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THE MANY IMPACTS HUMAN ACTIVITIES HAVE IN ANTARCTICA

Javier A. Arata *

Association of Responsible Krill Harvesting Companies (ARK), Margate, TAS, Australia

YOUNG REVIEWERS:

DAVID
AGE: 13

IRMA
AGE: 14

Although Antarctica is the most remote continent in the world, humans have had an impact there ever since the early 1800s. The first explorers were hunting seals and whales, which had decreased in number elsewhere. It was not long before seal and whale populations in Antarctica also suffered. To protect the continent and the surrounding Southern Ocean, several international agreements were signed and implemented. Despite this protection, Antarctica is under new pressures due to the growing numbers of visitors and the effects of climate change. In this article, I will describe new evidence showing how human activities are affecting Antarctica and I will also highlight some of the challenges faced in trying to protect this remote and fascinating continent.

THE DISCOVERY ERA

Antarctica is the most remote and untouched continent in the world, and by far the most unwelcoming one. Yet, thousands of people visit Antarctica every year. Why do they want to go there? How do

they get there? Are there people living in Antarctica year-round? Most importantly, do all of these people generate the same kinds of pollution and environmental impacts that we see in cities and other coastal regions?

Antarctica was the last continent discovered, explored, and exploited. Around 1819, the first wave of visitors mapped the new continent and named the places now familiar to us, including Bransfield, Bellingshausen, and Weddell (Figure 1). However, the voyages of these early explorers were paid for by seal hunting, for the fur industry. The fashion business almost decimated Antarctic fur seals and other seals between 1820 and 1840, and the seal populations did not recover until the second half of the 20th century. These early encounters were followed by the golden age of Antarctic exploration. Many explorers tried to reach the South Pole during this period. Robert Falcon Scott, Ernest Shackleton, and Roald Amundsen led the exploration era, and there were also several scientific expeditions.

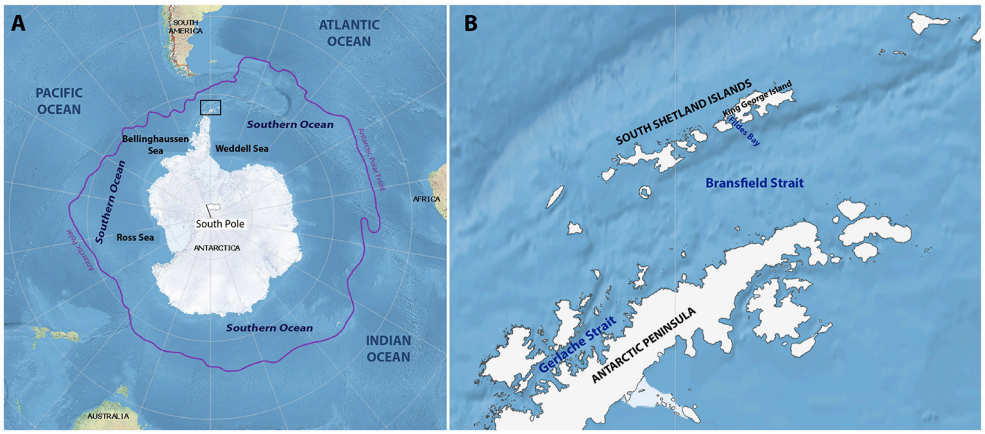

Figure 1

Figure 1

(A) Map showing the Antarctic continent and the Southern Ocean. **(B)** An enlarged map of the boxed area in **(A)**, with details of the Antarctic Peninsula region.

The development of the Antarctic whaling industry led to a new form of exploitation. The depletion of whales in the other oceans drove hunters to Antarctica. In a few decades, all great whales (humpback, fin, and blue whales) were almost extinct. We have only recently started to see signs of recovery.

As scientific studies of the Antarctic continent made people aware of its natural value, the Antarctic Treaty was signed in 1959, to reserve the continent for peaceful purposes and scientific research, and to ban any military activity. Scientific expeditions are now the leading activity in Antarctica. Despite the protection of the continent itself, the icy waters of the Southern Ocean surrounding Antarctica did not receive the same protection until 1981.

ANTARCTICA TODAY

Scientific research has taken over Antarctica. There are 102 research stations from 31 countries. At full capacity, these stations shelter about 5,000 people, between scientists and support personnel, with ~1,800 in the Antarctic Peninsula alone. In addition, several countries have research vessels exploring the Southern Ocean. There are 51 vessels in service from 21 nations, with a capacity for 4,413 bunks between crew and passengers. That is a lot of scientists!

These researchers have made crucial discoveries about our planet, including the discovery of a "hole" in the ozone layer in 1985, information about the importance of Antarctica and the Southern Ocean in regulating Earth's climate and sea level, and strong evidence of climate change. These findings are just the tip of the iceberg.

But not only scientists visit Antarctica. More than 74,000 tourists visited Antarctica during the continent's summer in 2019/20! As you may know, Antarctica has wild populations of species found nowhere else, including penguins, whales, and seals; the underwater biodiversity of the Southern Ocean is as impressive as the Amazon rainforest, boasting sponges, corals, shellfish, sea urchins, fishes and 8,000 other species!

Several fisheries also operate in the Southern Ocean, with 40 fishing vessels authorized in 2022. Although fishing in the region is now highly regulated, the Antarctic continent still faces challenges from fishing and other human activities.

HUMAN ACTIVITIES GENERATE SOOT

All scientists, tourists, and fishermen get to Antarctica on ships or planes, which run on fuel. Once there, almost all activities use fuel for generating heat and electricity. You might think that the amount of fuel used in Antarctica is very small compared to the amount of fuel used by the rest of the world, right? That was the question that scientists from Universidad de Santiago de Chile asked themselves [1].

Burning fuel, charcoal, and wood releases particles known as black carbon (soot), which can travel hundreds of miles from their origin. These particles then fall on surfaces, forming a thin layer that can blacken windows, cars, plants, and snow. Why is it a big deal if the Antarctic snow gets dirty? When black carbon particles land on snow and ice, they absorb sunlight and heat and reduce the albedo–the amount of light that is reflected back to the atmosphere. Because Antarctica is so isolated and black carbon particles do not travel very far from where they are generated, their concentration in Antarctica is very low—about half a teaspoon dissolved in an Olympic-sized pool. But what about fuels that are burned in Antarctica? The black carbon

particles are deposited on the snow-covered hills around research stations and tourist locations, speeding up melting.

Researchers found that the South Shetland Islands had the highest concentration of black carbon particles in the Antarctic Peninsula region because of the numerous research stations present. This concentration decreased further south, away from human activity. The amount of black carbon found in the South Shetland Islands could melt about 6 million tons of snow, or around 0.2–0.9 inches, every summer. Scientists have the highest snow-melting impact per person (about 600 tons of snow melted per scientist), due to the major use of equipment and transport. Although tourism has a lower impact (about 83 tons of snow melted per tourist), the higher numbers of tourists result in a total contribution of 4.8 million tons of snow prematurely melted each summer.

UNINVITED PASSENGERS

Most cargo, fuel, scientists, and tourists arrive in Antarctica by ship. These ships often have shellfish and algae attached to their hulls, which is called **biofouling**. The problem is that some of these species could detach and survive in the waters around Antarctica.

BIOFOULING

All surfaces exposed to water become the substrate to a complex community or organisms. Biofouling is the accumulation of such assortment of living organisms.

Ships that stop in Patagonia (South America) are the biggest problem. A group of scientists from the Universidad Austral of Chile found that mussels commonly found in Southern Patagonia, where the water is only about 7°C warmer than Antarctica, are living in Fildes Bay off King George Island [2]. The mussels seem to have traveled as biofouling on one of the many ships visiting Antarctica each summer season. The increasing water temperatures occurring in Antarctica, along with the increasing numbers of ships traveling to the Antarctic Peninsula, mean that more **non-indigenous species** could settle in Antarctic coastal regions in the future.

NON-INDIGENOUS SPECIES

Species found far from their normal distribution range, as a result of human activities. Non-indigenous species can be considered invasive if they damage the area where they are introduced.

Cargo transported by ships may also carry seeds and invertebrate animals. Although the successful settlement of these species in Antarctica has not been proven, at least one non-indigenous insect is now living in Antarctica. In addition, people landing in Antarctica carry an average of 9.5 seeds on their clothing and equipment. Scientists carry the most seeds, and although tourists carry fewer, the larger numbers of tourists in Antarctica mean that scientists and tourists introduce approximately the same number of seeds [3].

FISHING IN ANTARCTICA

In 1982, an agreement was signed that outlawed whale hunting. However, the Southern Ocean was already a prosperous fishing ground for Antarctic krill and several fish species [4]. To protect the

ECOSYSTEM

The unique system created by the interaction between all the living organisms and their physical environment, within a specific geographic area.

Antarctic **ecosystem** from damage caused by fishing, the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) was also born in 1982. CCAMLR introduced a new way to manage fisheries, known as the ecosystem approach. The ecosystem approach tries to protect not just the species being fished, but also the prey and predators of the fished species, to keep the whole ecosystem in balance.

CCAMLR manages four fisheries: Patagonian and Antarctic toothfish, mackerel icefish, and Antarctic krill. These fisheries have remained healthy and sustainable for 20–40 years. However, the management of krill is still challenging. Krill are the main food source for whales, seals, and penguins, so managing the krill fishery means managing an entire ecosystem, which is extremely complicated. To do so, CCAMLR is trying a novel solution: leaving 75% of the total krill population unfished, so whales and penguins can feed. The system also requires that at least 20% of mature female krill remain untouched, so that krill can reproduce. This method is not perfect, and scientists are still trying to find the best way to manage the krill population. The good news is that bycatch deaths of seals and penguins have been reduced by the use of the exclusion net (Figure 2A).

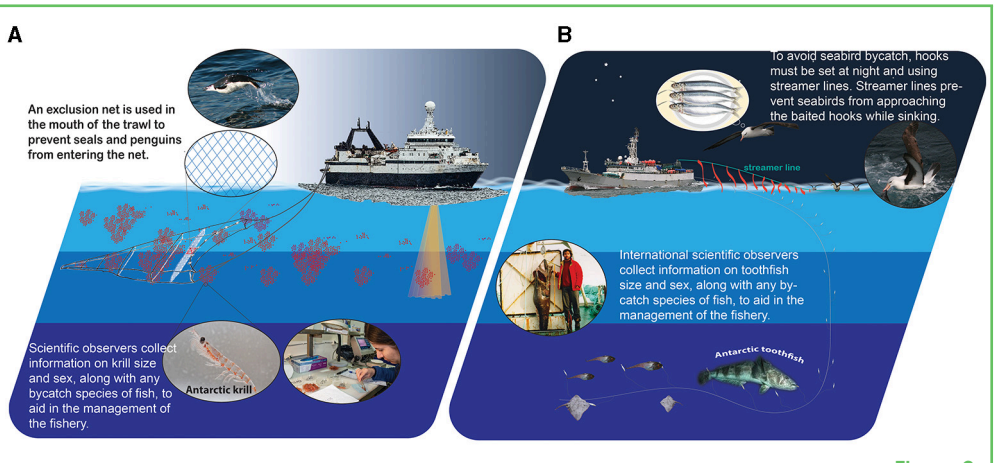

Figure 2

Figure 2

(A) To protect Antarctic krill and its ecosystem, CCAMLR states that 75% of krill must remain unfished. To protect seals and penguins, krill are fished using an exclusion net, which allows krill into the trawl (catch net) but prevents seals, penguins, and other large animals from getting caught. **(B)** To protect seabirds like albatrosses, a type of curtain called a streamer line is used, to prevent seabirds from accessing to baited hooks.

BYCATCH

It is all the species unintended capture by the fishing gear, other than the one the vessel has license to fish for. These includes fish (e.g., sharks), invertebrates, but also seabirds, marine mammals and sea turtles.

In addition, CCAMLR has almost completely eliminated seabird **bycatch** across its fisheries. Albatrosses are among the most threatened seabird species worldwide. They are attracted to fishing vessels to feed on the bait, but they can swallow the hooks or become tangled in the fishing lines and drown (Figure 2B). CCAMLR has implemented several measures to reduce albatross bycatch, including the weighting of the line for faster sink and the use of protection curtains to prevent access to baited hooks, reducing these deaths by 99%!

ANTARCTICA, A RESILIENT CONTINENT

The Antarctic continent and its surrounding waters remain an attraction to scientists, tourists and fishermen alike. Throughout its history, human actions have molded and changed its ecosystem. Concurrently, scientific research has unveiled its significance on a global scale, fostering its conservation. This new approach to nature is paying off and we are seeing strong signals of recovery from earlier impacts. Ongoing research and better practices on all human activities are imperative for sustaining the Antarctic ecosystem.

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CONFLICT OF INTEREST: JA was employed by company Association of Responsible Krill Harvesting Companies (ARK).

YOUNG REVIEWERS

DAVID, AGE: 13

I am David and a highschool student from Sydney, I am interested in programming, science, and problem solving. In my spare time I like to play Minecraft with friends.

IRMA, AGE: 14

Hey, I am Irma! I am an avid writer, guitarist, artist, and I absolutely love science. I am excited to learn more about the wonder of nature!

AUTHORS

JAVIER A. ARATA

I am a marine biologist from Chile specializing in seabird ecology. Early in my career, I had the great experience of being a scientific observer in Antarctica. I loved it and continued working on Antarctic issues, particularly fishery-predator interactions, on several expert groups in South America and Antarctica. Later, I joined the Chilean Antarctic Institute and participated in CCAMLR, which regulates Antarctic fisheries. Nowadays, I follow the same path from a different perspective, working in an organization of responsible fishing companies. Currently, I live in Canada with my family, where we enjoy swimming or snow tubing, depending on the season. *javier.arata@gmail.com