Southern elephant seals (Mirounga leonina L.) in the Antarctic Treaty Area

Authors

Marthán N. Bester, Mammal Research Institute, Department of Zoology and Entomology, University of Pretoria, South Africa

Horst Bornemann, Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany

Gustavo A. Daneri, División Mastozoología, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" CONICET, Argentina

John van den Hoff, Australian Antarctic Division, Tasmania, Australia

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Brief Overview

- Despite the wholesale slaughter of southern elephant seals for the commercial extraction of blubber-oil during the mid and late 1800's, their populations have persisted at almost all historical breeding locations
- There are presently an estimated 749,000 southern elephant seals in the Southern Ocean, about 2% (14,500) of which live permanently in the Antarctic Treaty Area south of 60º South
- Although these southernmost permanent breeding populations are relatively small, a large (yet to be determined) proportion of individuals originating from the main sub-Antarctic breeding locations spend 70 – 80% of their time at sea south of 60º South feeding on a range of prey over the Antarctic continental shelf and close to the sea ice edge; both areas are responding to climate change
- Southern elephant seals feed on a range of potential and realised commercial fish and squid species, and since their dives can reach depths of 1,000 – 2,000m they are exposed to potential incidental and often (~ 90%) lethal interactions with commercial fishery operations, particularly longline fisheries for toothfish (*Dissostichus sp.*)
- The relationship between southern elephant seals and the Antarctic Treaty Area krill (*Euphausia superba*) fishery requires exploration
- How elephant seal populations will respond separately and cumulatively to the effects of climate change and future potential increases in the commercial removal of food from their foraging areas remains largely unknown and uncertain

Detailed Overview

Distribution and abundance

Severely depleted populations of southern elephant seals (SES) *Mirounga leonina* have recovered under protection after being heavily exploited for the commercial extraction of blubber-oil during the mid and late 1800's. Their numbers decreased again due to unknown reasons from the 1950's to 1990's with a subsequent stabilization, and at some locations populations increased. Numbering around 749,000[1], SES populations occur in at least four genetically distinct stocks across their Southern Ocean range[2]. Two of these occur in the Southern Atlantic Ocean (SAO), one in the Southern Indian Ocean (SIO) and a fourth in the Southern Pacific Ocean (SPO). While their main breeding populations occur north of the Antarctic Treaty Area (ATA), smaller breeding populations occur primarily on islands in the Antarctic Peninsula Area (APA) within the ATA (Figure 1). Currently, an estimated 14,500 individuals, or ~ 2% of the total SES population, spend year-round within the ATA.

Since access to coastal Antarctica in October is restricted by sea ice, pupping on the continent is rare[3, 4]. However, small populations of between 20 to 500 mostly male SES of all age classes are known to visit ice-free areas on the Antarctic continent (Figure 1) for their annual moult (January – April) when the summer sea ice minimum allows access to the coast. Owing to the remoteness of some moult locations their numbers can be difficult to monitor, but where humans operate close to those locations their numbers are known to vary annually (van den Hoff unpublished data).

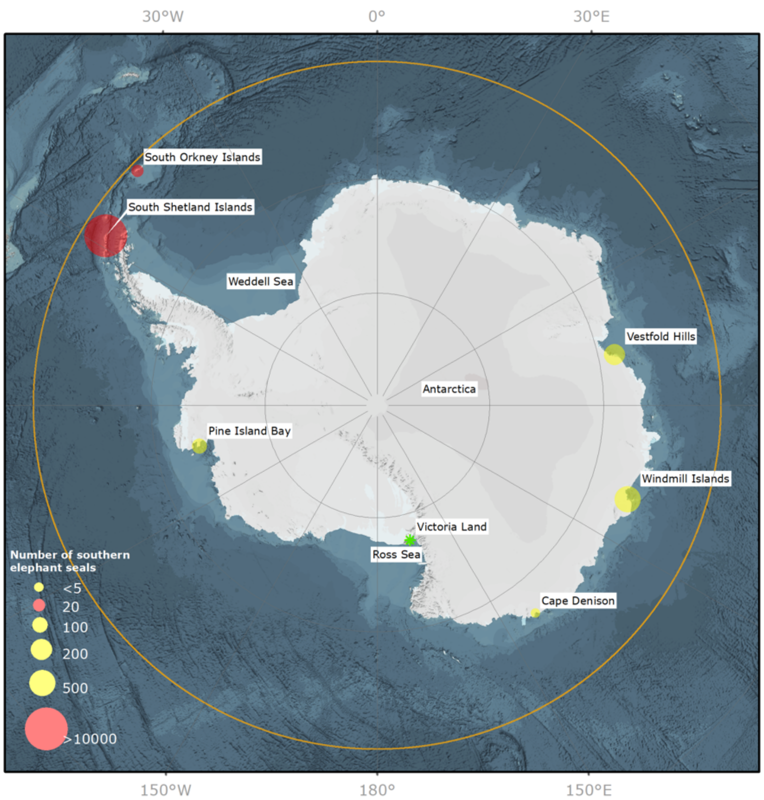

Fig. 1: South polar view of Antarctica showing the distributions and abundances of southern elephant seal (Mirounga leonina) at breeding (red dot) and moulting (yellow dot) locations. Orange line = northern boundary of the Antarctic Treaty Area at latitude 60º S. Green star = past breeding site.

Little is known regarding the natural regulation of populations of this species, especially for ATA populations. Predation by killer whales (*Orcinus orca*) in the sub-Antarctic region is a factor, particularly at smaller breeding populations[5]. Bite wounds, observed on surviving individuals, suggest that sleeper sharks (*Somniosus antarcticus*), and other shark species, also attack SES, but not all predation attempts are successful[6].

There is evidence that climate variability can have demographic consequences for female SES breeding at Macquarie Island[7]. The potential for climate to influence SES populations has implications for their regulation with future changes in the global climate. Yet after much research the causes of the observed long-term trends for SES populations to date remain obscure, as does their susceptibility to climate change. Other human-based pressures on SES populations are much clearer, coming from commercial fisheries. There is incidental mortality of individuals in association with established commercial, and exploratory, toothfish (*Dissostichus* spp.) longline fisheries[8, 9] (Figure 2), and the relationship between the seals, toothfish, and krill (*E. superba*) fishery within the ATA needs to be explored in more detail.

Fig. 2: Southern elephant seals (*Mirounga leonina*) are "incidental bycatch" in the Patagonian toothfish (*Dissostichus eleginoides*) longline fishery. Seal mortalities typically result from drowning during the longline soak period. This young seal was hooked in the mouth, became entangled in the longline and likely drowned at a depth of ~ 950 m. Inconsistencies in reporting across different fisheries plus unknown levels of illegal fishing

activities make it difficult to determine how many southern elephant seals are killed each year in Southern Ocean fishing operations. Seal species such as crabeater seals (*Lobodon carcinophaga*) are known incidental bycatch in longline fisheries within the ATA (https://www.ccamlr.org/en/system/files/appJ_1.pdf). Photo: name withheld for commercial reasons.

Haulout Behaviour

Although SES typically spend more than 85% of their lives foraging at sea, they haul out on land in the APA twice per year as adults, once to breed from late September to early November (austral spring) and once to undergo their annual moult from December to March (austral summer). Absent during the breeding season, younger age classes also come ashore twice each year. Juveniles commence their moult haul out as early as November and may briefly appear on land during the middle of the year for a period termed the mid-winter haul out.

The preferred habitat for SES moulting at ice-free areas on the continent and the islands within the ATA10 are gently sloping sandy beaches which provide access to communal areas known as moult wallows. That habitat preference often results in their co-occurrence with human operations, their associated infrastructures and activities (Figure 3).

Fig. 3: Looking north from the Vestfold Hills, East Antarctica, toward the advancing winter sea-ice edge. After completing their annual moult on land, these male southern elephant seals (*Mirounga leonina*) must cross the ice to reach their winter foraging areas. Note the nearness of the station infrastructure (wharf and containers) to the beach where the seals moulted. Photo: Rachel McInerney.

The cold, dry Antarctic environment, combined with repeated usage at some moult sites, has resulted in the preservation and accumulation of shed hair. Investigations of repeatedly used wallows in the Vestfold Hills revealed (van den Hoff unpublished data) that shed hair has accumulated to depths of 90 cm over several thousand years (Figure 4).

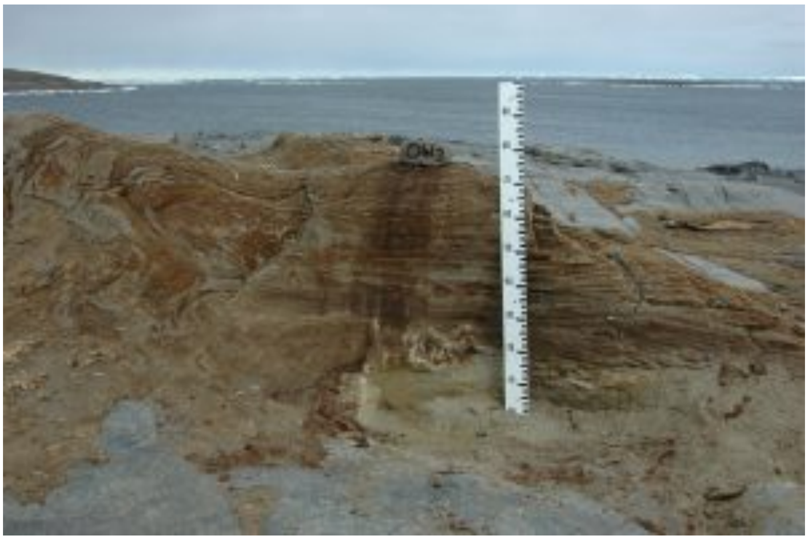

Fig. 4: Part of an extensive southern elephant seal moult site (wallow) in the Vestfold Hills, East Antarctica. Note the laminated deposition of the hair and faeces, which is in this case ~ 70 cm deep. Open water from February until early April allows the seals access to the area. Scale in cm.

Life History

SES females can grow to about 2.8m in length and weigh up to 900kg. Adult males are considerably larger, growing up to 5m in length and weighing up to 5,000kg. Females can live to 23+ years and become sexually mature at about 2-6 years. Males are able to breed at about 4-5 years, mature socially at 6-8 years, but the majority of breeding bulls are 9-12 years old. Females aged 3-23+ years give birth to single pups from late September to early November, usually within aggregations of two or more females, termed 'harems'[11]. Pups suckle for about 3 weeks, to late November, with the timing of events usually delayed at higher ATA latitudes where the peak of the female haul out is around 11 days later than at sub-Antarctic latitude[12]. Just before the pups wean, adult females mate on land with dominant males (beach masters). Less dominant males (assistant beach masters) have the opportunity to mate in harems generally greater than 60 females. After the breeding season, all participating adults depart to sea[13].

ATA populations in the APA have heavier pups at weaning[14] and females with the largest body size of all populations[15]. Those studies suggested locally high food availability in the APA contributed to the excessive body size of females, which benefitted their pups during the lactation period.

Diving Behaviour

Both dive duration and depth of SES vary between the sexes, age classes and among the regions. Adult SES from the APA make long, deep dives. Females dive to mean depths (± standard deviation) of 368 (± 83)m, however mean maximum depths are to 1,099 (± 400)m. The deepest dive yet recorded for a female SES in the region was down to 2,378m. Dives last for a mean 24.6 (± 5.6) minutes, mean maximum duration of 67.0 (± 18.2) minutes, and an absolute maximum of 92.3 minutes. Adult males dive to a mean depth of 399 (± 49)m, and a mean maximum of 1,275 (± 282)m.

The deepest dive yet recorded for a male in the region was down to 1,629m. The mean duration of these dives are 24.5 (± 3.8) minutes, a mean maximum of 70.6 (± 9.9) minutes, with an absolute maximum of 82.3 minutes[1]. The information suggests that SES are capable to travel up to 5km underwater in around 1.5 hours.

Generally, elephant seals from within the ATA dive deeply and feed primarily in the mid-water (meso-pelagic) regions of the water column. Long dives are punctuated with short surface intervals of approximately 2–3 minutes. They show diel diving patterns, diving to shallower depths at night/twilight, and to greater depths during the day. These diving patterns are likely a response to vertically migrating prey[11].

Foraging Ecology

The foraging ecology of SES tends to correlate with a number of physical oceanographic properties, in particular the concentration of sea ice cover and water temperature. At foraging depths, water temperature, surface light levels and the percentage of surface light reaching 150m also influences SES foraging during day, night and twilight periods, during late spring and early summer[16]. However, inter-population, inter-seasonal, latitudinal and sex differences exist in the nature of such relationships[1, 16].

Establishing the full complement of prey species consumed by SES during their extensive ocean migrations has many challenges. SES feed mainly on deep dwelling fish and squid species, but little information on where prey are eaten are available. Stomach lavage of adult female SES within the ATA indicated cephalopods, especially the Antarctic glacial squid *Psychroteuthis glacialis* and other muscular species such as *Alluroteuthis antarcticus* and *Moroteuthis knipovitchi*, as main prey, followed by fish. Fish are largely represented by mesopelagic lanternfishes such *as Gymnoscopelus nicholsi* and *Electrona antarctica*, including the Antarctic silverfish *Pleuragramma antarctica* in higher latitudes. Male SES share especially the suite of squid species consumed by females, but males also feed more on benthic *Pareledone* octopus[17, 18]. In addition to cephalopods and fish, euphausiid crustaceans, most probably *Euphausia spp.* (krill) may constitute important seasonal prey especially for juveniles[19, 20].

SES diet has been inferred from analyses of fatty acids and stable isotopes of nitrogen and carbon that accumulate in body parts as a product of ingestion. These studies generally confirmed those from lavage studies, showing that SES are mixed fish-squid predators and some juveniles may prey on euphausiids[20]. Moreover, studies of this type have also shown that the proportions of those broad prey groups (fish/squid/mixed) can vary both temporally and spatially[20, 21].

Migrating Behaviour

Temporally, SES move predictably: there is a post-breeding pelagic period of about 2-3 months in adult females (approximately late October to January) and about 4-6 months in adult males, after which they return to land for the annual moult. The terrestrial moult period is then followed by another period at sea until the seals return to breed. Spatially, mean trip distances (+ standard deviation) for SES breeding/moulting within the ATA around the Antarctic Peninsula amounts to 1,464 ± 767km (max. 3,547km) and 1,270 ± 1,105km (max. 3,133km) for adult females and adult males respectively[1]. Most remain on or close to the western Antarctic Peninsula shelf, although some undertake very long migrations to the west along the ice edge, overlapping with seals from the Macquarie Island population22. These numbers vary between populations and with the bathymetry at their foraging areas, as well as whether the animals use a pelagic or benthic diving strategy[23, 24]. Within the APA, elephant seals seasonally exploit the marginal sea ice zone and areas of increased productivity associated with the ice edge but may also venture into thick pack ice, including high sea ice concentrations over the continental shelf slope of the inner Weddell Sea[25, 26, 27].

SES that frequent ice covered areas are usually tracked from high latitude breeding colonies, such as those associated with the APA, but also from islands located to the north of the ATA[1]. Seals from the SIO and SPO generally rapidly transit southward into Antarctic waters followed by meandering movements, either in relatively confined, seasonally ice covered shelf waters along the East Antarctic coastline, partly in association with polynyas, or within the pack ice in the northern part of the Ross Sea.

Conservation status

Southern elephant seals are presently (2020) listed as “Least Concern” on the International Union for Conservation of Nature (IUCN) Red List. SES are also listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Within the Antarctic Treaty Area, SES are explicitly protected under the Convention for the Conservation of Antarctic Seals (CCAS). The Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol) applies generic protection measures to native fauna and flora. The Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) takes all seals into consideration as elements of the Southern Ocean ecosystem, which includes considerations of the impact of fishing operations on the seals’ foraging areas and prey. CCAMLR applies strong measures for the mitigation of incidental bycatch of seals and birds, but those measures do not preclude some level of mortality for affected species both within the ATA[9] and outside it (Figure 3).

Challenges

Our current state of knowledge shows that SES are impacted by humans directly through disturbance and incidental mortality, and indirectly through marine ecosystem changes that can be linked with global climate trends. The reasons for the past and present changes in SES numbers remain obscure. However, it is likely a result of habitat and ecosystem changes in relation to climate[2], associated with the marine ecosystem and mediated primarily via changes in prey distribution and abundance[28]. Importantly those observed changes in SES numbers are consistent with observed or forecasted changes in abundance of other top predators in the APA in response to climate changes[29]. However, there is substantial uncertainty in how SES will actually respond to natural and anthropogenic pressures across the Southern Ocean[30] which may continue undergoing substantial changes associated with warming water masses, strengthening westerly winds, poleward shifts in ocean frontal systems, as well as retreating sea ice and shelf ice in some regions[31].

One research challenge will be gathering a comprehensive understanding of SES foraging within the ATA. Long-term (10 or more years) and more direct observations of prey consumed are now acquired by animal mounted camera systems. Such information will contribute to valuable knowledge of prey species consumed, species overlap with fisheries activities, changes in prey species frequency over time and associated changes in feeding strategies that may permit this species to adapt to changes in prey resources throughout the ATA. Such studies would also allow better insights into the observed high trophic specialization among individual SES that could potentially limit that adaptation[32].

Demographic and morphometric data were collected for SES from an extensive range of populations, including within the ATA. There would be benefit in reinstating similar studies aimed at collecting comparable data to test how climate associated changes in habitat may have affected those populations. For example, the weaning masses for SES pups in the APA were considerably greater than at other locations in 1997, perhaps due to locally abundant food availability[33]. Is this still the case? The challenge here will be in co-ordinating such a study over multiple populations and years.

Within the ATA, regional changes in climate are widely expected to benefit SES through the creation of additional ice-free beaches suitable for terrestrial activities such as moulting and breeding[34]. In fact, inferences based on genetic data suggest that a now-extinct breeding population in the Ross Sea, Victoria Land Coast (Figure 1), was founded, subsequently increased in abundance with the retreating ice extent about 8,000 years before present (YBP), and then declined to extinction when the ice returned approximately 1,000 YBP[35]. Presently in the APA there are suggested increases in population sizes[36, 37], but due to the extent of sea ice which blocks access to beaches during the October breeding period, breeding locations in continental Antarctica remain minimal. In addition, little is known of changes in the non-breeding (moulting) population and whether any changes might be linked to alterations at the main sub-Antarctic SES populations, which act as source populations for the ATA. Better population monitoring and surveying at potential habitats within the ATA, as well as at sub-Antarctic source populations, is needed to address such questions.

There are also clear advantages of integrating biological data with concurrent in situ physical oceanography data which can be used to explore SES behaviour and its effects on population dynamics[1]. Such deployments should be encouraged as it would allow to quantify how changes in the environment, both within and among years, affect the behaviour of animals and how this is likely translated into population growth rates[1]. Presently, the sample sizes for instrumented individuals are small relative to the size of the ATA population (0.005%) and focussed mainly (>90% of deployments) on breeding-aged females. The challenge therefore is to instrument sufficient individuals to provide a representative understanding for each population, especially for larger populations that breed outside the ATA but forage extensively within it. Without improved sample sizes it will also be difficult to accurately quantify the degree of overlap (spatial and resource) between SES foraging areas and potential future fisheries operations which may negatively interact with SES within the ATA.

With recent advances in technology and use of more sophisticated modelling approaches, some of the challenges mentioned above can now be more easily addressed. Such studies have the power to more comprehensively discover how SES might respond to human activities over time.

Conclusion

Without contemporary data, it will be difficult to understand and predict how past, ongoing and expected climatic shifts, combined with the effect of increasing commercial fishing interest, will affect the global SES population. One hypothesis is that region-specific influences can be expected. Some ATA populations may potentially benefit through increased terrestrial habitat availability, while others may suffer declines as changes in prey availability and distribution necessitate individual behavioural changes, ultimately incurring population losses.

Amongst Antarctic seals, the distribution and abundance of the ice-tolerant SES are expected to be the least negatively influenced by changes in sea ice characteristics due to climate change. Indeed, with retreating ice, the incidences of elephant seals breeding along the Antarctic coast could increase as suitable breeding habitats became available. Additionally, SES may be required to adjust foraging strategies as impacts on marine mammals are expected to be mediated primarily via changes in prey distribution and abundance.

There is a need for continued and improved population size assessments, temporal assessments of seal body condition and the monitoring of immigration to and emigration from the ATA through mark-recapture studies. Also, more sophisticated dietary and foraging behaviour studies using a range of recently developed bio-logging instruments and chemical techniques have to be continued to complement the provision of a holistic understanding of the impacts of humans on SES. Considering the lack of contemporary vs historical data, it would be premature at this stage to conclude that SES living and feeding within the ATA are safe and secure into the foreseeable future.

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Resources

- Portal Graphics: https://environments.aq/wp-content/uploads/2020/10/Southern-Elephant-Seals_landscape-1.png

Key words

Southern elephant seals, commercial fishing, sea ice, moulting, breeding, feeding