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Antarctic fur seals: tracking the Southern Ocean's changing climate and ecosystem



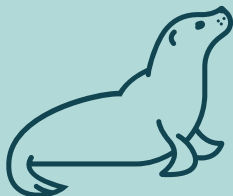
The Southern Ocean's environment is changing rapidly due to climate change and human activity, with cascading effects on marine food webs.



Due to their key position in the marine food web, Antarctic fur seals are helping scientists track environmental and ecosystem changes in the Southern Ocean.



Monitoring of Antarctic fur seals helps inform ecosystem-based management and conservation policy by supplying relevant data to regulatory bodies.



Antarctic fur seals are increasingly threatened by climate change and human activities.

Introduction

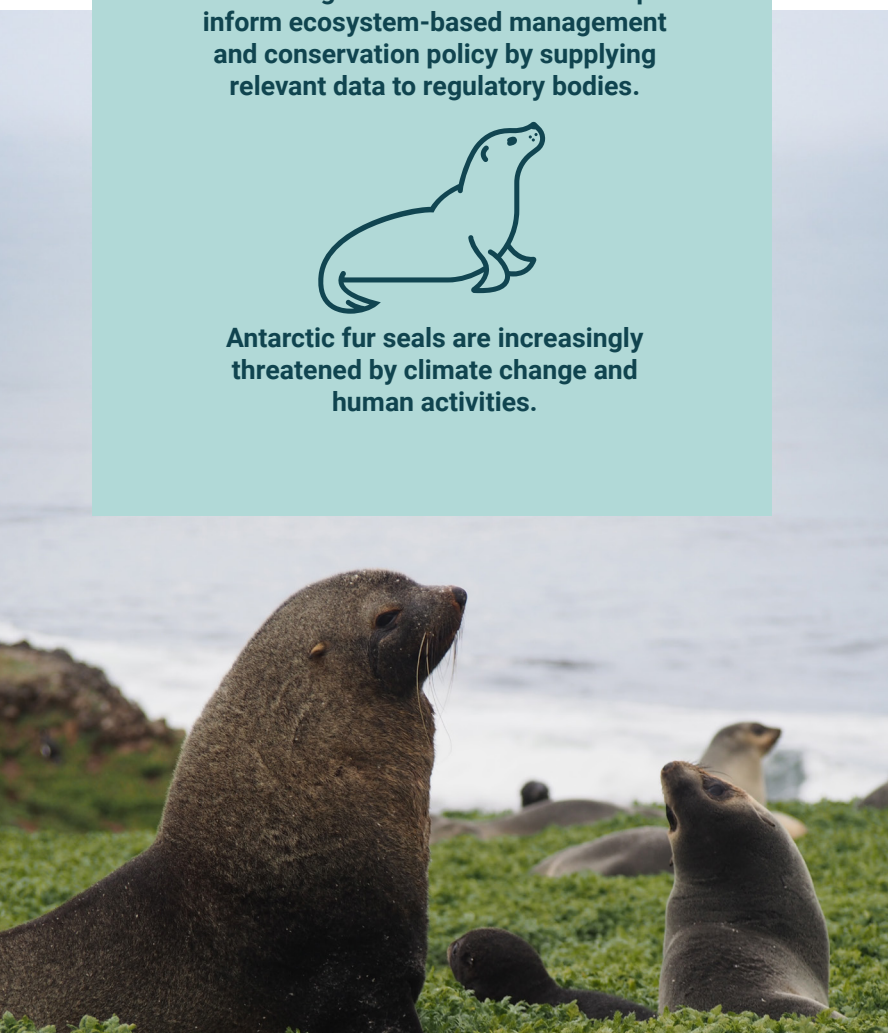
The Southern Ocean is one of the most remote and rapidly changing regions on the planet.

As climate change progresses and human activity expands, its ecosystems are undergoing profound changes.

Roaming widely across the Southern Ocean, Antarctic fur seals (*Arctocephalus gazella*; Figure 1) are helping scientists monitor these changes due to their key position in the marine food web. Acting as upper-level predators, Antarctic fur seals mainly feed on Antarctic krill, fish and squid (Figure 2), and are preyed upon by large predators, including orcas and leopard seals.

When ocean temperatures rise, sea ice declines or fishing activity increases, the availability of krill and other prey changes, which in turn impacts how seals search for food, the distribution and abundance of species they eat, their breeding success and even their survival. Seals are also highly sensitive to changing ocean and sea ice conditions themselves.

By tracking changes in the behaviour, diet and population size of Antarctic fur seals, scientists can detect early-warning signals of environmental shifts and ecosystem disruption, making them a key Southern Ocean ecosystem indicator species.

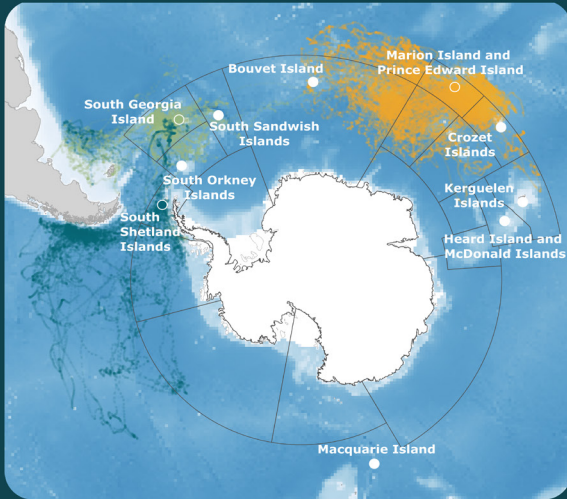


**Figure 1. Left: Male and pup Antarctic fur seals at Kerguelen Islands. Credit: Mary-Anne Lea
Right: Antarctic fur seal pup with tagged mum (Global Location Sensing tag). Credit: Mary-Anne Lea**

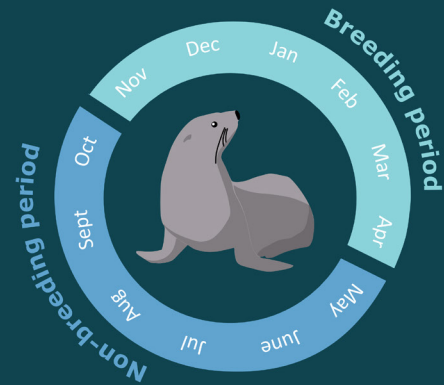
THE ANTARCTIC FUR SEAL

a. DISTRIBUTION

- Breed on land
- Circumpolar distribution of colonies
- Wide-ranging



b. ANNUAL CYCLE



c. DIET



- Key preys: Antarctic krill, fishes and squid
- Spatial and seasonal variation in diet

Figure 2. a. Antarctic fur seals breed in subantarctic and Antarctic colonies all around the Southern Ocean². During winter, tracks of female Antarctic fur seals from Cape Shirreff (South Shetland Island; dark green, 37 females), Bird Island (South Georgia Island; green, 26 females), and Marion Island (yellow, 71 females) reveal wide-ranging movements. The CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) Convention Area is shown in light grey lines. b. The breeding period of Antarctic fur seals occurs from November to April, with males arriving at breeding beaches in early November to establish territories and females arriving later to give birth. They mate about a week later, and alternate foraging trips with pup attendance until the pup is weaned at approximately 4 months of age². During the non-breeding period (May–October), they remain at sea, undertaking extensive foraging migrations across the Southern Ocean². c. The diet of Antarctic fur seals is dominated by Antarctic krill, fish and squid, with marked spatial and seasonal variation².

Why are seals good indicator species?

1. Key position in the marine food web

Antarctic fur seals sit high in the marine food web. When environmental conditions change, impacting prey such as krill and fish, these effects ripple through the food web and are reflected in the seals' behaviour, health and reproductive success¹.

2. Long-term monitoring

Antarctic fur seals live in the waters surrounding Antarctica, with breeding colonies located from various sub-Antarctic islands to the northern tip of the Antarctic Peninsula (Figure 2)². Females return each year to the same breeding colonies

during the breeding season² (November–April; Figure 2), making them relatively accessible and well-suited for long-term ecological monitoring.

3. Reflecting local conditions

Antarctic fur seals breed on land and forage at sea. Females are central place foragers: during the breeding season, they take foraging trips at sea to feed, but always return to the colony (the central place) to nurse their pups². Their diet varies by colony and season, reflecting local environmental conditions and prey availability^{2–5}. This allows scientists to monitor local environmental and ecosystem changes near breeding sites.

4. Wide foraging range

When they are not breeding (May–October), Antarctic fur seals will forage over larger areas of the Southern Ocean (Figure 2), reflecting broader, large-scale changes.

What can Antarctic fur seals tell us?

1. Changes in local environmental conditions, prey availability and food web structure

In the Atlantic sector, Antarctic fur seals primarily feed on Antarctic krill^{2–4}, but krill availability is highly sensitive to environmental conditions. When sea ice declines and the ocean warms, the abundance and distribution of krill change⁶. In poor krill years, mothers will need to take longer foraging trips to find alternative prey like fish or squid^{7,8}, which may delay pup growth and cause higher pup mortality, and also lead to lower reproductive success during the breeding season^{9,10}.

These biological responses, occurring over days and within limited spatial ranges near breeding colonies, can serve as early warnings of environmental changes and shifts in local food webs.

2. Ecosystem responses to long-term environmental changes

Antarctic fur seals' foraging behaviour is shaped by long-term changes in their habitat and climate patterns like the Southern Annular Mode and El Niño–Southern Oscillation^{11,12}. These changes can affect prey availability, forcing Antarctic fur seals to change their foraging areas, which can ultimately impact pup growth, population abundance and genetic diversity^{13–15}.

These trends incorporate multi-year dynamics, providing a broader, long-term perspective on the Southern Ocean ecosystem's response to climatic changes.

3. Spatial overlap with krill fisheries

By tracking where seals feed (using miniature tracking devices; Figure 3), and combining this information with energy needs and prey encounter rates (e.g. from animal-borne cameras), researchers can help estimate Antarctic fur seal consumption rates and their spatial overlap with krill fisheries^{16,17}.

This information can support management decisions on the timing, location, and intensity of krill fishing, ensuring that fishing does not coincide with periods of high demand for those predators.

4. Areas of ecological significance

Tracking data can also reveal important foraging areas for the Antarctic fur seals and other marine predators, offering valuable input for Marine Protected Area design and management¹⁸.

The emergence of new monitoring techniques for Southern Ocean ecosystems

Antarctic fur seal monitoring informs ecosystem-based management and conservation policy by supplying important data to regulatory bodies, including the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).

One of CCAMLR's main tools for ecosystem monitoring is the CCAMLR Ecosystem Monitoring Program (CEMP), which assesses the impact of fishing and environmental changes on krill-dependent predators, such as Antarctic fur seals, in the Convention Area. This assessment includes monitoring the foraging behaviour of Antarctic fur seals and pup growth at key breeding sites in the South Shetland Islands, South Georgia, and Bouvet Island.

However, Antarctic fur seal monitoring under the CEMP is currently limited to the summer breeding season and focuses on the foraging habitat of females through tracking and pup growth. Dietary information is not routinely collected, despite being crucial for assessing the impacts of fisheries on predators through changes in their diet.

New monitoring techniques, such as stable isotope analysis of fur seal whiskers (see explainer on pg.6), as well as DNA and trace element analysis, allow researchers to close this gap and reconstruct seasonal foraging patterns and dietary shifts over months to years, including the winter period. For example, stable isotope analysis suggests that krill is a consistent component of at least part of the Antarctic fur seals' population at Marion Island during the winter season^{19–20}. In addition, changes in the average isotopic values in seal populations over time may also indicate changes in krill abundance and highlight long-term ecological trends, providing a more robust understanding of the effects of climate change on the Southern Ocean food web^{12,20,21}.



Figure 3. Left: Female Antarctic fur seal and pup at Marion Island (Indian Ocean); a Global Location Sensing (GLS) flipper tag is visible on the adult female's fore flipper. Credit: Chris Oosthuizen. Right: Close-up of a GLS on an Antarctic fur seal's flipper. Credit: Mary-Anne Lea.



Figure 4. Antarctic fur seal pup entangled in fishing gear on Bouvet Island. Credit: Chris Oosthuizen

Towards improved monitoring and ecosystem management

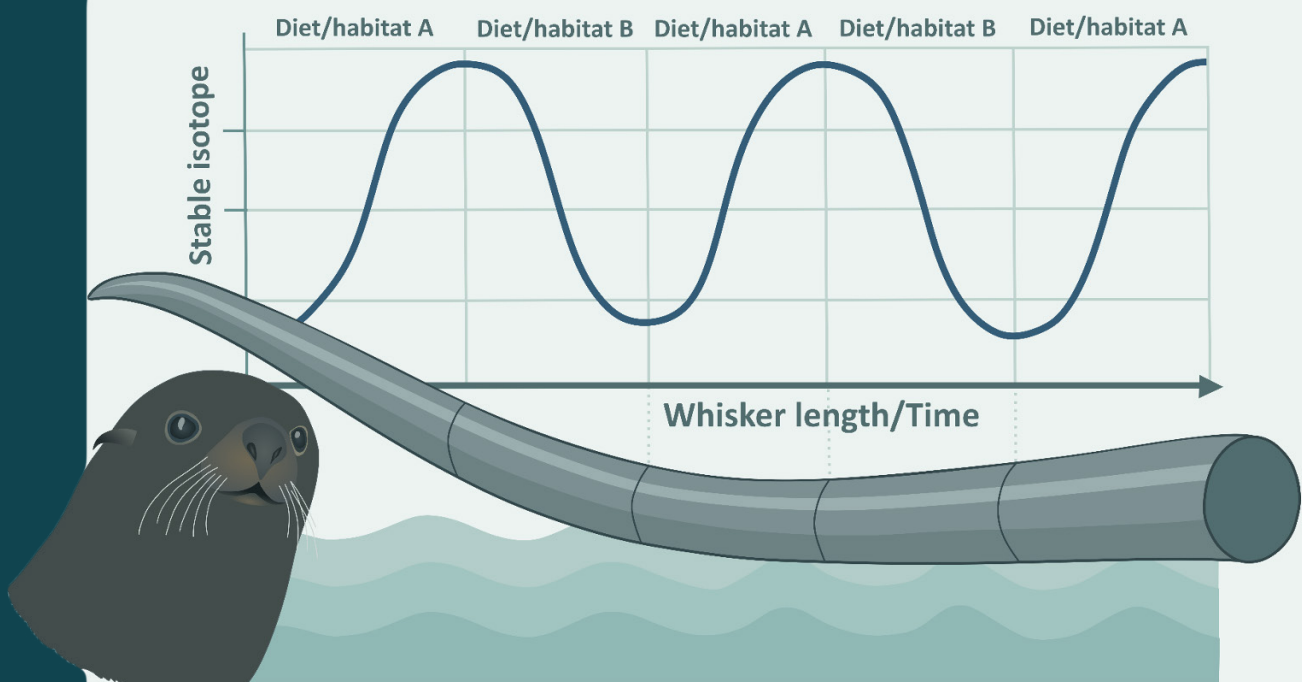
Despite their growing potential, most of the new monitoring techniques are not yet integrated into the CEMP. Combining these innovative approaches with existing methods in the program would provide a better understanding of local food web dynamics and potential conflicts with fisheries.

Additionally, to achieve a truly ecosystem-wide understanding, broader spatial coverage is needed. Currently, most ecological data for Antarctic fur seals stem from a handful of long-term study sites such as Bird Island and Cape Shirreff (Antarctic Peninsula). Other colonies in the Atlantic (e.g. South Orkney Islands), Pacific (e.g. Macquarie Island) and in the Indian sectors of the Southern Ocean (e.g. Marion, Heard and Kerguelen Islands) will need to be included.

Future research should also include male Antarctic fur seals, which remain largely overlooked despite being significant consumers and potential competitors for krill, especially in the context of an expanding krill fishery¹⁷.

Finally, while seals are valuable indicator species of climate change and fishing activity in the Southern Ocean, they are themselves directly or indirectly affected by these threats as well as a range of others, including the pathogenic Avian Influenza H5N1, resource competition from recovering baleen whales, pollutants, tourism, incidental mortality in krill fisheries, debris entanglement (Figure 4) and ingestion. While some populations are stable, others, mostly in the Atlantic sector, are in sharp decline^{22–24}.

Recognising and understanding these regional differences and cumulative threats will be crucial for implementing effective policies to protect these unique marine mammals and the broader Southern Ocean ecosystem they reflect. The species is currently under review for an updated IUCN Red List assessment.



Adapted from an original design by Indi Hodgson-Johnston

Explainer

Stable isotope analysis

Stable isotope analysis is a cost-effective and minimally-invasive tool used to study the diet and habitat of marine animals, especially species that spend much of their lives far from land, beyond the reach of direct observation by scientists. Elements like carbon and nitrogen occur in nature as different forms, or isotopes, which are stable (non-radioactive). By measuring the ratio of these isotopes in animal tissues, scientists can uncover patterns of feeding and movement over time. For example, nitrogen isotopes ($\delta^{15}\text{N}$) provide information on what an animal has been eating, with higher values indicating a diet richer in prey from higher up the food web, such as fish or squid. Carbon isotopes ($\delta^{13}\text{C}$) help identify where an animal has been feeding, as water masses or habitats (e.g. coastal vs. oceanic) have distinct carbon signatures. These isotopic values in the tissues of marine predators like blood or whiskers (Figure 5) offer a crucial first window into the animal's ecology over weeks to years, and importantly through the little studied austral winter months (see infographic).

Figure 5. Female Antarctic fur seal from the Kerguelen Islands. The long whiskers (also called vibrissae) are clearly visible. Antarctic fur seals possess some of the longest vibrissae among pinnipeds, which can be used to reconstruct individual ecology. Credit: Mary-Anne Lea



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