or died subsequently. Of the 179 animals, 51 (28.5%) died as a result of direct or indirect interaction with humans. Twenty (39%) of the deaths caused by humans were the result of violent events directed at the pinnipeds (i.e. shot, speared, or clubbed). The most common cause of unnatural death was gunshot wounds (n = 16). A total of 45 sub-Antarctic fur seals were encountered in the 17 years covered by the Western Australian review. Roughly 62% were found dead or died in treatment and 37.7% were released. Two of seven seals for which the cause of death was known were shot or drowned in fishing gear. A total of eight southern elephant seals were found, all since 1990. Seven of these (87.5%) returned to the wild but a newborn pup died.

Summary

- Numbers of southern elephant and sub-Antarctic fur seal venture north beyond the sub-Antarctic to reach Tasmania and mainland Australia, with the potential for negative interactions with humans. An issue for these individuals is disturbance from members of the public trying to help stranded animals.

2.8 Climatic and oceanographic change

Background

Measurements between 1947 and 1980 suggest that glacial retreat has been marked on Heard Island, particularly on the eastern flanks. This has been associated with changes in weather patterns, and over the past 50 years has resulted in a 1˚C increase in temperature (eg, Allison and Keage 1986). On Macquarie Island, there has also been a 1˚C rise in air temperature, between 1949 and 1986, with the greatest increase occurring over the last decade of this period (Adamson *et al*. 1988). These changes may be associated with global warming caused by increased release into the atmosphere of greenhouse gases.

Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases' has been declared a Key Threatening Process under the EPBC Act. The threat is described as reductions in the bioclimatic range within which a species or ecological community exists due to emissions induced by human activities of greenhouse gases. More information can be found at: (www.deh.gov.au/biodiversity/threatened/ktp/greenhouse.html).

The listing of this threat recognises that the distribution of the process is continental. Non-biological components of the process include air temperature rise, alterations in rainfall patterns, changes to the El Niño Southern Oscillation (ENSO), and sea level rise (eg, Chittleborough 1991). In turn, changes in sea-ice positions, fluxes and glacier melt rates (Morison *et al*. 2000; Vincent *et al*. 2001) are predicted to result in changes in flows of ocean currents (Hansen *et al*. 2001). These changes are likely to cause shifts in the locations, behaviour, species composition and abundance of the prey of both seal species, and hence affect seal populations. Other implications of warming include ice thinning, which may impact directly on seals that haul-out in the Antarctic (Wadhams and Davis 2000, for the Arctic).

Alterations in environmental conditions such as sea ice extent have been linked to two irregular fluctuations in climatic conditions in the Southern Hemisphere (Kwok and Comiso 2002; White *et al.* 1998). These are the Antarctic Circumpolar Wave (ACW), which is a four-year cycle of anomalous atmospheric pressure (White and Peterson 1996), and ENSO, which is an approximately 7-8 year pattern of anomalous sea temperatures (Allan et al. 1996). ENSO and the ACW may affect marine predators by modifying the availability of food sources such as krill (Murphy and Reid 2001; Priddle *et al.* 1998), or by affecting sea ice production (Gloersen 1995) and, through that, primary production (Smith and Nelson 1985a; Smith and Nelson 1985b). The direct effects of ENSO events on a number of marine and land-based predators have been documented (e.g., Trillmich and Ono 1991; Guinet *et al.* 1994; Vergani *et al.* 2001), but understanding of the links between physical processes such as the ACW and ENSO, and biological processes remains poor (Hindell *et al.* 2003a; McMahon *et al.* a in review).

The consequences for seal populations of climate change or fluctuations are unknown but the following potential impacts have been suggested:

- An adverse effect on prey abundance or availability through sea temperature increases.
- Reduction in the pack ice, where southern elephant seals feed, particularly during winter.
- Increase in the likelihood of epizootics in seal populations due to increased ambient temperature (Lavigne and Schmitz 1990).

One explanation offered for the reduction in the southern elephant seal population is that changes in the environment of the southern ocean may have had an adverse affect on their prey (Burton 1986; Burton *et al*. 1997; Hindell *et al*. 1994, 2003b; McCann and Rothery 1988). Any such effect is likely to be amplified because, although elephant seals may forage widely, within each of the sub-populations individuals share common foraging areas (Hindell *et al*. 1991; Jonker and Bester 1998; McConnell *et al*. 2002; McConnell and Fedak 1996; Slip *et al*. 1994b; van den Hoff *et al*. 2002). However, phocid populations undergo periodic fluctuations, and long-term data are necessary to understand trends (Testa *et al*. 1991).

Fur seals are highly sensitive to changes in sea surface temperature. A 1% increase in sea surface temperature can result in >10% reduction in fecundity (Figure 5; Goldsworthy *et al*. 2002b). Hence, global warming may be a threat to seals if it drives fur seal prey to greater depths or locations far from breeding colonies (Trillmich and Ono 1991).

A reduction in the emissions of greenhouse gases requires an internationally coordinated effort. Australia has made a commitment to limit greenhouse gas emissions. In addition, the States and Territories are pursuing additional opportunities to abate greenhouse gas emissions in a cost-effective and environmentally sensitive manner.

Summary

- Loss of climatic habitat, including an increase in sea surface temperature, caused by anthropogenic emissions of greenhouse gases, is a potential threat. Management of this process requires both domestic and international action.
- Understanding of the links between physical processes such as the ACW and ENSO and biological processes remains poor.

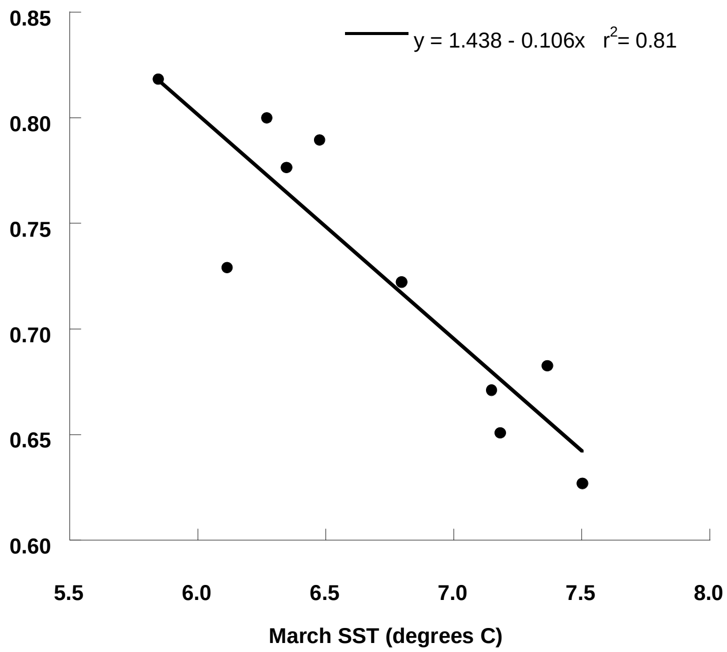


Figure 5 Relationship between March mean sea surface temperature in the 1° x 1° region immediately north of Macquarie Island and fecundity (births per adult females known to be alive) in the subsequent breeding season (November-December) for combined Antarctic and sub-Antarctic fur seal population (Goldsworthy *et al*. 2002b).

2.9 Disease

Background

As noted by Shaughnessy (1999), the gregarious habits of seals provide opportunity for the rapid transmission of infectious diseases. Increased human visitation to both Heard and Macquarie Islands increases the risk of introduction and spread of disease. Occasional large-scale mortality in colonies overseas has been attributed to disease (eg. phocine distemper, Mahy 1988; Kennedy 1990, 1998; Kennedy *et al*. 2000). Nevertheless, many populations have shown the ability to recover quickly (ICES 1994).

Antibodies to phocine distemper virus (morbillivirus) have been reported from the southern ocean in crabeater seals (Bengtson *et al*. 1991). There have been two epizootics recorded in Hooker's sea lion, which breeds on Auckland Island, New Zealand, and visits Macquarie Island. The first outbreak was in 1998 where at least 50% of pups died. It was estimated that the disease affected a maximum of 20% of the adult population, many of which appeared to survive, suggesting that impact on the population was unlikely to be serious (Nick Gales pers. comm.).

Tuberculosis (TB) is highly virulent in fur seals and other seals (Cousins 1996) and has been detected in Australian seals, including a dead fur seal on Macquarie Island (Cousins *et al*. 1993). The incidence and impact of TB in Australian seals is not well known for all species and is worthy of further study.

Other diseases reported to cause significant numbers of seal deaths in the Northern Hemisphere include calicivirus (San Miguel sea-lion virus), which causes pup deaths following premature birth (Gilmartin *et al*. 1976), and the bacterial disease leptospirosis (Harwood and Hall 1990), which caused deaths of sub-adult males and is implicated in abortions. The nematode hookworm, which causes anaemia in pups and has caused seal deaths in Alaska (Keyes 1965), has been reported in Australian fur seals and southern elephant seals (Norman 1996; Harvey Johnston and Mawson 1945) but its pathogenicity is unknown. A novel arbovirus has been described from Macquarie Island southern elephant seals, to which most seals had neutralizing antibodies but displayed no pathology (Linn *et al*. 2001).

Linn *et al*. (2001) concluded that there is no evidence of widespread disease in southern elephant seals. Nevertheless, viral infections may not always manifest themselves in dramatic mass mortality events as observed in the Northern Hemisphere (Visser *et al*. 1991), but may be more insidious.

Rehabilitation of sick and injured seals is often viewed as a priority by the public. The care period should be minimized and the seal released at an appropriate location near the point of capture (St Aubins *et al*. 1996). However, the conservation significance of the rescue of individual seals is questionable, as is their release back to the wild after a period in captivity (eg Haebler 1992). The Scientific Committee for Antarctic Research (SCAR) discourages such practices because of the risk of introducing pathogens. The Australian National Committee on Antarctic Research adopted this recommendation in 1995, and the AAD and State wildlife authorities were advised.

The AAD administers the *Heard and McDonald Islands Act 1953* and the *Environment Protection and Management Ordinance 1987*. Interim guidelines for visitors have been followed for several years under which it is prohibited to, among other things, interfere with fauna or flora or introduce disease.

Late in 2002, the Australian Wildlife Health Network, based at Taronga Zoo, Sydney was launched. One of its key roles will be to establish collaborative links and communication networks between these three areas as well as with universities, zoos, museums, CSIRO and other organisations. A national coordinator has been appointed to oversee the development of a national database of diagnostic and surveillance information, an expertise registry and a website.

Summary

- Seals are gregarious animals on land and sometimes at sea, which increases the risk of transmission of infectious disease. Infectious diseases, some of which occur in Australian seals, have been identified as the cause of mass seal deaths in the northern hemisphere and, to a much lesser extent, the southern hemisphere.

2.10 Predation

Background

Several large predators prey on both southern elephant and sub-Antarctic fur seals. As elsewhere, killer whales associate with Australian colonies of fur seal and elephant seal, particularly at the time that weaned seals are learning to swim (Morrice *et al*. 2002). The whales can take all but elephant seal bulls. Leopard seals, Hooker’s sea lion and possibly sleeper sharks are also capable of taking smaller individuals and age classes.

A Hooker’s sea lion has been recorded killing elephant seal pups on Macquarie Island (Johnston pers. comm to Geof Copson; Geof Copson pers. obs.). The sea lion also kills live fur seal pups on the island (Robinson *et al*. 1999) and is capable of killing adults and juveniles. In New Zealand, the sea lion preys mainly on pups and its impact on fur seal populations is considered to be negligible (Bradshaw *et al*. 1998).

At Macquarie Island, predation by the sea lion accounted for about 24% of all recorded fur seal pup deaths between 1994 and 2001 (n= 289; Goldsworthy 2002). In 1996, this was due to one individual animal, which accounted for 56% of deaths in that year (as documented in Robinson *et al*. 1999). Fur seal remains have also been found in the scats of itinerant Hooker's sea lions on the island (McMahon *et al*. 1999b).

While the predation by vagrant sea lions can cause significant pup mortality, the Hooker's sea lion itself is a globally threatened species (vulnerable; IUCN Red List of Threatened Species 2002), and despite being exposed to predation, the fur seal population on Macquarie Island is increasing, as are rates of annual pup production (data in Goldsworthy 2002). Furthermore, demonstration of a significant impact at the population level by any predator would be difficult because mortality factors tend to be compensatory, leaving the rarely measured but critical life history variable of rate of recruitment into the breeding population, unaffected.

Increased predation by killer whales has been suggested as a possible cause of southern elephant seal declines at Marion Island and Îles Crozet, principally through predation of weaners (Condy *et al*. 1978; Guinet 1992; Guinet *et al*. 1999). However, the whales are present at all the major colonies and there is no evidence that differential predation rates between larger populations correspond to population trends (e.g., South Georgia versus Macquarie Island). While predation may become important when populations reach low numbers as at Marion Island (McMahon *et al*. 2003), it is unlikely to have impact at the large colonies at Macquarie and Heard Island. McMahon *et al*. (2003) and McMahon *et al*. (a in review) concluded that resource limitation was the main cause of the broadscale declines observed in the Pacific and Indian Oceans since the 1950s, and proposed that predation is just one of many factors that contribute to differences between populations in the extent of the declines.

Summary

- Various predators gather around Australian seal colonies and prey on individual seal pups, but there is no evidence for impact on seal populations or interference in the recovery process.
- The sub-Antarctic fur seal population is potentially at risk because its numbers are so low, but it is buffered from predation by large numbers of other fur seals.

2.11 Introgression and other genetic effects in the sub-Antarctic fur seal

Background

In recommending that the sub-Antarctic fur seal be listed under the EPBC Act as Vulnerable, the TSSC considered the small numbers of adults and the extent of hybridisation meant that the estimated total number of mature individuals in the population was extremely low.

Macquarie Island is the only island where three *Arctocephalus* species are sympatric (Figure 2; Shaughnessy and Goldsworthy 1993). There, even though outnumbered by New Zealand fur seals, Antarctic fur seals are the predominant breeders, and all three species are increasing in numbers. At present, at Secluded Beach, which was recolonised first, most sub-Antarctic fur seal breeders gather at the rocky southern end where there is the greatest level of intermixing with Antarctic fur seals. There is also extensive intermixing at Goat Bay. Only few hybrid females are among the Antarctic fur seals at the beaches on the north-east section of Hasselborough Bay.

For some time, interspecific mating and pups with intermediate characteristic have been reported at Macquarie Island (Kerley and Robinson 1987; Shaughnessy *et al*. 1988a; Goldsworthy 1999b). Hybridisation was thought to be mainly between Antarctic and sub-Antarctic fur seals, as interpreted from allozyme and DNA studies and observed matings (Shaughnessy *et al*. 1998;

Wynen 2002). Based on external characteristics and skull morphology, Antarctic and sub-Antarctic fur seals have been reported to hybridize on two of the three islands on which they are sympatric (Condy 1978; Kerley 1983; Kerley and Robinson 1987; Shaughnessy *et al*. 1988a; Hofmeyr *et al*. 1997; Wynen *et al*. 1999). Sub-Antarctic fur seals have begun to colonise Heard Island (Shaughnessy *et al*. 1988b), where Antarctic fur seals are common, but hybridization has not yet been observed there.

Recent DNA studies have revealed that hybridization and back-crossing on Macquarie Island between sub-Antarctic and Antarctic fur seals is more extensive than previously thought (Goldsworth *et al*. 1999; Lancaster 2001; Wynen 2002; Goldsworthy 2002). Of 259 fur seal pups sampled, 35% were hybrid, 4% were sub-Antarctic fur seals and 61% Antarctic fur seals. Most (76%) of the hybrid pups (n=92) on the island were fathered by New Zealand males (Lancaster 2001). Eighty percent of the pups (n=34) of sub-Antarctic fur seals were hybrids, 89% fathered by New Zealand males, and there was considerable backcrossing. Yet, females prefer to mate with conphenotypics and are seldom seen to mate with New Zealand fur seal males, which rarely hold harems (Goldsworthy *et al*. 1999). It is thought that matings with New Zealand fur seal males take place outside the breeding colonies, in the males' haul-out areas. Whether these males are more sexually attractive or insistent than those of the other species, and whether the species and mate recognition processes that usually serve to separate closely related, sympatric species have broken down, remain to be fully investigated (for preliminary research see St Clair *et al*. 2001, Page *et al*. 2001, 2002).

An additional potential problem is a loss of genetic diversity due to over-harvesting by sealers. This has been investigated for the sub-Antarctic fur seal by Wynen *et al*. (2000) and found not to be the case. Population structure is still present and there are three lineages, or clades, which differ only in the percentage of each in the various populations, rather than having a fixed geographic distribution. The study suggested that Iles Crozet and Macquarie Island populations were the closest genetically, and pointed to Prince Edward as the main source of recolonising sub-Antarctic fur seals. Greater genetic variability was detected in the sub-Antarctic fur seal than in the Antarctic fur seal, which was attributed to greater levels of sealing in the latter species.

It is thought that the majority of sub-Antarctic fur seals on Macquarie Island are immigrants and not the result of intrinsic increase (Simon Goldsworthy pers. comm.). If this is the case, the hybridization currently taking place may be immaterial to the future of the population, which will depend on colonizers from other islands until such time that a viable population establishes on Macquarie Island. Indeed, at least two factors potentially augur against the establishment of a viable pure-bred population: the vastly greater numbers of the other two species of fur seal, and uncertainty over the original species composition of the fur seal population before harvesting.

Summary

- Greatly reduced seal numbers from historical over-harvesting potentially has at least one effect on the genetic composition of the sub-Antarctic fur seal population: introgression.
- Loss of genetic diversity from past over-harvesting does not appear to be an issue as population structure is still present and there is some intermixing between populations.
- Hybridisation and resulting introgression appears to be a natural phenomenon and as such is impossible to control. However, at Macquarie Island the rates may be unusually high because of the artificially reduced numbers of one species, the sub-Antarctic fur seal, in the presence of greater numbers of close congeners, which may also be more sexually competitive.

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Appendix I Commonwealth legislation relevant to Macquarie Island seals

(compiled by Geof Copson)

Legislation	**Purpose**
Commonwealth Quarantine Act 1908	Regulates quarantine matters
Protection of the Sea (Discharge of Oil from Ships) Act 1953	Prohibits the pollution to the sea by the discharge of oil from ships
Fisheries Management Act 1991	Regulates commercial fishing operations in the Australian Fishing Zone
Environment Protection (Sea Dumping) Act 1981	Regulates the dumping of waste and other matter into the sea
Protection of the Sea (Powers of Interaction) Act 1983	Authorises the Government to take measures to protect the sea from pollution by oil and other noxious substances discharged by ships
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	Protects the sea from pollution by oil and other harmful substances discharged from ships
Hazardous Wastes (Regulation of Imports and Exports) Act 1989	Regulates the import and export of hazardous wastes to ensure that such activity does not present a safety risk for human beings or the environment
Environment Protection and Biodiversity Conservation Act 1999 *Environment Protection and Biodiversity Conservation Regulations 2000*	Protect matters of national environmental significance, which include migratory species, nationally threatened species and ecological communities, World Heritage, and the marine environment

Appendix II Tasmanian state government legislation relevant to Macquarie Island seals

(compiled by Geof Copson)

Legislation	Purpose
Oil Pollution Act 1961	Provides for control of oil discharge from ships
Environment Protection Act 1973	Provides for environmental assessment of projects and enforcement of environmental regulations
Marine Act 1976	Regulates refuse disposal
Animal Welfare Act 1993	Regulates research, experimentation and wildlife management for vertebrate species
Living Marine Resources Management Act 1995	Regulates the fishing industry and protects fish and their habitat within State waters
Threatened Species Act 1995	Provides for the listing and protection of threatened species in Tasmania
National Parks and Reserves Management Act 2002	Provides for establishment and management of national parks and reserves
Nature Conservation Act 2002	Provides for the conservation and management of native flora and fauna in the State

Appendix III Commonwealth legislation relating to Heard Island

(in addition to that listed in Appendix I)

Responsible agency	Legislation
Australian Antarctic Division	*Antarctic Treaty (Environment Protection) Act 1980*, particularly its *Antarctic Seals Conservation Regulations 1986*[1] *Antarctic Marine Living Resources Conservation Act 1981* *Environment Protection and Management Ordinance 1987* made under the *Heard Island and McDonald Islands Act 1953*

[1]apply only to the part of the HIMI continental shelf that is south of 60º S, the Antarctic Treaty area, which is outside the HIMI EEZ boundary.