Chapter 2: Affected Environment — The Physical and Biological Environment

Chapter 2. Affected Environment — the Physical and Biological Environment

2.1. Introduction

This chapter presents an overview of the physical and biological environment, including the areas where nongovernmental activities occur. For U.S. operators, nongovernmental expeditions are primarily ship-based tours by commercial operators in the Peninsula area. Some U.S. operators also conduct ship-based tours that extend beyond the Peninsula area into the McMurdo Sound area of the Ross Sea, and one U.S.-based private researcher operates in the Peninsula area. Tourism is also the primary nongovernmental activity for non-U.S. operators and generally includes ship-based tours in the Peninsula and Ross Sea areas, adventure tourism to continental areas including Queen Maud Land and the South Pole, and commercial tour overflights of the Peninsula area and of the Ross Sea to the South Pole. Greenpeace International, a non-U.S. headquartered nongovernmental environmental-interest organization, also has ongoing activities in Antarctica. Chapter 3, The Affected Environment — Human Activities in Antarctica, describes the range of historic and present-day human activities in Antarctica including ship-based tourism.

2.2. Antarctica — General Overview of Physical Features

Covering almost 10 percent of the land surface of the Earth and surrounded by the Southern Ocean,[1] Antarctica is the fifth largest continent. At 13.9 million square kilometers (5.4 million square miles), it is 1.5 times the size of the continental United States, centered asymmetrically around the geographic South Pole (Figure 2.1). The Antarctic Treaty applies to the area south of 60° south latitude, including all ice shelves, but not affecting rights with regard to the high seas (Figure 2.2).

Figure 2.1.

Source: External Panel 1997

Antarctica is the coldest, driest, windiest, highest (on average), and most isolated continent on Earth. Distinct climatic and topographic regions exist across the continent with each region unique in its ability to support life forms which are sparse on the continent because of the severe climate (U.S. Antarctic Program External Panel 1997). Changes in the weather can be dramatic: winds can shift from calm to full-gale in a brief period of time; a drop of 36°C (65°F) was once recorded in 12 minutes (External Panel

[1] The term "Southern Ocean" is widely used in Antarctic literature to denote the southern portions of the Pacific, Atlantic, and Indian Oceans.

Figure 2.2. Antarctica

1997). Generally speaking, and from an operations perspective, Antarctica's climate is characterized by a cold, nearly continuously sunlit summer field season (October through February), and a very cold, nearly perpetually dark winter (March through September).[2]

Annual average temperatures vary according to location ranging from 10° to 15°C (50° to 60°F) in the northern regions of the Antarctic Peninsula during the austral summer, to -80° to -90°C (-112° to -130°F) in the interior high altitude regions during the austral winter (National Science Foundation 1992). Winter temperatures in the Peninsula area range from -8° to -20°C (17° to -4°F). The mean annual temperature of the continental interior is -57°C (-70°F). South Pole temperatures range from -32°C (-25°F) in the summer to -59°C (-74°F) in the winter. Russia's Vostok Station recorded -89.2°C (-126.9°F), the lowest temperature ever recorded on Earth. Coastal locations are warmer, and in summer occasionally rise above the freezing point. The monthly mean temperatures at McMurdo Station in the Ross Sea area range from -2°C (27°F) in January to -27°C (-18°F) in August.

Cloud cover is more extensive along the coastal areas than over the interior. Temperature inversions are common in the interior where there is little wind and infrequent cloud cover. Inversions are not as common along the Antarctic Peninsula where winds mix the layers creating an overall warmer air mass. Meteorological observations have been recorded only in recent decades, and only in scattered localities, thus, long-term temperature trends remain uncertain. The longest instrumental temperature records are from the relatively warm Peninsula area, often referred to as the "Banana Belt" of Antarctica (External Panel 1997).

The cold is so intense that most of Antarctica is arid with little or no moisture existing as unfrozen water despite the immense amount of water locked in the ice cap. Annual snowfall in much of the continental interior is less than 5 cm (2 in) making it one of the Earth's driest deserts with an absolute humidity lower than that of the Sahara Desert. The highest snowfalls occur in the coastal areas, including the Peninsula area, where annual precipitation averages over 20 cm (8 in) annually (External Panel 1997).

Katabatic winds[3] sometimes flow down the surface of the continental ice sheet toward the coast commonly reaching speeds of 50 km per hour (kph) (31 mph). In the coastal regions of Terre Adelie, the daily average winds exceed 66 kph (40 mph). Winds on the Adelie Coast in the winter of 1912-1913 averaged 18 meters per second (m/s) (60 fps) 64 percent of the time, and gusts have been recorded at nearly 320 kph (nearly 200 mph) (National Science Foundation 1992).

[2] The austral seasons are those of the southern hemisphere, opposite those in the northern hemisphere: mid-September to mid-December, spring; mid-December to mid-March, summer; mid-March to mid-June, fall; and mid-June to mid-September, winter.

[3] Katabatic winds are gravity-induced as supercooled, dense air gathers momentum and rushes down unimpeded from the higher reaches of the Polar Plateau to the lower coastal areas.

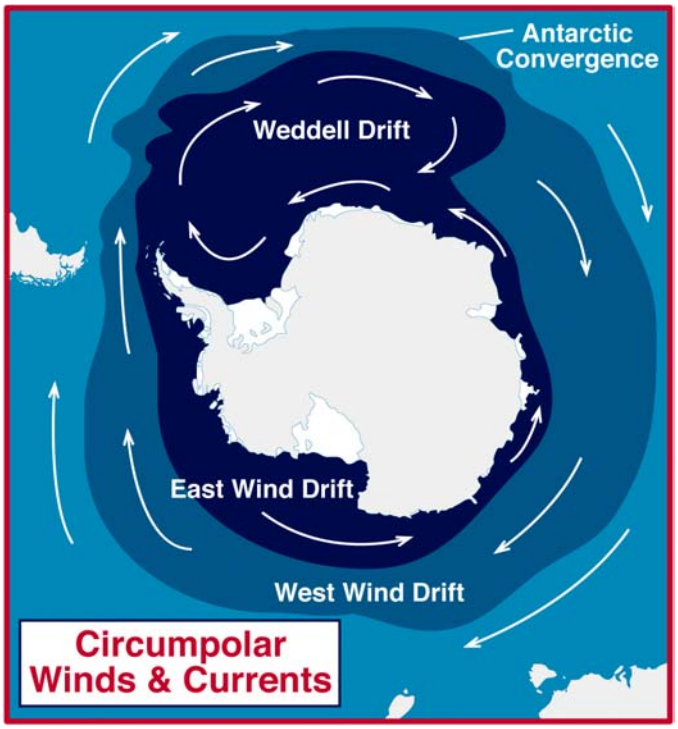

Figure 2.3.

Figure 2.3 illustrates the general pattern of winds over the Antarctic continent. The Antarctic Trough, a permanent ring of low pressure, results as cold air masses developed over the ice cap interact with the warmer winds moving over the ocean creating massive cyclonic depression systems that spiral toward the continent dissipating their energy as storms over the ocean and along the coastlines. Intense winds generated over the continent produce blizzards, with localized blizzards and dense fog produced as cold continental winds meet the relatively warmer and moist maritime air. Larger storms may move inland onto the Polar Plateau causing blizzards far in the interior before the system finally dissipates. Changes in weather can be dramatic with winds shifting from calm to full-gale in a brief period of time (External Panel 1997). Offshore storms may occur with little warning. Winds may reach hurricane strength within an hour and persist for several days. The concentration of storm formation and/or intensification at approximately 50° south latitude is associated with some of the most violent seas in the world. The Drake Passage, the ocean passage between the tip of South America and the Antarctic Peninsula, is considered the most hostile in the world and has claimed numerous ships over the centuries (External Panel 1997).

During the winter months, circulating air masses in the upper troposphere and the stratosphere effectively isolate the airmass above Antarctica. The circulation pattern around the South Pole sets up a vortex which deflects poleward-moving air from warmer regions and causes the airmass inside the vortex to cool strengthening the vortex. Ice crystals form in the extremely cold air of the vortex and provide a reaction substrate for the catalytic chemical processes that destroy atmospheric ozone (Salby and Garcia 1990).

Ozone depletion is attributable to pollutants, particularly chlorofluorocarbons (CFCs), related halogen compounds, and nitrogen oxides (NOx) released in populated regions of the Earth and dispersed globally. These chemical components and ice crystals are retained inside the vortex throughout the winter months. When sunlight returns in the spring and summer, stable CFC molecules are converted into highly reactive molecules that catalyze the destruction of ozone (Figure 2.4). Atmospheric ozone selectively absorbs ultraviolet (UV) radiation, and it is the midultraviolet (UVB) radiation, which is extremely injurious to organisms, that increases most significantly when stratospheric ozone is reduced. Research indicates that there is a measurable ozone-induced loss of phytoplankton blooms in the marginal ice zone. As the stratospheric ozone layer thins in the spring, the resulting increase in UVB radiation penetrating the ocean surface may harm phytoplankton

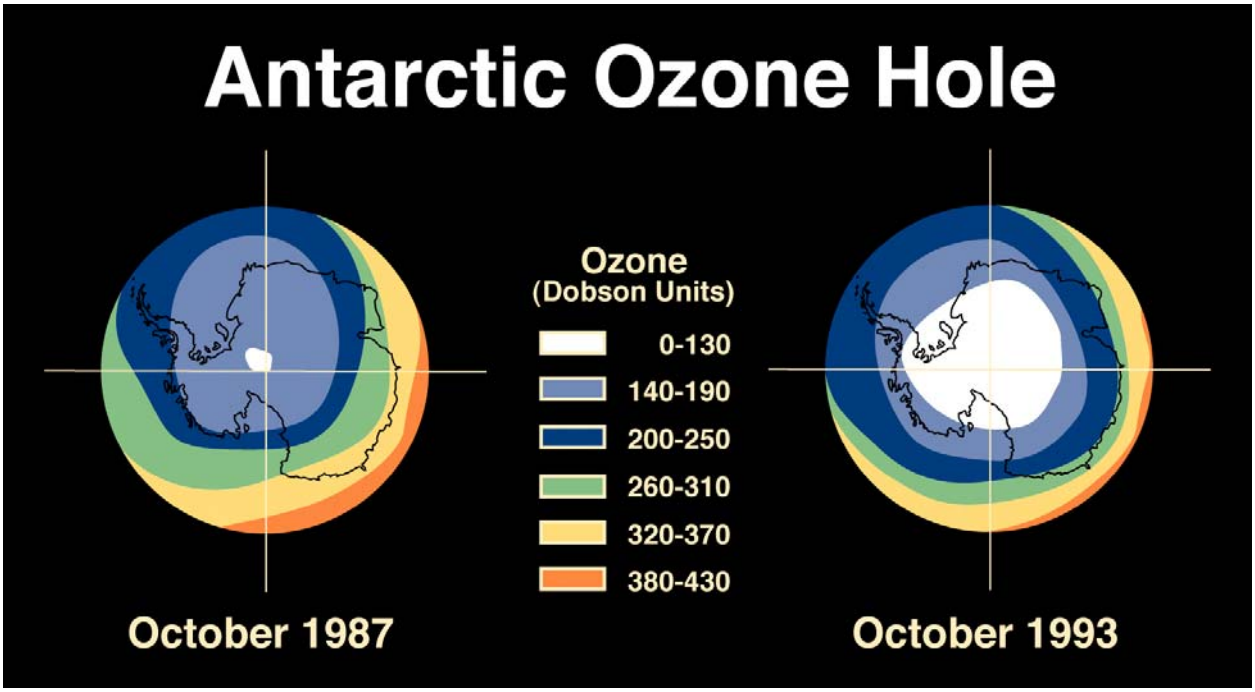

Figure 2.4.

Source: Karentz 1991

communities inhabiting near-surface waters. Because phytoplankton communities are the base of the marine food chain, these disruptions could alter the dynamics of entire Antarctic marine ecosystems (Smith et al 1992; Karentz 1991; and Vernet, Mitchell, and Holm-Hansen 1989). [4]

Antarctica is surrounded by the southern parts of the Pacific, the Atlantic, and the Indian Oceans, waters commonly referred to as the Southern Ocean. At 36 million square kilometers (13.9 million square miles), the Southern Ocean constitutes nearly 10 percent of the Earth's ocean waters and extends from the Antarctic

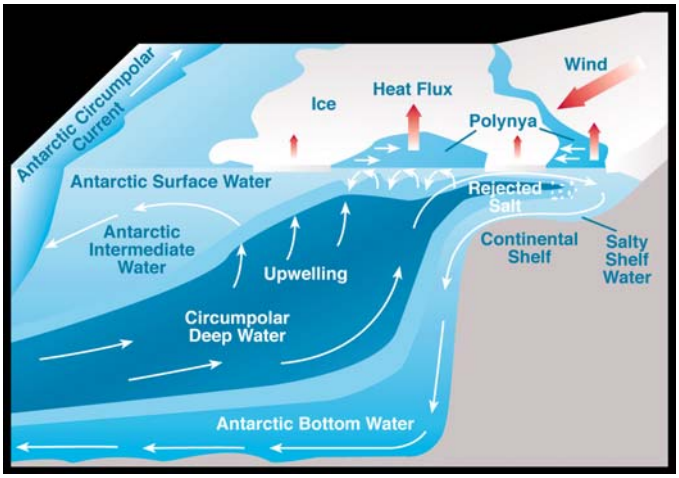

Figure 2.5. Physical characteristics of the Southern Ocean (water layers and currents)

Source: External Panel 1997

[4] The Montreal Protocol on Substances that Deplete the Ozone Layer is the primary international agreement providing for controls on the production and consumption of ozone-depleting substances. As of June 1994, 136 states are Parties to the Protocol, including virtually all major industrialized countries and most developing countries. Recent observations show that tropospheric chlorine levels have been declining, indicating that stratospheric chlorine concentrations should begin decreasing in the near future. Complete recovery of the ozone layer is not expected, however, until the middle of the next century, assuming full compliance with the Montreal Protocol.

continent, including the permanent ice shelves, to the Antarctic Convergence.[5] With temperatures ranging from -1.8° to 4°C (28° to 39°F) seasonally, the cold waters are part of the global water transport system. The cold surface waters serve as a sink for dissolved gasses, important in the regulation of atmospheric carbon dioxide levels (Jones et al 1990). The circumpolar current, termed the West Wind Drift as depicted in Figure 2.3, transports more water than any of the other ocean current systems (National Science Foundation 1992). Massive upwellings south of the Antarctic Convergence provide the inorganic nutrients that support photosynthesis and phytoplankton growth, the basis of the Antarctic food web (Jones et al 1990 and Quentin and Ross 1991). The physical characteristics of the Southern Ocean are depicted in Figure 2.5.

Antarctica is characterized by the highly variable amount of ice that exists south of the Antarctic Convergence including the Antarctic ice sheet, ice shelves, glaciers, icebergs, and annual sea ice. The ice on the continent is the result of millions of years of snowfall. Ice is highly reflective of sunlight, thus, Antarctic ice is a factor in the regulation of the world's climate by reducing the overall global heat budget (Livermore 1997).

The Antarctic ice sheet, termed the Polar Plateau, currently covers approximately 98% of the continent and contains 90% of the world's ice and nearly 70% of the Earth's fresh water. The

Figure 2.6. Changes in the U.S. coastline should the Antarctic ice cap melt

Source: NSF/OPP (February 1997© Popular Science, Infographic© 1997 J. Grimwade)

[5] The Antarctic Convergence, generally located between 47° and 63° south latitude and encircling Antarctica at roughly 1,500 km (932 mi.) off the coast, is the boundary where northward-moving cold Antarctic water meets southward-moving warm subantarctic water from the Atlantic, Pacific, and Indian Oceans.

Polar Plateau is, on average, 2,160 m (7,130 ft.) thick making Antarctica the highest continent (National Science Foundation 1992). The continent itself is depressed more than half-a-mile to near sea level under the tremendous load of the ice sheet, with some regions well below sea level (External Panel 1997). The maximum ice thickness of 4,776 m (3 mi.) occurs in Wilkes Land, about 1,200 km (750 mi.) east-northeast of Russia's Vostok Station in East Antarctica. If the ice sheet melted, global sea level would rise by 60 m (196 ft.) inundating coastal land areas as depicted in Figure 2.6. With ice covering 98% of the continent, Antarctica's ice-free areas (Figure 2.7) are generally near the coast and also include the McMurdo Dry Valleys of southern Victoria Land, the Bunger Oasis in Wilkes Land, isolated spits of land, and nunataks (National Science Foundation 1992).[6]

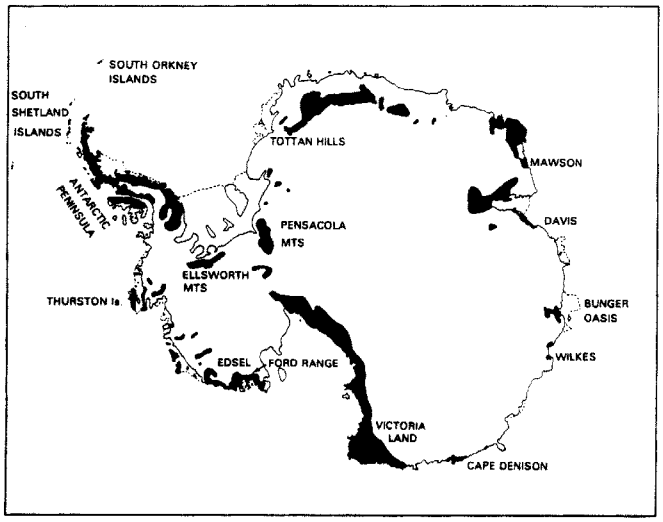

Figure 2.7. Distribution of exposed rock and snow-free ground on the Antarctic continent in Summer

Source: Walton (1984).

Ice shelves occur where large areas of the ice sheet flow (by internal ice deformation and/or by sliding on the rock base) to the coast where these areas of fresh water then float in the ocean. The Ross Ice Shelf and the Ronne/Filchner Ice Shelf are the largest in Antarctica (and the world) with the Ross Ice Shelf covering an area of half a million square kilometers (193,000 square miles), ranging up to about 800 km (497 mi.) across. These, and the other Antarctic ice shelves, typically range in thickness from about 1,000 m (3,280 ft.) at the floating ice/grounded ice boundary to 300 m (984 ft.) near the edge where the ice calves off to form icebergs (Jacka 1999).

Glaciers flow from the continent towards coastal areas where the ice may melt or be incorporated into floating ice shelves or break away to produce icebergs (Crossley 1995 and National Science Foundation 1992). Lambert Glacier, the world's largest glacier, is over 40 km (25 mi.) wide, flowing for 400 km (250 mi.). It is the outlet for about a quarter of the Antarctic ice sheet, flowing into the Amery Ice Shelf. Nearly 90% of the ice flowing across West Antarctica converges into ice streams that are the most dynamic, and perhaps unstable, components of the Antarctic ice sheet (External Panel 1997). About 5,000 to 10,000 major icebergs are calved yearly from Antarctica. Icebergs larger than the state of Connecticut have been observed (External Panel 1997). Icebergs calved from the numerous ice shelves of the Antarctic Peninsula move north and west through the Weddell Sea where they may be so enormous and numerous that it can be difficult to determine where one begins and another ends (Naveen et al 1990).

[6] Nunataks are exposed rock outcrops and include the isolated peaks of the mountains.

The millions of square miles of sea ice in the Southern Ocean around Antarctica increase and decrease on an annual basis as depicted in Figure 2.8. Annually, the extent of sea ice experiences a five-fold increase and decrease with the winter maximum more than doubling the region's area of ice coverage (External Panel 1997). Sea ice up to 3 m (9.8 ft.) thick forms outward from the continent every winter, making a belt 500 to 1,500 km (310 to 932 mi.) wide. The summer sea ice belt is 150 to 800 km (93 to 497 mi.) in most places (National Science Foundation 1992). The minimum areal extent of the sea ice in January is approximately 4 million square kilometers (1.5 million square miles), or 11 percent of the Southern Ocean's surface, and the maximum areal extent

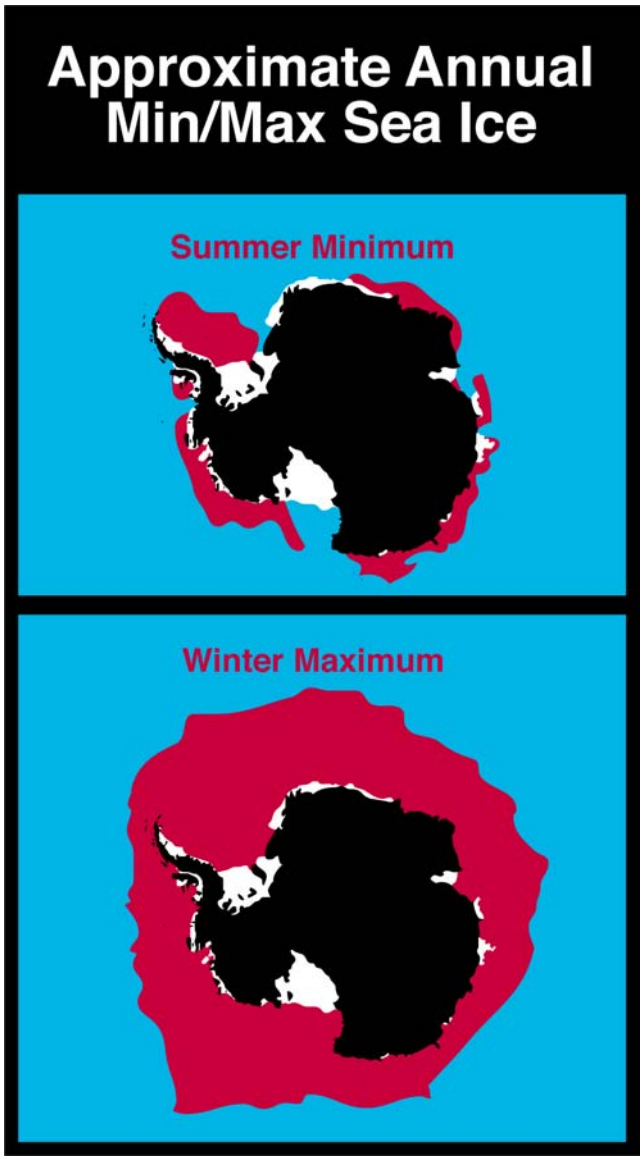

Figure 2.8.

Source: Stammerjohn and Smith 1996 and Foster 1984

in September is about 20 million square kilometers (7.7 million square miles), or 57 percent of the

Southern Ocean's surface (Stammerjohn and Smith 1996).

The temperature gradient associated with the sea ice is one of the strongest on Earth with the seasonal variability in the extent of sea ice serving as an important climate regulator in the Southern Hemisphere (External Panel 1997). The supercooled saline water formed in regions of the Antarctic's continental shelf flows into the global ocean as Antarctic Bottom Water, the coldest and saltiest water mass in the deep ocean, where it becomes a primary driver in global ocean circulation (Figure 2.9) (External Panel 1997).

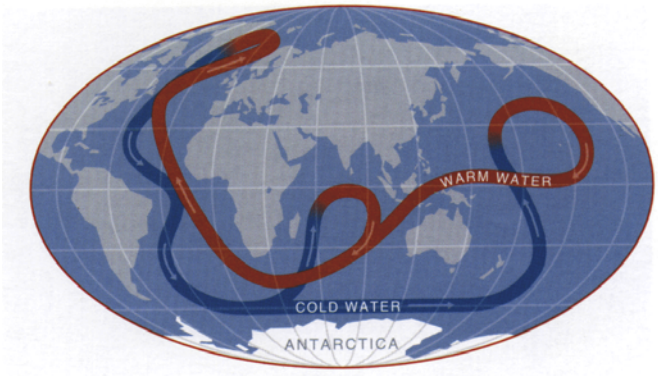

Figure 2.9. Influence of circulating Antarctic bottom water on Global ocean circulation

Source: NSF/OPP (February 1997© Popular Science, Infographic© 1997 J. Grimwade)

The annual cycle of Antarctic sea-ice growth and recession also affects the total primary biological productivity in the Southern Ocean, and thus the Antarctic food web as depicted in Figure 2.10 (Quetin and Ross 1991 and Smith et al 1992). Sea ice provides habitat (feeding sites, refuge, and breeding areas) for a variety of organisms. Krill, a key component of the Antarctic food web, feed primarily on phytoplankton including the ice algae that frequent the undersides of sea ice during the winter.[7] During the spring and summer, blooms of ice-colonizing phytoplankton and microbial populations may contribute as much as 60 percent of the Southern Ocean's primary productivity (Quetin and Ross 1991; Palmisano and Garrison 1993; and Stammerjohn and Smith 1996).

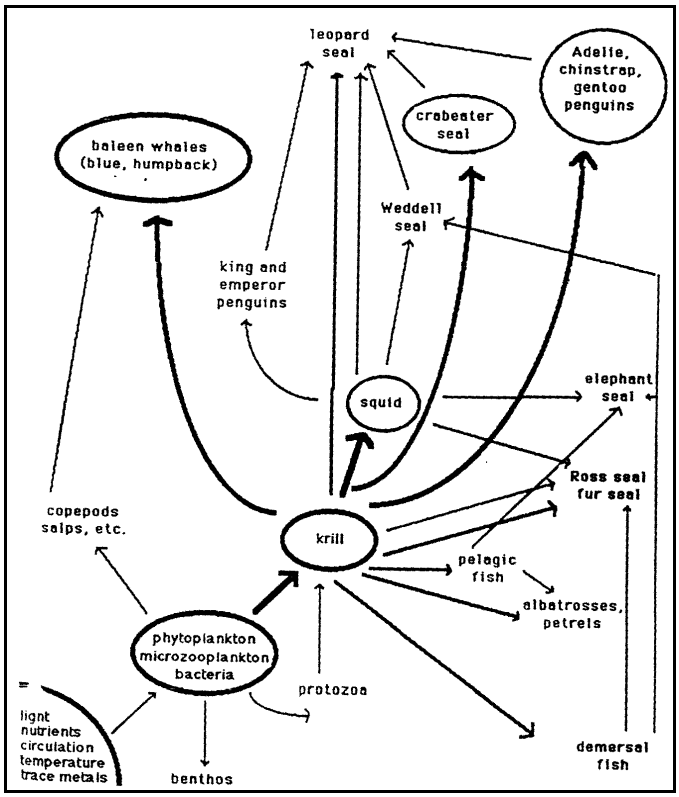

Figure 2.10. Antarctic food chain

Source: Quetin and Ross (1991)

The edge of the ice pack, or marginal ice zone, is the transition area between sea ice and open water and is

[7] Krill, a general term used to describe about 85 species of open-ocean crustaceans known as euphausiids, are herbivorous that feed on phytoplankton, the microscopic suspended plants, of the Southern Ocean; zooplankton, planktonic animals, may also form a part of their diet (Nicol and Clippingdale 1999).

habitat for many species of birds and marine mammals. The marginal ice zone varies from year to year, location to location, and from time to time within a season. The amount of pack ice surface area affects the summer and winter distribution of Antarctic fauna as species rely on pack ice for shelter, breeding habitat, and access for ocean feeding. Several scientific investigations are looking at the effect of physical factors, such as increase in sea ice, on the variability of penguin populations in the Southern Ocean (Fraser et al 1992; Trathan, Croxall, and Murphy 1996; Fraser and Trivelpiece 1996; and Trivelpiece and Fraser 1996).

2.3. East and West Antarctica

Antarctica consists of East and West Antarctica, two distinct geologic provinces bridged by the vast Polar Plateau ice sheet (Figure 2.2). The regional distinctions are based primarily on the geologic origins of the rock that form the two landmasses.

The 3,200 km (2,000 mi.) long Transantarctic Mountains transect the continent separating East and West Antarctica, dividing the ice sheet into two parts. Their average elevation is 2300 m (7,545 ft.), with the highest mountains rising to elevations over 4,270 m (14,000 ft.), about the height of the U.S. Rocky Mountains (External Panel 1997). Other mountain ranges are the Prince Charles Mountains in the Mac. Robertson Land area, and smaller groups near the coasts. Various mountains extend the length of the Antarctic Peninsula. The Ellsworth Mountains in West Antarctica are the tallest, with Vinson Massif at 4,897 m (16,067 ft.) above sea level.

Vulcanism occurs to varying degrees along the Transantarctic Mountains and on some of the islands around Antarctica. Mt. Erebus, bordering McMurdo Sound in the Ross Sea at 77.5^{o} south latitude, is the southernmost of the active Antarctic volcanos (Figure 2.2). The Antarctic Peninsula and the surrounding islands are volcanically active. At least eight of the eleven islands of the subantarctic[8] South Sandwich Islands contain fumaroles. Deception Island (in the South Shetlands directly west of the Peninsula) is extremely active. The British and Chilean research bases on Deception Island were abandoned due to extensive ash damage following eruptions in 1967 and 1969. The sunken caldera of Deception Island where seawater is heated by submarine vents is a favorite tourist landing site that provides an opportunity for tourists to swim in the heated waters.

East Antarctica is about two-thirds of the Antarctic landmass, comprised of land that is mostly above sea level (National Science Foundation 1992). The polar ice cap, East Antarctica's most prominent feature, is, on average, thicker than the ice in West Antarctica. As of winter 1999, there are 20 permanent research bases operated by 12 countries located in East Antarctica (SCAR Bulletin 1999) including the United States' McMurdo Station and New Zealand's Scott Base on Ross Island in the Ross Sea at the edge of the Ross Ice Shelf (Appendix 2). The Ross Sea and McMurdo Station are routinely visited by U.S. ship-based tour expeditions. Tourist activities that are not U.S.-based also occur in East Antarctica; these include: mountain climbing on Vinson Massif

[8] The rule to be promulgated by EPA will apply to expeditions organized in the U.S. or proceeding to the Antarctic Treaty area from the U.S. The discussions in this EIS will focus on the area south of 60^{o}, however, the subantarctic islands and other such areas are included in this EIS, as appropriate, to provide the broader context for the topics of discussion.

in the Ellsworth Range, the Transantarctic Mountains, and the mountains in the Dronning Maud Land area; private flights to the South Pole; and visits to the Dawson-Lambton Emperor penguin rookery (Adventure Network International 1998). These and other nongovernmental activities are further described in Chapter 3.

Much of the inland environment of East Antarctica is relatively pristine, and as such, provides a baseline for studies including global background levels of airborne contaminants and ancient climatic records through coring in the ice sheet. In addition, the relative abundance of meteorites on the surface of the ice sheet in certain areas lends to the knowledge of meteorites, in general, and to the knowledge of the solar system.

West Antarctica, which includes the Antarctic Peninsula, is about one-third of the Antarctic landmass and is comprised of land that is mostly below sea level (National Science Foundation 1992). Unlike East Antarctica, West Antarctica is composed of crustal blocks which would exist as islands if the polar ice cap were removed. This region is characterized by a varied landscape of undulating ice rises and mountainous nunataks, including Vinson Massif, the continent's highest mountain. Nearly 90% of the ice flowing across West Antarctica converges into ice streams with the Larsen Ice Shelf and the Weddell Sea along the eastern edge of the Antarctic Peninsula.

The Antarctic Peninsula in West Antarctica is the major peninsula of Antarctica and the northern-most extension of the continent. South America is the closest continental land mass at a distance of only about 800 km (500 mi.). By comparison, the distance to the continent from New Zealand is about 2,400 km (1,500 mi.) and from Africa, about 4,000 km (2,500 mi.).

Numerous islands border on the north and west of the Peninsula ranging from the South Orkney Islands at the north to Alexander Island in the south. Ship-based tours cruise the waters around the Peninsula and the area islands with many of the islands serving as onshore visitor sites (Figure 2.11). Few ship-based tour expeditions travel beyond the Peninsula area. However, those traveling from the Peninsula area to the Ross Sea and McMurdo Sound area journey through the Bellingshausen and Amundsen Seas, skirting the coast of West Antarctica (Figure 2.2).[9]

[9] In 1996-1997, an expedition by Quark Expeditions, Zegrahm Expeditions, and Aurora Expeditions circumnavigated the continent (Quark, Zegrahm, Aurora IEE 1997 and Splettstoesser, Headland, and Todd 1997).

Eleven countries maintain a total of 17 year-round stations in West Antarctica, particularly in the Peninsula area, with additional seasonal research sites located throughout the region (Appendix 2) (SCAR Bulletin 1999). Eight of these 17 stations are located on King George Island (Figure 2.11). The United States' Palmer Station is located on the southwestern coast of Anvers Island and is routinely visited by U.S. ship-based tour expeditions. The Polish Station, Arctowski, on King George Island, recently opened a "Tourist Information Center" (Antarctic and Southern Coalition 1998).

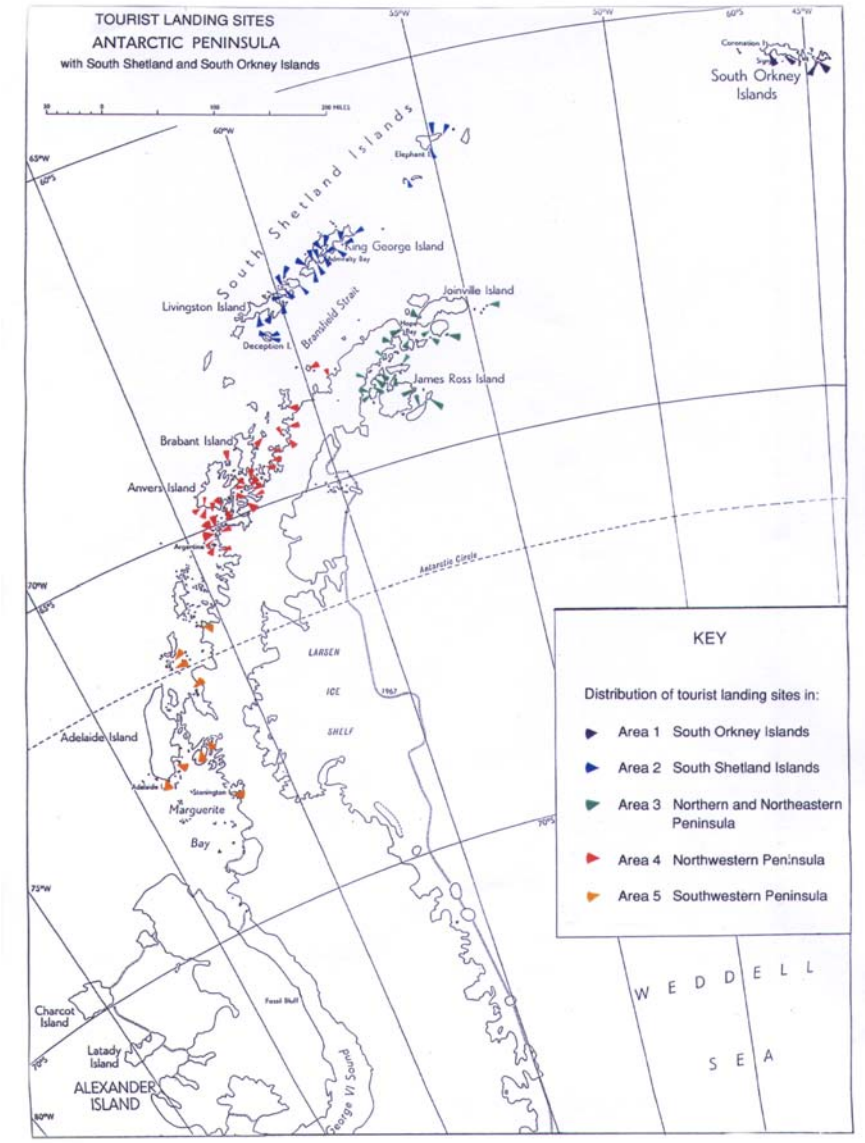

Figure 2.11. Distribution of Antarctic tourist landing sites along the Antarctic Peninsula

Source: Crosbie (unpublished)

2.4. General Overview of Antarctic Flora and Fauna

Only two percent of Antarctica is ice-free with virtually all extensive areas of ice free terrain, excluding nunataks, within a 2 km (1.2 mi.) coastal area from the sea (Smith 1993). Soils are generally unconsolidated materials such as talus, moraines, and beach deposits (Smith 1996). However, despite the harsh conditions, bacteria and yeast have been found growing only 290 km (180 mi.) from the South Pole, a lichen was found in a sunny canyon 340 km (210 mi.) from the Pole, and blue-green algae were observed in a frozen pond 360 km (220 mi.) from the Pole (External Panel 1997). The majority of the Antarctic terrestrial biota is confined to the ice free coastal ecosystems but, by comparison to most other coastal regions of the world, the southern polar zone is floristically and faunistically impoverished due to its isolation from the other Southern Hemisphere continents and to the extremely cold summers (Smith 1993).

Antarctica is divided into two climatically distinct regions (Smith 1993). Maritime Antarctic is the more northerly, milder and wetter semi-desert region which includes the west side of the Antarctic Peninsula and the offshore islands including the South Shetland Islands, South Orkney Islands, and South Sandwich Islands.[10] The maritime Antarctic generally receives more precipitation, which may fall as rain in the summer, and is climatically more favorable for terrestrial plant life and microscopic animals. The Antarctic Peninsula supports the continent's greatest diversity of native flora and fauna. The rest of coastal Antarctica comprises the colder, drier circumpolar coastal continental Antarctic desert region which includes the continental mass and the eastern Antarctic Peninsula (Seppelt and Connell Feb. 8 1999 and Smith 1993). Although the coastal continent is extensive, barely one-third of the coastline has a seaboard, and the other two-thirds is separated from the open sea by ice shelves. Of the coastline with seaboard, less than one-tenth is snow- and ice-free terrain in summer (Smith 1993). Unlike the maritime Antarctic, the greatest expanses of ice-free land occur inland in the cold, barren ablation (or dry) valleys and only relatively small areas of these dry valleys extend to the coast (Smith 1993). Table 2.1 summarizes these two geobotanical regions, zones based on distinctive climatic, oceanic, and biotic characteristics.

Table 2.1. Geobotanical Regions of the Antarctic

Region	Province	Climatic Features	Biotic Features	Localities
Maritime Antarctic	Northern (55-66°S)	Cold moist maritime climate, mean monthly temperatures exceed 0°C for 3-4 months in the summer, but rarely fall below -10°C in winter; precipitation 35-50 cm per annum with much falling as rain in summer.	Semi-desert dominated by cryptogams but including small closed stands of the only two phanerogams in the Antarctic; locally diverse vegetation near coast; mosses form closed stands in wetter habitants locally accumulating peat, lichens predominate in exposed situations and inland; liverworts frequent. Snow algae and macrofungi frequent in summer. Abundant marine bird and mammal fauna; substantial invertebrate fauna dominated by mites and springtails and including the only higher order insects (Diptera) in the Antarctic.	South Sandwich, South Orkney, South Shetland Islands, west coast of Antarctic Peninsula and offshore islands to about 68°S.
	Southern (66-70°S)	Cold dry maritime climate, mean monthly temperatures exceed 0°C for 1-2 months in summer but rarely fall below -15°C in winter; precipitation 35 cm or less water equivalent; occasional rain.	As for northern province but cryptogamic diversity less and closed stands restricted in area; two phanerogams not infrequent to 68°S; liverworts, macrofungi and Diptera rare; no accumulation of peat moss.	West coast of Antarctic Peninsula and offshore islands from 66-70°S; also northeast coast of Antarctic Peninsula to 63°S.
Continental Antarctic	Coastal	Cold arid climate, mean monthly temperatures exceed 0°C for 0-1 month in summer; winter means from -5 to -25°C, but some maritime influence	Semi-desert with moss and alga vegetation present on ahumic soil but restricted in species and extent; lichens numerous and locally form extensive stands; snow algae occasional in some localities.	Coastal fringe of East Antarctica and West Antarctica south of 70°S and on east coast of Antarctic Peninsula south of

[10] The South Sandwich Islands, located northward of the Antarctic Peninsula, are outside the Antarctic Treaty area.

Region	Province	Climatic Features	Biotic Features	Localities
		narrowing temperature range; precipitation above 10-15 cm water equivalent. Rain very rare.	Invertebrates locally abundant and diverse. Seabird colonies frequent and large; marine mammals abundant (mainly offshore).	63°S; includes ablation areas (dry valleys and oases).
	Slope	Cold and more continental climate, all mean monthly temperatures below -5°C, low winter temperatures; precipitation about 10 cm water equivalent; no rain.	Desert with mainly open very discontinuous lichen vegetation; occasional moss patches near rare snow and Antarctic petrel colonies and other favorable oases. Some mites, springtails, and other invertebrates.	Mountain and glacier zone inland from coast encircling the central ice plateau; includes isolated nunataks in plateau.
	Ice Plateau	Extreme continental conditions, all mean monthly temperatures below -15°C, falling well below -30°C in winter; slight precipitation.	No life besides occasional microorganisms and stray birds.	Interior of the continent, generally above 2,000 m altitude.

Source: Smith 1984

2.4.1. Antarctic Flora

Antarctica's flora is dominated by lichens (about 200 species) and mosses (about 100 species) of various forms, and, in suitable habitats, by species of foliose algae and cyanobacteria (blue-green algae) (Smith 1993). In addition, there are about 20 species of liverworts, 15 species of macro-fungi, and 2 angiosperms or flowering plants (Smith 1993).[11] [12] Lichens and bryophytes[13] dominate the macro-flora, with lichens growing in most areas of Antarctica capable of supporting plant life. By mass, algae are the most abundant plants in Antarctica and can be found growing on open ground and ice, and in fresh water ponds (Llano 1965). Terrestrial algae are found growing in snow banks or in the soil itself, and soil algae (along with bacteria and cyanobacteria) are ecologically important as they help bind the soil together with their byproducts (mucilage and slime) (Seppelt and Connell Feb. 3 1999). The National Science Foundation has designated native Antarctic flora and fauna in order to include them in a regulatory framework to conserve and protect them as part of the Antarctic Treaty System (45 CFR 670).[14] Native plants are designated as all

[11] The National Science Foundation has designated native plants as all plants whose normal range is limited to, or includes, Antarctica, including: Bryophytes, Freshwater algae, Fungi, Lichens, Marine algae, and Vascular plants. (45 CFR 670)

[12] The native flowering plants include a grass (Antarctic hair grass, *Deschampsia antarctica*) and an herb (Antarctic pearlwort, *Colobanthus quitensis*).

[13] Mosses and liverworts, with mosses being the dominant bryophyte (Smith 1996).

[14] In 1964, the Antarctic Treaty Parties adopted the Agreed Measures for the Conservation of Antarctic Fauna and Flora, and in 1991, the Treaty Parties adopted the Protocol on Environmental Protection to the Antarctic Treaty with five annexes which codify and strengthen previously adopted environmental provisions. Annex II to the Protocol provides for measures to conserve Antarctic plants and animals and for a permit system for various activities in Antarctica and designation of certain Antarctic mammals and geographic areas as requiring special attention. These measures are implemented in the United States through the Antarctic Conservation Act of 1978 (16

plants whose normal range is limited to, or includes Antarctica. These include: bryophytes, freshwater algae, fungi, lichens, marine algae, and vascular plants (45 CFR 670). None of these plants are designated as Specially Protected Species.

Antarctic plant communities are often small stands, commonly less than 25 square meters (270 square feet). Many plant species are sensitive to minor nutrient changes (especially nitrogen and calcium), moisture, texture and stability of the substratum, micro topography, exposure to wind and protection by winter snow cover (Smith 1993). The two angiosperms, the macro-fungi and the liverworts are restricted to the maritime Antarctic.[15] Growing conditions tend to be relatively constant throughout the coastal snow-free zone, consequently, maritime plant communities often occur well inland, and "montane" communities extend to sea level (Smith 1993). Lichens growing under favorable maritime Antarctic conditions may reach growth rates of 1 cm (.4 in.) or more per 100 years, while in the harsher coastal continental Antarctic, growth may be as little as 1 cm per 1,000 years for *Buellia frigida* in the Dry Valleys region (Seppelt and Connell Feb. 3 1999).

Figure 2.12 illustrates the distribution of the principal dry ecosystems across a typical coastal area of the Antarctic. The absence of the zoned lichen communities on sea cliffs in the continental regions is the major difference between the maritime and continental regions. In continental locations, the extent of vegetation, in general, is usually more fragmentary due either to the lack of snow-free ground or to the severity of the environment (Smith 1993).

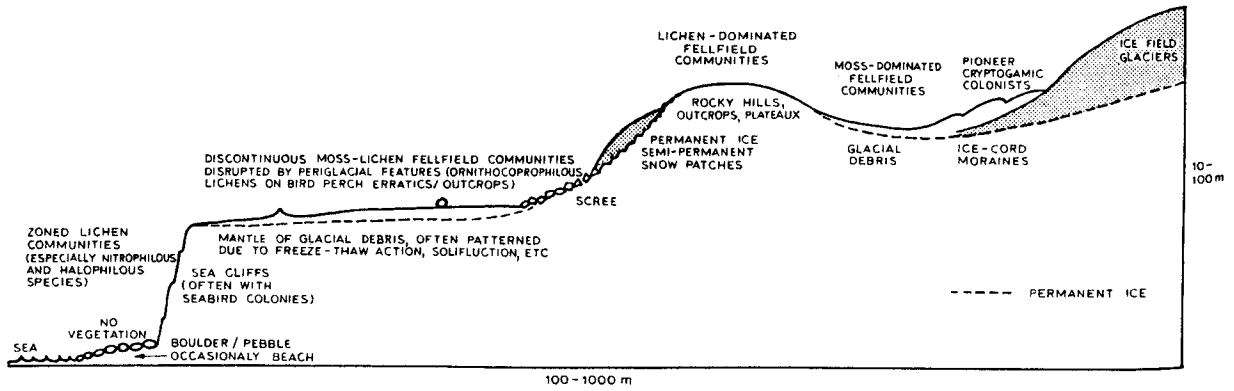

Figure 2.12. Typical coastal area of the Antarctic

Source: Smith 1993

U.S.C. 2401 *et seq.*). In accordance with 45 CFR 670, the National Science Foundation has designated native mammals, birds and plants, and requires permits authorizing the taking or harmful interference with mammals, birds, or plants.

[15] The liverwort, *Cephaloziella exiflora*, is known from four continental localities (Smith 1993).

There are several localized habitats with unique flora, and to a lesser extent, invertebrate fauna, most located in the northern maritime Antarctic (Smith 1993). The calcareous soils and rocks of Signy Island are dominated by short cushion mosses and fruticose lichens. The fine, porous, base-rich black ash soils on several of the South Sandwich and South Shetland Islands and Bouvetoya are sparsely vegetated. However, zoned moss and liverwort communities are located around fumaroles in the South Sandwich Islands, and heterogeneous communities occur on heated ground on Deception Island and Bouvetoya. In wetter areas colonized by mosses and occasional lichens and flowering plants, areas of *Deschampsia antarctica*, covering several hundred square meters, occur in sheltered moist sites. In some dry coastal areas, a unique community of micro-algae and cyanobacteria exists on raw soil beneath translucent boulders (Smith 1993). In the continental Antarctic, the volcanic soils of Ross Island are extremely dry, unstable because of wind action, and barren except along temporary melt stream channels or around or down-wind from penguin rookeries. In these areas, stands of barely 1 square meter (10 square feet) are comprised of scattered moss cushions with associated micro-algae and cyanobacteria, and lichen crusts (Smith 1993). Mt. Melbourne, an inactive volcano in the Ross Sea area, supports the only known Antarctic occurrence of the moss *Campylopus pyriformis* (Seppelt and Connell Feb. 8 1999).

The prominent marine flora in the Southern Ocean are the phytoplankton which form the basis of the marine food chain. As the primary producers, phytoplankton convert light energy from the sun into chemical energy which is made available to zooplankton and, indirectly, higher order predators in the food web process. Phytoplankton contribute 30-40% of the biomass of the Antarctic ecosystem, and up to 60% during spring and summer blooms (Seppelt and Connell Feb 3 1999; Quetin and Ross 1991; Palmisano and Garrison 1993; and Stammerjohn and Smith 1996). The majority of Southern Ocean phytoplankton species are diatoms (18.5%) and Prymnesiophytes spp. (80.4%). The distribution of phytoplankton is patchy throughout the Southern Ocean. Blooms occur in the spring, fall, and several times throughout the summer as sunlight duration and intensity increase and affect other physical and chemical characteristics of the ocean (Bidigare et al 1996).

2.4.2. Antarctic Fauna

Certain mammals and birds have been designated as native to Antarctica (45 CFR 670). Designated birds include penguins and flying birds, and the mammal designations include pinnipeds, large cetaceans (whales), and small cetaceans (dolphins and porpoises). Two seal species have been designated as Specially Protected Species (45 CFR 670). Whaling is regulated under the International Convention for the Regulation of Whaling through the International Whaling Commission. Commercial fisheries in the waters of the Antarctic Treaty area are addressed under the Convention for the Conservation of Antarctic Marine Living Resources under the Antarctic Treaty System[16] which is discussed further in Chapter 5. No fish have been designated as Specially Protected Species.

[16] The Antarctic Treaty was signed in Washington, D.C. on December 1, 1959. The Convention for the Conservation of Antarctic Marine Living Resources was concluded in 1980.

About 270 demersal and pelagic fish species have been recorded from the Southern Ocean which account for only 1.5% of the world's approximately 20,000 fish species. With the Scotia Ridge as the only shallow water 'bridge' to the continental shelf of South America, the Antarctic Convergence has had a marked effect on the evolution and composition of the shallow-water and pelagic fish. Deep-sea fish are not confined by this barrier. As a result, about 25% or less of the deep-sea species are endemic to the Southern Ocean, while there are fewer pelagic species than deep-sea species and more than 85% of the coastal species do not occur elsewhere (Kock 1992).

Pelagic fish,[17] including opahs, porbeagle, trumpet fish, and southern blue tuna, are occasional or even permanent invaders of the peripheral parts of the Southern Ocean. There are no true families that are confined more or less to the surface waters of the Southern Ocean during their life cycle. Pelagic fish also consists of early life stages of a large number of notothenioids and of juveniles and adults of the families Nototheniidae, Bathydraconidae and Channichthyidae. The most numerous of the mesopelagic fauna are the lanternfishes. Mesopelagic fauna overlap with bathypelagic fauna making separation between the two faunas somewhat artificial (Kock 1992).

Bottom, or demersal, fish make up almost 75% of the species so far recorded. These are divided into two groups: the deep sea species inhabiting the continental slope and deep sea basins and trenches, and the coastal species living on the continental slope. This distribution pattern becomes blurred because of the submergence of the shelf regions and the presence of inner-shelf depressions, especially in East Antarctica. Apart from the few representatives of the truly coastal fish families,[18] the deep sea species seem to be widespread with 57 species of families known to be common in other parts of the world ocean (Kock 1992).

The single endemic suborder, the Notothenioidei, dominate the coastal fish of the Southern Ocean in terms of species and biomass. This group includes more than 66% of the species and accounts for more than 95% of the individuals in most areas of the Southern Ocean. Comprised of a variety of ecomorphological types, they have adapted to nearly all habitats from shallow tidal pools to the continental slope down to more than 2,000 m (6,561 ft.). All other coastal fish families are not specifically Antarctic and are much less in terms of numbers of species and individuals (Kock 1992).

The abundance of life in the Southern Ocean derives from an abundance of phytoplankton and zooplankton, the flora and fauna base of the food chain (Figure 2.10). Southern Ocean marine invertebrates are the main trophic link between the region's primary producers and apex predators (Ross, Quetin, and Lascara 1996). The most prominent and important of the marine invertebrates is the shrimp-like crustacean, the Antarctic krill (*Euphausia superba*). Estimated at 5 billion tons, krill comprise from 75 to 90 percent of the marine invertebrate biomass in the Peninsula area (Ross, Quetin, and Lascara 1996 and Schnack-Schiel and Mujica 1994). Several species of copepods and

[17] Antarctic pelagic fishes are descendants of several faunal groups of different origins: bathypelagic species, mesopelagic species and species originating from coastal fish families that have secondarily adapted to temporary or permanent life in midwater (Kock 1992).

[18] Artedidraconidae, Bathydraconidae, Channichthyidae and Nototheniidae species.

salps may make up as much as 24 percent of the zooplankton biomass in this area (Ross, Quetin, and Lascara 1996). Salps are ecologically important as phytoplankton predators[19] and in the rapid transport of carbon from the sea surface to the deep sea (Chiba, Hosie, and Belbin 1999). *Salpa thompsoni* and *Ihlea racovitzai* are common in Antarctic waters with the former abundant in ice-free areas and the latter distributed exclusively in high-latitude ice edge areas. It may be that in a year when Antarctic krill are less abundant, *S. thompsoni* is abundant, and vice versa, possibly attributable to yearly variations in the extent of the sea ice; salps are dominant in years of poor ice extent while krill are dominant in other years (Chiba, Hosie, and Belbin 1999).

The prominent benthic invertebrates include crustaceans, mollusks, polychaetes, porifera, bryozoa, and echinoderms (Clarke 1996). The marine benthic diversity in the Southern Ocean as compared to the estimated number of such species world-wide is illustrated in Table 2.2. The abundant and varied bottom life in coastal areas includes starfish, urchins and shellfish.

Table 2.2. Marine Benthic Diversity in the Southern Ocean

Taxon	Estimated Number of Southern Ocean Species	Estimated Number of World Species
Porifera	>300	6,000
Cnidaria	101	?
Brachiopoda	16	335
Bryozoa	>350	5,000
Priapulida	3	9
Mollusca	~870	130,000
Sipunculida	~15	320
Polychaeta	562	12,000
Pycnogonida	>150	1,000
Crustacea	970	29,820
Echinodermata	346	6,700
Tunicata	130	3,000

Source: Clarke 1996

In Antarctica, animal life on land is found in coastal areas. In contrast, sea life abounds with animals including seals, penguins and flying birds that come ashore only to breed. With the exception of a couple of shore and wading birds and the terrestrial invertebrates, animals are entirely dependent on the sea (Beltramino 1993).

Native terrestrial invertebrates are limited to arthropods including insects (2 species) and mites (150 species). Springtails, midges and mites generally live along the coast among plant

[19] With high filtration rates, a salp swarm can harvest a large portion of the phytoplankton of an area, sometimes to the exclusion of other herbivores such as zooplankton.

colonies. A mite, the southernmost known animal, has been found 500 km (310 mi.) from the South Pole (External Panel 1997). There are no terrestrial invertebrates designated as native to Antarctica, nor are there any designated as Specially Protected Species (45 CFR 670).

Mammals designated as native to Antarctica include seals, whales, dolphins and porpoises and are listed in Table 2.3. In the waters of the Antarctic Treaty area, these mammals are addressed under the Convention for the Conservation of Antarctic Marine Living Resources under the Antarctic Treaty System[20] (Chapter 5).

Table 2.3. Native Mammals of Antarctica	
Pinnipeds:	
Crabeater seal	*Lobodon carcinophagus*
Southern elephant seal	*Mirounga leonina*
Southern fur seals	*Arctocephalus, spp.*
Leopard seal	*Hydrurga leptonyx*
Ross seal	*Ommatophoca rossii*
Weddell seal	*Leptonychotes weddelli*
Large Cetaceans (Whales):	
Blue whale	*Balaenoptera musculus*
Pygmy blue whale	*B. musculus brevicauda*
Fin whale	*Balaenoptera physalus*
Humpback whale	*Megaptera novaeangliae*
Minke whale	*Balaenoptera acutrostrata*
Sei whale	*Balaenoptera borealis*
Southern right whale	*Balaena glacialis australis*
Sperm whale	*Physeter macrocephalus*
Small Cetaceans (Dolphins and porpoises):	
Arnoux's beaked whale	*Berardius arnuxii*
Commerson's dolphin	*Cephalorhynchus commersonii*
Dusky dolphin	*Lagenorhynchus obscurus*
Hourglass dolphin	*Lagenorhynchus cruciger*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melaena*

[20] The Antarctic Treaty was signed in Washington, D.C. on December 1, 1959. The Convention for the Conservation of Antarctic Marine Living Resources was concluded in 1980. Whaling is regulated under the International Convention for the Regulation of Whaling through the International Whaling Commission.

Table 2.3. Native Mammals of Antarctica	
Southern right whale dolphin	*Lissodelphis peronii*
Southern bottlenose whale	*Hyperoodon planifrons*
Spectacled porpoise	*Phocoena dioptrica*

Source: 45 CFR 670

The six species of seals represent nearly half of the 19 known genera of the world's pinniped types (Laws 1984). The Southern Ocean is estimated to contain 50 percent of the world's seal population and 80 percent of the world's seal biomass, with the crabeater estimated to account for 56 percent of the world's pinniped stock and, because of its size, nearly 79 percent of the world's total pinniped biomass (Laws 1984). Two seal species, the Kerguelen fur seal (*Arctocephalus tropicales gazella*) and the Ross seal (*Ommatophoca rossii*), are designated as Specially Protected Species (45 CFR 670). The estimated abundance and status of the Antarctic seal populations are summarized in Table 2.4.

Table 2.4. Abundance Estimates for Antarctic Seal Populations		
Species	**Population Since 1982**	**Status**
Crabeater	15,000,000-30,000,000	Increasing
Southern elephant	750,000	Stable, some decreasing
Antarctic fur	1,500,000	Increasing
Leopard	220,000-440,000	Increasing
Ross	220,000	Not Known
Weddell	800,000	Stable, some decreasing
Total	18,490,000-33,710,000	

Source: Laws 1984 and Boyd and Roberts 1993

Climate, breeding substrate (ice floes or land), and food availability influence the distribution of Antarctic seals (Costa and Crocker 1996 and Croxall 1992). Ice breeders include the crabeater, leopard, Weddell and Ross seals. Land breeders include the Antarctic fur and the Southern elephant seals, both with breeding habitat in the Peninsula area. Figure 2.13 shows the timing of breeding activities for the Antarctic fur, Southern elephant and Weddell seals; the timing of tourism in the Peninsula area is also depicted. Seals in the Peninsula area at the eleven sites with 10,000 or more visitors during the 8-year period 1989-1997 include: crabeater, Southern Elephant, Antarctic Fur, and Weddell seals on land; and leopard seals in the ocean (Naveen 1997).

Eight species of large cetaceans (whales) and 9 species of small cetaceans (dolphins and porpoises) have been documented within the Southern Ocean and are designated as native mammals; none is designated as Specially Protected Species (45 CFR 670 and Brown and Lockyer 1984). Traveling alone or in small pods, none of the cetaceans documented within the Southern Ocean is exclusive to the Antarctic region, and their populations are widely distributed throughout the Southern Ocean.

Birds designated as native to Antarctica are listed in Table 2.5; none is designated as Specially Protected Species (45 CFR 670).[21]

Table 2.5. Designated Native Birds of Antarctica Under 45 CFR Part 670	
Non-flying Birds	
Penguin:	
Adelie	*Pygoscelis adeliae*
Chinstrap	*Pygoscelis antarctica*
Emperor	*Aptenodytes forsteri*
Gentoo	*Pygoscelis papua*
King	*Aptenodytes patagonicus*
Macaroni	*Eudyptes chrysolophus*
Rockhopper	*Eudyptes crestatus*
Flying Birds	
Albatross:	
Black-browed	*Diomedea melanophris*
Gray-headed	*Diomedea chrysostoma*
Light-mantled sooty	*Phoebetria palpebrata*
Wandering	*Diomedea exulans*
Fulmar:	
Northern Giant	*Macronectes halli*
Southern	*Fulmarus glacialoides*
Southern Giant	*Macronectes giganteus*
Gull:	
Southern Black-backed	*Larus dominicanus*
Jaeger:	
Parasitic	*Stercorarius parasiticus*
Pomarine	*Stercorarius pomarius*
Petrel:	
Antarctic	*Thalassoica antarctica*
Black-bellied Storm	*Fregatta tropica*

[21] In order to preserve and protect the native mammals, birds, plants, and invertebrates of Antarctica and the ecosystems upon which they depend and to implement the Antarctic Conservation Act of 1978, as amended by the Act, the National Science Foundation has listed "designated native birds;" these regulations also designate specially protected species of native mammals, birds and plants (45 CFR 670).

Table 2.5. Designated Native Birds of Antarctica Under 45 CFR Part 670	
Blue	*Halobaena caerulea*
Gray	*Procellaria cinerea*
Great-winged	*Pterodroma macroptera*
Kerguelen	*Pterodroma brevirostris*
Kerguelen	*Pterodroma macroptera*
Mottled	*Pterodroma inexpectata*
Snow	*Pagodroma nivea*
Soft-plumed	*Pterodroma mollis*
South-Georgia Diving	*Pelecanoides georgicus*
White-bellied Storm	*Fregetta grallaria*
White-chinned	*Procellaria aequinoctialis*
White-headed	*Pterodroma lessonia*
Wilson's Storm	*Oceanites oceanicus*
Pigeon:	
Cape	*Daption capense*
Pintail:	
South American Yellow-billed	*Anas georgica spinicauda*
Prion:	
Antarctic	*Pachyptila desolata*
Narrow-billed	*Pachyptila belcheri*
Shag:	
Blue-eyed	*Phalacrocorax atriceps*
Shearwater:	
Sooty	*Puffinus griseus*
Sheathbill:	
American	*Chionis alba*
Skua:	
Brown	*Catharacta lonnbergi*
South Polar	*Catharacta maccormicki*
Swallow:	
Barn	*Hirundo rustica*
Tern:	
Antarctic	*Sterna vittata*
Arctic	*Sterna paradisaea*

Source: 45 CFR 670

The population of birds in the Antarctic is estimated to be 350 million, of which about half are penguins. The total weight of birds is estimated in excess of 400,000 tons, greater than the combined weight of Antarctic seals and whales (External Panel 1997).

Antarctic penguins have evolved in relative isolation adapting to their environment in the absence of land-based predators. All Antarctic penguins are exceptional thermoregulators and are able to maintain constant body temperature even under the widely variable environmental conditions of Antarctica. Several species withstand prolonged periods of fasting on land during incubation and molting during which they deplete their metabolic reserves (Williams 1995).

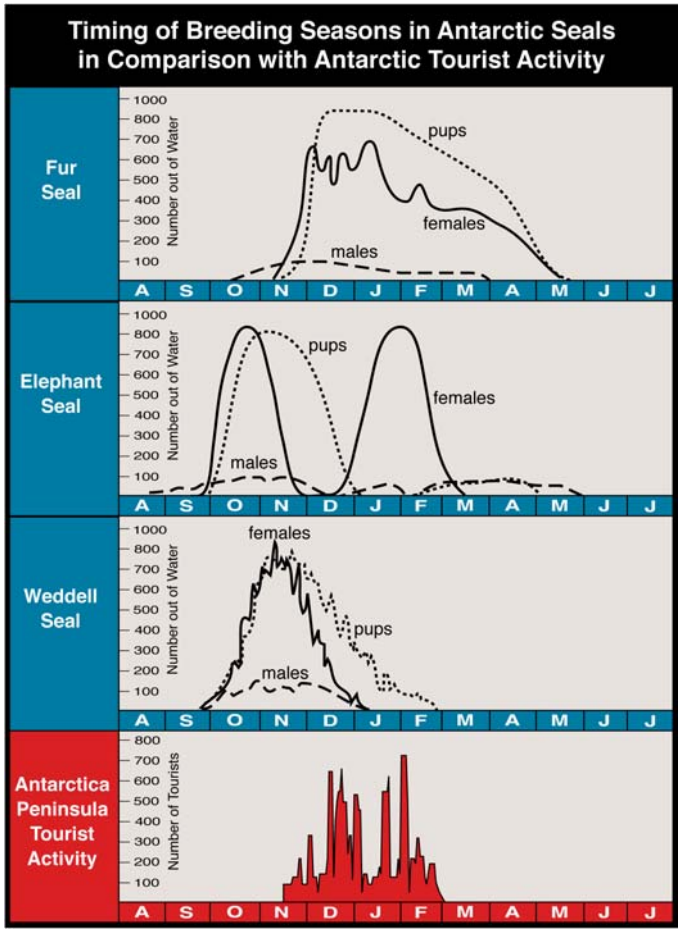

Figure 2.13.

Source: Croxall 1984, IAATO IEE 1998, and Orient Lines IEE 1998

Penguins are restricted to habitat areas with the characteristics necessary for their reproductive activities; however, these factors vary among species. Habitat requirements include adequate food and nesting resources. All penguins eat krill, and different species use the land or the ice for breeding habitat thus minimizing niche overlap and maximizing available habitat. Some species congregate in large groups to breed, while others breed in relative isolation (Williams 1995). Reproductive success is further maximized by timing of breeding activities to coincide with the few months of summer's relatively milder conditions. The exception to this is the Emperor penguin which breeds on the fast ice along the continent during the winter.

Three species of brush-tailed penguins (*Pygoscelis*), the Adelie, chinstrap and gentoo, commonly nest in the Peninsula area and on the surrounding islands (Woehler 1993). A small colony of macaroni penguins (*Eudyptes*) is regularly encountered at Hannah Point on the South Shetland Islands west of the Antarctic Peninsula (Naveen 1997); however, most macaronis live and breed north of 60° south latitude outside the Antarctic Treaty area. Closely related, all three brush-tailed penguins are medium-sized and feed primarily on krill. Adelies nest farther south than any other living bird including the Antarctic petrel and the Emperor penguin (Croxall 1985). The

Peninsula represents the northernmost extension of its normal breeding habitat, while a rookery at Cape Royds on Ross Island near the Ross Ice Shelf is nearly 1,500 km (932 mi.) south of the Antarctic Circle. The larger gentoos range around the peripheries of Antarctica mostly on islands near the Antarctic Convergence extending only to the northern tip of the Peninsula. The Peninsula is the primary habitat only for the smaller chinstrap penguins. Table 2.6 lists the estimated abundance and status of the three common Peninsula area penguin species. Figure 2.14 shows the timing of penguin breeding activities; the timing of tourism in the Peninsula area is also depicted.

Table 2.6. Abundance Estimates and Status of the Three Common Peninsula Area Penguins (1)

Species	Population Size (breeding adults)	Status (3)
Adelie	5,220,000 (2)	Stable/increasing
Chinstrap	14,980,400 (3)	Stable/increasing
Gentoo	628,000 (4)	Stable/increasing

(1) Estimates include both Antarctic and sub-Antarctic areas.
(2) Croxall 1985
(3) Woehler 1993
(4) Williams 1995

Four of the seven native penguin species were found nesting in the Peninsula area at one or more of the eleven sites with 10,000 or more visitors during the 8-year period 1989-1997. Those typically breeding at these eleven locations include: gentoo (6 sites), chinstrap (4 sites), and Adelie (3 sites). Macaroni penguins typically breed further north, but also breed at one of these eleven sites (Naveen 1997 and Naveen et al 2000).

The movements of the flying seabirds are highly dependent on the availability and distribution of food, as well as physical factors such as temperature, ice cover, and climate (Knox 1994). The winter distribution of Antarctic seabirds is less well known than their

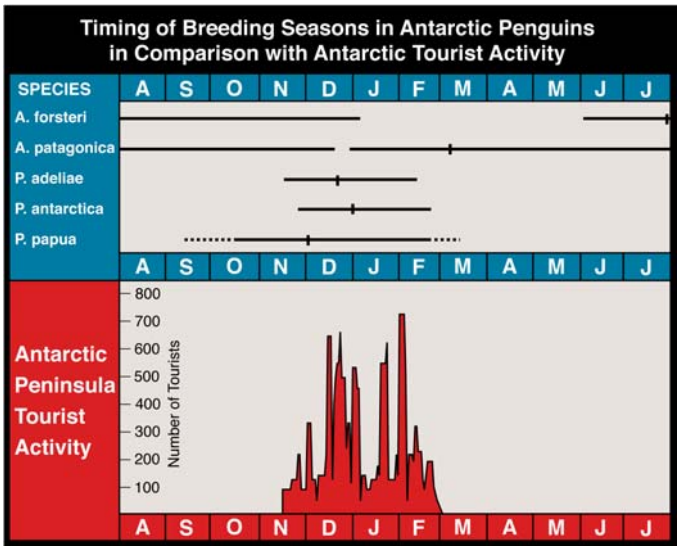

Figure 2.14.

Source: Croxall 1984, IAATO IEE 1998, and Orient Lines IEE 1998

summer distribution. Each winter, all flying seabird species, except the Antarctic tern and Antarctic petrel, migrate to more northern latitudes.

Most of the flying seabirds are pelagic foragers, avoiding land except to breed. Skuas, gulls, petrels and sheathbills are also scavengers opportunistically feeding on penguin, seal, whale and seabird carrion (Croxall 1984). The most prevalent predators are the skuas while petrels are the leading scavenger (Naveen, Monteath, and DeRoy 1990).

The breeding biology of flying seabirds is similar to that of Antarctic penguins with the reproductive season corresponding to the summer. Figure 2.15 shows the timing of flying seabird breeding activities; the timing of tourism in the Peninsula area is also depicted. Several of the flying seabird species use previous nesting sites returning to rebuild these rather than creating new sites (Knox 1994). Several of the smaller bodied species burrow in the ground, building nests between rocks, in soft mud, or in other areas difficult to access. Breeding colonies are scattered, and annual migrations carry most flying bird species far away from the continent during winter months (Knox 1994).

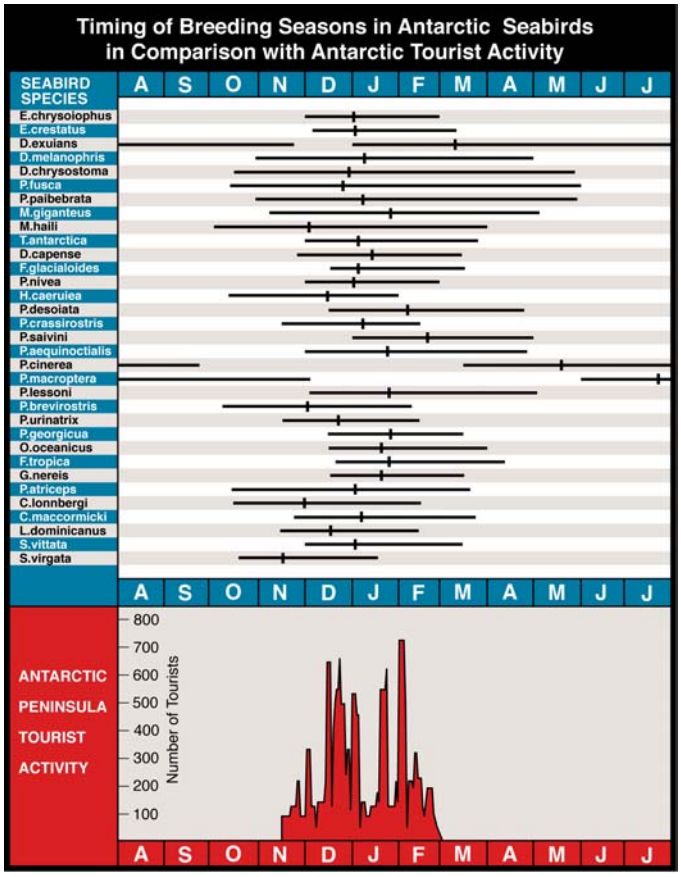

Figure 2.15.

Adapted from: Croxall (1984), IAATO IEE 1998, and Orient Lines IEE 1998

Ten flying seabirds were found nesting in the Peninsula area at ten of the eleven sites with 10,000 or more visitors during the 8-year period 1989-1997. These include six of the flying birds designated as native to Antarctica as shown in Table 2.7.

A recent report on the census of penguins, blue-eyed shag and southern giant petrel populations in the Peninsula area indicates that breeding chronologies vary from site to site, north to south through the area. The peaks in egg-laying and chick creching are not the same throughout the Peninsula area, and there may be seasonal variations in breeding chronologies expected at each particular site (Naveen et al 2000 and Naveen 2001).

Table 2.7. Flying Seabirds Nesting at Peninsula Area Sites with 10,000 or More Visitors, 1989-1997.	
Species	**Designated Native Birds**
Gulls:	
Kelp	No
Petrel:	
Snow	Yes
Southern Giant	No
Pintado	No
Wilson's Storm	Yes
Shag:	
Blue-eyed	Yes
Sheathbill:	
Snowy	No
Skua:	
Brown	Yes
South Polar	Yes
Tern:	
Antarctic	Yes

Source: Naveen 1997 and 45 CFR 670

2.5. Antarctic Areas Visited by Tourists

Because of its proximity to South America, the relatively moderate summer climate, the area's physical features, and the richness of the fauna and flora, nearly all U.S. nongovernmental expeditions[22] occur in the Antarctic Peninsula area.[23] Appendix 3 lists the 143 sites visited in the Peninsula area from 1989 through 1997, as reported by the tour operators to the Antarctic Treaty Consultative Meeting and the National Science Foundation, and as summarized by Naveen (1997).

[22] For purposes of this EIS, the definition of *expedition* for U.S.-based operators is taken from 40 CFR Part 8.3 and means any activity undertaken by one or more nongovernmental persons organized within or proceeding from the United States to or within the Antarctic Treaty area for which advance notification is required under Paragraph 5 of Article VII of the Treaty.

[23] There is at least one U.S. ship-based tour operator with expeditions to the Ross Sea area. As discussed in Chapter 3, the relative numbers of landings and visitors in the Ross Sea area are fewer than those in the Peninsula area.

Appendix 3 includes the site location, region[24], and for the 8-year period 1989-1997, the number of landings and the total passengers for each site (Naveen 1997).

Eleven of the 143 sites were visited by over 10,000 passengers during the period from 1989-1997, with an 8-year total of 195,096 visitors and 2,193 landings for these eleven sites. The annual average number of landings and visitors at these eleven sites ranged from 18 landings with 1,578 passengers per year in the vicinity of Poland's Arctowski Station on King George Island, to 37 landings with 3,069 passengers per year at Whalers Bay, Deception Island. Tourism in the Peninsula area is discussed further in Chapter 3.

Naveen's description of the physical characteristics of the eleven most visited sites is presented in Appendix 4. These site descriptions include listing of any stations, historical artifacts, and Specially Protected Areas.[25] Appendix 5 identifies the Specially Protected Areas and historic monuments.

Within the Peninsula area, the South Shetland Islands and the NW Peninsula area are the most heavily visited by ship-based tours. Of the eleven sites with 10,000 or more visitors for the 8-year period 1989 through 1997, nine of these sites are in the South Shetland Islands and NW Peninsula area, and of the 31 sites with 1,000 to 9,999 visitors during this same 8-year period, 21 of these were in the South Shetland Islands and NW Peninsula area. These figures comprise 74% of the landings and 74% the passenger visits of the total landings and passenger visits to sites in the Peninsula area for this 8-year period.

For the eleven sites with 10,000 or more visitors, Table 2.8 lists those sites where science stations, Sites of Special Scientific Interest and historic monuments are located.

[24] The Antarctic Site Inventory, compiled by Oceanites, Inc., divides the Peninsula area into five regions: (1) South Orkney Islands including Laurie, Coronation and Signy Islands, and Elephant Island including nearby islands; (2) Northeast Antarctic Peninsula from Cape Dubouzet (63°16'S 64°00'W) to James Ross Island; (3) South Shetland Islands including Deception, Low and Smith Islands; (4) Northwest Antarctic Peninsula from Cape Dubouzet (63°16'S 64°00'W) to the north end of the Lemaire Channel; and (5) Southwest Antarctic Peninsula from the north end of the Lemaire Channel to the northern part of Marguerite Bay (68°18'S 67°11'W).

[25] When Annex V of the Protocol enters into force, Specially Protected Areas, Sites of Special Scientific Interest, and some historic sites will be combined into a single category of protected area, Antarctic Specially Protected Areas (ASPAs). An additional category, Antarctic Specially Managed Areas (ASMAs), will also be created for areas where activities pose risks of mutual interference or cumulative environmental impacts and sites of recognized historic value that do not require strictly controlled access. Entry into an ASPA will require a permit, while entry into ASMAs will not.

In 1998, legislation implementing the Environmental Protocol combined areas previously designated as Specially Protected Areas and Sites of Special Scientific Interest into a single category of Antarctic Specially Protected Areas (ASPAs). These are defined as an area designated by the Antarctic Treaty Parties to protect outstanding environmental, scientific, historic, aesthetic, or wilderness values or to protect ongoing or planned scientific research (45 CFR 670).

Table 2.8. Antarctic Peninsula Area Sites with 10,000 or More Visitors: Locations with Scientific Stations, Historic Monuments, and Sites of Special Scientific Interest (SSSIs)

Rank	Site	Country/ Station	Historic Monuments	SSSIs
1	Whalers Bay, Deception Island		HSM 31, 58	SSSI 21-E
2	Half Moon Island	Argentina/ Camara Station		
3	Port Lockroy, Wiencke Island		HSM 61	
5	Pendulum Cove, Deception Island	Chile-closed		SSSI 21-D
7	Petermann Island	Argentina-closed	HSM 27	
8	Almirante Brown St., Paradise Bay	Argentina/ Almirante Brown-closed		
9	Waterboat Point, Paradise Bay	Chile/ Gonzales Videla	HSM 30, 56	
10	Paulet Island		HSM 41	
11	Arctowski Station, King George Island	Poland/ Arctowski Station	HSM 51	SSSI 8

Source: Naveen 1997

Ship-based tour expeditions to McMurdo Sound in the Ross Sea area provide an opportunity to visit science stations and historic huts. There are fewer large animals in this area due to the lower temperatures, limited coastline and the influence of nutrient-poor waters flowing from beneath the Ross Ice Shelf. Helicopter excursions to the Dry Valleys are also included in the itinerary of U.S. ship-based tour operators operating aboard the *Kapitan Khlebnikov* (Quark, Zegrahm, Aurora IEE 1997, Quark, Zegrahm, Aurora IEE1998, Quark, Zegrahm, Aurora IEE 1999, and Quark IEE 2000).

The Dry Valleys are a unique feature of East Antarctica covering an area of 15,400 square kilometers (5,946 square miles) on the edge of the Ross Ice Shelf at McMurdo Sound (Figure 2.16). The region includes about 3,800 square kilometers (1,467 square miles) of bare ground kept ice-free by winds that blow away the snow and keep precipitation out of the Valleys. The average annual temperature is -20ºC (-4 ºF), and the average precipitation, which occurs as snow, is less than 10 cm (3.9 in.) of water equivalent per year. Glacial melt forms a single 29 km (18 mi) long river for one or two months each year. The Dry Valleys include three parallel valleys: Victoria, Wright, and Taylor. Several large lakes have formed within these Valleys along with a number of ponds. The lakes and ponds, formed by groundwater seepage and glacial melt, vary in temperature and salt content. Although their surfaces remain frozen, one lake was measured as 25ºC (77 ºF) at its bottom, and one pond, far saltier than the Great Salt Lake, does not freeze all winter even at temperatures of -50ºC (-58 ºF) (Parfit 1998). Life forms include microscopic communities of algae, fungi and bacteria living within the minute gaps in the rocks,[26] and algae at the bottom of the lakes.

[26] The cryptoendolithic environment of certain granular rocks, an atypical habitat only recently discovered, provides habitat for bacteria, fungi, algae and lichens in the Dry Valleys. Widely fluctuating temperatures and moisture derived from melting snow penetrates slightly porous rock where a typically zoned community of cyanobacteria (lower layer), green algae (middle layer) and fungal hyphae (upper layer) exists under the surface of

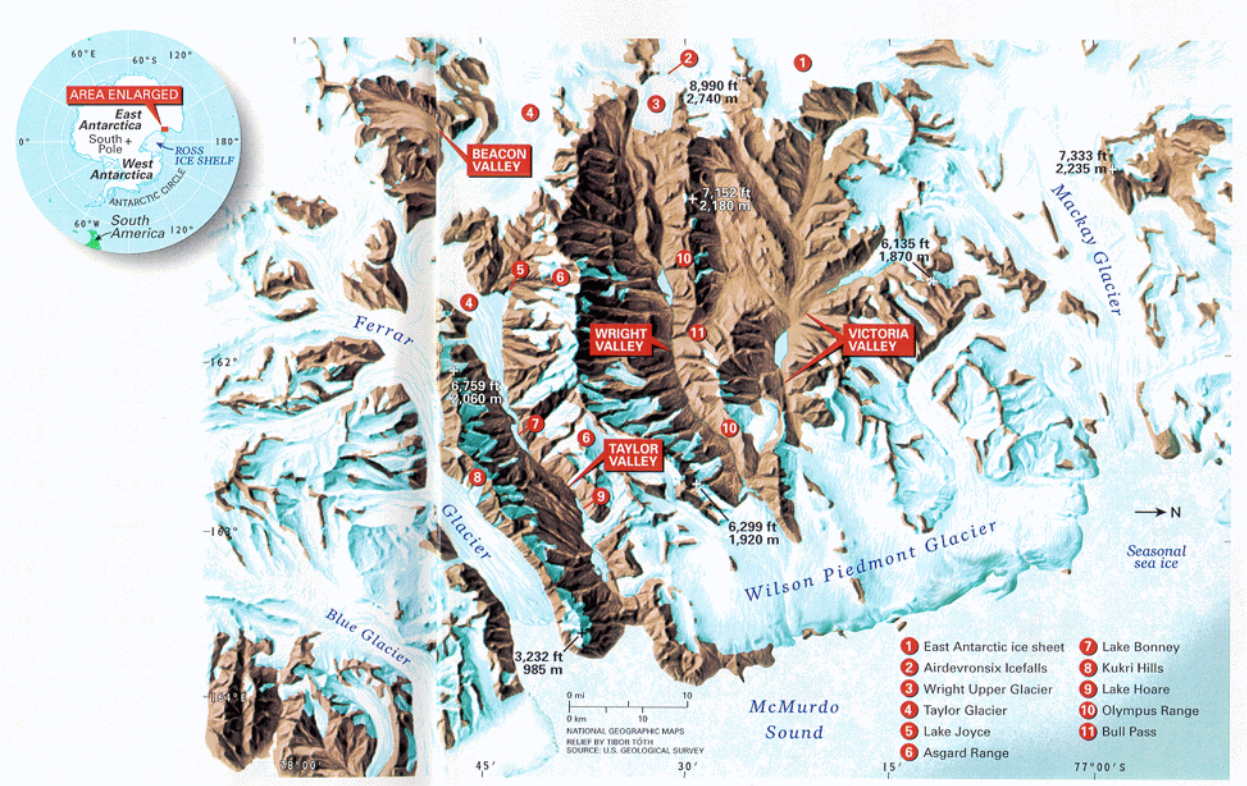

Figure 2.16. Antarctica's Dry Valleys

Source: Parfit (National Geographic, No. 4, Oct. 1998)

2.6. Summary of the Physical and Biological Environment

Antarctica is the coldest, driest, windiest, highest, and most isolated continent on Earth, unique in its physical and biological characteristics. Millions of square miles of sea ice surround Antarctica, with an annual five-fold increase and decrease. With the overwhelming presence of ice on land, vegetation is modest and not significantly visible in the landscape, restricted to the ice-free regions in the coastal areas, on islands, and among the isolated inland peaks. Sea life abounds with animals including seals, penguins and flying birds that come ashore only to breed, with most animals entirely dependent on the sea. The Antarctic Peninsula, the northern-most extension of the continent, and the surrounding islands support the continent's greatest diversity of native flora and fauna.

translucent (generally quartz) coarse-grained rock. These lichens are often the only form of macroscopic vegetation present and are revealed only when the rock surface exfoliates (Smith 1993).