
ICE
Ecosystem

In this section, I explain some of the physical workings of the Antarctic ecosystem, such as the carbon cycle and the biological pump and how it relates to Antarctica's Southern Ocean as a carbon "sink," as well as some of the key biological and natural history elements in the area, beginning at the foundation with phytoplankton and zooplankton, focusing on Antarctic krill. Although not directly addressed in the remainder of my project, even a vague understanding of these processes is vital in order to appreciate the implications of climate change on the Antarctic ecosystem.

**The Carbon Cycle**

A brief discussion of the carbon cycle is necessary for an understanding of nature's approximately 3 billion year old system of carbon recycling. Carbon is the "building block of life" and is the "element that anchors all organic substances, from fossil fuels to DNA" (Herring [1]). Only the biological/physical carbon cycle is within the scope of this project:

> Through the process of photosynthesis, green plants absorb solar energy and remove carbon dioxide from the atmosphere to produce carbohydrates [. . .]. Plants and animals effectively "burn" these carbohydrates [ . . .] through the process of respiration, the reverse of photosynthesis. Respiration releases the energy contained in sugars for use in metabolism and renders the carbohydrate "fuel" back to carbon dioxide. Together, respiration and decomposition [ . . .] return the biologically fixed carbon back to the atmosphere (Herring [1]).

Antarctic phytoplankton plays as important a part in this global carbon cycle as do the densely forested tropics.

> In the oceans, carbon dioxide exchange is largely controlled by sea surface temperatures, circulating currents, and by the biological processes of photosynthesis and respiration. [. . .] [C]arbon dioxide can dissolve easily

> into the ocean and the amount of carbon dioxide that the ocean can hold depends on ocean temperature and the amount of carbon dioxide already present. *Cold ocean temperatures favor the uptake of carbon dioxide from the atmosphere whereas warm temperatures can cause the ocean surface to release carbon dioxide.* Cold, downward moving currents such as those that occur over the North Atlantic absorb carbon dioxide and transfer it to the deep ocean. Upward moving currents such as those in the tropics bring carbon dioxide up from depth and release it to the atmosphere [ . . . ] Life in the ocean consumes and releases huge quantities of carbon dioxide. But in contrast to land, carbon cycles between photosynthesis and respiration vary rapidly; i.e., there is virtually no storage of carbon as there is on land [ . . .]. Photosynthetic microscopic phytoplankton are consumed by respiring zooplankton [ . . . ] within a matter of days to weeks. Only small amounts of residual carbon from these plankton settle out to the ocean bottom and over long periods of time represent a significant removal of carbon from the atmosphere (Herring [2]; italics mine for emphasis).

**A Few Processes Defined: Biological Pump and Carbon Dioxide Sinks**

Phytoplankton, which I will discuss later, are an important element in the carbon cycle and carbon dioxide sinks. "[By] absorbing carbon dioxide, [phytoplankton] contribute to the uptake of $CO_2$ from the atmosphere, thereby moderating the global Greenhouse Effect. The Southern Ocean is one of the world's important 'sinks' where carbon is transported to the deep ocean by sinking particles" (Wikipedia [3]). A carbon dioxide sink is essentially a growing reservoir of carbon; photosynthetic

organisms are considered sinks because they remove the carbon from the atmosphere and convert it into biomass (Wikipedia [3]). This biomass, in the form of photosynthetic organisms, dead sea creatures, other detritus, and animal waste byproducts such as fecal pellets or krill spit-balls, is then carried to the sea floor through gravitational sinking or downward currents, creating the process known as the biological pump (Wikipedia [2]). Once in the depths, the carbon is stored or re-circulated through upwelling.

Because of its reliance on photosynthesis, the biological pump cannot be expected to regulate the extra carbon created by human activity:

> Land-use changes, the combustion of fossil fuels, and the production of cement have led to a flux of $CO_2$ to the atmosphere. Presently, about one third [. . .] of anthropogenic emissions of $CO_2$ are believed to be entering the ocean. However, the biological pump is not believed to play a role in this flux. This is because the biological pump is ultimately limited by the availability of light and nutrients, and not by carbon. The extra carbon provided by anthropogenic activities does not lead to an increase in biological productivity in the oceans. [. . .] However, climate change may affect the biological pump in the future by warming and stratifying the surface ocean. It is believed that this could decrease the supply of nutrients to the euphotic zone, reducing primary production there. (Wikipedia [2]).

**Plankton, Specifically Diatoms**

In the Antarctic ecosystem, the foundation of life is made up of plankton (singular, "plankter")—simple, often (but not always) single-celled organisms such as algae and the larvae of various sea creatures that drift freely in ocean currents. Plankton sustains, either directly or indirectly, essentially all life in the Antarctic. For my purposes I will be focusing on algae, the single-celled plant-like protists called phytoplankton which comprise the "bottom of the food chain," and zooplankton, particularly krill, the small crustaceans which feed upon phytoplankton and in turn feed the rest of the ecosystem.

The most important forms of phytoplankton in the Southern Ocean are diatoms, the golden algae, which are characteristically encased in a silicate cell wall called a frustule. Most cannot move of their own volition but some can swim with an oozing motion; some diatoms also can regulate their own buoyancy. Besides the drifting diatoms which are the focus of this section, there are also diatoms which affix themselves to other objects such as ship propellers, rudders, and the bellies of blue whales. There is also a significant population of ice diatoms such as *Nitzschia* sp. which live and grow while frozen within the winter pack ice (Moss, 1988, p. 46; Jacques, 1994, p.8; *Microbial,* 2006). The more productive species of Antarctic diatoms prefer cooler water. When nutrients are depleted or the water warms to an unfavorable degree, as in summer, diatom cells sink to deeper, cooler water below 60 meters, beyond the depth penetration of potentially damaging ultraviolet rays (Nilsson, 1996, p. 13). Although photosynthesis is diminished to a degree, there is enough activity for the plankton population to remain fairly constant (although many diatoms in the open ocean may sink too far) until conditions are better and vertical mixing again entrains them toward the surface; this sinking also prevents them from a dangerous acceleration of their

metabolism.

Phytoplankton are photosynthetic, deriving much of their energy from the sun and releasing oxygen into the water and consequently the atmosphere. Because they rely primarily on sunlight, marine phytoplankton must live near the ocean surface; waves caused by the wind mix the surface waters horizontally and this action is usually enough to keep the cells afloat. This turbulent mixing by the wind, particularly in winter, also stirs up nutrients such as silica, potassium, phosphates, calcium, and nitrates from the deeper water into the surface layers, contributing to phytoplankton "blooms" when living diatoms frozen in the ice are released back into the sea when the ice melts in spring and early summer (Kimball, 1990, p. 4; Moss, 1988, pp.48, 49, 50). Iron is particularly rare in the Southern Ocean, leading some researchers and environmentalists to believe that iron seeding in the area would dramatically increase diatom population and consequently help control global warming by increasing carbon dioxide synthesis and transportation to the sea floor (Broady 2006). According to Paul Broady, however, this plan may be fatally flawed for practical use because in experiments, there has been little actual recorded sinking—most of the diatoms have instead been ingested by other organisms on the surface, consequently releasing the synthesized carbon back into the atmosphere and negating the purpose of the iron seeding. Many opponents of the plan feel that iron fertilization on a large scale could upset the ecological balance and cause more problems than it might solve (Broady 2006).

Antarctic diatoms are very important for the Antarctic and world ecosystems, and changes in the Antarctic phytoplankton community have "two important implications."

> One is that there will be less food for [. . .] krill. [. . .] The other reason to worry about the fate of phytoplankton

> [. . .] is the role they play in the global circulation of carbon [. . .]. For the global climate, the prolific plankton blooms in the Southern Ocean have the same role as the trees growing in the tropical rain forest (Nilsson, 1996, p. 34).

Because these diatoms are the foundation on which the entire food web depends, a collapse in their production could potentially devastate the biosphere.

**Krill**

Krill are tiny crustaceans resembling shrimp; they feed on phytoplankton (particularly diatoms) and, to a lesser extent, zooplankton. They are the largest animal able to efficiently utilize individual diatoms, ranging in size from less than one to more than four centimeters in length. There are many species of krill in the Antarctic but the two most common are *Euphausia superba,* which prefers open water north of the pack ice zone, and *E. crystallorophias,* which makes up much of the krill population under the ice (*Antarctic Biology,* 2006). *E. superba* are considered to be probably the most successful animal species on the planet, and "[. . .] form dense swarms, typically hundreds of metres across and 20 or so meters deep. The largest swarms can spread over several square kilometres and may extend to a depth of 200 metres. Swarms of such dimensions may contain up to $10 \times 10^3$ tonnes of krill [. . .]. It has been estimated that there are over $6 \times 10^{11}$ individual krill with a biomass of around $250\text{-}600 \times 10^6$ tonnes [. . .]" (*Antarctic Biology,* 2006). Put another way, Moss (1988) estimates that "the median [standing crop of krill] runs close to between 500 and 750 million metric tons, with an annual production of between 750 and 1,350 million metric tons. [. . . ][S]ome fishery experts feel that the krill catch may someday exceed the present world-wide

harvest of all seafood" (p. 70).

As stated above, krill feed directly on phytoplankton, using their six thoracic legs to filter diatoms from the water and sweep them into the krill's mouth opening. During the dark winter months, when phytoplankton are dormant below the upper mixed layers, krill feed more extensively on zooplankton and, during periods of low food intake, their ability to shed their exoskeleton into adulthood has the adaptive effect of decreasing body size and energy requirements (*Antarctic Biology,* 2006). Especially during the spring, krill utilize the dense film of algae that grows on the underside of the pack ice, scraping it off with the rake-like tips of their thoracic legs while swimming upside-down (Moss, 1988, p. 62).

**The Keystone of the Ecosystem**

The Antarctic food web is unique because it is comprised of as few as three steps, with phytoplankton and krill being at the bottom. Krill are the primary food source for the huge baleen whales, such as humpback whales and blue whales, as well as the common Adelie, Gentoo, and Chinstrap penguins. In addition to whales and penguins, other birds, seals, fish, and squid also rely on krill as an important part of their diets, which means that all of these species would suffer greatly if the krill population were to plummet. Krill are also important to the carbon cycle. As their digestive systems cannot completely process the carbon from the diatoms they eat, much of their carbon-rich detritus rapidly descends to the carbon reservoir at the seafloor (Wikipedia [1]). Some of this detritus is re-circulated by upwelling currents and becomes food for other organisms, which also helps restore other nutrients to the area (Gili, 2001, p. 481).


REFLECTIONS
At the End of the Earth

*Illustration 1. M/V Polar Star anchored off Half Moon Island. A. Filbert, 4 January 2007.*

I spent the end of December and the beginning of January on a retired Swedish icebreaker-turned-expedition ship, the M/V Polar Star, cruising from South America through the Southern Ocean and around the Antarctic Peninsula as the field portion of an interdisciplinary class on Antarctica the semester before. While on the ship, my classmates and I studied marine resource management, tourism, and ecology, taking firsthand measurements of bird and mammal populations and associated weather and climate, including water and air temperature, wind speed and direction, latitude and longitude, and sea height. From these travels I have selected seabird and marine mammal species of particular notice at each site at which we landed, and devote a paragraph or two to describe each one. Observations, identifications and population estimates are primarily my own although my classmates and I often worked together to collect and analyze data. The organization of this section is in chronological order from the eastern edge of the Antarctic Peninsula to the west, following a generally southward route. To illustrate, say that on day two I visited an island with 5,000 individuals of one penguin species, and 10,000 individuals of another species. I discuss the latter species under the first location, and the former species under whichever site at which they were observed in the most numbers, thereby allowing me to give roughly equal attention to each place and species instead of overemphasizing the first few landings. Despite its northerly location, I begin in the Drake Passage, both for its wild reputation and for the great soaring albatrosses ever present just off the bow of our ship.

The infamous Drake Passage, located between Cape Horn, Chile, and the Antarctic Peninsula, has a reputation for

being the roughest stretch of sea in the world. In fact, during a Passage crossing one may anticipate weather conditions ranging anywhere from the "Drake Lake" to the "Drake Shake," with a 35° pitch and roll considered perfectly normal (Polar Star Expeditions [1]). Although today's voyagers (including myself) are usually grateful for the Drake Lake effect, the languid, glassy, windless Passage was often the irk of yesteryears' sailing vessels, as ships often found themselves stalled for days "as idle as a painted ship upon a painted ocean" (Coleridge, 1970, p. 20). At their worst, however, those deserted slate-grey seas have claimed the lives of countless sailors.

*Illustration 2. The Drake Passage inaction, er, in action. This unusual calmness, the Drake Lake effect, was the mixed blessing of many a sailing ship of old. A. Filbert, 31 December 2006.*

Some of the first birds we encountered in the Drake Passage were the legendary albatross, the most romanticized birds in nautical lore and the fabled bird of "The Rime of the Ancient Mariner." Albatrosses are divided into two groups, the small albatrosses (such as the black-browed albatross in Illustration 3) that have some amount of dark colour on their backs and wings, and the great albatrosses—the royals and the wanderers—which are nearly completely white as adults. The wandering albatross is well-known for its incredible wingspan of over three meters—more than nine feet—and its amazing ability to soar almost motionless amongst the fierce wind and waves of the Southern Ocean. In fact, albatrosses spend most of

their lives at sea, coming to land only to breed every other year, beginning in their sixth or seventh year for small species and their ninth year for wandering and royal albatrosses. They feed mainly on squid caught adrift at the surface, and often follow ships in hopes of scavenging galley waste or offal. These two habits have increasingly caused trouble for albatrosses because of long-line fishing, to be discussed later. Perhaps it is the ferocity of the Drake Passage combined with the ubiquity of the soaring albatrosses which inspired the mythology of the albatross as the reimbodiment of sailors lost at sea.

*Illustration 3. Black-browed albatross, Drake Passage.*
*A. Filbert, 31 Dec. 2006.*

Although this natural history of albatrosses is necessarily brief, the mystery and mythology of this bird goes back hundreds of years. As noted above, the souls of lost sailors were traditionally believed to come back within the bodies of albatrosses, doubtless because of the albatrosses' seeming invincibility in even the most extreme seas near both poles. Particularly in the early 17th century this mythology was a fortunate one for the albatrosses, for they were considered bad fortune to kill at a time when any other bird was fair game (Soper, 2004, p. 44). This is illustrated clearly in "The Rime of the Ancient Mariner," wherein the main character and his crewmates are blown south to Antarctica by a storm, at which point an albatross appears to lead them out of the "land of mist and snow." They follow the albatross out of the ice and into the northern Pacific Ocean, until our narrator shoots and kills it with his crossbow, angering his crewmates because they believe the albatross brought the South wind that carried them. Incidentally, shortly after this, the breeze disappears and the fair weather becomes more of a curse than

*Illustration 4 Southern giant petrel, Paradise Bay, Antarctic Peninsula. Note the "tube" on the upper mandible and the droplet of concentrated saltwater at the tip of the beak. A. Filbert, 5 January 2007.*

a blessing as the crew, except our narrator, die from dehydration. More adventures ensue, with the dead albatross hung (literally as well as figuratively) around our mariner's neck ever reminding him of his sin.

For the sake of brevity, I lump fulmars, petrels, and *procellaria* species petrels under the single moniker "petrel." This is not entirely a flight of fancy, for there is much controversy regarding classification of species (Wilson, 2006). Petrels were our most loyal followers through the Drake Passage and throughout our voyage. We encountered up to 12 different species including white-chinned petrels, giant petrels (both northern and southern), the lovely black-and-white checkered pintados, tiny storm-petrels, and on our return, an Antarctic petrel, a species which resembles a brown pintado and which our expedition leader Damon Stanwell-Smith noted had never before been seen on an expedition. As can be seen, they are a widely varied group of birds but can be generally characterised by a tubular beak structure with deep grooves and sharp hooks—visible (with some imagination) on the southern giant petrel (Illustration

*Illustration 5. Pintado, Brown Bluff, Antarctic Peninsula. A. Filbert, 2 January 2007.*

4). While albatrosses have their nasal tubes concealed within their bills with the nostril openings near their eyes, petrels such as the southern giant petrel and the pintado have theirs set externally on the top of the beak. Besides their usefulness for respiration, these tubes serve another very useful purpose wholly unrelated to breathing. Because petrels take in considerably more salt through drinking and fishing than their bodies can process, the excess salt is diverted through blood vessels to fine tubes connected to their nasal glands, where it is concentrated and released through the tubes in a steady drip, often seen falling from the tip of the beak (Soper, 2004, p. 56).

*Illustration 6. Brown Bluff, Antarctic (Tabarin) Peninsula. Three Weddell seals are visible lazing in the snow in the foreground. A. Filbert, 2 January 2007.*

Our first landing site was at Brown Bluff on the northern tip of the Tabarin Peninsula, on the Antarctic Peninsula itself. Making their homes in the shadow of this magnificent bluff, breeding colonies of some 70,000 Adelie penguins and hundreds of gentoo penguins wander, swim, argue, care for their chicks, and live their lives, keeping up a continuous braying serenade that could be heard from the ship. Kelp gulls, snow petrels, Antarctic skuas, and pintados also nested on the island—the kelp gulls on top of the many creatively shaped

volcanic boulders littering the beach, and the others on the upper slopes. The Bluff itself is an igneous dike, that is, an underground pool of magma which has cooled and is now exposed to the elements. It is slowly being weathered away by cold, wind, and glaciation—the fate of many a mountain here—and the eroding fumaroles (volcanic gas vents) are visible as blackened tubular lines through the rock face.

*Illustration 7. Prince Charming? Weddell seal, Paulet Island. Notice the typical Weddell seal coat color on the back and across the shoulders. A. Filbert, 2 January 2007.*

I made my first aquaintance with a Weddell seal at Brown Bluff, where three of them were lounging in a snow drift on the beach. At first sight resembling nine-foot-long slugs, their snubbed noses, smiling face, bright black eyes and sleepy demeanor make it easy to imagine them begging for scraps at the kitchen table. Their coats are a dusty brown except following a moult, when they darken and develop lovely silver-grey spots. Appearances aside, these seals will let humans approach quite closely, although once they feel threatened they will not hesitate to bite; the penguins, on the other hand, have nothing to fear from Weddells and they would toddle within inches of the dozing, swollen seals. Watching these seals on the rocky beaches made me wonder why they have evolved to return to land at all, as it seems to require intense effort to make even the slightest headway. Once in the water, Weddell seals seem like different beasts entirely as they roll and glide lithely, regarding the goings-on with an expression of bemusement and curiousity. One can imagine they wondered just what we were; our lanky,

*Illustration 8. Brown Bluff, Antarctic (Tabarin) Peninsula. An Adelie penguin colony is in the foreground, surrounded and interspersed by volcanic boulders. The vertical striations at the top of the bluff are weathering fumaroles.*
*A. Filbert, 2 January 2007.*

vertically-oriented forms moving around on the beach with such apparent ease must have been quite a sight to behold. Feeding on krill, squid, and favoring giant cod found at depths of 2,460 feet, Weddell seals can remain underwater for over an hour and swim a fair distance from their breathing-holes in the fast ice. Although they often take advantage of tidal cracks, Weddell seals are fully capable of carving their own breathing-holes by sawing with their upper incisor and canine teeth in a side-to-side motion. This ability comes at a cost to fishing due to the wearing down of essential teeth, however, and while other seal species may live up to forty years, the average life expectancy of a Weddell seal is a mere 12 years. Despite this barrier to longevity, Weddell seals are quite common; however, in comparison with their ever-present comrades, the Adelie penguins, their numbers are not at all impressive.

*Illustration 9. Weddell seal pup, exhibiting the coat pattern characteristic of newly moulted Weddell seals. Brown Bluff, Antarctic Peninsula. A. Filbert, 2 January 2007.*

The Adelie penguin is one of the most charismatic animals we encountered and could almost be considered the mascot of Antarctica because of its vast numbers and recognisable tuxedo pattern. Tiny (less than 24 inches tall), chunky, and endearing on land with their inelegant waddle and curious eye, Adelies too seem different creatures entirely in the sea, using their powerful wings to "fly" through the water with unbelievable speed and precision. As with all penguins, their rotund, sleek shape is perfectly engineered to reduce drag to almost nothing when in the water. They may often be seen "porpoising" at the surface, that is,

leaping into the air much in the manner of dolphins, and they do this to gain and easily maintain speed as well as to breathe while on the move (see Illustrations 11 and 16). This skill frequently affords penguins protection from leopard seals, their main predator, which they are often able to outdistance.

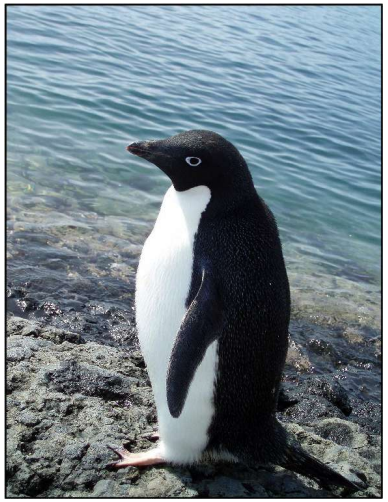

*Illustration 10. Adelie penguin who wanted her rock back. Brown Bluff. A. Filbert, 2 January 2007.*

Adelies are truly charming and we were fortunate to have seen nearly 400,000 of them during the course of our cruise. They are curious but shy and easily alarmed, which they communicate through wide eyes, by waving their flippers, and by fluffing their neck and body feathers. The overall effect was comical rather than threatening, although the penguins undoubtably thought themselves quite menacing indeed when the strange two-legged intruders moved away to gawk elsewhere. As my two companions and I were sitting on an outcropping of rock, absorbing the scene and listening to all the sounds of the Antarctic Peninsula, this photogenic female (Illustration 10) came within three feet of us before casually slipping away into the sea. At first we believed her to be male, assuming that the females were sitting on the nests on the slope, and we consequently dubbed her "Ben" after a friend I had made the day before. As I later learned, the males tend the chicks while the females fish for a few weeks until they switch. We were early enough in the season that I believe the females were still fishing. Whether or not this "parent-swap" still holds true when the nests are so close to the water, I do not know. When it was time to catch the last Zodiac back to the ship, we cast a final glance hindwards towards the outcropping to see a small black-and-white body regarding our departure with a sulking air. I could imagine her

*Illustration 11. Adelie penguins porpoising in front of ice sheet, Brown Bluff, Antarctic Peninsula.*
*A. Filbert, 2 January 2007.*

mumbling under her breath, "... They took my rock and didn't even ask if I minded! Humans are so rude."

Our second landing site was Paulet Island, just off the extreme northern tip of the Antarctic Peninsula. A volcanic island containing at least two freshwater lakes, it is home to breeding colonies of Adelie penguins and Antarctic shags, to the count of 300,000 Adelies and 1,000 shags, with the latter mainly congregating on one of the upper slopes facing the northwest. Proving that Antarctic weather is, indeed, extremely volatile, a strong, bitterly cold wind picked up after two hours of calm, and within 10 minutes the water was too rough on the northwestern side of the island for the Zodiacs to return us safely to the ship. We walked around to the southeastern side and waited for the ship to join us so we could cross in the relative calm afforded in the lee of the island.

*Illustration 12. Polar Star staff preparing for the Zodiac landing at Paulet Island. A. Filbert, 2 January 2007.*

Paulet Island was my first introduction to scree, the dull reddish brown rocky substrate comprising the majority of the steep slopes we were to encounter many times during the course of the trip (much to the dismay of my lazy muscles). Its loose, gravelly texture made walking in rubber boots more awkward than it might have been, particularly on the steep, abruptly conical slopes. Patchy concentrations of shale could be found particularly in zones along the coastline, and

these were avoided by penguins and humans alike when possible, for they further hindered an already somewhat taxing hike around the interior of the island.

Antarctic shags are known by many names, including imperial shag, king or imperial cormorant, blue-eyed shag, and various others. What this impressive list of common names refers to is a large cormorant with striking black and white plumage, a cobalt blue eye ring, and, during the breeding season, bright orange caruncles (callous-like growths) on the upper beak near the eyes. Although otherwise behaviorally similar to the cormorants from warmer regions, Antarctic shags do not hold their wings open to dry after diving for fish, squid, crustaceans, and invertebrates (Soper, 2004, p. 86). Unlike penguins, shags use their feet for propulsion.

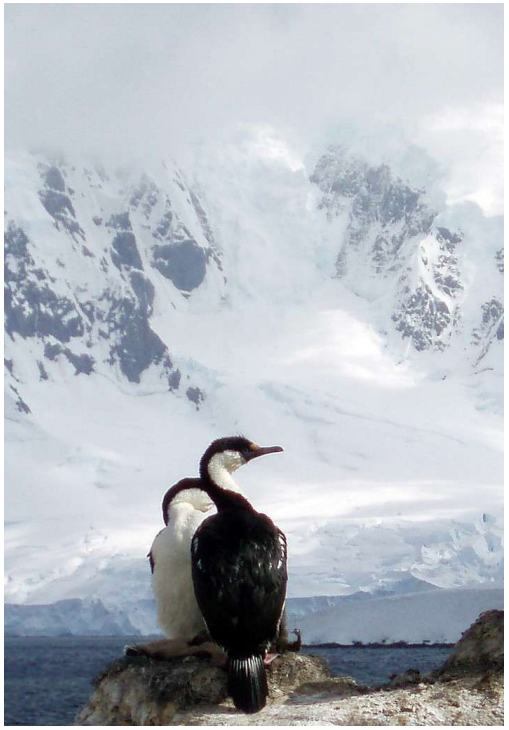

*Illustration 13. Nesting Antarctic shags, Jougla Point, Port Lockroy. Notice the blue eye-ring. A. Filbert, 5 January 2007.*

While at Paulet Island, I was fortunate enough to spot a single leopard seal lying on an ice floe just off-shore. It was the only one that was seen and there was speculation that it may have been either a Weddell seal or a hallucination, but I remain convinced that I was seeing correctly. My only regret is not seeing any leopard seals at closer range, as they are magnificent in appearance, earning their common name by virtue of the dark leopard-like spots adorning their pale underside. More striking than their spots is their 9 to 11 foot long, sinewy body topped by a reptilian head that seems overlarge in comparison, with a wide, snakelike gape and a

formidable arsenal of teeth. Known for their aggression and ferocity, there has actually been only one fatal attack—in 2003 a marine biologist was diving at Rothera Point when she was attacked and dragged to her death. Expedition leader Damon Stanwell-Smith offered that perhaps the seal believed the diver was a territorial threat, a competitor for the use of the seal's breathing hole. Whatever the reason for the attack, it is unlikely that the seal viewed the biologist as prey, for the bulk of their diet is comprised of krill, squid, and fish, with penguins, juvenile cormorants, crabeater seal pups, and young seals of other species making up the remainder.

*Illustration 14. Snow Hill Island is usually inaccessible because of ice in the channel . A. Filbert, 3 January 2007.*

Our next stop was Snow Hill Island, never before on the itinerary because of the difficulty of getting to it through the ice usually spanning the channel. We were fortunate that a few days before, a large icebreaker had cleared a passage through the channel by which we could access the island, where a newly discovered emperor penguin colony resides in the winter. It is the northernmost location in which they breed, and is also the site of a perfectly preserved refuge hut from the ill-fated Nordenskjöld Swedish Antarctic expedition of 1901-1903 (Stanwell-Smith, 2007). The island's scree slopes are covered

in coiled invertebrate (ammonite) fossils and strange round stones which we soon discovered enclosed yet more fossils, apparently caused by sediment buildup around the shells in a sort of "snowball effect." We kept a sharp lookout for emperor penguins in the water, despite the unlikelihood of spotting one—and while we were not lucky that day, I will devote some words to this beautiful bird.

The emperor penguin was made famous in 2005 by the film March of the Penguins, which documented the remarkable yearly journey that these penguins make from the sea over 100 kilometers to their breeding grounds on the inland pack ice. The mission is fraught with danger from the very first day and mortality is high, from starvation, exposure to the elements, and predation from skuas and leopard seals. If successful, the parents will rear one chick, which will be ready to take to the sea in spring; the sea comes to them rather than the chicks having to make the same trek as their parents, as the breeding grounds are only a few hundred feet from the water when the ice melts in summer. The emperor is the only penguin species to breed in the harsh Antarctic winter, somehow surviving extended periods of temperatures near -80ºF. They are large birds—the largest of the penguins—and may stand up to four feet tall. They mainly feed on fish and squid, not unlike most Antarctic animals.

*Illlustration 15. The precipitous "Left Horn" of Devil Island.*
*A. Filbert, 3 January 2007.*

Next we steamed north to Devil Island, so named because of the sharp peaks at either end known as the "Left Horn" and the

*Illustration 16. Porpoising Adelies. Extremely difficult to photograph!*
*A. Filbert, 2 January 2007.*

"Right Horn" of the "devil." A large colony of Adelie penguins resides just above the beach, and brown skuas nest amongst patches of moss in the central valley. We climbed up to the precarious ridge at the top of the Left Horn, from which vantage point we could see Vega Island to the northwest as well as the 25,000 Adelies looking like a dusting of snow on the beach far below us.

In the Erebus and Terror Gulf on the way to Devil Island, we saw the highest numbers of crabeater seals that we would see all trip (20), although crabeater seals are considered the most common species of seal in the world (Soper, 2004, p. 106). Contrary to their common name, they do not actually eat crabs, as there are none to be found south of the Antarctic Convergence; instead, their interlocking tri-lobed teeth are perfectly designed to filter krill from the water, which they do in a manner reminiscient of the great baleen whales.

*Illustration 17. Crabeater seal, Paradise Bay. Note the scars on the shoulder from leopard seal attacks.*
*A. Filbert, 5 January 2007.*

Although at first glance they resemble Weddell seals with their dusty tan coats, crabeater seals are smaller and slimmer with longer, more pointed faces, and can move quite quickly on ice. Many crabeater seal pups are killed by leopard seal predation, and those that survive the attacks are easily identified by the deep, lingering scars on their bodies, particularly around the head, neck, and shoulders. Crabeater seals may begin to feel an impact from the rising temperatures soon to

threaten the ice on which they depend for survival—they, like emperor penguins, live out their lives on the ice and never come to land even to breed.

Half Moon Island is so named because of its shape; this small crescent-shaped island lies in a sheltered bay at the eastern end of the much larger Livingston Island, between Livingston Island and Greenwich Island in the South Shetland Islands. This island is the site of both a small colony of 10,000 chinstrap penguins at one end and the Argentine Camara Station at the other, with a good mile between them and fascinating distractions every five feet or so. I have a well-earned reputation for never getting anywhere very fast, particularly on beaches or in forests, for the simple, childlike reason that I feel I must stop and look at every feather or bit of shell that I encounter. This particular "20 minute walk" across Half Moon Island became one of roughly an hour and a half; as a result, I did not have much time to spend with the chinstrap penguin colony. The treasures that I had found so distracting included an assortment of curious seaweeds, a myriad of bemusingly shaped bones, a broad miscellany of unidentifiable objects which I could only guess were of vegetal origin, a dead seal pup and the rather more easily identified various whale, seal, and penguin bones littering the waterline. As a side note, although many of the dead animals that we

*Illustration 18. Half Moon Island with Livingston Island in the background, Antarctic Peninsula.*
*A. Filbert, 4 January 2007.*

found on the beach looked as though their life ended a mere three weeks prior—if indeed that long ago—there is every likelihood that they were literally hundreds of years old; the cold, dry Antarctic air mummifies bodies unsettlingly well.

Chinstrap penguins are some of the more streamlined penguins on land as well as in the water, being taller than the Adelies and trimmer than the Gentoos. Their soldierlike helmeted appearance, serious expressions and marching waddle contrasts with the fussy, tuxedoed Adelies, and true to their military air, the chinstraps seemed unconcerned about our sudden appearance on their beach. Perhaps one reason for this is that their nests are built on ice-free rocky hummocks above the beach, and they most likely did not feel that we threatened their nests on the beach below, as they would if we had approached the colony itself. Their breeding season is also longer than that of the Adelies—beginning around November and ending when the chicks go to sea, sometimes as late as May—so chinstraps need not stress as much about the time. Chinstrap penguins feed closer to shore than do the Adelies and dive more often, allowing the two species to coexist quite efficiently, despite the occasional pirated nest.

*Illustration 19. Chinstrap penguins, Half Moon Island. A. Filbert, 4 January 2007.*

Although we were unable to land at Deception Island because of near-gale-force winds, it is certainly worth a mention. This is a volcanic caldera, and within its high cliffs are the remnants of the Chilean President Pedro Aquirre Cerda Station and a British Antarctic Survey post, destroyed by eruptions in 1967 and 1969, respectively. The Argentine research

station Decepcion is currently in use, and we might have been able to meet the scientists but for the wind. We would also have been able to swim in one of the coves, as geothermal vents warm the water of the caldera and the black sand of the beaches. The caldera of Deception Island is entered through a narrow passage between two sharp cliffs, known as Neptune's Bellows because of the strong winds channeled through the opening. Unbeknownst to me at the time, in this channel there is a ridge of rock a mere 10 feet below the water's surface, shallow enough that a ship could easily run aground. Fortunately for us, the wind-driven current rushing over this ridge is enough to lift a ship several feet and carry it across unscathed.

While underway to Deception Island from Half Moon Island, a pair of humpback whales graced us with their presence, albeit from quite a distance. This was our second sighting; we had first seen humpbacks in the Southern Ocean just within sight of the South Shetland Islands, and they came close to the bow as they surfaced and dove. Encountering the humpback whales reminded me that while the sea is desert-like from our terrestrial vantage point, and beautiful in its desolation with its grey shifting dunes and wind ripples, there is another vast world beneath the waves and untold mysteries only whales have seen. It is stunning to think that these majestic animals, huge as they are at up to 52 feet long, feed all but exclusively on plankton in the Southern Ocean and small fish like herring. In the Southern Ocean they feed almost exclusively on Antarctic krill, *Euphausia superba.* Humpback whales are lunge feeders, which means that they feed by opening their mouths and engulfing shoals of krill, often by swimming directly into the center of a swarm. They then use their tongues to squeeze the excess water through their baleen, leaving a mouthful of krill. If the prey is too thinly distributed to lunge into, humpback whales will often work to concentrate the prey in a central location by creating a rising, concentrically spiraled "net"

of exhaled bubbles (Sumich, 1999, p. 369). Humpback whales are also notable for the songs sung by the males possibly for breeding purposes, which have made their way onto many a new age music recording, and for their acrobatics at sea, often leaping clear out of the water for no apparent reason.

These majestic animals have been endangered by human activity, particularly commercial whaling when it was still legal; even today, Norway and Japan are permitted to take whales for allegedly "scientific purposes," although a substantial portion of the meat is eaten. As the American Cetacean Society notes, "They're not saved yet!." Currently they number only around 30-35% of their original population. Humpback (and other) whales are still threatened by human activities such as ocean pollution from Persistent Organic Pollutants (POPs) like DDT and dioxin, toxic compounds which resist degradation and are stored in the fatty tissues of any creature who comes into contact with them; anthropogenic noise pollution from naval sonar, ship engines, underwater explorations for natural gas or crude oil, and other noise sources, which affects the whales' ability to navigate as well as causing pain, fear, and disorientation, sometimes leading to beachings; marine debris such as fishing nets, in which the whales may become entangled and drown; global warming, insofar as it concerns the supplies of krill; and overfishing of the humpback whale's northern fish prey such as herring (Whalesong.net).

*Illustration 20. Outbuilding, Port Lockroy, Antarctica. A. Filbert, 5 January 2007.*

Our last day of landings saw us in the morning at Port Lockroy on Goudier Island and Jougla Point on nearby Weineke Island, between which sites Zodiac shuttles divided the ship passengers to avoid overcrowding. Port Lockroy is a cozy two- to four-person base containing the southernmost gift shop in the world, as well as the world's most southerly post office. What Jougla Point lacks in human constructions, it makes up for with a colony of 1,500 gentoo penguins and 35 shags, not to mention a complete whale skeleton on the beach.

We had encountered gentoo penguins at Brown Bluff, our first landing site, and at several subsequent landings, but they were never as prominent as on Goudier Island and Weineke Island, with their estimated total of 1500 birds. No one seems sure how the gentoo got its name, but Soper (2004, p. 35) notes a rumor that members of a Hindu sect in India, known for their small white cotton caps, were termed "Gentoos" by the British. Like chinstraps, gentoos feed close to shore, and I was able to capture digital video of a gentoo feeding on krill in extremely shallow water, probably no deeper than a foot. This video highlights the perfection of their body shape in terms of streamlining; the bird seems to cut through the water like a knife.

*Illustration 21. Gentoo penguins, Weineke Island, near Port Lockroy.*
*A. Filbert, 5 January 2007.*

Although they were present at all of the prior landings and breeding at Brown Bluff and Devil Island, I describe the brown skua here because it was only at Port Lockroy that I was able to get a proper photograph. The main aerial predator and pirate in Antarctica, skuas resemble fierce, heavy gulls and are in fact related to them. Similar in appearance to the south polar skua, the brown skua boasts a collar of golden brown feathers visible in contrast to the dark golden-

brown of the rest of the body; in both species, distincive white wing patches are conspicuous particularly in flight. Skuas will pursue shags and terns in flight and force them to drop what food they have caught, and will scavenge carrion, galley waste, penguin regurgitation, and fish offal. Nor are penguin chicks or eggs safe, as skuas may carry eggs and larger chicks away and swallow small chicks whole right where they are found (Soper, 2004, p. 93). As dark and forbidding as these birds look, their angelic-plumaged counterparts, the snowy sheathbills, in fact share many of the skuas' somewhat gruesome habits.

Given the rather undeservedly poetic and possibly facetious Spanish name of Paloma-Antártica (Antarctic dove), snowy sheathbills are now thought by many to be a "missing link" of sorts between gulls/skuas and wading shorebirds. Rather distasteful in both mannerisms and appearance despite their attractive white plumage, they scavenge carrion, feces, regurgitated food dropped by penguins during chick-feeding, "the extruded stomach linings of penguins," and will take penguin and shag eggs and chicks (Soper, 2004, p. 38). Their bald, wattled face speaks to their choice diet; like vultures, the bare skin is more sanitary than feathers. Sheathbills are the only bird species found south of the Antarctic Convergence without fully webbed feet, but as they are strong fliers they are not put to disadvantage in this realm of sea and ice, despite their inability to swim. I confess an affection for these birds, for the dissimilitude between their "pure" color and their "evil" habits is not unlike the dichotomy within each of us as humans.

*Illustration 22. Snowy sheathbill and gentoo penguin, Weineke Island. A. Filbert, 5 January 2007.*

*Illustration 23. Humpback whale, Southern Ocean.*
*A. Filbert, 1 January, 2007.*

*Illustration 24. Anvers Island, Antarctica, near Paradise Bay.*
*A. Filbert, 5 January 2007.*

*Illustration 25. Brown skua on the wing. Port Lockroy, Antarctica.*
*A. Filbert, 5 January 2007.*

Our final landing site was the aptly named Paradise Bay, just east of Anvers Island and Port Lockroy. Tall, ice-covered peaks rise straight out of the sea in some areas while ice cliffs hundreds of feet high separate the mountains from the waves. Wildlife abounds, and every few minutes brings delight to the birdwatcher or whale enthusiast. Shags, terns, and gentoo penguins nest here, and several species of whales may be spotted, including minke whales, of which we saw five; there is also a "mothballed" Argentine station here, Almirante Brown. As with Port Lockroy, we passengers were divided into two groups, one first to cruise the pristine, silent bay in Zodiacs and the other to hike up the snow-covered slope, which included a snowslide for the more athletic among us. We all hoped to see whales while cruising as they are frequently spotted in Paradise Bay and are often quite friendly and curious, no longer to their great detriment since the ban on whaling was instituted. One species, however, the minke whale, has had the mixed blessing of avoiding historical whale hunts, which was good for the whales at the time but means that they are not protected today.

*Illustration 26. Minke whale spyhopping.*
*Near Paradise Bay, Antarctica.*
*A. Filbert, 5 January 2007.*

Minke whales are the smallest of the baleen whales, averaging a mere 24 feet in length. Dark blue-grey uppersides contrast with the pale belly, with characteristic lightening behind the flippers and below the dorsal fin. Some minkes have a pale chevron behind their heads, and present in individuals from the more northern latitudes are white bands across the flippers. This stripe is usually absent in Antarctic

populations. Like all baleen whales in Antarctic waters, minkes feed nearly exclusively on krill. Because of their small size, they have until recently been able to avoid being hunted, and as the larger whale species decline, minke populations are growing.

While there is little species diversity in Antarctica in terms of megafauna, insofar as there are petrels, penguins, seals, whales, and not much else, there are great population densities and a high degree of specialization within each individual species. With only a few exceptions, each species depends primarily on krill for survival and is also dependent to varying degrees on the existence of the ice, whether in the form of icepack, icebergs, or even just as a means for temperature control. In fact, the earth as we know it relies on Antarctica for climate control: the circular, dome-shaped icecap directs wind circulation for the whole globe, as well as ocean currents and associated weather patterns. In this way, Antarctica keeps the average world climate temperate and capable of sustaining current life forms, and significant changes to its existence could pose serious problems for the rest of the world, including flooding, drought and desertification, heat waves or deep freezes, and changes in species composition, among other possible consequences. Furthermore, the strong Antarctic winds cause upwelling of nutrients and minerals from the deep waters to the surface of the Southern Ocean; these cold, nutrient-rich waters are then carried north by the wind-driven currents, contributing to phytoplankton blooms in the mid-latitudes. Because of the importance of this oft-neglected continent to the survival of the current biosphere, we must all understand Antarctica's global connection and the threats that we humans pose.


FIRE
Issues

Antarctica faces many challenges in today's changing environment, including global climate change and the ozone hole. The wildlife, too, is threatened by human activities such as fishing, tourism, and pollution, while measures such as the Antarctic Treaty, the Kyoto Protocol, the Montreal Protocol, and IAATO have been instituted to protect Antarctica from human damage.

## Global Warming: What Is It?

Global warming is the term often used to describe the global trend of climate change which has been occurring at an accelerated pace since the 1950s, caused primarily by the increased emission of carbon dioxide from the continued use of coal to drive power plants and the burning of fossil fuels by automobiles. Carbon dioxide gas acts as a blanket, trapping heat from the sun within the atmosphere. The meteorological effects of global warming can be readily seen, according to the National Resources Defense Council (NRDC),

> Over the past 50 years the average global temperature has increased at the fastest rate in recorded history. [ . . . ] The 10 hottest years on record have all occurred since 1990. [. . . ] In 2002, Colorado, Arizona and Oregon endured their worst wildfire seasons ever. The same year, drought created severe dust storms in Montana, Colorado and Kansas, and floods caused hundreds of millions of dollars in damage in Texas, Montana and North Dakota. Since the early 1950s, snow accumulation has declined 60 percent and winter seasons have shortened in some areas of the Cascade Range in Oregon and Washington. [ . . . ] The impacts of global warming are not limited to the United States. In 2003, extreme heat waves caused more than 20,000 deaths in Europe and more than 1,500 deaths

> in India. And in what scientists regard as an alarming sign of events to come, the area of the Arctic's perennial polar ice cap is declining at the rate of 9 percent per decade.

Wildfire season in Oregon is one thing, but what about Antarctica, which holds frozen within its icecap enough water to raise sea levels by hundreds of feet?

Rising temperatures are a great threat to the Antarctic and particularly around the Antarctic Peninsula nearest to South America for several reasons, the most obvious and compelling of which is, of course, the fact that Antarctica is 98% ice and practically every living being in the region is specially adapted to the harsh environment—in fact, many species need the harsh environment in order to survive. In general, penguins and seals cannot raise their young without the pack ice, and many organisms such as plankton require cooler temperatures for maximum productivity. Of even greater concern than the survival of penguins is the sobering thought that world sea levels could rise by as much as 200 feet if the icecap were to melt completely away. This is enough to completely submerge much of the dry land currently inhabited by humans and other animals; for example, a 200 foot rise in sea level would completely submerge the entire state of Florida as well as dramatically restructure coastlines around the world. Fortunately, this point is still in the relatively distant future, but unless preventative action is taken soon, that “relatively distant future” could come much sooner than expected. For the Antarctic Peninsula, the “relatively distant future” is already nearly here, for while the average temperature on the icecap is far enough below freezing to have a "buffer zone" in case of warming, the Peninsula can only afford a very few degrees of increase before warming-related concerns become a serious problem. The Kyoto Protocol is a timely action against this possibility.

## What Is the Kyoto Protocol?

The Kyoto Protocol to the United Nations Framework Convention on Climate Change is a document designed to require all developed nations to reduce their collective emissions of carbon dioxide and other greenhouse gases by an average of at least five percent by between 2008 and 2012. Real emissions reductions are expected to be considerably greater than the mandated levels, with roughly 20% being the official estimate when compared to emissions levels projected for 2010 if control measures are not adopted. The Protocol was adopted in December 1997 by consensus at the third session of the Conference of the Parties (COP3), and is legally binding; it opened for signatures in March 1998 and was ratified by the European Union and its Member States in May 2002, coming into force in August 2002 (European, 2007). Although the United States is responsible for around 25% of the world's emissions, President George W. Bush refused to sign the Protocol, citing the exemption of India and China as legitimate support for the exemption of the U.S., despite the fact that India's and China's exemption is called for under the Protocol as they are considered “economies in transition” (Cook 2007).

## The Ozone Hole

The oft-discussed hole in the ozone layer, while not a direct contributing factor to global warming, although the associated gases also trap heat, is certainly of particular concern to the Antarctic, which lies directly beneath it at the height of the austral summer. When short-wavelength photons such as UV-B rays collide with oxygen molecules, “the oxygen atoms break loose from each other. The odd oxygens are very reactive and soon combine with normal oxygen molecules forming a new compound--ozone [trioxide]” (Nilsson, 1996, p. 15.)

For millions of years despite its instability, ozone has maintained a balance between creative and destructive chemical reactions, acting as a buffer into which harmful solar rays are absorbed and converted into chemical energy and heat before reaching earth's atmosphere. But beginning in the 1970s, with the increased use of anthropogenic chlorine-based chemicals (chlorofluorocarbons, or CFCs), the amount of ozone in the stratosphere has been decreasing at a faster rate than ever before, to its most extreme extent over the continent of Antarctica. Annika Nilsson explains the process this way: "Ultraviolet radiation splits off the chlorine atoms from CFC. An odd chlorine is very reactive and immediately attacks ozone, producing chlorine monoxide and oxygen. Any free oxygen atom soon steals the oxygen from the chlorine monoxide, leaving the odd chlorine ready for another attack on ozone" (1996, p. 17). Negative effects of short-wavelength radiation include, but are by no means limited to, blindness and DNA damage, which has been particularly observed in phytoplankton and ice-fish.

Ozone depletion over Antarctica is accelerated because of the many unique factors associated with the area, particularly the extreme cold during the winter caused by the polar vortex. The low air temperatures combined with a total lack of sunlight seeds the formation of ice clouds, thereby providing "a surface on which the chlorine is converted to an active form when the light returns in the spring" (Nilsson, 1996, p.19). The total ozone has been recorded to decline by between 60% and nearly 100% for approximately two months in the austral spring, depending on elevation and year. Without the ozone layer, not only can harmful UV-B radiation enter unimpeded, but even harsher radiation could begin to negatively affect the earth as a whole including its associated living beings.

Fortunately, because of the signing of the Montreal Protocol in 1987 and subsequent amendments in 1990 and

1992, continued emission of CFC has diminished; the international treaty was designed to eliminate the production of CFC and other ozone-depleting chemicals by the year 2000 and it has succeeded to that degree. However, the protocol is only a stop-gap because CFC remains chemically reactive for a long time and the main CFC-replacing chemicals also deplete the ozone, although at slower rates (CIESIN; Union).

**Potential Effects of UV Radiation and Global Temperature Increases on Antarctic Phytoplankton and Wildlife**

Antarctic plankton has much more difficulty with increases in UV radiation from the hole in the ozone, owing to its adaptation to a low-light environment. Unlike the plankton elsewhere in the world's oceans, which can repair most radiation damage in reasonable time, Antarctic phytoplankton suffer damage which seems to be irreparable for several hours after varying levels of exposure and which results in decreased or eliminated photosynthetic ability. One hour of exposure to the damaging radiation is apparently sufficient to "completely stop all photosynthetic activity" in the affected cells (Nilsson, 1996, pp.40, 41). Because of the typically rough seas, most individual cells probably do not get the full hour of sunlight and consequently the full brunt of the damage, but this may not necessarily be favorable either:

> [. . .] There is a risk that it can instead increase the damage as the plankton community is more adapted to low light conditions deep in the water than to the sun-lit surface. Each plankton can adjust to strong light by producing sun-screening pigments, but this adjustment takes a while. If the plankton never remain long enough at the surface, they might never get time to produce enough pigment. John Cullen describes this as a "conveyer

> belt of doom" - the water constantly brings up light[-]sensitive plankton to the strongly illuminated surface water (Nilsson, 1996, p. 43).

These "sun-screening pigments" are referenced in more detail in M. Hernando (2001) as being "mycosporine-like amino acids," at least with regard to a single genus of Antarctic diatoms (pp. 12-20). As suggested above by Nilsson, these amino acids help protect the DNA and RNA within the diatom cell from UVR damage. The potential for decreased efficiency in the Antarctic phytoplankton community as a result of the hole in the ozone layer is disturbing considering the importance of these organisms to the Antarctic ecosystem, to the carbon cycle, and to the biosphere.

*Illustration 27. Panting Adelie penguin, 48° F. Paulet Island, Antarctica. A. Filbert, 2 January 2007.*

Global warming may also pose a challenge to the continued success of Antarctic diatoms, since the more productive species grow better in cooler water and on the underside of the pack ice. The decomposition of the ice packs because of rising temperatures could thus discourage the growth of these efficient species of phytoplankton by removing the shelter of the pack ice, thus leaving the diatoms exposed to harsher radiation, increasing temperatures, and the gale-driven seas.

Penguins and seals are also suffering from the effects of global warming, and a decline of up to 50% in Adelie penguin populations is believed to relate closely to the changing temperatures. Adelies live on pack ice for much of the year, and emperor penguins never touch land. Both of these species, especially the Adelies, depend heavily on krill to survive, as do crabeater and Weddell seals. Adelie penguins are also extremely sensitive to temperature, and I witnessed this one (Illustration

27) and many others like him panting heavily at 9°C/48°F weather. Crabeater seals, too, rely on the ice as shelter and protection from leopard seals, and like emperor penguins, never set flipper to land even to breed. Furthermore, as I witnessed at Paulet Island, leopard seals use the ice when hunting, either by watching and waiting from ice floes or by breaking through up to a foot of ice to catch wandering penguins off-guard (Stanwell-Smith, 2007). If the ozone hole and climate change were not enough, humans also threaten wildlife populations through fishing and related activities.

**Other Anthropogenic Threats to Wildlife Populations**

Despite the current high numbers of krill that have, in fact, already decreased by about 80% over the last 40 or 50 years (Wikipedia [1]) some researchers and environmentalists fear that global warming and other issues such as poaching may compromise the continued success of krill and the Antarctic ecosystem as a whole. Although the warming itself may not pose a direct threat to krill populations, the associated deleterious effects that global warming has on phytoplankton and on the pack ice, upon which krill and other species depend, is a real and imposing threat:

> [Declining krill biomass] could be caused by the reduction of the pack ice zone due to global warming. [ . . . ] Antarctic krill, especially in the early stages of development, seem to need the pack ice structures in order to have a fair chance of survival. The pack ice provides natural cave-like features which the krill uses to evade their predators. In the years of low pack ice conditions the krill tend to give way to [s]alps, [. . . ] barrel-shaped free-floating filter feeder[s] that also [graze] on plankton (Wikipedia [1]).

Yet another increasing anthropogenic threat to the stability of krill populations is a rising demand for krill as feed

for farmed salmon. Because of this, fishing may soon become a serious issue. “'[Fishing of krill] has not yet reached a crisis yet, and conservationists want to keep it that way', said Clifton Curtis, director of the Antarctic Conservation Project. [. . .] 'Current fishing for krill is below mandated limits, but there is localized depletion, [Curtis said]'” (Zabarenko, 2006, p. 1). New technology for fishing krill has upgraded the threat. While previously krill fishers had to wrestle the laws of physics using fine mesh nets to catch their quarry, now vacuum hoses and pumps do the work for them, continually siphoning up hundreds of gallons of water, and with it thousands of krill at a time.

Krill are not the only animals beginning to feel human pressure; the survival of albatrosses is also increasingly uncertain due to (often illegal) longline fishing for species such as the protected "Patagonian toothfish." The problem, like the solution, is simple: baited hooks are set out on fishing lines that may be many miles long, and albatrosses, which follow fishing vessels for offal and also feed on common bait animals procured from the surface, get hooked and drown when the line sinks. One easy solution is to attach shiny streamers to the lines; as with crows, albatrosses shy away from the noise and movement and will not chase the bait. This method alone could drastically cut the number of albatross fatalities, and the cost is minimal, around $200 USD per line. Other easy but less effective (when used solely) solutions are thawing the bait so it sinks faster, and setting out the lines only at night with lights directed only inwards, towards the ship itself. Whatever the chosen resolution, something must be done, and soon. Longline fishing is killing albatrosses faster than they can reproduce, leading to a serious population decline, and some estimate that over a thousand albatrosses are killed in this manner *every day* around the world; approximately one every 5 seconds for an annual total of around 100,000.

Tourism, too, is an increasing concern because of Antarctica's sensitivity and the sheer numbers of visitors: a dated annual estimate for the 1999/2000 season was 14,298 tourists, roughly 41% more than in the 1998/1999 season. While there was concern in 1999 that Antarctic tourism had already reached carrying capacity, this upward trend continued and today nearly 30,000 tourists per year visit the Great White South (Landau, 2007). An influencing factor in this increase is the recent, misguided interest in the Antarctic region by tour operators running ships large enough to accomodate thousands of people. These ships pose serious potential damage to the environment. Consider, for example, the possibility of "[. . .] a wreck, a huge oil spill in Antarctica. And there is the problem of search and rescue, because if you [sic] have 2,000 passengers on a vessel and the vessel sinks, what will happen, who will come to rescue them?" said French diplomat Michel Trinquier (qtd. in Mackenzie, 2006). As a result of these and other concerns, in 1999 the International Association of Antarctica Tour Operators (IAATO, the main regulatory agency of tourism in the Antarctic) upheld a limit of 400 total passengers and staff on their member operators (Clark, 1999).

Although I confess to having visited the Antarctic Peninsula onboard a tour ship (the M/V Polar Star), she is well within the IAATO guidelines for tour operators, with a maximum carrying capacity of roughly 150 including passengers, crew, and staff. Her small size and strengthened hull allows her to travel safely and less intrusively where larger ships cannot go, with much less risk of wrecking as well as greater ease of cleanup in the event a wreck should occur. Most of the larger, "luxury" ships do not offer the educational lectures that we recieved onboard and that are required of IAATO member operators, which encourage respect and concern for conservation and sustainable ecotourism, nor do many such ships set clear

protocols of onshore behavior.

IAATO is a "member organization founded in 1991 to advocate, promote, and practice safe and environmentally responsible private-sector travel to the Antarctic," and it does so by a system of procedures, guidelines, and strict regulation of tours conducted by its 80 voluntary members, including the M/V Polar Star. Southbound tour operations are subject to "regulations and restrictions on numbers of people ashore; staff-to-passenger ratios; site-specific and activity guidelines; wildlife watching; pre- and post-visit activity reporting; passenger, crew and staff briefings; previous Antarctic experience for tour staff; contingency and emergency medical evacuation plans; and more" (Landau, 2007). IAATO operates within the framework of the Antarctic Treaty System, an extremely complex, international system managing Antarctica's preservation in the interests of peace and science. See the United States Antarctic Program (http://www.usap.gov/theAntarcticTreaty/) for more information on the Antarctic Treaty.

## To Conclude

Antarctica is earth's most critical continent and is an essential support for the present biosphere, strongly influencing, if not controlling, the world's wind patterns, ocean currents, global climate, and associated flora and fauna. Within Antarctica's own environmental niches, phytoplankton and krill support the entire local food web. Because of this ecosystem's vulnerability to temperature changes and the specialization encountered in many Antarctic life forms, we cannot ignore the potential dangers posed by human actions. To do so is not only to doom Antarctica but also to jeopardize the success of the living earth system itself.

Resources

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*Illustration 28. Iceberg and Adelie penguins with Antarctic Peninsular icecap visible in distance.*
*A. Filbert, 2 January 2007.*