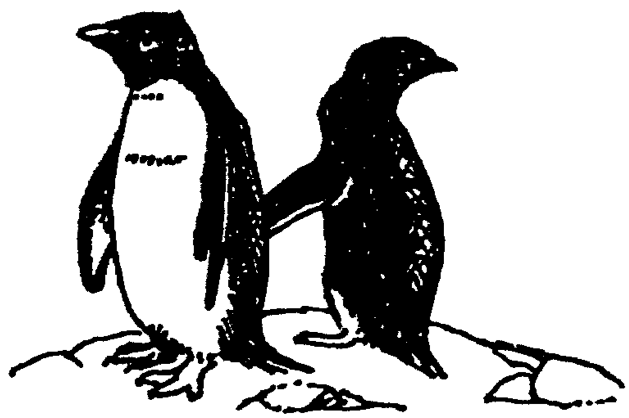
THE

ANTARCTICA

PRIMER



Written and illustrated by
Tom Ritchie

© 2002, 1990

Presented by:

LINDBLAD EXPEDITIONS
720 Fifth Avenue
New York, NY 10019
Tel: (800)762-0003, (212)765-7740
Fax: (212)265-3770
<www.expeditions.com>

Member of IAATO

CONTENTS

THE SOUTHERN CONTINENT

Antarctica is the fifth largest continent with an area of roughly 14 million sq km (5.3 million sq mi). Most of this area, however, is made up by a vast permanent ice sheet averaging 2,000 m (6,600 ft) in thickness. The actual landmass of Antarctica is only about seven million sq km (2.7 million sq mi) in area and includes an archipelago of island mountains. Only about one fortieth of its land is visible, as mountains and coastlines.

Antarctica is the coldest continent. Mean temperatures in the interior during the coldest month (August) range of -40° to -70° C (-40° to -94° F) and in the warmest month (February) range from -15° to -45° C (5° to -49° F). The lowest environmental temperature ever recorded on Earth was -89.6° C (-129.3° F) noted at the Soviet base "Vostok" on the inland ice cap.

Antarctica is also the windiest of the continents. Apart from global wind currents, Antarctica actually creates its own wind systems. Cold dense air essentially slides from the high interior ice fields towards the lower areas along the coasts. At the edges of the ice plateau the winds accelerate, thereby lifting and blowing clouds of snow high into the air. The strongest winds are habitually found on the long coastal slopes of Greater Antarctica. Some coastal areas endure almost constant strong winds, whereas other areas may be quite calm much of the time and then suddenly experience hurricane force winds as air rushes down through glacial valleys. These sudden and unexpected winds are called katabatic, or down slope, winds. The famous Australian explorer Douglas Mawson established a base at Cape Denison in 1912, and recorded wind speeds for two years. This is reputed to be the windiest place on Earth, because the average wind speed during that time period was 72 kph (45 mph), and gusts of more than 240 kph (150 mph) were common.

Surprisingly, Antarctica is also the driest continent. By definition, most of the continent is a desert. There is very little precipitation each year in the interior, and the vast amount of ice and snow that make up the polar ice cap has accumulated over millions of years. The mean annual accumulation for the entire continent amounts to less than 5 cm (2 in) of water equivalent, which is just slightly more than what the Sahara Desert receives. Some coastal areas, particularly the west side of the Antarctic Peninsula, receive much more precipitation (the tip of the peninsula receives about 90 cm, or 35 in, of water equivalent each year).

The continent is shaped somewhat like a giant stingray. The semi-circular main body part is called Greater Antarctica, and much of its edge lies conveniently along the Antarctic Circle (66° 33' S) in the Atlantic, Indian, and western Pacific Oceans sectors. The curved tail, which is made up of an expanded land mass at its base known as Lesser Antarctica and a long narrow part named the Antarctica Peninsula, extends some 1,200 km (744 mi) towards the southern tip of South America and is located in the eastern Pacific Ocean sector.

Greater Antarctica is mostly ice mantle, but in some coastal areas jagged mountains project through the ice. The Antarctic Peninsula, on the other hand, is a long chain of alpine mountains, topped by an ice plateau and carved by many active glaciers. Most of the coastline is actually ice cliffs, but there are some areas, particularly in the Pacific Ocean sector, where one encounters rocky, exposed shorelines. These ice-free shorelines, such as along the western side of the Antarctic Peninsula and within its island archipelago, and the Ross Sea area, are the places that are most accessible and are, therefore, of most interest to us.

Taking the ice cap into account, Antarctica is also the highest continent. The highest point is the peak of Vinson Massif (elevation: 5,140 m, or 16,960 ft) in the Sentinel Range of Lesser Antarctica. There are many mountains over 3,000 m (9,900 ft) high, but most are smothered by ice. The ice dome covering most of Greater Antarctica reaches a height of 4,200 m (13,860 ft), while the ice plateau of Lesser Antarctica has an average height of about 2,000 m (6,600 ft). The Transantarctic Mountain range is exposed for nearly 2,000 km (1,240 mi) along the coast of Victoria Land in Greater Antarctica where it holds back the huge ice dome. Glaciers squeeze through this range and eventually merge into the Ross Ice Shelf. The Transantarctic Mountains are covered over with ice near the South Pole, but are exposed at the other end of the range where they are known as the Pensacola Mountains in Coats Land on the opposite side of the continent. There is another mountain range in Greater Antarctica which is 1,300 km (800 mi) long and 3,000 m (9,900 ft) high, but it is completely obliterated by the ice dome. There are other enormous ranges along the coastal areas of the Atlantic and Indian oceans sectors that only appear as isolated peaks and rock cliffs in the ice.

Between these vast ranges of mountains are extensive, low-lying plains and basins, which are covered over by some of the thickest ice on the continent. In fact, the South Pole is located 2,800 m (9,240 ft) above sea level on top of a layer of ice of about that same thickness (the underlying bedrock is almost at sea level). There are other areas of Greater Antarctica where the bedrock is well below sea level, but is covered with ice more than 4,000 m (13,200 ft) thick.

Greater Antarctica is basically a giant shield of metamorphic rock dating from Precambrian and early Paleozoic times more than 500 million years ago. This base rock contains more recent intrusions and is covered over by sediments, except for some areas in Droning Maud Land and the coastal mountains in the Indian Ocean sector, where it is now exposed. The younger sedimentary rock, or Beacon Series, was formed from marine muds, estuarine and fresh water deposits, shales, coal measures, and desert sandstones dating from late Paleozoic to middle Mesozoic times (400 to 200 million years ago). The Beacon Series is about 2,500 m (8,250 ft) thick, and is best seen in the Transantarctic Mountains which were uplifted within the last 35 million years. One can see within this sandstone numerous inter-layers of dark dolerite which were injected long after the sandstone was formed.

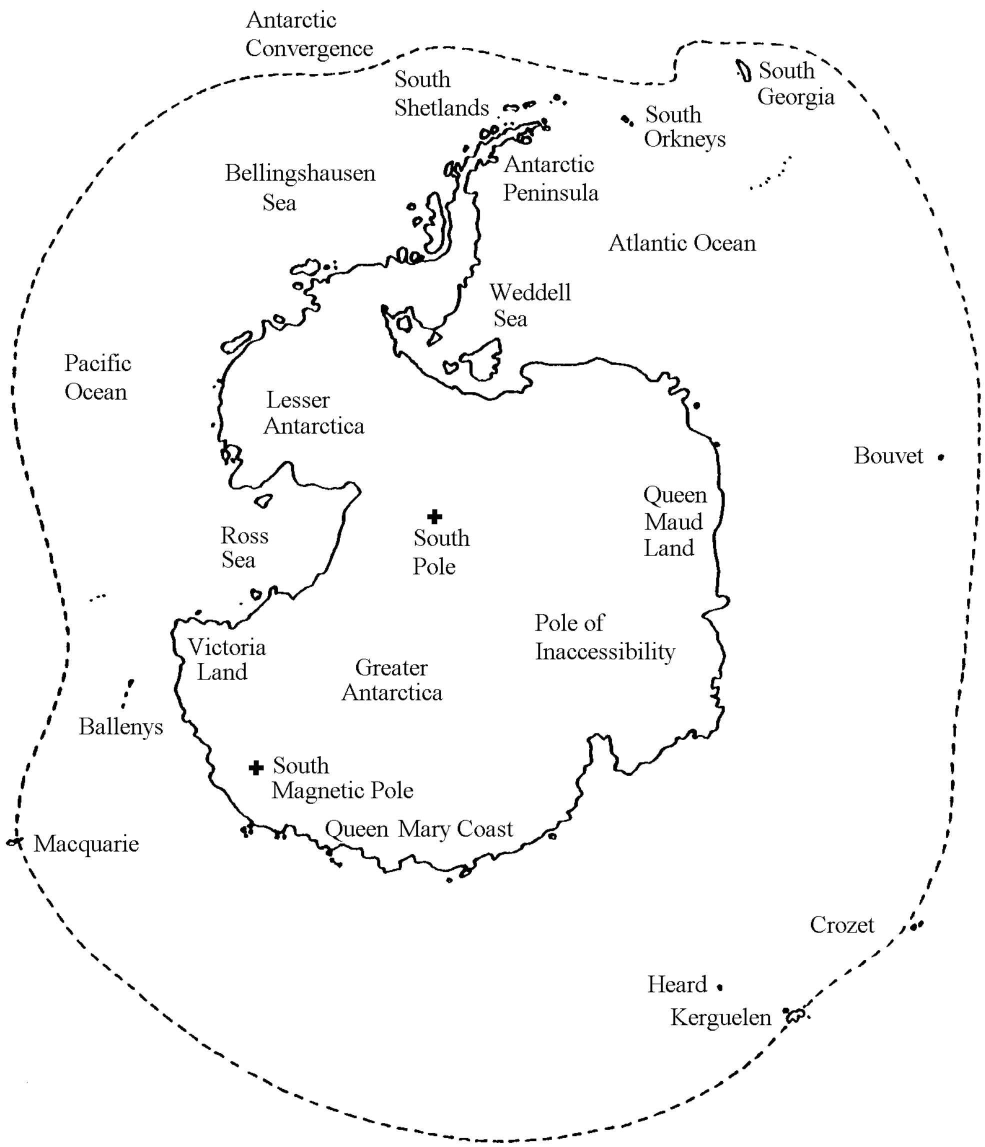


FIGURE 1. The Antarctic environment includes all the area south of the Antarctic Convergence.

Lesser Antarctica and the Antarctic Peninsula together consist primarily of two separate mountain ranges made up of metamorphosed sedimentary rocks that were formed in deep sea and contain beds of volcanic ash and lava intrusions. The alpine mountain range forms the Antarctic Peninsula and extends from the peninsular tip to Lesser Antarctica, but disappears under the ice of Ellsworth Land and Byrd Land where it becomes much more widespread. Many of the mountains in this range extend above the ice and form the isolated peaks and outcrops that are seen today in Lesser Antarctica. A second line of mountains runs along the northwestern coast of the peninsula that forms Adelaide Island, the Biscoe Islands, the Palmer Archipelago, and the South Shetland Islands. There is also a long continuous series of stresses in the sea floor linking the South Shetland Islands with the South Orkney Islands, the South Sandwich Islands, South Georgia Island, and the South American continental shelf. This chain of islands and the connected sea floor ridges are referred to as the Scotia Arc, which has a long history of volcanic activity and Earth movements.

The mountains of Lesser Antarctica display a tremendous amount of deposition, folds, uplifts, and erosion starting in Precambrian times. During the late Cretaceous or early Tertiary (70 to 60 million years ago) violent upheavals and volcanic activity lifted both the archipelago and the islands of the Scotia Arc. This heavy volcanic activity continued until about 35 to 40 million years ago. Several islands in the South Shetland and South Sandwich Groups are volcanically active even today, and much of Lesser Antarctica still commonly experiences Earthquakes. Greater Antarctica is more stable, but it does have two very confined areas of volcanic activity (Mount Erebus on Ross Island and Mount Melbourne in Victoria Land).

THE SOUTHERN OCEAN

The Southern Ocean consists of a broad band of generally turbulent water ringing the southern hemisphere between 40° S latitude and the continent of Antarctica. Westerly gales and strong surface currents act upon ships and force them in an easterly direction as they cross the roaring 40's and the Furious 50's. As we sail for Antarctica from South America or New Zealand our ship must, therefore, head in a south-southwesterly direction to counteract the effects of the winds and currents.

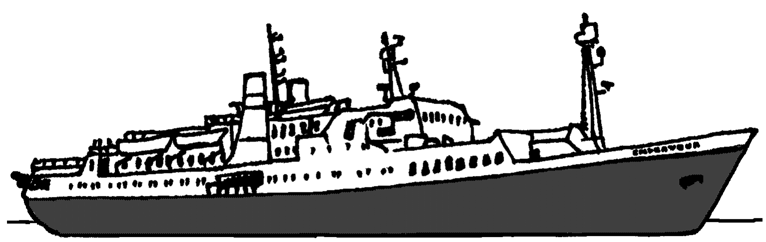


FIGURE 2. Lindblad Expedition's Antarctic vessel *M.S. ENDEAVOUR.*

As a ship sails southwards it will encounter a sharp drop in temperature somewhere between 49° and 55° S latitude. At that point one can usually detect subtle changes in both the ocean and the atmosphere. If the weather is calm there may be a sudden fog bank, a line of turbulence, and/or concentrations of feeding sea birds. This delineates the Antarctic Convergence, which completely surrounds the continent. During the time of year we visit these waters, throughout the southern summer, the sea temperature may drop from 6° C to 3° C (43° F to 37° F) at the convergence. During winter months the differences in sea temperatures may be as great as 10° C (18° F). The Antarctic Convergence is a natural boundary between the relatively warm Sub-Antarctic Surface Water and the cold Antarctic Surface Water. The convergence is easily detected by a drop in sea temperature, and can usually be detected visually in the Atlantic Ocean sector (but less so in the Pacific Ocean sector). The location of the convergence varies only slightly throughout the year, or from year to year, or even century to century. The water south of the convergence is often referred to as the Antarctic Ocean.

The Antarctic waters run deep. As our ship approaches the Antarctic continent we must cross water that is more than 3,000 m (9,900 ft) deep. The deepest trough in this area, located east of the Scotia Arc, is 8,000 m (26,400 ft) deep. The Antarctic Ocean is especially interesting because it is made up of three distinct layers of water masses which differ in their temperatures, salinities, and directions of flow. The three sandwiched layers move in constant eastwardly spirals around Antarctica because of the west winds. The upper and lower layers also move gradually northwards carrying cold waters from the Antarctic to the tropics, while the middle layer flows southwards (replacing the water lost to the other two currents) and brings nutrients and warmer water from temperate and tropical regions in the north.

The top layer, or Antarctic Surface Water, varies from 70 to 200 m (230 to 660 ft) in depth and is the water which most directly affects Antarctic plants and animals. It originates at the Antarctic Divergence, which is a narrow zone in the most southerly waters near the continent where subsurface water is pulled up between divergent bands of surface waters. The Antarctic Divergence is caused by sharp differences in prevailing winds- south of the divergence, easterlies pull surface water westward about the continent, whereas north of the divergence the strongest and most persistent winds are the already noted westerlies. These strong westerlies push the main body of the Antarctic Surface Water slightly north of east and pull replacement water up from below the divergence. This layer is constantly chilled by ice and cold air from the continent. In winter it remains below -1° C (30° F), but for a short time in the summer it may warm up to about 3° C (37° F) near its northern boundary at the convergence. Melt water from sea ice and icebergs reduces the salinity to a summer low of 34.1 ppt. This layer is characterized by low temperature and low salinity.

As the Antarctic Surface Water reaches the Antarctic Convergence it comes into contact with the Sub-Antarctic Surface Water (which is warmer by 3° to 10° C, or 5° to 18° F, and has a higher salinity value of 35 ppt). There is very little mixing between these two bodies of water. At the point of contact the Antarctic Surface Water sinks below the Sub-Antarctic Surface Water and continues spiraling northward with a new name…the Antarctic Intermediate Current. The Antarctic Intermediate Current cools the coasts of New Zealand, southern Australia, and many oceanic islands. It is still detectable as a subsurface current north of the equator in the Atlantic Ocean.

Antarctic Waters

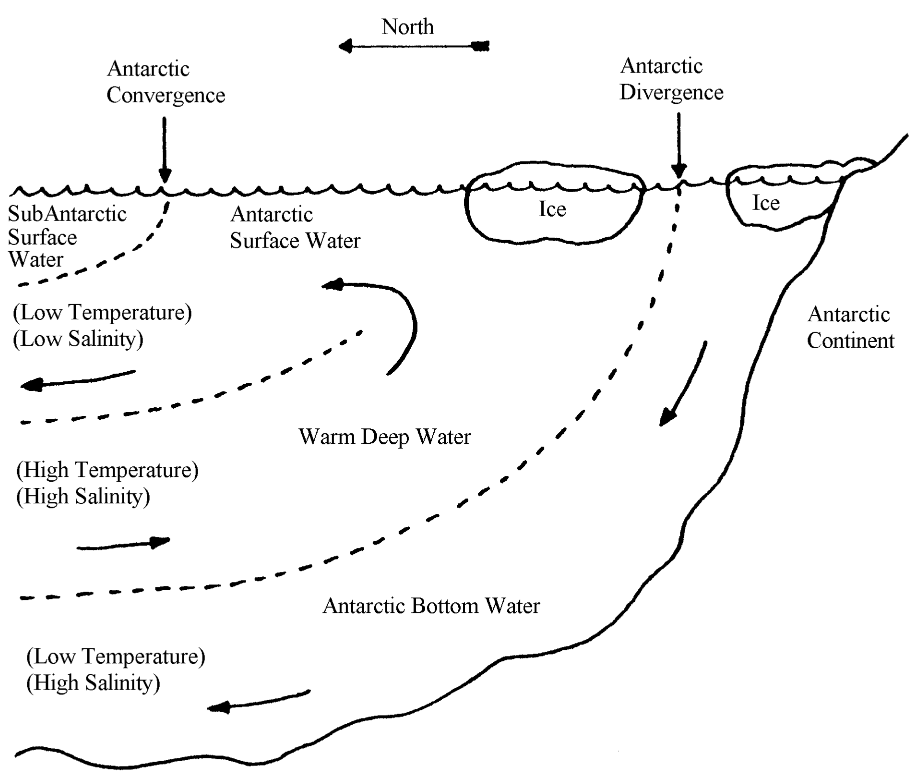


FIGURE 3. Antarctic Waters. This two-dimensional diagram depicts only the North-South movement of the currents surrounding Antarctica. The surface waters are also greatly affected by the prevailing winds. The Westerlies cause the Antarctic Surface Water to also exhibit a strong eastward movement as it moves away from the continent, while the Easterlies cause the surface

water south of the Divergence to exhibit a strong westward movement close to the continent.

The middle water layer, or Warm Deep Current, is a southward flowing water mass originating from the surface waters of the Atlantic, Pacific, and possibly Indian, oceans. This current is characterized by a high salinity (34.5-34.7 ppt) and a relatively high temperature of about 3° C (37° F). The Warm Deep Current wells up at the Antarctic Divergence where it is affected by winds, air temperatures, ice, low saline melt waters, etc. When this water layer reaches the surface at the divergence it becomes cooled. Some of it takes on a lower salinity and begins to move back northwards as the Antarctic Surface Water. The lowered salinity of the Antarctic Surface Water makes the water less dense than the Warm Deep Current, and causes it to flow in the uppermost position.

The lower layer, or Antarctic Bottom Water, forms from the remainder of the Warm Deep Current water at the divergence which is pushed toward the continent where it is cooled under extremely cold conditions. The colder water then sinks down along the continental slope and flows away from Antarctica along the ocean floor in a northward direction as the Antarctic Bottom Water. The sea ice which forms close to the continent concentrates the salt molecules in the water which remains liquid (sea ice is basically frozen fresh water). The Antarctic Bottom Water is, therefore, characterized by a low temperature (-0.5° C, or 31° F) and a high salinity (34.5 ppt or more). This layer spreads very far into the Atlantic and Pacific Oceans carrying south polar water into the northern hemisphere.

POLAR ICE

There are two major types of ice in the polar regions, sea ice and glacial ice, and they form through different methods. Sea ice forms in oceanic water when the ambient temperature is lowered to the freezing point of salt water. Glacial ice (including ice caps) forms through the simple accumulation of snow which becomes compressed by its own weight into solid ice. Sea ice formation is a seasonal phenomenon (although individual pieces of sea ice may last for several years), while glacial ice is generally a long term structure lasting decades, centuries, or even millennia.

Sea water generally freezes at about -1.9° C (28.5° F), but this may vary somewhat depending upon its salinity (the higher the salt concentration-the lower the freezing temperature). It is interesting to note, however, that surface ice which forms slowly under calm conditions is not salty, because salt molecules in solution tend to concentrate in the remaining liquid as ice crystals form. Each winter, the sea surface around Antarctica freezes, thereby forming a layer of ice 1 to 3 m (3 to 10 ft) thick and extending 100 to 200 km (60 to 120 mi) offshore. As the surface water cools down to the freezing temperature, ice crystals start to appear. If conditions are calm, the crystals join together, thicken, and form a fibrous structure called young ice.

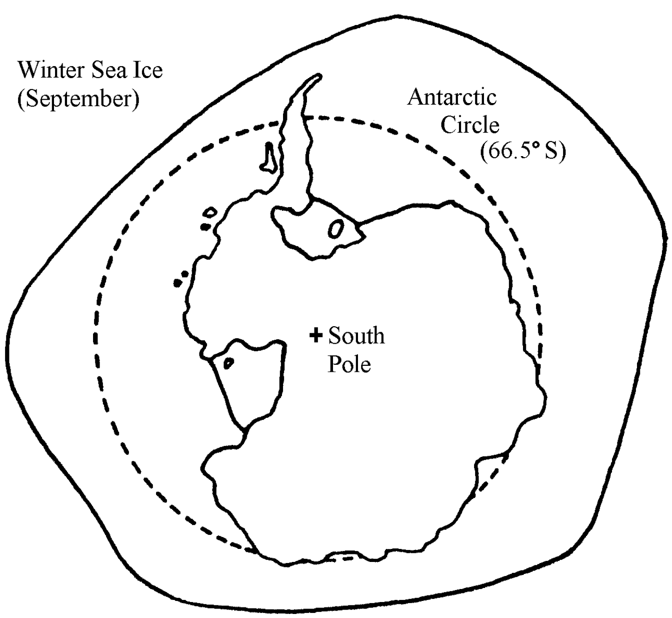


FIGURE 4. Maximum extension of Antarctic Winter Sea Ice.

Very often a slight swell occurs which causes the young ice to break apart into small sections which then continue to bump and grind against one another. This action forms roughly circular bits of thin ice with raised edges called pancake ice. As time progresses and air temperatures remain low, more crystals form and the pancakes eventually freeze together and create a solid layer several centimeters thick. Continued cold causes this layer to become fast to the shore, and it is then termed fast ice. Fast ice generally lasts throughout the winter. Currents, storms, and tidal movements tend to buckle and crack fast ice, which produce open water areas and give access and breathing spots to penguins, petrels, seals, whales, etc. Fast ice breaks apart and forms ice floes during normal summers, and the floes are moved around by currents until they pack up tightly together and cover large areas as pack ice. Areas of pack ice are often graded for the benefit of non-ice breaking ship movements...1/10 ice coverage means 10% of the water's surface is covered with ice and ships can move freely, whereas 10/10 ice coverage means 100% of the surface is covered with ice and ship movement is severely restricted or impossible. Polynyas, or open water areas, form offshore when winds and/or currents disperse the pack ice. Near the continent the pack ice drifts in a westerly direction, but north of 65° S it drifts in an easterly direction. Pack ice areas are difficult to predict, but concentrations generally occur in the Weddell Sea, Ross Sea, and off the Pacific Ocean sector of Lesser Antarctica. The northern limit for the pack ice varies, but in winter and early spring it may extend 800 km (500 mi) from the coast in some areas. The pack ice generally increases the area of the continent another 50% during this time of year by enclosing an area of approximately 19 million sq km (7.2 million sq mi).

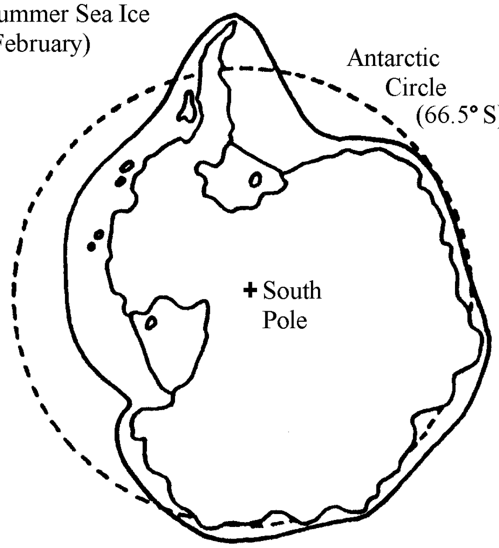


FIGURE 5. Minimum extension of Antarctic Summer Sea Ice.

In some areas, a cold spring season may allow fast ice to remain in place for more than one year. It is then called bay ice. Bay ice which persists for years is termed shelf ice, and may become very thick (perhaps measuring as much as 300 m, or 1,000 ft, in thickness). Shelf ice accumulates thickness from not only freezing sea water, but also from snow fall, and very often from glacial ice which moves to the coasts from higher areas on land. Occasionally, huge pieces of shelf ice break loose and drift away in the currents. These pieces of ice are called tabular bergs and can be enormous, perhaps hundreds of square kilometers in top surface area, and may drift for years before melting or becoming grounded. These are not to be confused with ice bergs, which break off from glaciers which reach the sea. In the Autumn of 1987, a huge tabular berg, more than 5,000 sq km (2,000 sq mi) in surface area, broke off from the Ross Ice shelf and began drifting in a north-northwesterly direction at a speed of 3 km (2 mi) per day. A data transponder buoy was dropped onto its surface in the winter of 1988, and its movements were followed for several years by satellite photographs. Its convoluted path of drift helped scientists study the deep current patterns in the

Ross Sea.

Most animals of Antarctica are adapted to a life with sea ice. Crabeater seals and Ross seals live on or about the pack ice, and although leopard seals and Weddell seals often spend time ashore, they also are dependent upon ice during much of the year. Emperor penguins breed on sea ice in the winter, and form colonies as soon as the ice is strong enough (in April). The other penguins all breed on land, during the summer, but they live on the pack ice the rest of the year. It greatly extends their feeding ranges. Many other seabirds use the ice for roosting, as well as a base for hunting. On the other hand, the presence of ice discourages plants and animals from settling in shallow coastal waters and intertidal zones. Algae, seaweeds, marine worms, sponges, sea stars, brittle stars, sea urchins, etc., flourish lower down on the continental shelf where ice does not scour the substrate.

Sea ice prevents the ocean waters from warming the coasts significantly. It is important to note that islands within the limits of winter pack ice (such as the South Shetlands, South Orkneys, etc.) compare closely with the continent in seasonal temperatures, soils types, flora, and fauna. Islands located outside the range of pack ice (such as South Georgia, Kerguelen, etc.) have continual open waters, milder winters, longer growing periods, and much more diversified and advanced flora, and to a great extent, a different fauna.

Glaciation, however, is much more complicated. Geological evidence indicates that throughout most of the Earth's history not only have the climatic zones between polar, temperate, and tropical sectors been much less distinct than they are today, but the polar regions were free of permanent ice. The poles have always received their quota of the sun's radiant energy at a low angle, and therefore have always been cooler than the equatorial region. Why, then, is it so different today?

There have actually been three major periods of extensive glaciation during the Earth's long history. The first occurred about 650 million years ago (during the Precambrian) and the second was between 250 and 300 million years ago (during the Permian Period). These ancient events happened so long ago, they do not concern us in this discussion. Instead, we will consider only the most recent one which occurred fairly recently, within just the last several million years (during the Pliocene and Pleistocene epochs).

The polar ice caps developed after a long period of general cooling of the Earth. This event began in the Middle Jurassic Period some 150 million years ago and continued until the Early Pleistocene, about 3 million years ago. Scientists have determined the mean surface temperature of our planet dropped from about 20° C to about 10° C (68° F to 50° F) during that time period. This world-cooling process was probably caused by changes in the distribution of land masses and open water in the polar regions themselves. The makeup of the polar regions has changed considerably in the last 200 million years because the continents have shifted their relative positions through plate tectonics. Scientists believe that the polar regions did not become frigid enough for permanent ice formation until continental land masses or land-locked seas disrupted the movements of polar ocean currents. While the poles were located in open water, major ocean currents moved relatively warm waters from low latitudes into high latitudes which would have dispersed seasonal sea ice before it had a chance to become permanent.

Today, the north pole is located in the Arctic Ocean which is isolated by the Asian, North American, and European continents, and since there is very little mixing with warm water currents, ice is present year round. The south polar region is isolated on the Antarctic continent which not only prevents warm waters from reaching it, but the high elevation of the continent makes it even more conducive to the formation of permanent ice. It is a self-perpetuating process in that the shiny white surfaces of snow fields and sea ice reflect back considerable radiation and prevent normal seasonal warming trends. In fact, except for a brief period during the height of summer, the center of the Antarctic continent radiates more heat than it receives from the sun. Geological evidence shows that cold temperate climates still persisted in the polar regions as recently as five to six million years ago. By four million years ago, however, the first Antarctic glaciers reached the coast line and started to produce ice bergs and tabular bergs which spread around the continent, signaling the beginning of the Antarctic Ice Age. The effects of the formation of the Antarctic Ice Cap were felt throughout the world, but it is interesting to note that the ice age in the northern hemisphere began somewhat later. Permanent ice covered the mountains of North America, Greenland, and Iceland between two and three million years ago and appeared in central Europe and Asia soon afterwards. The ice sheets have fluctuated considerably in the northern hemisphere over the last million years, but the Antarctic Ice Cap has remained relatively stable.

Within this latest ice age, as much as 30% of the Earth's land surface became covered with permanent ice during the four major periods of glaciation in the northern hemisphere, and each included several advances and retreats of ice fronts. One could argue we are still within the ice age, but at the moment find ourselves existing in a relatively warm interval, or interglacial period. The most recent glacial period started about 115,000 years ago, and ended about 14,000 years ago. However, there were several interglacial periods interspersed within that 100,000 years. During the time of greatest ice formation, nearly all of Canada, Greenland, and most of the northern United States were covered with ice up to 2,000 m (6,600 ft) thick. In Eurasia, the land covered by ice amounted to only about half that found in North America, and was limited to Scandinavia, the Barents Sea (which at that time was land), and northwestern Siberia. Recent geological studies have demonstrated that there have been numerous Arctic "mini-glacial" periods within the past 14,000 years, some within historical times.

The movement of continents seems to adequately explain the reasons behind the formation of permanent ice in the polar regions, but what has caused the variations between glacial and interglacial sequences which have been chronicled throughout recent geological history, especially in the northern hemisphere? Several other factors also come into play in the formation of permanent ice. The Earth undergoes precession, which mean our planet wobbles like a spinning top thereby changing the inclination of any given spot on Earth at the same time of year or season, relative to the sun through time. One complete period of precession takes about 23,000 years.

It is also known that the angle of inclination, or obliquity, of the Earth varies considerably over time, and this changes the angle of the rotational poles relative to the sun. A more vertical rotational angle (relative to the plane of orbit) reduces the difference between seasons throughout the year, while a more angled rotation increases seasonal climatic variations. The periodicity of this changing axis of rotation is about 43,000 years.

The shape of the Earth's orbit varies considerably over time, which is known as eccentricity, and changes from nearly circular in shape to very elliptical. When the orbit is circular, the sun's radiant energy reaching Earth remains constant throughout the year. However, when the orbit is elliptical, the incoming radiant energy varies greatly throughout the year because the distance between the Earth and the sun can vary by more than three million miles. The periodicity of the Earth's eccentricity is about 115,000 years.

In the Arctic and sub-Arctic regions especially, vegetation zones must also be taken into account when analyzing ice ages. It makes a big difference whether the flora consists of tundra or boreal forest. Snow-covered tundra habitat reflects 50 to 70% of incoming sunlight back to space, whereas boreal forest habitats reflect back only 15 to 20% of incoming sunlight because the dark branches of evergreen trees absorb 80 to 85% of incoming radiation. A cooling of Earth temperatures directly causes a corresponding increase and in tundra habitat. Variations in the combination of all these factors most likely are what determine whether the Earth experiences a buildup of permanent ice (a glacial period), or a reduction (an interglacial period). Recent computer programs using these variables have ‘predicted’ a past glacial history which agrees almost exactly with the geological history worked out by field geologists.

The Earth's gaseous envelope today consists almost entirely of nitrogen (N2) and Oxygen (O2). Together, these two gases compose about 97% of the atmosphere, but it also contains many other essential gases in small amounts. Various of these gases, primarily water vapor (including clouds), carbon dioxide (CO2), and methane (CH4), are known as greenhouse gases, because they entrap the heat formed within the biosphere when sunlight is absorbed by the Earth's surface and re-radiated as heat. If it were not for the greenhouse gases, the overall temperature of the Earth would be about -20° C (-4° F). Scientists have been able to determine the amount of CO2 found in the atmosphere during past times, but a direct correlation has not yet been firmly established regarding ambient temperature and the measured past amounts of such gases. The average quantity of atmospheric CO2 which existed during ice ages was 200 ppm, but during interglacial periods it was 280 ppm. Today, we measure 360 ppm of CO2 in the atmosphere, and it is estimated this will reach 600 ppm in about two decades. The last time the Earth's atmosphere held as much as 600 ppm CO2 was during the equable conditions of the Cretaceous Epoch (100 million years ago it actually held as much as 1,000 ppm)...a time when palm trees grew in Siberia and alligators swam in Alaskan waters.

One must also consider the effects of large-scale volcanic activity upon the Earth's overall ambient temperature. There are massive, active volcanoes beneath the Antarctic ice sheet, which may have caused cataclysmic climatic changes at various times in the past, and may again in the future. For instance, it is now believed volcanic activity on an unimaginable scale occurred at the end of the Permian Period some 225 million years ago at the Siberian Traps locale. The huge amounts of methane and carbon dioxide gases released from this event must have caused a significant pulse in the Earth's temperature, and it may also have played a role in causing the greatest extinction of life on Earth. Such immense volcanic eruptions would not only melt huge amount of nearby ice, they would also spew tremendous amounts of gases and particulate matter into the atmosphere. This would probably also cause the release of large quantities of methane from icy gas hydrates on the sea floor, in permafrost, and under glaciers...thus increasing the effect even more. Methane quickly oxidizes into CO, and known stores of methane-rich gas hydrates contain up to 30 times the amount of CO2 found in the present atmosphere.

The Earth's Carbon Cycle determines both directly and indirectly the amount of CO2 in the ecosystem at any particular time. Sea floor spreading releases enormous amounts of CO2 through volcanic vents at the sites of spreading, while at the same time volcanic island arcs and chains at the corresponding sites of subduction also release CO2. The seafloor spreads at different rates through time. A faster rate gives off relatively more CO2. Carbon dioxide dissolves in rain water and produces a weak acid, which then etches and dissolves terrestrial rocks and causes erosion. Chemical reactions lock up the carbon and wash it downstream to oceans where it is transformed into carbonic rocks, especially limestone. The erosion of continental rock reduces the amount of CO2 in the atmosphere. The compressional raising and subsequent erosion of the Himalayan Mountains began 35-40 million years ago when India began grinding into Asia...this seems to correspond to a dramatic drop in the amount of CO2 in the atmosphere. Therefore, perhaps the formation of the Tibetan Plateau has been a significant factor in the general cooling trend of the Earth in the past 35 million years.

Some scientists have suggested that the solar radiation output has varied to a significant degree through time, thereby affecting the Earth's overall temperature in a more direct way. This, however, is difficult to verify and is discounted by most authorities.

The northern ice sheets began retreating about 20,000 years ago, and have since uncovered vast areas of land which are now covered with tundra and taiga. Antarctica, on the other hand, is still locked in its ice age. Relatively minor changes in the Antarctic Ice Cap have occurred, however, as evidenced by glacial moraines and ice-caused scratches in mountain peaks which are now high above the surface of the ice. Much of the Antarctic continent is surrounded by a ridge of moraine between 100 and 300 km (60 to 180 mi) offshore and in waters up to 500 m (1,650 ft) in depth, which demonstrates a former edge of the ice mantle. The massive bulk of the ice cap probably would have protected it from changes caused by minor climatic fluctuations, but changes in world sea levels generated by glaciations in the northern hemisphere would expand the coastline of Antarctica considerably, allowing its ice mantle to enlarge respectively. Glaciologists don't really know what is happening to the Antarctic ice sheet today, but there are reasons to believe it has actually grown in recent decades.

The Antarctic Ice Cap contains about 85% of the world's ice, or about 80% of all the fresh water on Earth. It is estimated to weigh about 24,500 million billion kg (27 million billion tons), and each year it receives 1,800 trillion kg (2 trillion tons) of new snow and ice. However, it loses about the same amount of ice that it gains each year to melting, evaporation, snow blown out to sea, and of course, huge tabular bergs that break away from ice shelves and ice bergs which break off glaciers and drift away to sea. The enormous weight of the ice cap has forced the underlying continent to sink approximately 1,000 m (3,300 ft) into the Earth's crust.

LIFE IN ANTARCTICA

Antarctica is very cold, very dry, and very windy. These three qualities inhibit life to a great extent. The harsh climate freezes living organisms, dries them, and blows them away. These conditions also help to prevent the formation of mature soils. Normally, as rocks are broken down into gravel, sand, clay, and silt, bacteria and algae generate a flora in the mineral soil. In other parts of the world higher plants then move in to colonize the new soil and through chemical processes cause the release of various minerals which can then be utilized by the growing plants.

The minerals also buffer the excess acidity or alkalinity in the soil, and allow the build up of humus. This produces an organic, or humic, soil which provides a hospitable and nutritive substrate for complex vascular plants. In Antarctica, however, this soil maturing process is prohibited in several ways. In many areas the constant freezing and thawing cycles break apart rocks, and the constant winds force rapid erosion through the effects of sand abrasion, sea salts, etc., all of which produce rock debris at a faster rate than primitive plants can colonize them. Low temperatures, frost action, winds, and surface streams of melt water make it difficult for immature soils to become stabilized. This causes much of the soil to remain ahumic and poor, and therefore unattractive to both vegetation and animals. Many inland peaks contain mineral soils which are virtually sterile, and some of the dry coastal areas contain small amounts of only the simplest microscopic organisms in the sand and gravel substrate.

The peninsular region, and some of the coastal areas which receive heavy snowfall, hold richer soils. Sufficient precipitation washes harmful concentrations of minerals down through the soil, and creates subsurface reservoirs that help to keep plants from drying out during summer months. In these areas algae, lichens, and mosses grow, but even here no truly mature organic soils have formed. However, in some regions one may encounter richly organic "ornithogenic" soils (these are formed at penguin colonies where guano gets mixed into the soil).

Considering the harsh climatic conditions and the poor soils, it is easy to understand why Antarctica has so few species of plants and animals. There are about 360 species of algae, 400 species of lichens, 75 species of mosses, but there are no ferns or any of the more familiar bushes or trees. In fact, only two species of flowering plants can be found in the warmer maritime region of the Antarctic Peninsula-a grass (*Deschampsia antarctica*) and a pink (*Colobanthus quitensis*). All the plants in Antarctica grow very slowly, and only a few species grow taller than 3 cm (1.25 in). The scarcity, small biomass, and slow growth of the plants preclude the existence of the usual assortment of herbaceous animals. The only terrestrial herbivores to be found are tiny insects and mites that feed mainly on algae, fungi, and rotting plant material. Likewise, the only terrestrial carnivores are tiny mites that feed on the herbivorous mites and insects.

However, life abounds in the seas surrounding Antarctica, and migratory birds and mammals are found in tremendous numbers around the coastal areas during the summer, and on the sea ice during the rest of the year. The reasons for the abundance of life in Antarctic waters are threefold: 1) the sea water is cold (cold water holds dissolved gases, such as carbon dioxide and oxygen, much better than does warm water); 2) the sea waters are turbulent (upwellings, strong currents, and storm-tossed waters keep essential nutrients, such as phosphates, carbonates, and nitrates, and minerals in suspension where they can be easily utilized by the immense growths of phytoplankton); and 3) the long hours of daylight during the summer months promote almost continuous photosynthesis (this cultivates algal blooms which form the huge base in the Antarctic food chain).

The phytoplankton of Antarctica consists of about 99% diatoms (unicellular plant-like organisms with cell walls made up of silica), with the rest being primarily dinoflagellates. The Antarctic Convergence is actually a biogeographic boundary, since one finds different populations of planktonic organisms, fishes, and even birds, on either side of it. North of the convergence the sea floor is primarily calcareous silt formed from the empty shells of countless Globigerina protozoans. South of the convergence the sea floor consists almost entirely of the siliceous remains of diatoms. Where the Antarctic Surface waters and the Sub-Antarctic Surface waters come together at the convergence, the sudden meeting of the two different water temperatures incapacitates or kills much of the plankton and brings it to the surface. For this reason seabirds often flock along the convergence.

The biological productivity in Antarctic waters is the highest in the world. This productivity can be determined by two methods of measure. The first is the Standing Crop of Phytoplankton which is a measure of the amount of chlorophyll in a given sample of surface water. The second is the Yield, or Water Productivity, which is figured by assessing the amount of Carbon 14 assimilated by a given sample of plants. Both the standing crop and the yield are highest near the islands and along coastal areas because of upwellings and turbulence, and lowest in the mid-oceanic regions. The inshore waters of the Antarctic Peninsula contain a standing crop that is as much as 10 times greater than neighboring waters, while the yield in the peninsular region is as much as five times greater than that of surrounding waters. The standing crop in Antarctic waters varies from 0.5 to 10 milligrams of chlorophyll per cubic meter of surface water. The average yield in Antarctic waters is 0.9 gram of carbon assimilated beneath each square meter of surface water per day (the average yield for the other oceans of the world is 0.15 g C/m2/day).

The Antarctic Ocean (the ocean water south of the Antarctic Convergence) contains only about one twentieth of the world's sea water, but it contains one fifth of the world's marine biological production of carbon (3 trillion kg, or 3.3 billion tons of per year). Antarctic phytoplankton reaches its lowest standing crops and yields between April and July, when the sun is low or below the horizon, sea ice spreads, and the planktonic populations descend to subsurface layers. In October, after the ice starts to break up and drift, algal blooms begin and spread south as the ice recedes.

ANIMAL ADAPTATIONS TO ANTARCTIC CLIMATE

All the organisms that live in the Antarctic area must deal with very harsh living conditions. Under normal conditions the environmental temperature limits for animal activity range from slightly below 0° C (32° F) when body fluids freeze, up to 45° or 50° C (113° to 122° F) when proteins coagulate and dissolved albuminoids break down. The optimum temperature for life processes is often close to the maximum temperature an animal can tolerate. Climatic fluctuations demand constant adaptation, and in both aquatic and terrestrial habitats animal diversity decreases where conditions approach limiting values, such as in polar areas, deserts, and high mountains.

With regards to metabolism, animals can be classified as poikilothermic (the internal body temperature, and therefore metabolism, varies according to the ambient temperature), or homoiothermic (the internal body temperature remains relatively constant independent of the ambient temperature). The homoiothermic animals of Antarctica (birds and mammals) have an advantage in that they maintain the optimum temperature inside their bodies regardless of how cold it is outside. Living at the optimum temperature means their life processes such as nerve transmission, muscle contraction, digestion, etc., operate at their most efficient rates. Apart from marine creatures, there are very few species of poikilothermic animals in Antarctica (only the aforementioned tiny mites and insects). They are directly affected by the ambient temperature insofar as their metabolic processes are concerned. In other words: the lower the body temperature the lower the metabolic rate. This also means poikilothermic animals run the risk of freezing.

In Antarctica, terrestrial animals must endure tremendous variations in temperature, whereas the aquatic animals live in a much more uniform environment. In order to survive freezing, an insect or mite must prevent ice from forming inside its cells, and at the same time induce ice formation slowly within the rest of its body, including the contents of the gut, the blood, and the spaces between the cells. At least some of them appear to become dehydrated (much like what happens in the primitive plants) when exposed to low temperatures, and this causes the salts, sugars, and other constituents to concentrate in tissues, thereby reducing the freezing point. If the cells are not ruptured during freezing the animal stands a good chance of surviving. Freeze-tolerant insects and mites produce cryoprotectant chemicals, such as glycerol, which allow body tissues to survive freezing by reducing the proportion of body water locked up in ice.

The marine Antarctic environment is very stable, but its temperature is close to or below the freezing temperature of fresh water. Many marine invertebrates deal with this situation by accumulating salts and organic compounds, such as glucose and amino acids, which lower the freezing point temperatures of the body fluids. Antarctic fishes, like all marine fishes, maintain a body salinity slightly lower than that of the sea water in which they live. Theoretically they should freeze at a slightly higher temperature than does sea water (sea water freezes at -1.9° C, or 28° F). However, some Antarctic fishes can actually lower their freezing point temperature by accumulating an abundance of sodium, potassium, or chloride ions, or urea, in their body tissues. The enzyme systems of Antarctic fishes are so efficient they are able to maintain a high level of activity even in these extremely cold waters. One family of Antarctic fishes is able to synthesize glycoproteins which act like an antifreeze by inhibiting the normal growth of ice crystals within their tissues. The content of dissolved oxygen is so high in the cold Antarctic waters, many fishes are able to survive with very few or no red blood cells. This gives them a white or nearly colorless appearance. It is interesting to note that if these fishes come into sustained contact with sea ice, their tissues will freeze and death results.

The homoiothermic animals, in order to maintain stable high internal body temperatures, must insulate themselves from the cold. The two different groups found in Antarctica, e.g. birds and mammals, accomplish this with different methods. Air is a very poor heat conductor and is readily available as an effective insulator. The birds take full advantage of this by trapping an encircling layer of air around their bodies within their feathers. Coverts and contour feathers cover fluffy down which holds the air close to the body. Those birds with flexible wings can hold their wings close to the body and receive even more protection from wind and low temperatures. Birds lack highly vascularized exposed structures such as ears and tails, their legs are tendinous, their beaks are nonvascular and horny, and many species utilize large internal air chambers. It is very important for birds to keep their feathers from getting waterlogged, because this condition nullifies the effect of air insulation. Water has a thermoconductivity value about 25 times greater than that of air, so it very quickly absorbs heat away from a warmer object. Most Antarctic birds have a very well-developed oil gland near the base of the tail which produces a secretion that the birds rub all over their plumage in order to make it water resistant.

Penguins are much more aquatic than the other seabirds, and they have modified their plumage to make it as insulative as possible. Penguins, unlike almost all other birds, have feathers which grow out all over their bodies. Other birds grow feathers in narrow tracts, and then fluff them out to cover all the exposed skin. Penguins, therefore, have more feathers, and the entire body surface is covered with a dense, tightly packed growth of feathers. Besides feathers, penguins also utilize a layer of insulative subcutaneous fat. In fact, penguins have a harder time dealing with warm temperatures than they do with cold. The skin of the exposed feet is much more vascularized than in other birds, so they can dissipate body heat from the capillaries through the skin of their feet if necessary. They have the ability to constrict the blood vessels of the feet when they are in water to conserve body heat, and dilate the vessels when they are on land in order to shed excess body heat. This accounts for the rosy pink feet of the nesting or roosting penguins encountered on land, as opposed to the white feet of penguins which have just come out of the water.

All the native mammals found in Antarctica are aquatic. The cetaceans (whales, dolphins, and porpoises) protect themselves from heat loss with a thick layer of oil-rich, subcutaneous fat, or blubber. Unlike most mammals, including the Antarctic pinnipeds (seals and fur seals), the cetaceans have no hair and cannot use air for insulation. The reason for this may be that they are unable to leave the water in order to preen, clean, and aerate their fur (it is interesting to note the only other completely aquatic mammals, the manatees and dugongs, also have essentially hairless bodies).

Fat serves dual purposes since not only is it an excellent insulator, it also provides stored energy to allow the animals to survive when food is scarce. The internal body heat of homoiotherms is produced either as a by-product of the metabolization of food or from muscular action which releases heat through the utilization of stored energy. When the ambient temperature is low, the needs for food consumption increase in order to maintain the necessary heat production. Food intake requirements during winter are generally 1.5 times as great as in summer, but food is harder to come by in winter. Therefore, the cetaceans, most pinnipeds, and most sea birds migrate to lower latitudes and a warmer, more productive climate during the Antarctic winter. However, penguins and some seals remain in Antarctic waters year round. They simply move their base of operations from the coastal areas in summer to the edge of the sea ice in winter.

The Antarctic pinnipeds have a thick layer of insulative fat, like cetaceans, but they also have fur as an added protection against the cold. As much as 50% of the body weight of some seals is skin and fat. In fact, seals have such efficient protection against heat loss, they cause little or no visible melting on ice even after having lain in one spot for several hours, and will retain a high internal body temperature many hours after death. The fur of seals and fur seals is made up of two different types of hair- long, coarse guard hairs and short, wooly underfur. Most seals have only 2 to 5 underfur hairs for each guard hair, which provides a fur coat of minimal value as insulation. Therefore, they rely almost entirely on their fat to prevent heat loss. Fur seals, however, have as many as 70 underfur hairs for each guard hair, and this provides a fur coat which has excellent insulative value. Unfortunately, the dense luxurious coat of fur seals has long been highly valued as a commercial commodity. In fact, it was the ever-increasing search for fur seals as their known populations were destroyed which led to the eventual discovery of Antarctica in the early 19th century.

ANTARCTIC KRILL

The zooplankton of Antarctica basically follows the same trends as the phytoplankton, as it is dependent upon the phytoplankton for food. The zooplankton is relatively diverse in species, and contains many of the types of creatures found in other oceans, such as copepods, larval crustaceans, jellyfish, larval sea urchins and sea stars, arrow worms, larval fishes, etc. However, the dominant species within the zooplankton is the 5 cm (2 in) long, shrimp-like krill (*Euphausia superba*).

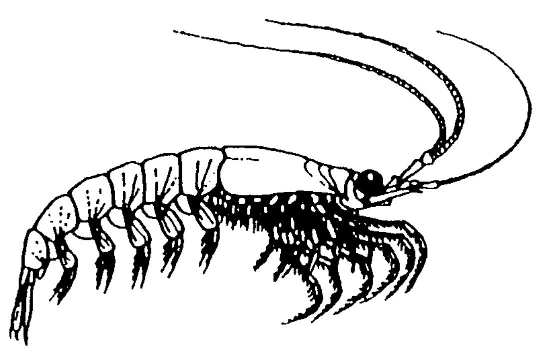


FIGURE 6. The shrimp-like krill, *Euphasia superba* (5 cm).

The Antarctic food chain is much simpler than those found in other oceans in that there are fewer levels to go through from the primary producers (diatoms) to the top level carnivores (sea birds, seals, whales, etc.). Interestingly, krill, which feed directly upon the phytoplankton, seem to form a major link in that food chain, since it is the primary food for the millions of fishes, squids, penguins, albatrosses, petrels, some seals, and the large baleen whales which inhabit the Southern Ocean. In fact, virtually all the animals we encounter in Antarctica are completely dependent upon the vast populations of krill for their livelihood either directly or indirectly.

Krill only inhabit water with a temperature below 4° C (39° F), and can survive for two to three years. Recent research has found that when phytoplankton is scarce in the winter, the adult krill regress to a smaller juvenile-like stage. At the onset of summer they regrow sex organs and begin the reproduction cycle again. Females produce 2,000 to 5,000 eggs in a season, which, after fertilization, are deposited in open water. The eggs sink to about 1,000 m (3,300 ft), then hatch into larvae that appear similar to tiny tadpoles. The animals must go through 12 molts before they become adults. Krill often form dense swarms just below the surface, which may actually make the water appear pink. These gatherings, usually made up of animals within a single age class, enable their predators to capture them with a minimum of effort.

The great baleen whales migrate to Antarctic waters every summer to spend several months just feeding on krill in order to build up their body mass and accumulate fat which will get them through the rest of the year when food is more difficult to come by. The baleen whales increase their body weight by as much as 50% during this period of intensive feeding. An adult blue whale can consume up to 4,500 kg (5 tons) of krill in a day. It has been estimated that the rorquals (baleen whales with expandable throats) consumed 160 billion kg (180 million tons) of krill annually, before whaling practices so reduced their populations. Today, it is estimated that whales take 27 billion kg (30 million tons) every year.

Since the destruction of the great whale populations, seabirds and seals have greatly increased their numbers to take up the slack, so to speak. The crabeater seal (it actually feeds on krill, not crabs) is the most numerous seal in Antarctica, and probably consumes more than 90 billion kg (100 million tons) of krill annually. Sea birds take approximately 36 billion kg (40 million tons), while fishes and squids probably consume 135 to 180 billion kg (150 to 200 million tons) of krill each year.

Therefore, roughly 320 billion kg (350 million tons) of krill are consumed on an annual basis, which represents about 10% of the total estimated krill stock of 3 trillion kg (3.5 billion tons). Both Russia and Japan have begun large-scale krill fisheries, and several other nations are making plans to start their own krill fisheries. Estimates for the annual maximum sustainable yield of krill harvests range as high as 110 billion kg (120 million tons). This would essentially double the entire world's present annual marine harvest. Krill has an amazingly high protein content of about 55%, but processing must be immediate, as the organisms spoil quickly in storage. In Russia, the krill harvest is used primarily for animal feed and for mixing with other meats to produce sausages and fish balls, while in Japan it is sold as a flavoring, cheese, soup mixes, a paste, and a drink. Now, it is important to determine how much krill can safely be harvested by humans without causing adverse effects on the simple and fragile ecosystem.

ANTARCTIC SQUIDS

The squids are abundant in the Southern Ocean, and make up an important, but little-studied part of the Antarctic ecosystem. There are some 20 species of squids found here, usually inhabiting deep waters. Most species are small in size, being less than 40 cm (16 in) in length, and feed primarily upon krill. A few species are much larger (the giant squid grows to a length of 15 m or 50 ft), and act as major predators upon fishes. In turn, squids are extremely important in the diets of seals and toothed whales, as well as the larger fishes and sea birds.

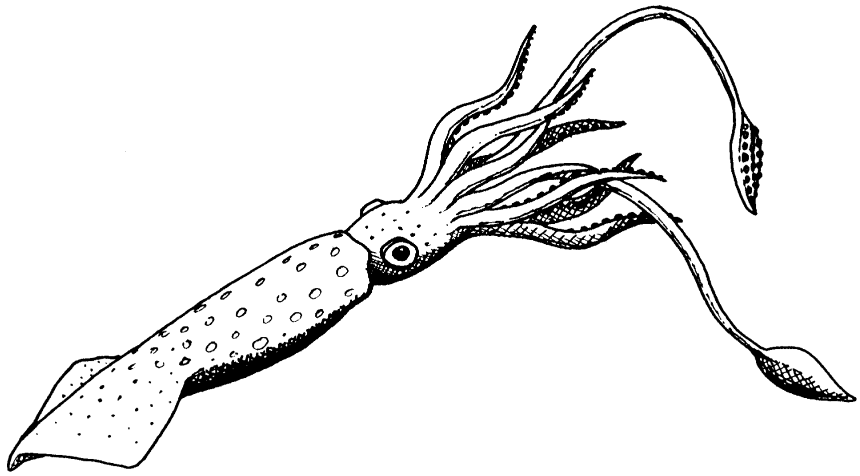


FIGURE 7. The Antarctic squid, *Gonatus antarcticus* (1 m). Squids comprise a significant portion of the marine biomass of Antarctica, and they range in size from the tiny Patagonia squid (15 cm) to the giant squid, *Architeuthus* sp., which grows to a length of at least 15 meters.

Squids and their close relatives, the octopuses, are known as cephalopods, and are grouped together taxonomically with the the more familiar mollusks...snails, slugs, clams, oysters, etc. However, their highly evolved nervous and sensory systems make them comparable to many of the large, carnivorous vertebrates. They have very well developed eyes, which are surprisingly similar to the eyes of vertebrates, and it is believed they hunt mostly by sight. Squids normally grab their prey with the two longest tentacles (there are ten altogether). Suckers on each tentacle help them hold onto their struggling prey until the victim can be shifted to the mouth and sliced up into small, bite-sized pieces by a hard, powerful beak.

With their two fleshy fins, squids can maneuver and swim slowly, but underneath the head is a funnel tube through which the animals can squirt water under pressure, thereby creating a water jet. This allows them to move very fast either forward or backward, and it helps them in catching prey or avoiding predators. Squids have the ability to change color almost instantaneously, which may confuse potential prey and predators alike. They can also spew sepium (black ink) into the water, which spreads quickly as an opaque cloud, thereby allowing their escape predators.

It is difficult to study squid biology, species compositions, etc., in Antarctic waters, because being very strong swimmers, they easily avoid small scientific sampling nets. Most studies must focus upon the nearly indestructible squid beaks that are retrieved from their predators, especially in the regurgitated pellets found around albatross nests. In fact, there are several species of Antarctic squids known to scientists only from their beaks.

At this time there is virtually no information available on life cycles, growth rates, or reproductive biology of Antarctic cephalopods. Large-scale cephalopod fisheries have existed for generations in the Mediterranean, Southeast Asian, and Japanese waters. Japan has operated a fleet of commercial squid fishing boats in the waters around New Zealand since the late 1960s, and has recently begun fishing the waters around the Falkland Islands. Because of the ever-increasing pressures to find new and unexploited fisheries and fishing areas, many scientists are concerned about the inevitable development of squid fisheries in Antarctic waters. Much study needs yet to be done in order to accurately estimate Antarctic squid stocks and construct reasonable management schemes. It stands to reason that over exploitation of this major link in the food chain would likely have significant effects on the populations of vertebrate predators that rely upon squids so heavily.

ANTARCTIC FISHES

Almost all the fishes to be found in Antarctica are bottom dwellers, and because surrounding waters are very deep many of the species are rarely encountered. For our convenience, however, the fishes may be categorized into two environmental groupings: deep-sea fishes and coastal fishes. The coastal group contains the better known species, such as ice fishes, eel pouts, Antarctic cods, Antarctic herrings, Antarctic shads, Antarctic perches, and dragon fishes, and accounts for about 60% of the species and perhaps 90% of the individuals. Among the deep sea species is the highly sought toothfish…a species of real concern. The common names applied to the various groups found here are a bit misleading, because they are not closely related to the true eels, cods, herrings, and shads of the Northern Hemisphere.

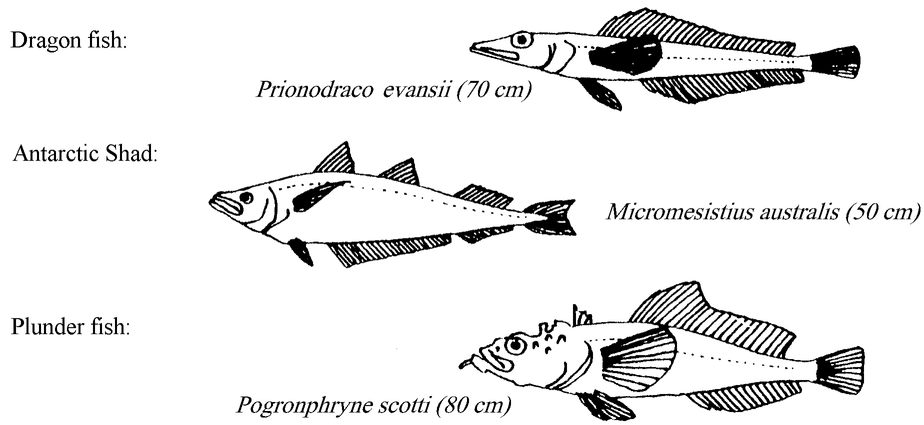
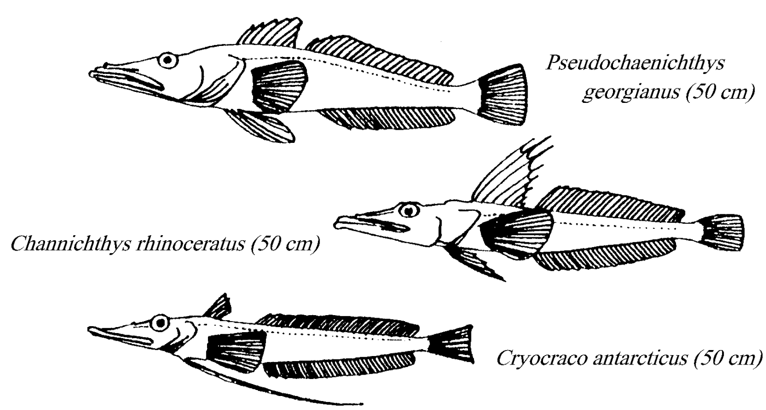


FIGURE 8. Representative species of three unrelated inshore families of Antarctic fishes.

As expected, the species diversity is low in Antarctic waters (only about 150 species have as yet been identified), but the number of individuals in these rich waters is high. For reasons dealing with osmotic excretory processes, marine fishes must maintain a body salinity lower than that of the surrounding sea water. As discussed earlier, the presence of dissolved salts lowers the freezing point temperature of sea water from 0° C (32° F) to about -1.9° C (28° F). In order for fishes to survive in this near freezing sea water, they must concentrate something other than salts in their blood and tissues to lower their own freezing point temperature to at least that of sea water. The ions of salts, such as sodium ions, potassium ions, and chloride ions seem to work very well. Some species even produce glycoproteins, which like an antifreeze inhibit the formation of ice crystals within their tissues.

A few species apparently live their entire lives under the fast ice. The cold water environment may be the reason why so many species appear rather sluggish and it also probably accounts for the high number of bottom-dwelling species. Even so, they are able to maintain considerable activity in these low temperatures because of the presence of very efficient metabolic enzymes. There are a few free-swimming species, such as the Antarctic herrings and Antarctic shads, and both these groups feed on plankton.



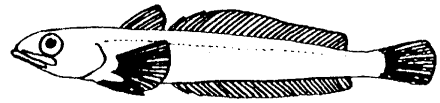
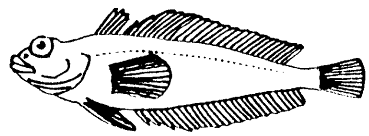


FIGURE 9. Four representative species of the true Antarctic ice fishes.

The ice fishes all lack the oxygen-carrying pigment hemoglobin, which is common to all other vertebrate animals. Therefore, they have no red blood cells, and this gives them a pale and nearly colorless appearance. The cold waters hold a high level of dissolved oxygen and the ice fishes take it in through their gills as do other fishes, but it is transported dissolved in the blood plasma (not attached to specialized oxygen-carrying molecules). Likewise, the muscle tissues of these fishes lack myoglobin and this only adds to the whitish or pale look.



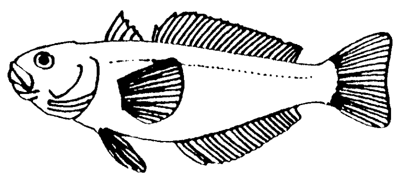


FIGURE 10. Two of the better known species of Antarctic cods.

The Antarctic cods are the most sought after, because they can attain large sizes...the largest individuals grow to as much as 70 kg (155 lbs). One must remember, however, that most of the Antarctic fishes tend to be very slow growing, take a relatively long time to reach sexual maturity, and seem to have a low fecundity. Before fisheries are developed on too large a scale it is important to evaluate the gross potential of fis h resources, study their population dynamics, develop systems to monitor fish stocks which are being exploited, and evaluate the effects of these fish exploitations on other elements of the ecosystem.

Commercial fisheries have already been instigated by several nations to harvest the rich fish fauna of Antarctica. Most species are bottom dwellers and are too small to be of significance to major fisheries. Much attention has been focused on about a dozen species which are the largest and most common fishes encountered around the continental coast and the Scotia Arc. The most valuable fish sought after in these waters is the Antarctic or Patagonia toothfish. It is a large, slow-growing and slow-re[producing fish with delectable white flesh. Scientific studies have shown the species to be dangerously overharvested in some regions, so strict control has been instigated on the fishery. Policing that control is difficult and poaching remains a serious problem. Unscrupulous fish traders often call it Patagonia sea bass to get around the restrictions.

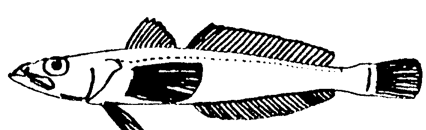


FIGURE 11. The valuable Antarctic or Patagonia toothfish.

ANTARCTIC BIRDS

The most famous animals of Antarctica must surely be the birds. The species diversity is very low, for reasons already explained. There are only 43 species of birds which normally occur south of the Antarctic Convergence, and nearly all of them are sea birds. Of the approximately 8,600 species of living bird species known today, only 287 are classified as sea birds (about 3%). However, keeping in mind that about 70% of the world is covered by oceans, it is not surprising that the bird species with the largest populations are sea birds. Some ornithologists believe the Wilson's storm petrel, which breeds by the millions in Antarctica, may be the commonest bird in the world.

The Antarctic bird fauna consists of seven species of penguins, four albatrosses, 15 petrels and shearwaters, three storm petrels, two diving petrels, one cormorant, one gull, three terns, two skuas, two sheathbills, two ducks, and one pipit. The following list includes those species of birds normally found in Antarctica, that is, south of the Antarctic Convergence:

1. Emperor penguin (*Aptenodytes forsteri*)
2. King penguin (*Aptenodytes patagonica*)
3. Gentoo penguin (*Pygoscelis papua*)
4. Adelie penguin (*Pygoscelis adeliae*)
5. Chinstrap penguin (*Pygoscelis antarctica*)
6. Macaroni penguin (*Eudyptes chrysolophus*)
7. Royal penguin (*Eudyptes schlegeli*)
8. Wandering albatross (*Diomedea exulans*)
9. Black-browed albatross (*Diomedea melanophris*)
10. Gray-headed albatross (*Diomedea chrysostoma*)
11. Light-mantled sooty albatross (*Phoebetria palpebrata*)
12. Southern giant petrel (*Macronectes giganteus*)
13. Northern giant petrel (*Macronectes halli*)
14. Pintado petrel or Cape pigeon (*Daption capensis*)
15. Antarctic petrel (*Thalassoica antarctica*)
16. Snow petrel (*Pagadroma nivea*)
17. Southern fulmar (*Fulmarus glacialoides*)
18. Dove prion (*Pachyptila desolata*)
19. Fulmar or Thick-billed prion (*Pachyptila crassirostris*)
20. Thin-billed prion (*Pachyptila turtur*)
21. Great-winged or Gray-faced petrel (*Pterodroma macroptera*)
22. White-headed petrel (*Pterodroma lessoni*)
23. Kerguelen petrel (*Pterodroma brevirostris*)
24. Blue petrel (*Halobaena caerulea*)
25. White-chinned petrel (*Procellaria aequinoctialis*)
26. Brown petrel or Cape dove (*Procellaria cinereus*)
27. Wilson's storm-petrel (*Oceanites oceanicus*)
28. Black-bellied storm-petrel (*Fregatta tropica*)
29. Gray-backed storm-petrel (*Garrodia nereis*)
30. Georgian diving-petrel (*Pelecanoides georgicus*)
31. Common diving-petrel (*Pelecanoides urinatrix*)
32. Imperial cormorant (*Phalacrocorax atriceps*)
33. Kelp or Southern black-backed gull (*Larus dominicanus*)
34. Brown or Southern skua (*Catharacta skua*)
35. McCormick's skua (*Catharacta maccormicki*)
36. Antarctic or wreathed tern (*Sterna vittata*)
37. Arctic tern (*Sterna paradisea*)
38. Kerguelen tern (*Sterna virgata*)
39. Yellow-billed or American sheathbill (*Chionis alba*)
40. Black-billed or lesser sheathbill (*Chionis minor*)
41. South Georgia pintail (*Anas georgica*)
42. Kerguelen pintail (*Anas acuta*)
43. South Georgia pipit (*Anthus antarcticus*)

Penguins epitomize everyone's idea of the typical Antarctic animal. The 17 species of penguins are all found in the southern hemisphere, but most of them live north of the Antarctic Convergence. All penguins are flightless and adapted for life in cold water, so even those found in the low latitudes (the Galapagos and Humboldt penguins actually range up to the equator) are dependent upon cold water currents for their livelihood. Penguins are the most aquatic of the sea birds, and they spend most of their lives at sea (except when molting or rearing young). Their ancestors were flying birds, as evidenced by the similarities in their pectoral girdle to that of modern flying species. The normal functions of flight are to aid in searching for food, evading predators, and migrating, but penguins have evolved to achieve these same results by swimming rather than flying. The wings of penguins are much reduced, but are stiff, flat, tapered, and pointed in order to propel the birds through the heavy medium of water almost as though they were flying. They swim by flapping their wings underwater rather than paddling with their feet. Penguins have very well-developed pectoral muscles attached to a large keel on the sternum, like aerial flyers, which facilitates their being fast and powerful swimmers. They have taken ecological niches unfilled by flying birds. Penguins seem very similar to the now extinct flightless great auk (both in appearance and behavior) of the northern hemisphere, and in fact the name penguin comes from the scientific name of the great auk which originally was *Pinguinis impennis*. The first British sailors to sail around the Cape of Good Hope simply transferred the familiar name to these newly discovered flightless birds of the southern hemisphere so reminiscent of what they knew back home.

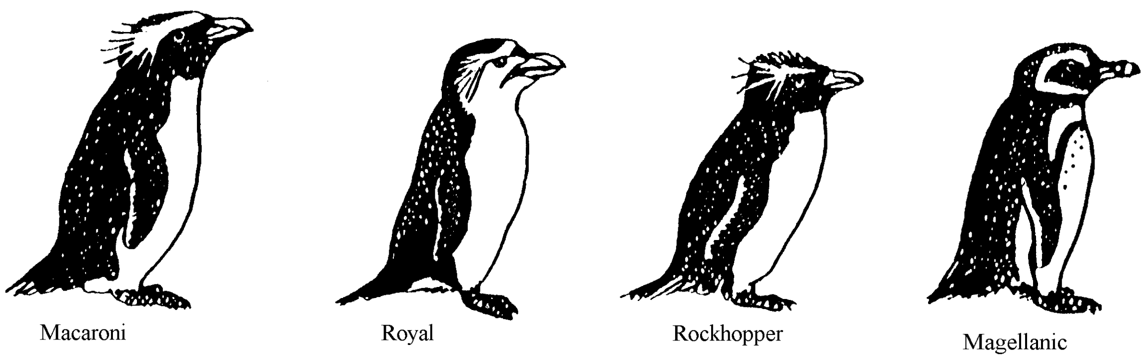


FIGURE 12. The small penguins we commonly see in the Falklands and Antarctic islands**.**

Birds which can fly, have light-weight, or even hollow, bones, and often have air sacs within the body to help reduce body weight and decrease the wing loading. Penguins, however, have dense, solid bones, and no air sacs, in order to counteract buoyancy, and they float very low at the water's surface. This means the animal expends little energy for either floating or submerging. Their bodies are very streamlined, but even so, when they relax their flippers while swimming the dense water quickly stops them from coasting. To avoid having to stop each time they surface to breathe penguins have developed a swimming method termed porpoising. This allows them to swim rapidly just below the surface and propel themselves out of the water in a low arc, take a quick breath, and continue on their way. In order to reduce their buoyancy during deep dives they exhale before descending. Most penguins can submerge for five to seven minutes, but the largest species (the emperor penguin) can submerge for up to 18 minutes. Studies have shown the emperor penguin can dive to at least 265 m (875 ft), but most other species do not normally go deeper than about 70 m (230 ft). Their maximum speed (about 24 km/hr or 15 mph) in the water is usually exaggerated, because their small size makes them appear faster than they really are.

FIGURE 13. The three closely related pygoscelid or brush-tailed penguins.

All penguins nest in colonies. In Antarctica, most species use open nests lined with rocks and pebbles, and other debris, and both sexes share in incubating the eggs and feeding the young. The two largest species (the emperor and king penguins) make no nest at all, and since they require more time to raise their young, the eggs are laid in winter so chicks can be fledged by the end of summer. Unlike all other penguins, which nest on land, the emperor penguin makes its colonies on the sea ice. The male emperor penguin incubates a single egg by balancing it on top of his feet and covering it with a special brood pouch (the same method used by the king penguin). He must stand upright and shuffle around with the egg for about two months, while his mate is out at sea feeding. If the egg hatches before the female returns to relieve him, the male can feed the newborn chick with small quantities of crop secretions containing fat and protein. In some species the young form groups, or creches, which can then be guarded by just a few adults rather than each chick being watched by one of its parents at all times.

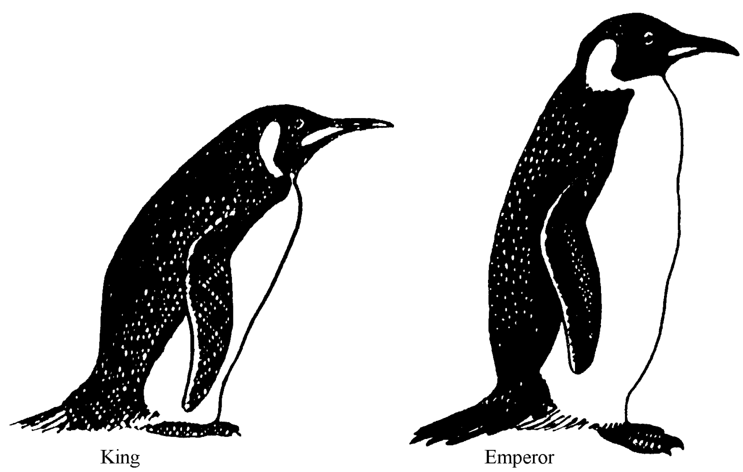


FIGURE 14. The two giants among the penguins.

Penguins generally feed on animals captured near the surface either close to shore or near the edge of pack ice. In Antarctica, the larger species feed on squids and fishes, while the smaller species feed mostly on krill and fishes. There is always a lot of activity at these colonies, and the sights, sounds, and smells are unforgettable. Usually, incubation takes five to six weeks, and fledging takes seven to 10 weeks. The young are fed by regurgitation, and they take the food from inside the mouths of the adults. The penguin rookeries we visit are usually stained bright red from the krill which is spilled while feeding chicks, and krill byproducts in the guano which coats everything.

Penguins typically have very strong feet with large, well developed claws with which to climb slippery rocks or ice. Except for the feet and perhaps bare patches on the face, the entire body is covered with small, dense, overlapping, scale-like feathers, and there is a downy tuft at the base of each feather which increases the heat retention abilities even more. Feathers account for about 80% of the penguins' insulative properties, while fat provides the other 20%. Penguins have very high internal body temperatures (about 38° C, or 101° F), as well as high metabolic rates. With all this taken into account it is easy to understand how they can survive, and even thrive, in the cold, harsh climate of Antarctica.

Albatrosses, along with shearwaters and petrels, storm-petrels, and diving-petrels, make up the Procellariiformes group. All of these sea birds have tubed nostrils and bills that are covered with horny plates, and they are often referred to as "tube-nosed swimmers". At sea, albatrosses are easily identified by their large size, long narrow wings, short tails, and distinctive flight patterns. They spend most of their lives in the air. They have perfected a gliding flight which allows them to stay airborne with a minimum of effort, and they actually seem to enjoy windy, stormy conditions. It is great fun to watch as they swoop downwards with the wind just over the waves, then turn into the wind to gain height, and then reverse themselves to pick up speed and glide with the wind again. They seem to go on for hours like this without ever having to flap their wings. We usually encounter albatrosses in the open sea, and they often follow our ship taking advantage of the currents of air produced as the vessel moves, hoping for something edible to be dumped overboard or stirred up to the surface by the propellers.

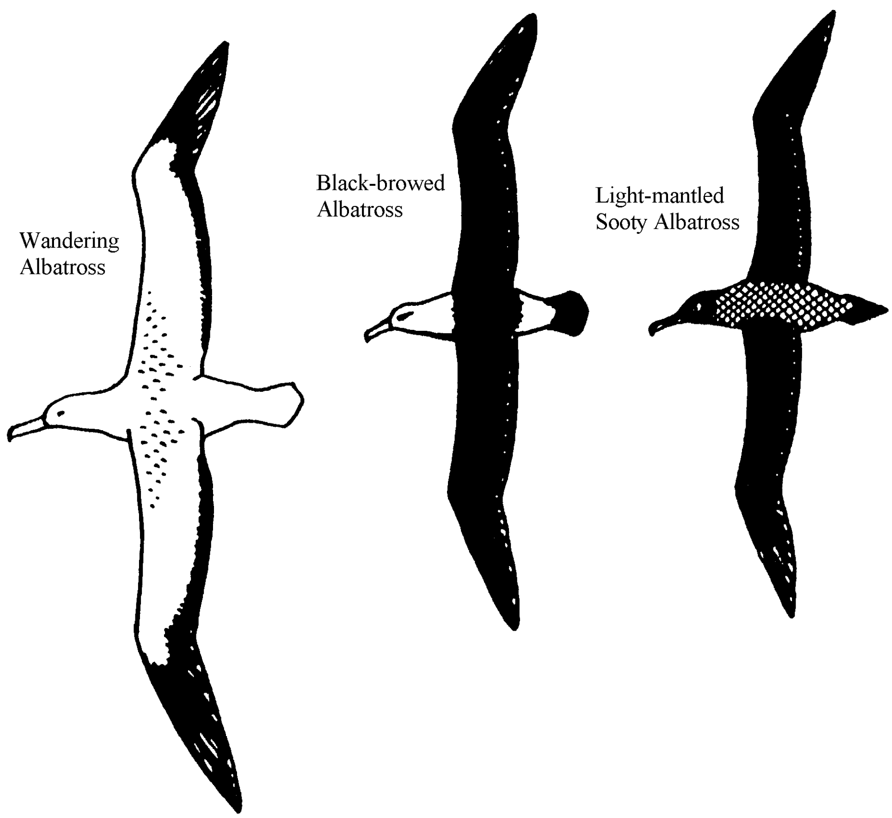


FIGURE 15: The three general ‘types’ of Antarctic and Sub-Antarctic albatrosses…Great (wandering albatross), Mollymawk (black-browed albatross), and Sooty (Light-mantled sooty albatross).

They feed mostly on squids, small fishes, and krill, which they catch by alighting on the surface and dipping their heads underwater. These birds have short, strong legs and webbed feet, and will alight readily on the water to rest or swim around after food. They usually must run along the surface into the wind in order to become airborne again. For identification purposes, albatrosses can be categorized as large or small. The two large species (royal and wandering albatrosses) have the longest wings of any living birds, reaching a total wingspan of more than 3 m (10 ft). The small albatrosses are often called "mollymawks", and usually have wingspans of about 2 m (6.5 ft). Most albatrosses have developed complex nuptial dances, and they begin to breed in late spring or early summer. They nest on islands that provide good sites for taking off into the prevailing winds. Their nests often consist of mounds built out of mud, grasses, moss, etc. and excrement, and they usually lay just one egg. Incubation normally varies from 60 to 70 days in the small species, and lasts about 80 days in the large species. Both sexes incubate the egg, and feed the chick at the nest with regurgitated food until it fledges. The small albatrosses breed every year, but the two large species only breed every other year.

Shearwaters and petrels, the true petrels, are small to medium-sized sea birds (with the exception of the albatross-sized giant petrel), which have long, pointed wings and hooked beaks with both nostrils encased together in a single sheath. Many ornithologists believe the extended tube enables the birds to eject the concentrated brine (produced by the salt gland) away from the face, so it will not dry and crystallize on the facial feathers. Thick salt deposits on the face could be a serious problem to birds that inhabit such cold and windy environments as Antarctica, because they do not normally get many chances to clean and preen themselves. The tubenoses also have a highly refined sense of smell, and their nostril design undoubtedly contributes to their sensitivity in detecting minute amounts of methane and other byproducts from the breakdown of organic substances…a sure sign of possible food resources. These birds spend their entire lives at sea, except during the breeding season, and have adapted themselves to the severest storms the Southern Ocean can produce. They are often seen flying just over the water's surface using the wind and air pressure along wave fronts as they glide, bank, and shear the water with their wing tips. It is thought they can survive very long periods on the wing without true sleep.

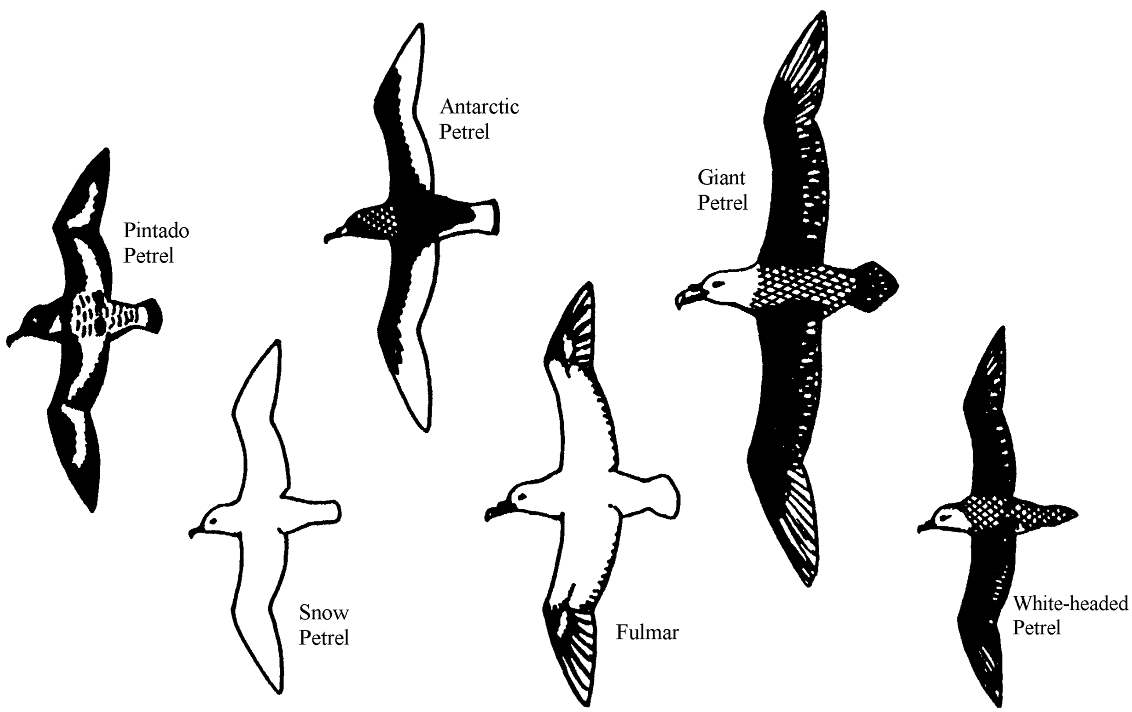


FIGURE 16. Though the body shapes of petrels are similar, there is great variation in size, coloration, and markings.

The shearwaters and petrels feed chiefly on plankton, crustaceans, squids, and small fishes, which they pick up from the surface. Some, especially giant petrels, will eagerly scavenge food both at sea and on land. Their feet are webbed and they float very high on the water as they paddle around looking for food. They can dive just below the surface...they are so buoyant, however, it is a struggle to stay submerged for more than a few seconds. Most species are gregarious, and some of them form colonies with many thousands of individuals. Most nest in holes, rocky crevices, or on rock ledges, while a few (including the giant petrel) actually construct a nest out of pebbles, feathers, and other available materials. All species normally lay a single egg, and both sexes share in the incubation and feeding of young (usually one mate is off feeding while the other one tends the egg or chick). Incubation varies from six to eight weeks, depending on the species. The chick is fed by regurgitation, and often this consists of a very aromatic and oily secretion. Some species, most notably the fulmar, can defend themselves by ejecting this oil at intruders. Fledging takes seven to eight weeks in most species, but 14 to 19 weeks in the largest species.

Storm-petrels are the smallest of the oceanic seabirds. They are about the size of swallows, and in fact are sometimes called sea swallows. Another common name given them by seafarers of old is "Mother Carey's chickens" (Mother Carey was a sea witch who could drown sailors and change them into birds and then send them out around the world's oceans in search of new victims). Their flight is fluttering, and much more erratic and weaker than the true petrels. Most species are dark-bodied with a white patch on the rump, but some lack the white rump, and others have white bellies and underwings. The name petrel comes from "Peter", and refers to the biblical story of Saint Peter trying to walk on the water. The storm-petrels have a habit of facing into the wind with outstretched wings, and appearing to walk or dance on the water as they try to pick up tiny crustaceans and other planktonic organisms between the waves. Like the albatrosses and true petrels, these birds are often encountered far out to sea in windy and stormy conditions. It is surprising to see these tiny birds far out to sea, perhaps hundreds of kilometers from the nearest land.

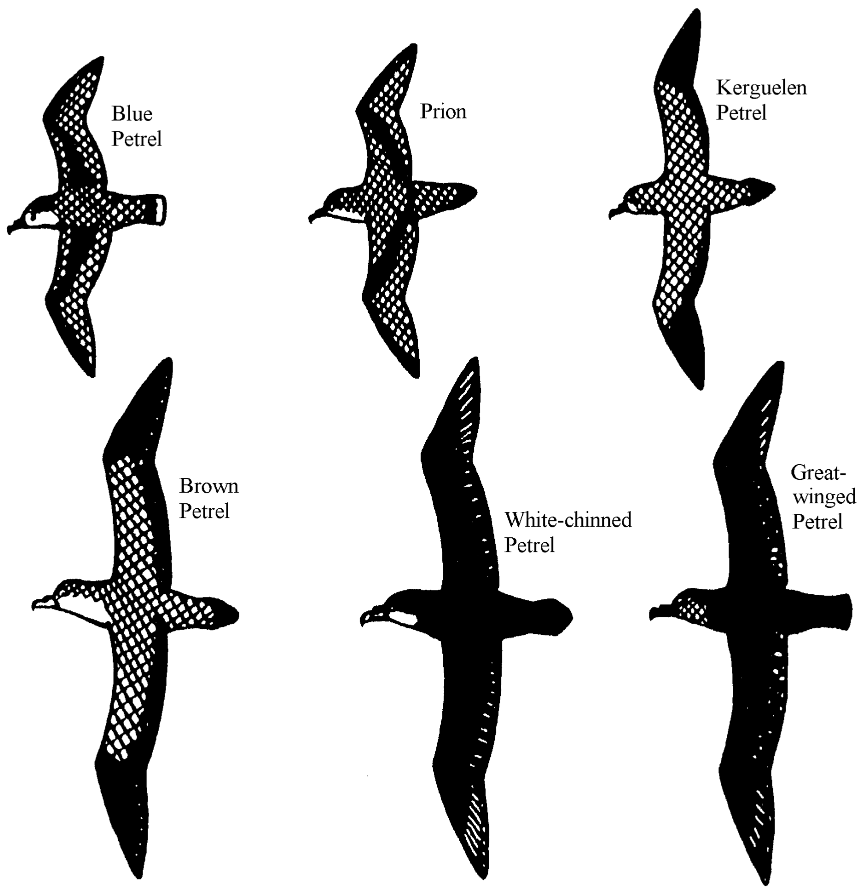


FIGURE 17. The smaller petrels (especially prions) require real patience to identify on the wing.

The nostrils of storm-petrels are encased together in a tube with a single opening, like the shearwaters and petrels. Their legs are long and spindly, and the feet are webbed. This helps them greatly when they flutter at the water's surface bouncing and skipping while trying to grab tiny food particles. Most species breed in colonies and nest in protected places such as crevices, under rocks, and within cavities or burrows which they may excavate themselves. Both sexes incubate the single egg, but the eggs and young are often neglected for varying periods during development. Incubation usually lasts five to six weeks, but may take longer if the egg has been left untended for extended lengths of time. They are fed by both parents, and grow very large and fat before their juvenile feathers appear. Fledging normally takes eight to 10 weeks.

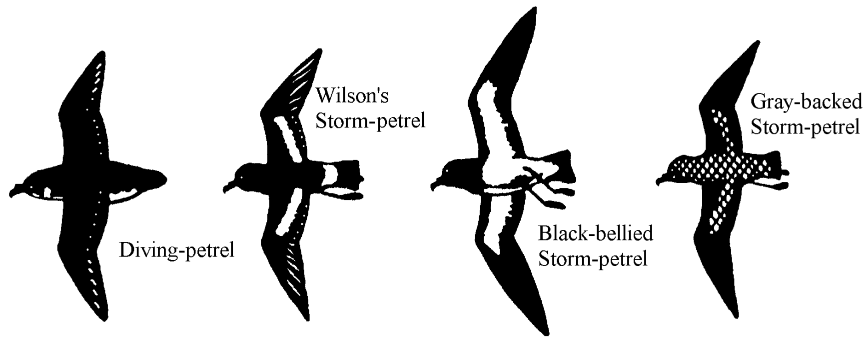


FIGURE 18: The small diving-petrels and storm-petrels can be difficult to identify at sea.

Diving-petrels are all found in the southern hemisphere (there are only four species). They are small stubby birds, and are almost identical in shape, plumage, and flying traits. The basic diving-petrel scheme is black upper body and white under body, with short wings, legs, and tail, and small bills with separate nostril tubes which open up instead of forward (this avoids driving water into the nostrils when diving into the water). They can fly, but not very well or very far. Usually they erupt from the water and fly a short distance with a rapid whirring flight, before diving back into the water. In outward appearance they are very similar to little auks, or dovekies, in the northern hemisphere, and indeed seem to be the southern equivalents. Diving petrels feed almost entirely on small fishes, which they chase down and catch underwater with their short hooked beaks. Like penguins, they swim underwater by propelling themselves with their wings, not their feet. Ornithologists believe penguins must surely have evolved from ancestral birds with habits much like the living diving-petrels. Diving-petrels have nearly lost the power of flight, and when they molt they are completely flightless and spend several weeks behaving very much like penguins. They breed on islands, and nest in long burrows which they dig themselves in open ground and under trees. Like all other tube-nosed seabirds, they only lay one egg which is incubated alternately by both sexes for about eight weeks. The chicks are fed daily by the parents, and fledging takes seven to nine weeks. Although these birds probably range far from their breeding islands, they are rarely seen outside of the inshore waters.

Cormorants and shags are medium to large birds with long necks, long hooked beaks, long rounded wings, and long, wedge-shaped tails. They are strong flyers, but usually fly in straight level paths, and often in V-shaped groups. The larger species are often called shags. Most species are black, but in the southern hemisphere many cormorants are black and white in coloration. The imperial cormorant is the only species found in Antarctica, but it consists of two distinct racial types (often referred to as the blue-eyed and king cormorants). Only the blue-eyed race breeds on the Antarctic continent. They are essentially coastal sea birds, although they can and often do make long trips over open water. This explains how they reach Kerguelen, Crozet, Macquarie, South Georgia and other such isolated islands, as well as Antarctica itself during the breeding season. Cormorants are all expert divers. They float very low in the water, and when they go under to pursue their prey (usually fishes) they dive with a characteristic forward leap, or jack-knife maneuver. They propel themselves underwater with their large webbed feet, while they often open their wings partly to aid in steering and making sharp turns when chasing fishes. Unlike most sea birds, which have webbing between the 3 forward projecting toes of each foot, cormorants have webbing that connects all four toes of each foot. This condition is termed totipalmate, and the larger amount of webbing produces a much more efficient swimming foot. They snatch the fish with their strongly hooked beaks and then surface in order to position the fish in their mouth to swallow it head first. Another important difference concerning cormorants (and their relatives the pelicans, boobies, frigate birds, tropic birds, and anhingas) as compared to other sea birds is that they have no external nostril openings. The birds must breathe through their open mouths, and they often seem to be panting when the gular pouch vibrates during their breathing. Cormorants usually breed in colonies, which may be located on the ledges of cliffs, rocky shores, and open ground areas. We often find cormorant colonies near penguin colonies. They build large bulky nests out of branches, seaweed, rocks, bones, or any other convenient material. The clutch normally consists of two to four eggs, and both parents share the incubation which lasts about four weeks. The young fledge after about five to six weeks and may move around in the colony. The parents feed them by regurgitation, and generally look after them for about 10 to 12 weeks. Like penguins, the immature birds often form creches.

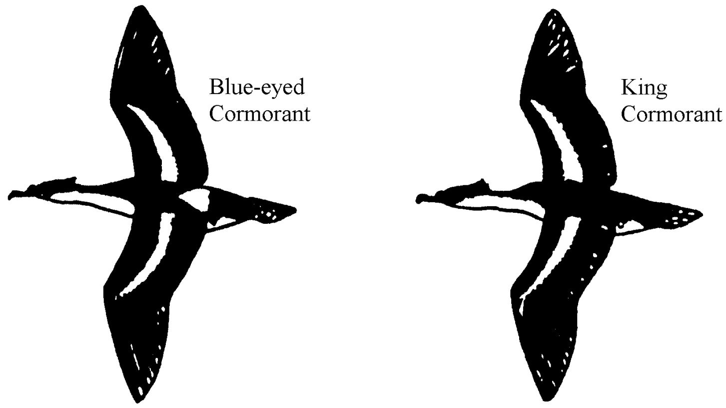


FIGURE 19. The two main races of the imperial cormorant or shag.

Skuas are superficially similar to gulls, and in fact probably evolved from them. They are much more pelagic than the gulls, however, and except for during the breeding season, they spend most of their time at sea. The skuas can all be differentiated from gulls because they have white wing patches at the base of the primary flight feathers, and they all have two elongated central tail feathers of varying lengths (which may or may not be easily seen). They have long, broad wings and are strong flyers. There are two species of skuas (the southern great skua and McCormick's skua) found in Antarctica. They are both stocky, brownish birds which are rather hawk-like in their habits, and have strong hooked beaks and relatively strong talons on their webbed feet to help them in their predatory life style. Skuas are also very aggressive when it comes to protecting their eggs and offspring. If one approaches too close to a nest, the adults will dive against the intruder to drive him away. The skuas of Antarctica are among the largest in their group, which makes them potentially dangerous to almost all the other birds and small animals. They are inveterate egg stealers and chick killers. Until penguin chicks are large enough to fend off skuas, they are at constant risk of attack. For the first several weeks the parent penguins spend much time protecting their offspring from skuas. Skuas are also pirates in that they will chase and harass birds that have food until they drop it out of desperation. They are active hunters and can kill quite large prey, such as wounded adult penguins, but they will also scavenge when necessary. Skuas do not nest in colonies, but they are often social nesters. This means several pairs may nest within the same vicinity, but their nests are well-spaced. The Antarctic skuas usually nest near the coasts, either on rocks or on open ground. They may actually construct a nest, and both parents take turns incubating usually two eggs for about four weeks. Fledging takes about 6 to 8 weeks, and in the chicks are fed by both parents.

The kelp gull is different from typical gulls in that it often migrates long distances over open water during winter months. This is why it is the only gull species found in Antarctica (most gulls are coastal bird and seldom fly out of sight of land). Gulls are generalized birds. They have long, broad wings and are good flyers, but cannot fly as well as the albatrosses and petrels. They have webbed feet and are good swimmers, but cannot swim as well as the penguins and cormorants. They are predatory birds, but are not as hawk-like nor as fierce as the skuas. Gulls are survivors and will take advantage of any situation they can. They will scavenge when necessary and will eat an impressive variety of foods. They often follow ships in hopes of receiving edible refuse, and many species have actually increased their numbers and ranges as a result of living off mankind's ever growing refuse problem. Gulls get their food either from the ground, or from the surface of the water. They rarely dive beneath the surface- they are very buoyant and float high in the water. The kelp, or southern black-backed, gull is a large gull, and typical in appearance. The head, body, and short rounded tail are white, while the upper surface of the wings is black. The bill and legs are yellow. Young birds, however, do not attain their adult plumage until their third winter, and for their first few years are a mottled brown. Most gulls nest in colonies, but the kelp gull usually nests as single pairs. The range for the species is very wide, and includes South America, South Africa, and New Zealand, as well as islands throughout the Southern Ocean. They nest in rocks, and on ledges, and often build a nest out of organic debris. Both parents incubate the three to four eggs, and both parents feed the chicks with regurgitated food. Fledging takes place in about 4 to 6 weeks.

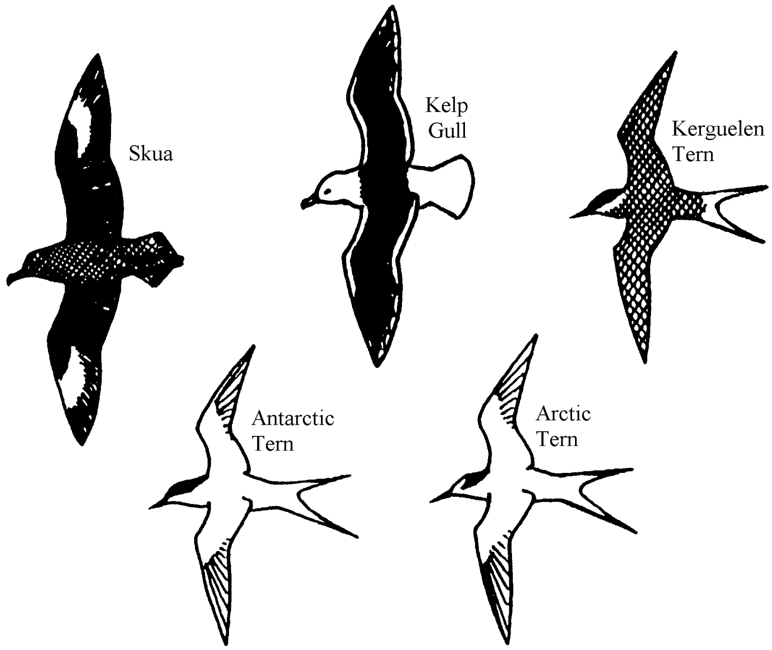


FIGURE 20. Despite the variation in body forms, skuas, gulls, and terns are closely related.

Terns are closely related to the gulls. In fact, some authorities consider the two groups as one family. The terns, however, are much more specialized when compared to the gulls. They all have graceful bodies, long, pointed wings, pointed beaks, and many of them have long forked tails. Whereas gulls often soar in updrafts and wind currents, terns have a buoyant, straight flight. Most terns are coastal birds, but the Antarctic species migrate varying distances over open water each year. The Arctic tern is notable for having the longest yearly migratory route of any animal on Earth, with some individuals flying 35,500 km (22,000 mi) during a round-trip flight from the Arctic to the Antarctic and back to the Arctic. The three species found in Antarctica are all very similar, in both appearance and habits. They feed almost entirely on fishes (although the Kerguelen tern may feed on flying insects during the summer), which they catch by dropping on them from above the water. Terns can hover as they search for prey and can dive a short distance into the water if necessary. Most terns nest in colonies, but the Antarctic and Kerguelen terns often nest as individual pairs, or at best in loosely organized and widely segregated breeding areas. The Arctic tern does not nest in Antarctica. They may lay from one to three eggs, and incubation lasts about three weeks. Both parents share incubating and feeding. Unlike most other seabirds, terns bring freshly caught fishes for their nestlings to eat rather than regurgitate predigested food. The nest usually consists of a simple scrape among loose pebbles. Fledging takes four to five weeks, but the parents continue to feed their offspring for some time after that.

Sheathbills are pigeon-sized, and indeed even look somewhat like pigeons. They seem to be a living example of the link between the gulls and waders. There are only rudimentary webs between the three front toes, and they have a well-developed hind toe. They are snow white (except when they have been scavenging in offal and mud), and are most often encountered as they walk deliberately among nesting penguins or along the shoreline. Sheathbills are not highly active birds, and fly rather laboriously with short rounded wings. They can swim, and are occasionally seen at sea on ice floes. Sheathbills usually nest in single pairs and are often found near penguin rookeries, their chief source of food. The nest may be set within a rock crevice, or in a cavity, or perhaps under a ledge, and is constructed with pebbles, feathers, bones, etc. Both parents incubate the two to four eggs, which takes about four weeks. Usually only one offspring is successfully fledged, and that takes about seven to eight weeks. They are the vultures of the Antarctic. They even have leathery facial wattles to avoid getting too much gore upon their facial feathers. Sheathbills will eat nearly anything of organic origin, including seal feces, spilled regurgitated food, placentae, dead seal pups, dead chicks, eggs, etc., and sometimes even kill live penguin chicks. There are only two species, and both of them breed in the Antarctic. The yellow-billed and black-billed sheathbills are nearly identical except for the color of the beaks, and legs (the yellow-billed sheathbill has black legs and the black-billed sheathbill has yellow legs).

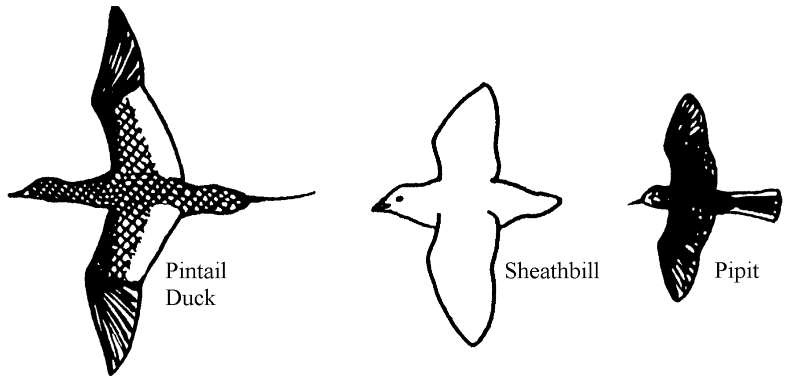


FIGURE 21. Some oddities among the Antarctic bird faunae.

Ducks are found throughout most the world, and many of them even breed in the high Arctic during summer months. However, only two ducks (both pintails) can be found in Antarctica and they are permanent residents on just three maritime islands. The South Georgia pintail seems closely related to the South American brown pintail, and probably represents a fairly recent natural colonization. The Kerguelen pintail is most likely a local variant of the northern pintail. They are typical-looking ducks, but like all pintails they are slim and very agile, with slender pointed wings. They are strong fliers, and take off from the water nearly vertically. The males have long, sharp tail plumes, and both sexes have a metallic speculum on their secondary flight feathers. The pintails normally form large flocks during winter months, but at the onset of spring they disperse and form pairs along the marshy ground found along the streams and ponds all over the islands. They are primarily fresh water birds. Unlike most other ducks, they have evolved to produce small clutches of only three to six eggs, which is to be expected since they live on isolated islands with relatively few predators. The nests are well hidden, and are constructed out of grasses, tussock stems, feathers, etc. Inland, the birds feed extensively upon plant life (both terrestrial and aquatic), as well as insects, arachnids, worms, etc. In the intertidal zone, they feed mostly upon crustaceans and small mollusks.

The South Georgian pipit is a sparrow-sized bird with a slender, pointed beak, and a long tail. It is reddish brown, with buff underparts, and a characteristic streaked plumage. This pipit is the only songbird native to the Antarctic region. It feeds on the ground, walks leisurely (it does not hop like most small songbirds), and it wags its tail continually. It most likely is descended from the South American pipit, which breeds in Patagonia and the Falkland Islands, and the ancestors were probably carried to South Georgia by the prevailing westerly winds. This species is remarkably difficult to spot among the tussock grass, and other vegetation, but can easily be seen as it prowls along the beaches and streams looking for insects, amphipods, and other small creatures. It breeds on the small, rat-free islands off the coast of South Georgia, but feeds on the main island. The nests are made of woven grasses, and are usually hidden among tussock grass roots. The clutch normally consists of three to four eggs, which is fewer than other pipit species around the world, but consistent with an isolated island population. It remains on South Georgia throughout the year.

ANTARCTIC SEALS

The order Pinnipedia is made up of the three families of fin-footed marine mammals: Phocidae (true, or earless, seals), Otariidae (fur seals and sea lions, or eared seals), and Odobenidae (walruses). The pinnipeds are found primarily in cold oceanic regions such as the Arctic and the Antarctic, but some species inhabit tropical regions which, in most cases, are affected by cold water currents. Only true seals and fur seals are found in Antarctica.

All pinnipeds are carnivorous, and except for the fact that their feet are flipper-like to accommodate an aquatic life style, they are very similar to the Carnivora order, which includes the cats, dogs, otters, bears, etc. The Pinnipedia and Carnivora orders are obviously closely related, but scientists are unsure of that relationship. Most authorities support the theory that all pinnipeds evolved from a single strain of early carnivores somewhere in the north Atlantic region, and that one branch later migrated to the north Pacific and gave rise to the eared seals, and walruses. A second theory speculates that the pinnipeds evolved from two different groups of carnivores: the eared seals and walruses originated from bear-like ancestors in the north Pacific region, and the true seals developed from primitive otter-like ancestors in Asia.

The pinnipeds make their living from the sea, and as expected they have evolved many different mechanisms to facilitate their success in a marine environment. They contain an enormous amount of blood in relation to their body size (about twice the amount found in a comparably-sized human). A larger content of blood obviously holds more dissolved oxygen and carbon dioxide, and the animal can therefore survive for longer periods of time without breathing. This gives them the ability to spend a great deal of time under water searching for food. During a dive the heartbeat rate slows from perhaps 100 beats per minute to four or five beats per minute. Pinnipeds have a venal shunt system which allows the blood to bypass muscles and organs which do not need a constant supply of oxygenated blood, and retain that blood supply for critical organs such as the heart, brain, and spinal cord. They normally exhale when they dive below the surface, but their lungs are dorsally located so as to give them extra stability when they are buoyant at the surface.

Many species, including some of those found in Antarctica, migrate long distances during different seasons of the year. They accumulate in and around the pack ice and shorelines during summer months in order to breed. The females only give birth to one young per season. Gestation for most species is about nine months, but because they scatter after the short breeding season, mating must take place soon after parturition. The next year's pup is born almost exactly one year later, which means the pregnant female has must have some physiological method by which she delays the development of the fertilized egg, or its implantation in the uterus.

Being mammals, the babies suckle milk from their mothers. The milk contains about 45% fat and 10% protein (compared to about 4% fat and 2% protein in cow's milk), and the offspring grow very quickly. Most species are weaned in about two months. The males have little or nothing to do with the raising of their offspring. There is tremendous variation in life styles and food preferences among the species, so instead of trying to make too many generalizations here, it is easier to discuss the various species individually.

As well as describing the pinnipeds in general as a group, it is also important to explain the differences within the group. The two families Otariidae and Odobenidae are closely related, and many of the following descriptions given for the eared seals also hold true for the walruses of the Northern Hemisphere (except walruses have huge tusks and are nearly hairless). Eared seals have external ears, their hind feet can be positioned beneath the body in order to walk or hop on land, the fore limbs are long and broad and provide the main power stroke for locomotion in water (because of this, much of the muscle mass is centered around the pectoral girdle and thoracic region), the soles of their flippers are naked, they have claws only on the middle three digits of each flipper, and there is sexual dimorphism. The true seals have no external ears, their hind limbs stick straight back in line with the body forcing the animals to crawl (rather like an inch worm) when on land, the fore limbs are short and the hind limbs provide the means for locomotion in water, the flippers are completely covered with fur, there are claws on all digits, and except for a few species which form harems, the sexes are similar in size. Of all the differences, however, the most important is the makeup of the fur. The fur seals are aptly named for they have dense, luxurious coats. Their fur consists of two different types of hairs, guard hairs and under fur, which are arranged in bundles. Each long guard hair is surrounded by up to 70 short under fur hairs, and this gives the animal a highly efficient protective layer of insulation against cold temperatures both in the water and on land. Unfortunately, it also gives them a pelt which is highly valued by mankind. The true seals, on the other hand, rely primarily on a thick layer of subcutaneous oil-rich fat, or blubber, to insulate their bodies from the intense cold. Therefore, their fur is not nearly so thick or luxurious. True seals also have both guard hairs and under fur, but on average there are only two to five under fur hairs associated with each guard hair. It was the expanding search for fur seals which led to the discovery of Antarctic continent in the early 19th century.The following pinnipeds are found in Antarctic waters:

1. Antarctic fur seal (*Arctocephalus gazella*)
2. Southern elephant seal (*Mirounga leonina*)
3. Weddell seal (*Leptonychotes weddelli*)
4. Crabeater seal (*Lobodon carcinophagus*)
5. Leopard seal (*Hydrurga leptonyx*)
6. Ross seal (*Ommatophoca rossi*)

The Antarctic fur seal is typical of the eared seal group, in that the male grows much larger than does the female. The male may weigh up to 180 kg (400 lbs), and is olive-gray to silver on the back with a brownish belly and a dark yoke over the middle. The guard hairs on the neck and shoulders form a thick mane, and the older bulls grow a crest on the top of the head. The female grows to 50 kg (110 lbs), lacks a mane and head crest, and has a creamier colored chest and throat. Fur seals favor rocky coastlines with sheltered beaches as communal breeding areas. The males arrive at the breeding grounds first (during November), after their winter feeding season has ended, and quickly start to establish territories on the beaches. These bulls are very pugnacious and there is almost constant fighting between them as they maintain and defend their territories from other males. The females begin to arrive at the beaches in late November, and usually give birth two to four days after arrival. Mating takes place about a week after the female gives birth. The females, or cows, form harems within the territories of the males, but they are free to move around between different territories. The males are more interested in maintaining their territories than they are in keeping individual cows in their harems. By the middle of January the harems start to break up, and the exhausted bulls begin to go to sea for short periods to feed. From the end of January to the beginning of March the animals molt. The cows and pups leave the beaches in April, but some of the young males may return to the beaches intermittently until the end of June. There are two closely related species found in the Southern Ocean, but only the Antarctic fur seal is found south of the convergence. Not surprisingly, it feeds to a great extent upon krill, which has led to the molar teeth being reduced in size compared to other fur seals. However, it also feeds on fishes, squids, and even penguins. During the winter they move northwards to stay with the krill which were located at the convergence during the summer, and individuals have ranged as far north as the South Island of New Zealand. The Antarctic fur seal was believed to have been hunted to extinction in the 19th century, but a small colony was discovered to have survived on Bird Island off the northwest tip of South Georgia in 1933. From this group other colonies have since repopulated the South Orkney, South Sandwich, and South Shetland Islands, as well as the Kerguelen Islands, and the species has made a tremendous comeback.

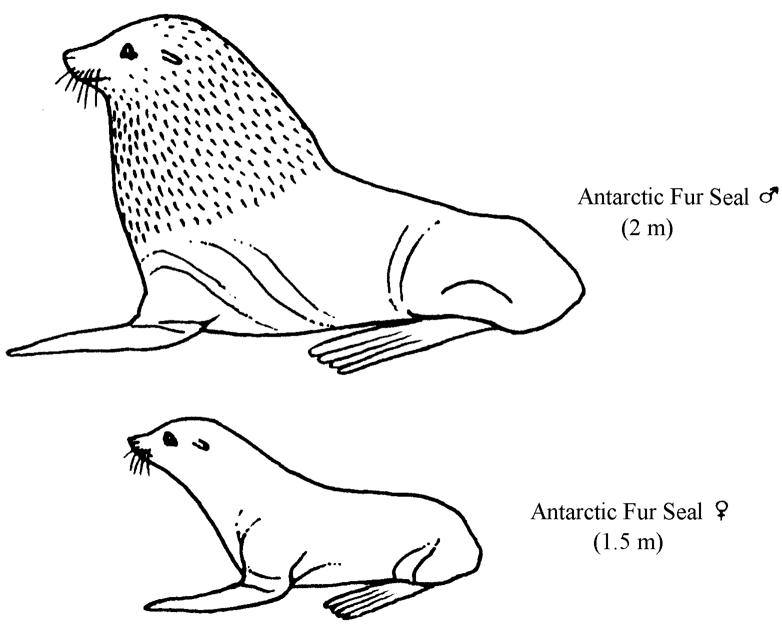


FIGURE 22. The Antarctic fur seal is the only eared seal in Antarctica.

The southern elephant seal has an enormous circumpolar range that includes not only the Antarctic mainland, but most of the sub-Antarctic islands as well. This is the largest seal species in the world, surpassing even the walrus in size. The male grows to 6 m (20 ft) in length and can weigh as much as 3,600 kg (4 tons). The female, though large, is much smaller than the males, and grow to 3.6 m (12 ft) in length and 900 kg (1 ton) in weight. The male elephant seal is distinguished by his immense size, large inflatable proboscis, and dark gray color. The females are brownish, and lacking the enlarged nose characteristic of the male, look typically seal-like. Elephant seals are unique among the true seals in that the males maintain and defend breeding territories and harems (as do the male eared seals). The males start coming ashore on the breeding beaches as early as late August to establish their territories in anticipation of the arrival of the females about two to four weeks later. A very successful bull may convene as many as 50 females in his harem. The precocious pups, which at birth are 1.5 m (4 ft) in length and 36 kg (80 lbs) in weight, are born about a week after the mother arrives, with the last being born in October. They have dark wooly fur when they are born, but within a month replace it with a dense, lighter coat. The mothers suckle their young for only about three weeks, and the pups put on weight very quickly at this time, up to 9 kg (20 lbs) per day. Copulation follows about three weeks after parturition. By mid-October the breeding season ends and the males start feeding again, ending their long, exhaustive fast, which has been one long series of bloody fights with other males. The pups have a very high mortality rate during the breeding season as many of them are crushed by the huge bulls as they move around defending their territories. Elephant seals do not truly migrate, because when they leave the breeding grounds and go to sea, they primarily just move along with the edge of the advancing ice pack. They feed mostly on squids (which account for about 75% of their diet), but also eat significant quantities of fishes. The elephant seal is the champion diver in the seal world...dives have been recorded to depths of nearly 1,000 m (3,300 ft) and can last more than a half hour. It was not until the fur seals were nearly extirpated in the mid-19th century that the elephant seals began to be hunted by man. Since the pelt of this seal is worthless, it was killed only for its oil. The animals were driven ashore to minimize transport problems after being killed and the blubber was removed to be rendered into oil. By 1900, so few elephant seals remained the industry essentially ended. A large male yielded about 400 l (100 gal) high quality oil. The species has recovered very well, and is once again common in many areas of its original range.

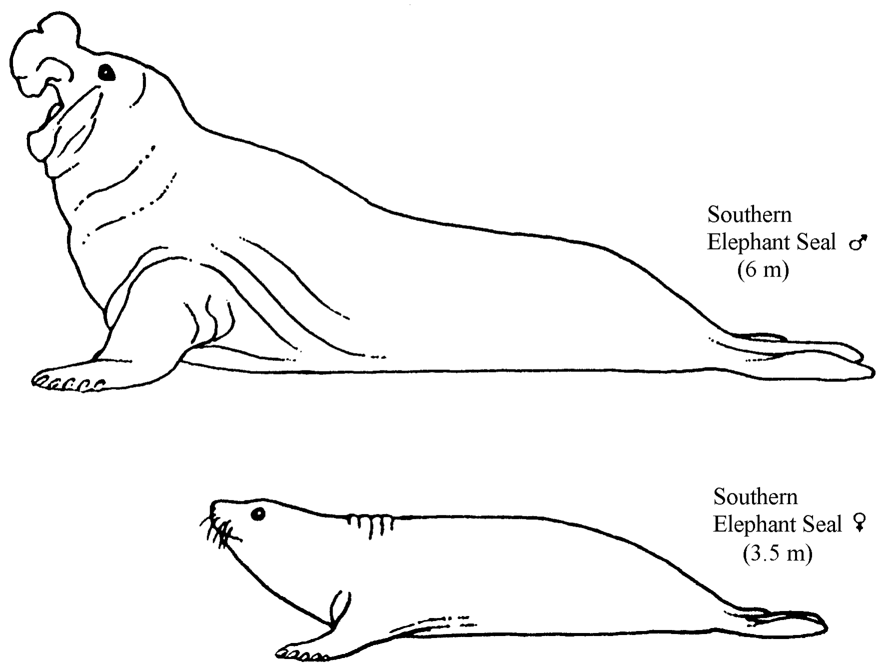


FIGURE 23. The male southern elephant seal is the largest pinniped in the world.

The crabeater seal is the most abundant pinniped in the world, and has even increased in numbers in recent decades presumably because of the drastic reductions of whale populations in Antarctic waters. The name crabeater is misleading because the animal lives almost entirely upon krill, not crabs. With the removal of the great whales from the Antarctic ecosystem many other species dependent on krill, including seals, penguins, albatrosses, petrels, squids, and fishes, have increased their numbers dramatically. Population estimates for the crabeater seal run as high as 25 million. The adults of both sexes are about the same size, growing to 2.7 m (9 ft) in length with a weight of 227 kg (500 lbs). This medium-sized seal is long and slim, and is often called the white seal because of its cream-colored fur. It has a long, rather pointed snout and is often encountered resting on pack ice. It is very common to see adults with long parallel scars on their flanks or bellies most likely caused by narrow escapes from killer whales and/or leopard seals. Their teeth have become highly adapted to an exclusive diet of krill. The premolars and molars have numerous projecting cusps arranged in line with the jaws so as to act as strainers when the jaws are closed. This allows the animal to take in a mouthful of water and strain out the krill while forcing the water out of the mouth with the tongue. It is an adaptation which works somewhat similar to the baleen plates of the filter-feeding whales. Little is known of the breeding practices of this species, because breeding occurs in the relatively inaccessible pack ice far from shore. The breeding season is known to last from October through December. Mating takes place two to three weeks after parturition, and the pups are weaned after about a month. Crabeater seals stay primarily near the edge of the pack ice as it grows or recedes, so it cannot be considered a truly migratory species. There is evidence that some individuals remain in southerly areas under the ice in the winter, like Weddell seals.

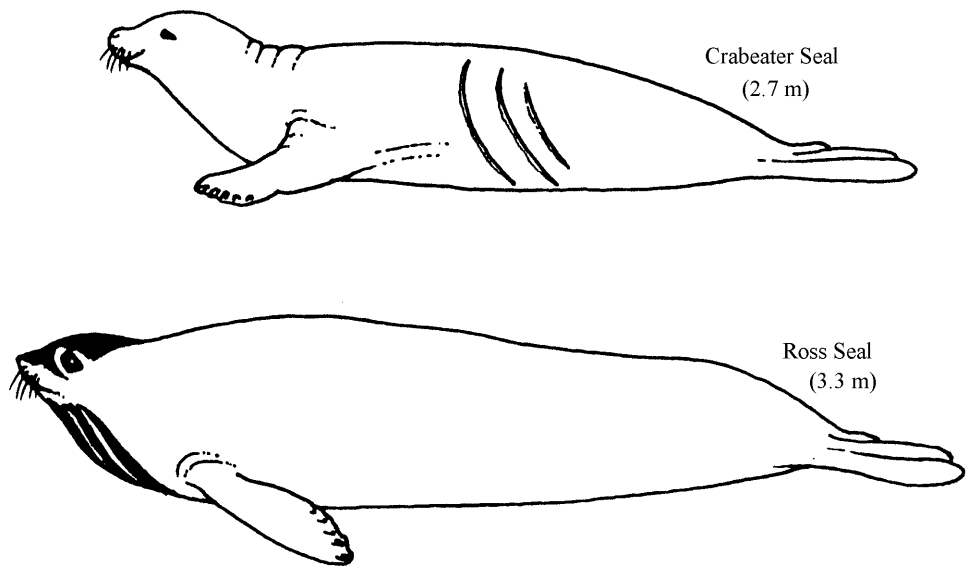


FIGURE 24. Two medium-sized seals that are truly dependent on sea ice

The Ross seal is probably the least known of all the pinnipeds. This is a solitary animal and is rarely seen because it inhabits the thick ice packs along the fringe of the Antarctic continent. The species was discovered by Sir James Ross during the British Antarctic Expedition of 1839-43. Both sexes are similar in size and appearance. They grow to about 3.3 m (11 ft), and are dark greenish-gray on the back fading to a light gray on the belly. The chin and throat are very dark, and there are light stripes from the shoulders to the flanks. It is a plump, rather shapeless seal, and has a short broad face with a protruding forehead. The head can be withdrawn into heavy rolls of blubber around the neck. The eyes are large and bulging, which helps the seal to discern food and obstacles in the dark waters under the ice. They have very large and well-developed flippers when compared to other seals. The incisor and canine teeth are delicate, sharp, and recurved for catching squids, their main source of food (they also eat fishes and krill). Very little is known of their breeding habits.

The leopard seal, as the name suggests, is highly predaceous. This is the only species of Antarctic seal that regularly eats warm-blooded prey. A large percentage of the diet consists of penguins, but it also includes fishes, squids, and even the young of other seals. Leopard seals have long, pointed cusps on their premolars and molars, somewhat like the condition found in crabeater seals (although the teeth of crabeater seals are much more blunted), which predisposes them to feed on krill when their normal prey is unavailable. The sexes are nearly identical, except the females attain slightly larger sizes than the males. The males grow to a length of 3 m (10 ft), and the females grow to 3.6 m (12 ft). The typical appearance is a dark gray back marked with lighter spots, shaded down to a light gray belly marked with darker spots. These spots, however, are nothing like the spot design of true leopards. Leopard seals are long and sinuous and have a very large and powerful head and neck. The snout is square-shaped and the mouth is enormous with a huge gape. It has none of the cute appeal of the other seals, and actually has a rather reptilian-like appearance. In spite of their ferocious reputation, there have been very few cases of unprovoked attacks upon humans (although there is one documented human death resulting from an attack). These are solitary animals and it is rare to see more than one individual in a given area. They can be found throughout the pack ice during the summer, but tend to stay near the outer edges of the ice during the long winter. Some animals spend their winters near isolated islands, such as South Georgia, Macquarie, etc., and a few individuals have even been found off South Australia and the South Island of New Zealand. The breeding habits of the leopard seal are poorly known because, like the crabeater seals, they breed and raise their young on the ice far from land. Pups are born between

November and December, and weaning takes about two months. Mating apparently occurs during January or February.

The Weddell seal is the most southerly of the seals and almost always are found fairly close to the Antarctic mainland in both summer and winter. Although individuals do sometimes wander long distances (they have been found off South Australia and New Zealand, as well as South Georgia, Macquarie, Kerguelen, Heard, South Orkney, and even the Falkland Islands), the species was not discovered until 1823 when James Weddell captured six specimens during his "voyage to the South Pole". Unlike those pinnipeds that maintain territories and harems, the males of this species are not larger than the females, and in fact the females tend to grow slightly larger than the males. It is a rather tubby animal which weighs up to 400 kg (900 lbs), with males measuring about 3 m (10 ft) and females measuring about 3.3 m (11 ft). Weddell seals are dark gray above and light gray below, and the entire body is covered with light blotches and streaks. The face is small, but the eyes are extremely large to facilitate hunting in deep, dark waters under the ice. Squids make up the majority of their diet, although they also eat fishes and crustaceans. The breeding season starts when the cows haul out in early September and give birth within a period of one or two days. The males come ashore at the rookeries in mid- to late-September. The males often fight with one another if they come too close together, and the females are fiercely protective of their offspring. The pups are weaned in about six to eight weeks, after they have more than quadrupled their weight to more than 120 kg (260 lbs). The cows will have lost about 136 kg (300 lbs) during the weaning ordeal. The pups enter the water very soon after birth, and many are crushed to death by the ice breaking up. It has been estimated the mortality rate of Weddell seal pups is as high as 50% during their first two months. During the winter they remain under the ice by maintaining breathing holes which give them access to air. The seal imbeds its lower incisor and canine teeth in the ice from below and then revolves its upper incisor and canine teeth in an arc until it cuts a hole. The teeth of older individuals are usually badly worn, and this condition may be an important cause of death in mature animals. Weddell seals have been known to reach depths in excess of 600 m (2,000 ft) and can remain submerged for more than an hour.

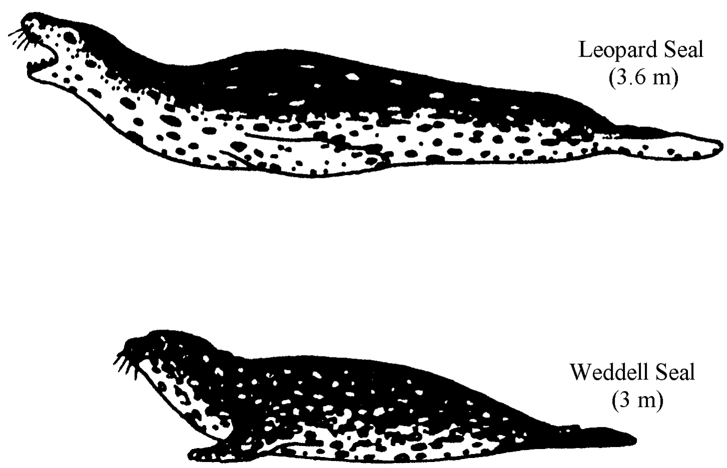


FIGURE 25. The two darkly-colored seals can be difficult to distinguish on sea ice.

ANTARCTIC WHALES

Whales (this term applies to all whales, dolphins, porpoises, etc.) are air breathing mammals, but have perfected the ability to live entirely in water over the past 50 to 60 million years. They belong to the order Cetacea, and are often simply referred to as cetaceans. Like the seals, they evolved from terrestrial carnivores, but they have taken their adaptations to living in a marine environment much further than have the seals. The hind legs have completely degenerated; they have developed fluked tails for propulsion; the front limbs have been transformed into stiff pectoral flippers; the nostrils have moved to the top of the head; they have lost their fur and instead opted for a thick layer of oil-rich blubber with which to insulate themselves from the cold waters; the vertebrae have lost their interlocking processes because their mass is essentially weightless in the buoyancy of water (this has allowed the gigantism of many species).

Aquatic life creates numerous problems for air breathing animals, but the whales have overcome them through many physiological adaptations. Muscle cells can survive several hours of oxygen deprivation, but nerve cells sustain damage within minutes from lack of oxygen. Whales have developed blood circulatory shunts which keep the oxygen-rich blood moving through those organs which need a constant oxygen supply while they are diving and "holding their breath". They inhale before diving (seals exhale before diving), but the tremendous pressure exerted by water causes the lungs to collapse thereby compressing the retained air into cartilaginous supply tubes in the bronchial system. Because they must return to the surface every time they breathe, whales live in a vertical world, and unlike fish, their tails are flattened horizontally which facilitates up and down movements. They have large lungs by comparison to most other mammals, and they typically exchange up to 85% of the air in the lungs at each breath (compared with the 15-20% exchange that occurs during normal breathing in humans). Most of the larger species produce a visible vaporous "blow" when they exhale at the surface. This blow forms mostly from instant condensation when the warm, moist air in the lungs is suddenly depressurized upon exhalation. The thick layer of blubber not only insulates them from the cold, it also aids in buoyancy because fat is lighter than water, and it is used as stored food during times of migration and fasting.

There are two basic types of whales, those which have no teeth and those which possess teeth. The toothless whales belong to the suborder Mysticeti, and include all the filter-feeding whales. These animals, including right whales and the rorqual whales, possess rows of horny baleen, or whalebone, which hang down vertically on both sides from the roof of the mouth. The inside edge of each plate has a frayed appearance of dense bristles, and the plates overlap one another so the frayed edges form a very efficient sieve. As the whale moves through the water it opens its huge jaws (most species also have expandable throats which increase the efficiency of this method of feeding) and takes a large quantity of water into the mouth. The water is squeezed out through between the baleen plates thereby trapping any small prey animals, such as krill, tiny schooling fishes, etc., inside the mouth. This food is then pushed back to the throat by the huge muscular tongue and swallowed. This process enables the baleen whales to take advantage of the almost limitless resource of krill and the secondary level of organisms near the base of the food chain. Different species of baleen whales have different sizes of baleen filter plates that allow them to coexist and yet feed on different prey. Baleen whales typically feed in the upper layers of water because the zooplankton which makes up most of their diet is dependent upon phytoplankton which in turn is dependent upon sunlight. Therefore, they are not normally deep divers like some of the toothed whales, and seldom dive to more than 90 m (300 ft) below the surface.

The Antarctic baleen whales live in an annual cycle of breeding in the warm waters of low latitudes in the winter, and feeding in the cold Antarctic waters in the summer. Baby baleen whales, especially the larger species, must undergo an accelerated rate of growth in order to be weaned at the feeding grounds in mid-summer. Cetacean milk has a high fat content and a thick consistency, which keeps it from mixing readily with sea water. This helps the baby whale avoid swallowing too much water when it nurses. The rich, highly nutritious milk understandably produces rapid weight gain and growth within the babies. The extreme example of this rapid growth is the blue whale whose offspring may gain weight at the rate of 4.5 kg (10 lbs) per hour, or 900 kg (1 ton) in 9 days.

Whales with teeth belong to the suborder Odontoceti, and include the dolphins, porpoises, beaked whales, killer whales, sperm whales, and others. These animals actively pursue motile and relatively large prey such as squids, fishes, birds, seals, and other whales. The toothed whales have developed very useful sonar (underwater echolocation) systems with which they can locate and capture prey or avoid obstacles and predators, even in dark or turbid waters. The echolocation system works by focusing sound waves (produced in the nasal passages) through an oil-filled lens, or melon, which is set in a cradle on the front of the skull. The reflected sound waves are thought to be sensed primarily through the lower jaw upon return and transmitted through fat to the ossicles of the inner ear. A rule of thumb is - the larger the melon, the better developed the sonar system, and the more time spent in deep (or turbid) waters. The following list includes those cetaceans that may be found south of the Antarctic Convergence:

1. Great right whale (*Balaena glacialis*)
2. Blue whale (*Balaenoptera musculus*)
3. Fin whale (*Balaenoptera physalus*)
4. Sei whale (*Balaenoptera borealis*)
5. Piked or Minke whale (*Balaenoptera acutorostrata*)
6. Humpback whale (Megaptera *novaeangliae*)
7. Southern fourtooth whale (*Berardius arnuxii*)
8. Southern bottlenose whale (*Hyperoodon planifrons*)

9. Great sperm whale (*Physeter macrocephalus*)
10. Killer whale (*Orcinus orca*)
11. Hourglass dolphin (*Lagenorhynchus cruciger*)
12. Piebald or Commerson's dolphin (*Cephalorhynchus commersonii*)

The great right whale is a very large whale found in the polar waters of both the Arctic and Antarctica. These two populations are completely separated, however, and never intermingle. Because it is a slow-moving species and its body is so rich in oil that it floats even after death, it was the "right" whale to hunt (hence the name). Both males and females average about 15 m (50 ft) in length, with a maximum of 18 m (60 ft), and average about 54,500 kg (60 tons) in weight, with a maximum of 96,000 kg (106 tons). The coloring is pure black with some mottling of brown, as well as white callosities above the eyes, near the tip of the snout and on the chin, and sometimes a white marking on the belly. Its body is very rotund, extremely broad, and smooth. There is no dorsal fin, which precludes it being mistaken for any other large whale in Antarctic waters. The right whale has two widely separated blowholes which produce a distinctive V-shaped double spout. The tail of this species, which is broad with very pointed tips and a deep notch, is usually raised above the surface when the animal dives. The head is very large, about 25% of the total body length, and there are no throat grooves. Therefore, the animal cannot expand its throat significantly when feeding, like most baleen whales. Instead, it has a narrow and highly arched upper jaw which holds baleen plates more than 2 m (7 ft) long. The right whale simply swims through the water with its mouth open and passively filters food items through its very long baleen plates as it moves along.

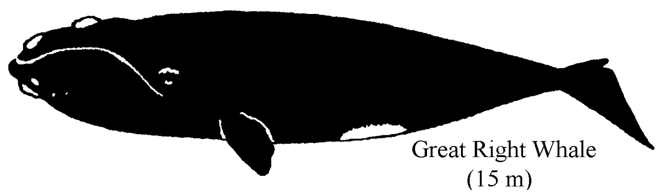


FIGURE 26. The slow-moving, heavy-bodied right whale is the only Antarctic whale without a dorsal fin.

All the rorqual whales share the characteristic of having many throat grooves, which allow the throat to be expanded when feeding. Unlike the right whales, they engulf a single, huge mouthful of water and then close their jaws and squeeze the water out through the short baleen plates. The advantage to this method is that when the throat area is constricted, they take on a surprisingly long and streamlined shape which allows some species to swim at speeds of over 16 knots. There are five species of rorqual whales found in Antarctic waters. Four of them, of the genus Balaenoptera, are closely related and differ primarily in size and coloration. Even so, it takes a trained eye to identify them when they are encountered at sea. It is interesting to note that among almost all the rorqual whales, the females grow to a slightly larger size than the males.

The blue whale is the largest of the rorqual whales, and is in fact the largest of all the living cetaceans. It averages 25 m (82 ft) in length, but several individuals longer than 30 m (100 ft) have been captured by whalers. The normal range of weight varies between 80,000 and 130,000 kg (90-144 tons), but the maximum recorded weight was 178,000 kg (196 tons). Because of the animal's speed and sleek grace it is easy to underestimate its size. The color is hard to evaluate unless one is fairly close, but is marine blue-gray, mottled with small spots of white or light gray. It has a tiny triangular dorsal fin which becomes exposed long after the blow, and often the flukes are exposed as the animal dives. The rostrum is broad and flat with a single prominent ridge running lengthwise down the center. Its blow is typical of all the species in this genus, a high powerful thin column, but it is comparatively bigger than all others. In Antarctic waters, blue whales feed almost entirely upon krill, and a large whale may eat 4,000 kg (over 4 tons) of these tiny animals in a day (this amounts to about 4 million krill). The krill season lasts about 120 days, after which the whales basically fast until the next Antarctic krill season.

The fin whale is the second largest cetacean, with lengths averaging around 21 m (70 ft) and a maximum of 27 m (89 ft). The weight varies from 35,000 to 45,000 kg (40-50 tons) with a maximum of 69,500 kg (76 tons). It is relatively easy to identify since it is a very large species and has a large falcate dorsal fin (hence the name) which quickly separates it from the blue whale. The fin whale is unique among the rorqual whales in that it is counter-shaded like an aggressive predator, that is, a black or dark brown back and a white or light-colored underside. However, a close look will show that the fin whale's coloration is somewhat asymmetrical, especially in the head region…the lower right lip is white and the lower left lip is dark. The fin whale is probably the fastest swimmer of the great whales, and is a generalist feeder meaning it eats not only krill, but also various schooling fishes such as sardines, anchovies, capelin, and pollack, as well as squids and many other small species of animals which form dense groupings. Because much of its food consists of fast and relatively intelligent prey, it needs the predatory counter shading to help surprise and confuse its prey, and it needs speed to overtake it. As a fin whale feeds it often rolls over onto its right side and arches its back and swims in a tight circle, which actually increases the speed experienced at the mouth region. When the animal rolls onto its right side the countershading about the head is dark on top and light underneath, precisely what is needed for a predatory lifestyle.

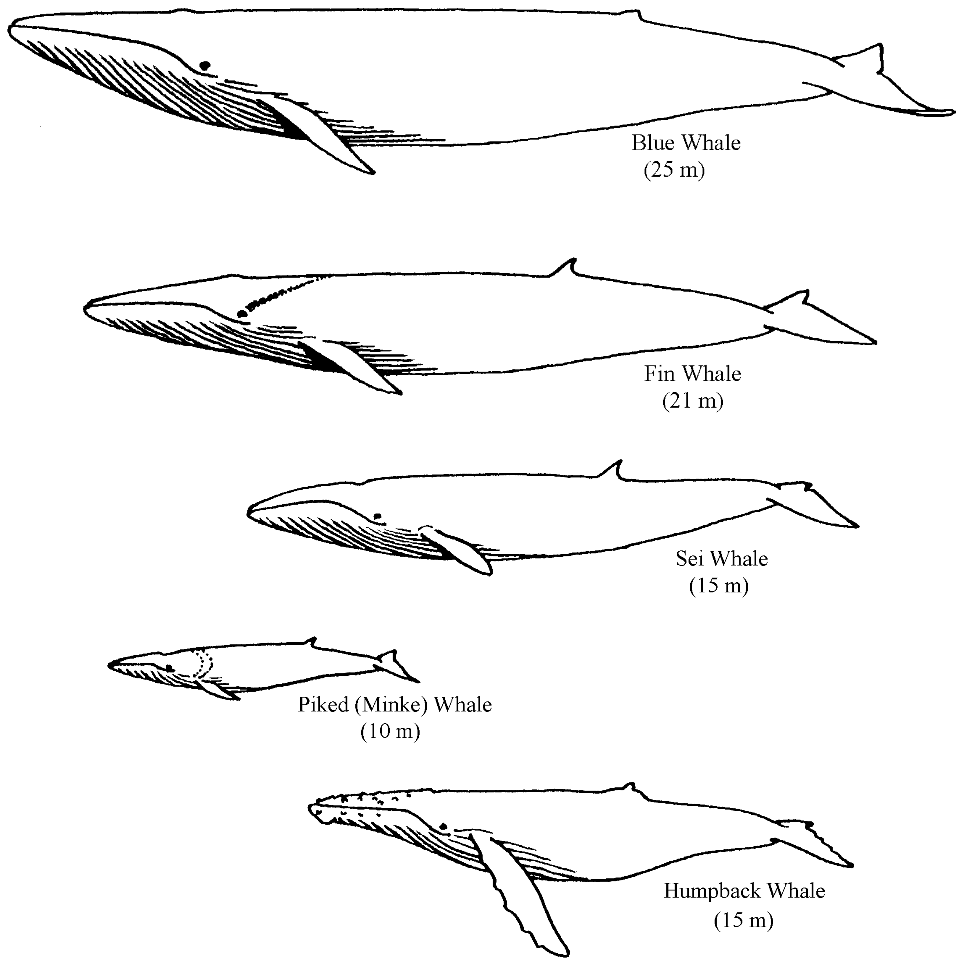


FIGURE 27. The rorqual whales of Antarctica all have expandable throats to aid in feeding.

The sei whale generally avoids the coldest waters closest to the ice, so it is rarely seen near the continent. This species is quite large, averaging about 15 m (50 ft) in length with a maximum of 20 m (66 ft), and 12,000 to 15,000 kg (14-17 tons) in weight with a maximum of 29,000 kg (32 tons). The coloration is mostly dark, steely gray, but with a lighter throat and belly. There are usually light mottlings on the flanks and belly. It has a high, vertical dorsal fin, rather like that of the fin whale, but it does not arch its back high out of the water like the fin whale when at the surface. The sei whale is a generalist feeder, specializing in planktonic crustaceans, but will also eat small schooling fishes when the opportunity presents itself. It is interesting to note that this species often rolls onto its side when feeding, like the fin whale, but will roll first onto one side and then the other side continuously. It does not have asymmetrical coloration like the fin whale.

The piked, or Minke, whale is the smallest rorqual whale. It averages about 8 m (26 ft) in length with a maximum of 10 m (33 ft), and 5,800 to 7,250 kg (6-8 tons) in weight with a maximum of 9,000 kg (10 tons). The rostrum is very distinctive in that it is narrow and very pointed, which is what gives the species one of its common names, e.g. piked. The coloration is dark blue-gray above and light gray underneath, and there are usually two pale bracket marks above the flipper extending across the back. In most populations there is a diagnostic bright white patch on each flipper. It has a relatively large, high dorsal fin located far back on the body. The piked whale does not always produce a distinctive high spout, because it often begins to exhale before it breaks surface. It often leaps clear of the water, usually two or three times in succession, and has the peculiar habit, for a baleen whale anyway, of approaching boats. This species is a very fast swimmer, and in places where krill are not readily available it often eats small schooling fishes and squids. It tends to be a rambunctious feeder with a lot of leaping and splashing accompanying what may almost be described as a feeding frenzy. Piked whales seem to be enjoying a population growth in Antarctic waters since the near eradication of the blue whales, because they have taken advantage of the increased food resource (krill).

The humpback whale is the only rorqual whale not in the genus Balaenoptera. It has the same general life history as the aforementioned rorquals, but does not have the same long and sleek body shape. The humpback whale is comparatively more broad and massive, and averages about 15 m (50 ft) in length with a maximum of 19 m (62 ft), and weighs about 30,000 to 40,000 kg (34-45 tons) with a maximum of 48,000 kg (53 tons). The body characteristics and behavior make this the easiest great whale to identify. Its coloration is basically black or dark gray with a white throat area. The ventral surface of the tail is also usually white, as well as most of the flippers (which are nearly one third the length of the body). The humpback whale's broad bushy spout is distinctive, as is its dorsal fin which is small, but mounted on a fleshy hump. It often leaps completely out of the water to land on its back in a tremendous splash. Besides breaching, the humpback whale waves and slaps its enormous flippers upon the surface of the water to make a loud sound rather like a gun shot, and almost always exposes its great tail when it dives. This species is amazingly acrobatic and energetic, and never fails to create excitement among its observers. In Antarctic waters, the humpback whale feeds primarily upon krill and other planktonic crustaceans, but in other areas they sometimes feed upon small schooling fishes. The normal feeding method is to lunge forward near the surface, but on occasion it may swim in a tight circle below its prey and blow a continuous stream of bubbles, which has the effect of corralling the prey into a concentrated mass, and then swimming straight up through the mass with its mouth open. Humpback whales are famous for producing the longest and most varied songs in the animal kingdom, and much research has been done in recent years upon these songs.

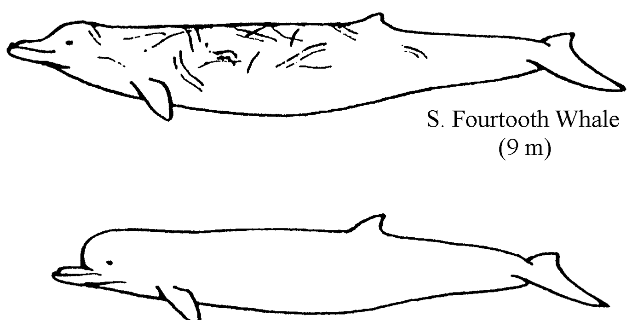


FIGURE 28. These are the largest and most commonly seen beaked whales in Antarctica.

There are two beaked whales found in Antarctic waters. The southern fourtooth whale, also known as Arnoux's beaked whale, averages about 9 m (30 ft) in length and 6,400 kg (7 tons) in weight. It is blue-gray (sometimes with a brownish tint) in color, and has a bulbous forehead, or melon, with a pronounced beak. The lower jaw extends beyond the upper, revealing the foremost pair of teeth. As the name suggests, this species only has two pairs of teeth, and they are all in the lower jaw. There are two grooves on the throat which nearly intersect beneath the chin to form a "V". The flippers are broad and rounded, the dorsal fin is small and triangular in shape and set far back, and the flukes are large and pointed with little or no notch between them. Both males and females usually bear numerous pale scars on their backs and flanks, caused by the teeth of others of their kind, presumably during mating conflicts. This species is very uncommon, and little is known of its life history. It is presumed squids make up the majority of its diet since squid beaks have been recovered from the stomachs of stranded specimens.

The other beaked whale, the southern bottlenose whale, is somewhat smaller with an average length of 7.6 m (25 ft) for males and 6.7 m (22 ft) for females, and an average weight of 3,600 kg (3 tons). The body is rather cylindrical in the fore section but tapers off into an elongated tail section, and it has an enormous melon which is evidence of its deep-diving ability. The tail is very broad with pointed tips and lacks a notch between the flukes. The coloring is usually deep metallic gray shading to blue on the flanks, but may also be slightly brownish. The melon, back, flippers, and flukes are dark, but the throat and belly are pale. The dorsal fin is sickle-shaped and placed far back on the body. The southern bottlenose whale has only one pair of small teeth located at the tip of the lower jaw. Stomach analyses show that this species feeds almost exclusively on squids. It is a rarely seen species, and most studies have been restricted to dead specimens that have washed up upon beaches.

The great sperm whale is by far the largest of all the toothed whales. Males average 15 m (50 ft) in length and 36,000 kg (40 tons) in weight, and the much smaller females average 11 m (36 ft) in length and 20,000 kg (22 tons) in weight. In the past, individual sperm whale bulls often grew to 20 m (65 ft) or more. The profile of this species is unmistakable, because the enormous squared head makes up one third of the total body length, and considerably more than one third of its mass. The lower jaw is very long and narrow, and actually rather puny compared to the overall size of the head. There is no true dorsal fin, but most animals have a series of knobs or lumps on their back with the front one being the largest. Much of the body surface is covered with crenellations giving it the appearance that its body has shrunk within its skin. The normal coloration is dark gray or brownish (pure white specimens like the mythical Moby Dick have actually been taken by whalers on occasion).

Unlike all other cetaceans, the blowhole of the sperm whale is at the foremost upper point of the snout and left of center. The blow is diagnostic because it shoots out in a forward direction and off to port. One can not only easily identify the whale from its blow, but can also tell which direction the animal is swimming. The flippers are short and stubby, and the tail is very strong and somewhat square-shaped (this species usually makes a steep dive when it leaves the surface and exposes its tail in the air). Sperm whales feed primarily on squids, including giant deep sea species, but also prey on skates, sharks, and a variety of large fishes. Judging from the huge development of the melon, or case, it is not surprising to learn this species is the champion diver of the cetaceans. Dives have been documented to a depth of 2,250 m (7,400 ft), but indirect evidence suggests they can dive much deeper than that. Specimens have been clocked underwater for more than an hour. Solitary males migrate long distances, ranging from equatorial waters in the winter right up to the edge of Antarctic ice in the summer. The females and young generally stay closer to the tropical waters throughout the year, and are not seen in Antarctic waters.

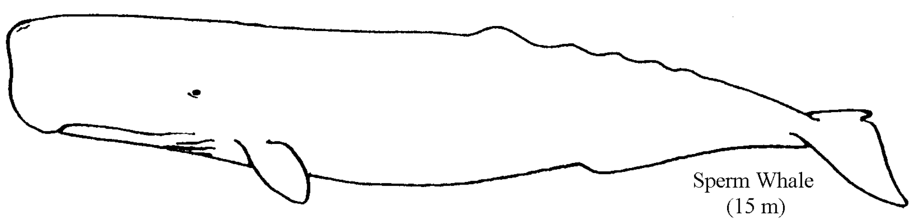


FIGURE 29. Male sperm whales, the largest of the toothed whales, range south all the way to the ice edge.

The killer whale is probably the most easily recognized of all cetaceans. It is a medium-sized whale averaging 8 m (27 ft) in length for males and 7 m (23 ft) for females. Killer whales are heavy-bodied animals and average 700 kg/m for males, with a maximum of 7,200 kg (8 tons), and 500 kg/m for females. The coloration is very striking with most of the body a glossy black, except for a highly contrasted bright white belly, white process on the flank, and a white patch just behind the eye. This black and white countershading seems to be very common among marine predators. There is also a faint gray saddle mark behind the dorsal fin. The flippers are very large and rounded, and the most diagnostic characteristic is the enormous dorsal fin grown by adult males which is the longer and more pointed than that of any other cetacean. In older males it grows erect and may measure 2 m (6 ft) in height, while in females and immature males it is curved and shark-like.

Killer whales normally travel in pods made up of 5 to 20 individuals, usually an extended family. These groups are very cohesive and exhibit a high degree of cooperation in hunting prey and caring for one another. They are highly predaceous and feed on a large variety of prey, including squids, sharks, rays, fishes, sea birds, seals, and even other whales. They seem to especially favor warm-blooded prey. Most prey animals are swallowed whole if small, or torn into smaller bite-sized pieces by the individuals which captured them, but there are accounts of large whales being attacked by groups of killer whales (rather like a moose being attacked by wolves) whereby all members of the pod shared in a mass feeding. They will also work together to capture prey that just one individual will get to eat…a strategy that certainly benefits all members of the pod in the long run.

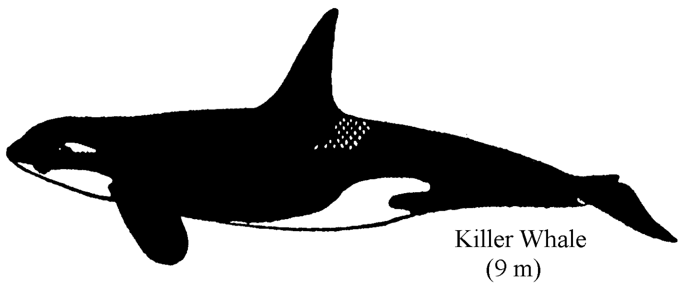


FIGURE 30. The killer whale is probably the most recognizable, beloved, and sought-after of the Antarctic whales.

There are two small dolphins which are sometimes encountered within the Antarctic Convergence. The hourglass dolphin can be found all the way to the edge of the ice pack, whereas the piebald, or Commerson's, dolphin can be found at Kerguelen and South Georgia Islands. Both species are highly contrasted with black and white markings. The hourglass dolphin averages 1.6 m (5.5 ft) in length and 100 kg (220 lb) in weight. It frequently leaps out of the water and likes to bowride ships, which makes identification very easy. The color pattern is unique: the animal is black, except for a white belly and an irregular white longitudinal stripe on each side which is wide in the head region, narrow in mid-body, and wide in the tail section (rather like an hourglass). It has a large shark-like dorsal fin, and has a typical dolphin body shape. The hourglass dolphin is a very fast swimmer, and can easily overtake ships moving at 25 kph (12 knots) when it wants to bowride. Little is known about the life history of this species, but it seems to be fairly common in cold southern waters, and feeds mainly on fishes and squids. The piebald dolphin is a thick-bodied little animal which averages 1.35 m (4.5 ft) in length and 50 kg (110 lb) in weight. Its body is more porpoise-shaped than that of typical dolphins, and it has a broad flat head, small rounded flippers, and a low rounded dorsal fin. The head, flippers, dorsal fin, tail stock, flukes, and vent area are black, but draped across the back in front of the dorsal fin is a white cape which wraps all the way around the belly. The chin is white, also. On close inspection the animal may not actually be black and white, but very dark gray and very light gray. They are usually found in shallow areas near land masses, including isolated islands. They sometimes jump clear of the water, but most often just roll at the surface.

FIGURE 31. Only two, small dolphins commonly range into Antarctic waters.

THE HISTORY OF ANTARCTIC EXPLORATION

The early Greek geographers knew the Earth was a sphere, and they reasoned there must be a large land mass covering the southern half of the globe to balance the known lands of the northern half. They named this yet undiscovered land mass *Terra Australis Incognita* (Unknown Southern Continent). Many centuries later, the renaissance geographers revived the legend of the great southern land mass. It is interesting to note that this situation reversed the traditions of exploration, because the charts all showed an enormous continent in the southern reaches of the globe, and over time the explorers discovered it to be not there. Each exploration pushed the imagined coastline farther south, from the tropics to the temperate region to the pack ice, and beyond.

The Age of Exploration (1492-1800): The end of the 15th century was the beginning of the Golden Age of Exploration not only for *Terra Australis Incognita*, but for the whole Earth. Apart from some Irish monks and Vikings of the first millennium A.D. who made discoveries in the north Atlantic region, it was Christopher Columbus who is given credit for making the European discovery of the New World. Columbus, a Genoese sailing on behalf of Spain, was trying to reach the Spice Islands of the Land of Ind (the modern-day East Indies) when he encountered the New World in 1492. Vasco De Gama (Portuguese) sailed south from Europe down the western coast of Africa and rounded the Cape of Good Hope in 1497. He then continued northward along the eastern coast of Africa to Mozambique and finally across to India, and proved Africa was not part of *Terra Australis Incognita*. Twenty three years later, in 1520, Ferdinand Magellan (Portuguese) explored the coastline of South America and discovered and sailed through a long winding channel at the tip of the continent which took him from the Atlantic Ocean to the Pacific Ocean. The southern shore of this channel was thought to be the coastline of *Terra Australis Incognita*, now referred to simply as Terra Australis since sections of its coastline were supposedly being identified. In 1578, Francis Drake (English) found the channel discovered by Magellan and proved it only separated an island, Tierra del Fuego, from the mainland of South America, and it was not part of the great southern continent. In 1599, more than a century after the discovery of the New World, Dirk Gerritsz (Dutch) was rounding Cape Horn and was blown off course by a storm. He reported seeing ice covered mountains some 500 km (300 mi) from South America, which were undoubtedly the South Shetland Islands. A few years later, in 1606, Dutch explorers believed they had finally found Terra Australis in the eastern Indian and Pacific Oceans. In 1642, Abel Tasman (Dutch) proved what they found was actually an immense island, now continent, known as Australia, but in the process Tasman discovered the western coastline of New Zealand and felt he had truly found the Southern Continent.

James Cook (English) was the most important early explorer with regards to Terra Australis, because he essentially proved where it was not. During his first voyage of discovery (1768-1772) on board the famous *ENDEAVOUR*, he isolated New Zealand as simply a pair of islands, and removed Terra Australis once and for all time from tropical and temperate latitudes. In 1772, Jacques Kerguelen-Tremarec (French) discovered and described a green fertile shoreline and named the land ‘South France’. It was believed to be the elusive continent. He returned the following year with settlers and domestic animals only to find it was actually a dreary island in a very cold ocean (it is now called Kerguelen Island). During Cook's second voyage (1772-1775), he circumnavigated the still unknown Antarctic continent. He became the first person to cross the Antarctic Circle (near Kerguelen island) and went on to explore the southwestern Pacific Ocean at a high latitude, crossing the circle again near Thurston Island (off Lesser Antarctica). Here he entered pack ice and continued south to the latitude 71° 10' S in what is now the Bellingshausen Sea, but he found no continent. Unfortunately, this was the only region where he could go so far south and not get close enough to the continent for discovery. In reference to the still unknown Terra Australis, Cook wrote that no one would probably ever go farther south than he had just been, but if so he would not envy him the fame of any discovery. He also felt the world would never derive any benefit from a continent that far south. Cook had discovered on this voyage the South Sandwich Islands and South Georgia Island, but his most important discovery was the wealth of fur seals and seals in the Southern Hemisphere. His reports of these huge populations of valuable fur-bearing animals spurred the next era of exploration in the Antarctic area.

Age of Discovery (1800-1900): Within a few years, sealers had become the explorers of the far south. In fact, it was the ever-increasing search for fur seals that eventually led to the discovery of Terra Australis. Within a few short years of the discovery of their breeding colonies on South Georgia in the late 18th century, there were 30 sealing vessels of American, British, and Russian origin taking more than one million skins a year. By 1800, the sealers had virtually wiped out all the fur seals of South Georgia, Kerguelen Island, and Heard Island. Searching ever farther south from their bases in New Zealand, sealers discovered and exploited the fur seals of the Antipode Islands in 1800, the Aukland Islands in 1806, and Campbell and Macquarie islands in 1810. Using South Georgia Island as a base, other sealers discovered and quickly exploited the animals of the South Sandwich and South Shetland Islands. As each new island was discovered and found to harbor fur seal colonies, they were usually wiped out within a few short seasons. For instance, the South Shetland Islands were discovered by William Smith in 1819 (who at the time was blown off course by a storm). News of his discovery brought more than 40 ships to harvest fur seal skins and oil from those islands the following season of 1820/1821. During the next season (1821/1822) there were more than 90 ships working the islands. By the end of the 3rd year after the islands' discovery, more than 320,000 fur seal skins and 940 tons of oil had been taken in the South Shetland Islands, and for all practical purposes the fur seal populations had been worked out.

The continent of Antarctica was officially discovered in 1820. The honor of who first sighted the continent, however, is still in some dispute. Ironically, none of the three men involved in the controversy realized at the time of his discovery he had actually sighted the Antarctic continent. In that momentous year, Thaddeus von Bellingshausen, during a Russian discovery expedition, possibly sighted the continent on January 27, 1820. Over the course of two summers he became the second man to circumnavigate Antarctica, and did it considerably farther south than Cook's route. Edward Bransfield, of the British Royal Navy, was sent to examine the South Shetland Islands in late 1819, and he sighted the Antarctic Peninsula on January 30, 1820. Nathaniel Palmer, a young American sealing captain working from the South Shetland Islands, also sighted the coast of the Antarctic Peninsula sometime that same year, but probably much later than Bransfield (Palmer went on to discover the South Orkney Islands in 1821). At this time, there may have been numerous small sealing boats exploring the region of the South Shetland Islands and the Antarctic Peninsula, and it was common for captains to keep their finds secret in order to protect their fur interests. Therefore, many discoveries never made it to public notice during these years.

On February 7, 1821, John Davis (an American sealer) became the first person to actually set foot upon the Antarctic continent when he landed in Hugh's Bay on the peninsula. It is interesting to note that at the time of his achievement he stated he believed the southern shore he landed on was a continent (it was not until the following decade that suspicion grew among geographers and scientists that the long-sought Southern Continent had indeed been found). James Weddell (British) conducted a voyage of discovery in 1822, working from the South Orkney Islands, and his expedition sailed to 74° 15' S in the Weddell Sea...the farthest south any man had ever been. Unlike today, there was very little ice there at that time. He found no new sealing grounds, but did discover a new species of seal which was later named after him.

John Biscoe, of the British Royal Navy, continued the search for new sealing grounds east of the South Sandwich Islands with two ships in 1830. He then sailed south to discover Enderby Land on the Antarctic mainland (in the Indian Ocean sector), but bad weather and ice conditions prevented him from landing. His expedition also discovered Adelaide Island, the Biscoe Islands, and more continental coastline. The return home was disastrous in that continued bad weather and disease took a very heavy toll on Biscoe's party. The last major expedition sent to search for new sealing grounds was made in 1838 by John Balleny (British). Although he discovered the islands that bear his name, and the Sabrina Coast of Antarctica, he returned from the expedition with only 178 seal skins. The sealing bonanza was over. Oil hunting had become very profitable, however, and ships' crews rendered elephant seals, several species of whales, and even king penguins into valuable oil. Fur seals had recovered some of their populations by the 1870s in the South Shetland and South Sandwich Islands, but when this was discovered they were quickly exterminated. The oiling gangs continued well into this century.

At this stage, numerous scientific expeditions and surveys were organized, primarily by the British, Americans, and French. There were two such expeditions in 1840. Jules Dumont d'Urville discovered a bare rocky shore directly south from Australia and named it Adelie Land after his wife, which turned out to be part of Greater Antarctica. He also made important measurements of the Earth's magnetic field in these southern waters, and he remapped the South Shetland Islands and some sections of the Antarctic Peninsula. Charles Wilkes led the first American expedition to the Antarctic, and he was the first important investigator to insist Antarctica was a continent rather than just endless ice packs and scattered islands. His initial attempt to explore the Antarctic region actually began in 1839 in the Weddell Sea, but had to be canceled because of leaking ships. He returned in 1840 to do studies on magnetism (and to possibly set up some American claims). He had sailed deep into the pack ice trying to find the South Magnetic Pole, or at least estimate its location, when he found a very long coastline that he followed for 3,240 km (1,944 mi). This proved the existence, beyond any doubt, of the Antarctic continent. His expedition was ill-prepared and wrought with problems. He originally set off with six ships (most of questionable seaworthiness) and returned with only two, and he had on-going disputes and personal conflicts with some of his officers. He was court martialled upon his return, but was eventually cleared of any wrong doing and spent the next 12 years writing the official reports of the expedition.

In 1841, James Clark Ross, of the British Royal Navy, was appointed to lead a national expedition to Antarctica. At this time he was already known as the most experienced captain in the Arctic region, because in 1827 he had made an unsuccessful attempt to reach the North Pole, and 4 years later succeeded in locating the North Magnetic Pole with his uncle, Sir John Ross. His main quest now was finding the South Magnetic Pole, but like Wilkes, he was unsuccessful. However, after learning of Wilkes great discovery he changed his course and ended up finding the most accessible part of Greater Antarctica in what is today called the Ross Sea. This allowed him to reach the farthest point south for anyone to that day, 78° 09' S. He named the coastline, with its majestic mountains, Victoria Land. His expedition accomplished much in the way of scientific discoveries, and he reported upon the vast numbers of whales encountered during his voyage which understandably created great interest.

At the other end of the globe, the British Royal Navy was about to make its final attempt to find a Northwest

Passage. The search for a route from Europe to the Orient across the top of North America had endured for centuries, because finding such a passage would mean merchant ships could avoid the long and dangerous journey down around the tip of South America. Sir John Franklin, the famous Arctic explorer, was chosen to lead the expedition, and he set off in 1845 amidst much notoriety and fanfare. Franklin and all his men were lost, and the next 12 years saw no fewer than nine expeditions sent out as rescue missions. Although Franklin was never found, the ensuing rescue attempts accomplished much discovery and charting of the islands in the Canadian Archipelago, and indicated a passage did indeed exist. All this took precedence over Antarctic explorations and the Southern Ocean was left to the whalers.

Half a century after the celebrated Ross voyage of discovery to the Antarctic, the Belgians sent out an expedition lasting from 1897 to 1899 in order to chart new lands along the western side of the Antarctic Peninsula. It was captained by Baron Adrian Victor Gerlache de Gomery, and was the first fully scientific expedition as well as the first group to spend a full winter so far south when their ship, the *BELGICA*, was trapped in the ice in the Bellingshausen Sea.

Carsten Borchgrevink (Norwegian-British) organized an expedition in 1898 in which he and his small party became the first men to spend a winter on the Antarctic continent. They built a small hut at Cape Adare for their base, and made the first sledge journey on the Ross Ice Shelf. Three years earlier, in 1895, Borchgrevink had been a deckhand on a whaling ship and became the first man to land on Greater Antarctica when his ship put in at Cape Adare.

<u>The Heroic Age (1900-1916)</u>: This period was characterized by great triumphs and tragedies, and was the beginning of the privately funded scientific investigations in the Antarctic. In 1901, Robert Falcon Scott (British Royal Navy) built a hut in McMurdo Sound, and spent the winter doing scientific research and testing different methods of exploration. Scott, with two comrades, Edward "Bill" Wilson and Ernest Shackleton, made a trek towards the South Pole using dogs to pull their sledges. They reached 82° S, but had problems with not only their dogs, but scurvy and snow blindness as well, and had to turn back only to suffer greater hardships on their return. Shackleton contracted a severe case of scurvy on this trek and was sent home on a relief ship by Scott (this started a long feud between them, and Shackleton vowed to return). Scott did not like or trust dogs, and felt they required too much food to be useful on long distance travels, and decided that man-hauling was the most reliable method. The remnants of Scott's party remained at McMurdo for another winter.

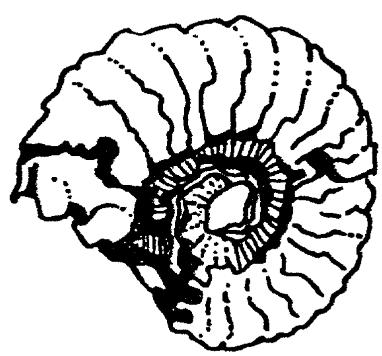


FIGURE 32. A Cretaceous ammonite fossil species discovered by Nordenskjold on Snow Hill Island.

Otto Nordenskjold (Swedish) led a national scientific expedition to the Weddell Sea in 1901, but his ship, the *ANTARCTIC*, could not penetrate the ice. He then decided to go ashore at Snow Hill Island and spend the winter mapping the Antarctic Peninsula. Captain Carl Larsen (Norwegian) then took the ship to the Falkland Islands to wait out the winter before returning the following summer to pick up Nordenskjold. The pickup was unsuccessful on the first try because of heavy pack ice. Larsen then sailed to Hope Bay and dropped off three men who were to hike across to Snow Hill and bring Nordenskjold's party back to Hope Bay if Larsen could not reach Snow Hill on his second attempt. Unfortunately, on the second attempt the *ANTARCTIC* was trapped in the ice and drifted with the pack ice for several weeks before being crushed. The three men left at Hope Bay became trapped by bad weather, and could not reach Snow Hill (they assumed Larsen would soon return for them). After the *ANTARCTIC* was lost, Larsen and his crew lived on the ice for several weeks until the ice broke apart enough for them to launch their salvaged lifeboat. They eventually made it to Paulet Island, where they killed 1,100 penguins and several seals in preparation to spend the coming winter there. In the meantime, the three men at Hope Bay made similar preparations, as did Nordenskjold's group back at Snow Hill. None of the three separated groups knew what had become of the other two. When the *ANTARCTIC* failed to return to its base, three rescue attempts were made in the summer of 1903. The first two failed, but Captain Irizar (Argentine) of the *URUGUAY* was successful in finally reaching Snow Hill on November 3, 1903. Nordenskjold had come across the three men of Hope Bay while he was out on a mapping trip, and returned with them to Snow Hill the same day that the *URUGUAY* arrived. Larsen's group first went to Hope Bay with the coming of summer and found a note left there by the three men stating they had gone to Snow Hill. They then headed for Snow Hill and in an incredible coincidence arrived there the very same day as the *URUGUAY* and the three men from Hope Bay. The scientific results from this whole ordeal proved to be very important, despite the major problems that had plagued the expedition.

Jean-Baptiste Charcot (French) had organized a national expedition in 1903, and was preparing to help rescue Nordenskjold when he heard of the rescue by Captain Irizar. He had decided to make a career of polar explorations, and was often referred to as the "polar gentleman". On this, his first voyage to Antarctica, he carefully charted the Antarctic Peninsula and his work was of great importance to sailors for the next 40 years. Charcot returned in 1908 in the most modern polar ship to date, the POURQUOI-PAS?, and used it to test a lot of new equipment such as electric lamps, anti- snowblindness goggles, a De Dion-Pouton motor boat, and different types of clothing. He was known as a very humane man, and he was the first scientist to point out the dangers of over-harvesting the whales. He conducted considerable research in hydrography, geology, botany, and zoology.

The two great quests of Antarctica- the South Pole and the South Magnetic Pole- still had not yet been achieved. Ernest Shackleton returned in 1907, this time in command of his own expedition. He hoped to take both prizes. Base camp was set up in McMurdo Sound, and acting upon Scott's earlier polar experiments, he had decided to use Siberian ponies, instead of dogs, to haul sledges across the Ross Ice Shelf and up to the polar plateau. There were two major drawbacks, however, to the use of Siberian ponies. First, they could not eat the same food as humans (as dogs could), and second, they were not nearly as hardy as Shackleton had hoped. All but four ponies had died before the actual trek to the pole had even started in October 1908, and the survivors only lived another one and a half months (one fell in a crevasse with a large portion of their supplies). Shackleton's polar party was reduced to man-hauling the sledges, and they needed to cover about 24 km/day (15 mi/day) in order to make the 2,768 km (1716 mi) round-trip to the South Pole. They endured very difficult conditions, including extremely low temperatures, blizzards, frostbite, low rations, and painful snowblindness. On January 9th, at 88° 23' S., Shackleton was forced to turn back in order to avoid running out of supplies. They had come within 133 km (83 mi) of the pole. Shackleton's second-in- command, Edgeworth David (British), in the meantime had led a successful trek to locate the South Magnetic Pole.

Roald Amundsen (Norwegian) had long planned to be the first man to the North Pole. He had already led three expeditions to the Arctic and had organized another which was to begin in early 1910, but four months before it started the world was informed that both Robert Peary and Frederick Cook claimed to have already reached the North Pole. Amundsen changed his plans and decided to be the first person to the South Pole instead. Robert Scott had already announced he was leading another expedition to Antarctica and would attempt to reach the South Pole, so Amundsen kept his plans secret. On his way south he felt obligated to inform his backers, as well as Scott. The race was on, although Scott refused to allow Amundsen to force a change in his plans. Amundsen set his Antarctic camp at the Bay of Whales, which put his starting point 97 km (60 mi) nearer the pole than Scott's base at McMurdo Sound. He believed strongly in dogs because they had proved themselves time and again on his journeys in the Arctic, and he was an accomplished dog handler. The trip to the pole was carefully and methodically planned to the last detail. To avoid having to take too much supplies, efficiency was heightened by killing some of the dogs at prearranged times to provide food for the others. This process assured him his success in the project, but brought him almost universal condemnation afterwards. He reached the pole on December 14, 1911, and to his relief, there was no sign of Scott. Amundsen had become the first man to reach the South Pole. He and his four companions set up a small tent at the pole, and left a letter for Scott to retrieve and send to King Haakon of Norway, just in case they did not make it back to their base camp. The entire round-trip to the South Pole went like clockwork, and took 99 days.

Robert Scott returned to Antarctica in early 1911, and constructed a base at Cape Evens on Ross Island. He then used the next nine months to conduct scientific research and prepare for the upcoming trek to the pole. In the middle of winter, Dr. Bill Wilson, an ornithologist at heart, and two companions made a trek to Cape Crozier on the other side of the island in an attempt to collect emperor penguin eggs for scientific research. They managed to collect six eggs, but broke three of them on their return to camp. This mission later became famous as The Worst Journey in the World, as told by Apsley Cherry-Garrard. On October 23, Scott received word that Amundsen had left his base camp for his attempt to reach the pole. Scott was still a week away from his planned departure, his animals had gone off their feed, and his party had suffered several accidents and illnesses. The plan was to use dogs, ponies, and motorized vehicles to transport supplies and set up depots as far as the Beardsmore Glacier, and then man-haul the remaining supplies to the polar plateau and continue setting up depots. Unfortunately, the ponies and vehicles gave out long before they reached the glacier. They experienced dismal weather along the way, and the entire group was stopped for four days. The last support party was sent back to base 240 km (150 mi) from the pole, and Scott and his four companions reached the South Pole January 17, 1912. Disappointed to find Amundsen had already been there before them, they collected the letter he left for them and started back on their 1,280 km (800 mi) return trip. They spent the next two months struggling from one depot to the next, and again were plagued by bad weather. Edgar Evens died one month into their journey back, and Lawrence "Titus" Oates died a month later (he walked off into a blizzard so as not to hold up his companions). The remaining three, Scott, Wilson, and Henry "Birdie" Bowers became trapped by a blizzard on March 21, only 18 km (11 mi) from a supply depot, and eventually froze to death. A search party found their bodies eight months later and buried them, tent and all, where they lay on the Ross Ice Shelf.

Douglas Mawson, an indomitable Australian who had accompanied Edgeworth David to the South Magnetic Pole on Shackleton's 1907 expedition, met with Scott in 1910 in order to convince him to include a side expedition to George V Land in his already ambitious program set for 1911. Scott refused, but wanted Mawson to accompany him anyway. Mawson discussed the situation with Shackleton who eventually convinced him to lead his own expedition. Mawson took that advice and landed his party at Cape Denison in Commonwealth Bay about the same time Scott reached the South Pole (January, 1912). The expedition was divided into two groups- Mawson and the Eastern Party remained in King George V Land, and the Western Party was landed at Queen Mary Land 2,410 km (1,500 mi) down the coast. Unfortunately, Cape Denison lies in the most violent wind corridor on Earth. The nearly constant gale force winds caused considerable problems with almost every project attempted, but in November the weather relented enough to allow the Eastern Party to break into five groups and go off in different directions to accomplish some very important geographical and scientific work. Mawson led the Far Eastern trek which was to become one of the great survival stories of Antarctica. He and two companions, Dr. Xavier Mertz and B.E.S. "Cherub" Ninnis, crossed the treacherous Mertz and Ninnis Glaciers with their dog sledges and after a month's time had gone about 500 km (310 mi). On December 13, 1912, Mertz was in the front of their line and Ninnis brought up the rear with the heaviest and most important sledge. Suddenly, Ninnis disappeared down a crevasse with his sledge, team of dogs, most of their food, all the dog food, the tent, and their spare clothing. The two survivors now had to race back to Cape Denison before they starved or froze to death. Unfortunately, they had set no depots for their return trip because they had planned to return by a different route. They threw out all the nonessential items to reduce weight, and killed the weakest of the six remaining dogs for food. This procedure was repeated over the next 10 days until the last dog collapsed. Two weeks later Mertz died. Mawson continued on, but was suffering terribly--his toes had turned black and began festering, his toe nails fell out, the soles of his feet separated from his feet and he had to bandage the thick skin back on, his fingers were festering, his hair was falling out, and his body was covered with raw sores. We know now that he was suffering from hyper-vitamin A poisoning, caused by eating the livers of the dogs. Mawson cut the sledge in half and hauled it the last 170 km (105 mi) back to camp. During this time he fell into a crevasse, but the sledge stuck and left him dangling on a rope. He barely managed to pull himself out. As he neared the camp he found a cairn of food set out by search parties, but just a short distance from the camp he was trapped in an ice cave for a week by a blizzard. He finally reached the base camp, just in time to see his ship, the *AURORA*, disappearing on the horizon. Six men had volunteered to stay behind in hopes Mawson's party would return, and they managed to contact the ship with news of his arrival. The ship tried to return to shore, but the ice conditions prevented it. Mawson and his six companions had to spend another winter at Cape Denison, and the *AURORA* returned to pick them up on Christmas Eve, 1913. He arrived back home to Australia more than two years after the expedition had begun.

Ernest Shackleton had failed in his attempt to be the first man to the South Pole, but he found another goal-to be the first man to lead an expedition clear across Antarctica. The plan was to take two parties in two ships and land them on opposite sides of Antarctica. Shackleton would land in the Weddell Sea and lead six men on a walk 2,900 km (1,800 mi) across the continent, via the South Pole. The other group would land in the Ross Sea and link up with Shackleton's group at the top of the Beardsmore Glacier in order to resupply them and escort them to the Ross Sea base. Just before their departure date in August 1914, however, there was an order for general mobilization to prepare for war. Shackleton offered up his ships, crews, and stores to the British Admiralty, but was wired by Winston Churchill to proceed with the expedition. Shackleton, onboard the *ENDURANCE*, entered the Weddell Sea in early December 1914 and found ice conditions especially bad. For more than a month the ship slowly worked its way through the pack ice, making little headway, and by January 19, 1915, it was hopelessly trapped. The ship drifted towards the interior of the ice pack, and began to leak in late October as she was being slowly crushed by the shifting ice. They abandoned the ship on October 27 and set up a camp on nearby ice floes. The ship sank a month later. The pack ice was so thick that they were unable to drag the three lifeboats and supplies either to water or land. By early April, 1916, they had drifted far enough north for the ice to start separating and they were finally able to launch their boats. They sailed for six days in stormy waters to Elephant Island 250 km (155 mi) north of the Antarctic Peninsula. Although there were no good campsites there, they found lots of seals and penguins on the beach which provided them with plenty of food. A deck was added onto the largest lifeboat, the *JAMES CAIRD*, so that Shackleton and five companions could sail to South Georgia to get help at a Norwegian whaling station. Shackleton set sail on April 24 and crossed 1,280 km (794 mi) of rough seas in 16 days to reach South Georgia. Unfortunately, they landed on the wrong side of the island and were forced to cross over an unknown mountain range with very little equipment in order to reach the station on the other side. Finally, on August 30, 1916, after four months and three unsuccessful rescue attempts, Shackleton returned onboard the Chilean vessel *YELCHO* to rescue the men left behind at Elephant Island. All of Shackleton's party had survived their ordeal, and had been living under their overturned lifeboats. Meanwhile, the Ross Island party had landed with the *AURORA* in January, 1915, and set up a base camp at Scotts' abandoned hut at Cape Evans. They were to set up depots for Shackleton's party coming across the continent from the other side. On May 6, 1915, a terrible blizzard struck and carried the *AURORA* (with most of its crew) away from its mooring, leaving ten men trapped ashore. The ship was caught in the pack ice for ten months and drifted 1,770 km (1,100 mi) to the north before eventually breaking free. The *AURORA* then sailed to New Zealand to wait out the winter and returned the following summer on January 10, 1917, to rescue the men left ashore. The men trapped at Cape Evans knew nothing of Shackleton's plight and assumed he would come across the continent as planned. They thought it of utmost importance to lay the necessary depots for him, and struggled needlessly through much of the summer of 1915/1916 doing just that. Only six men of the Ross Island party survived to be rescued.

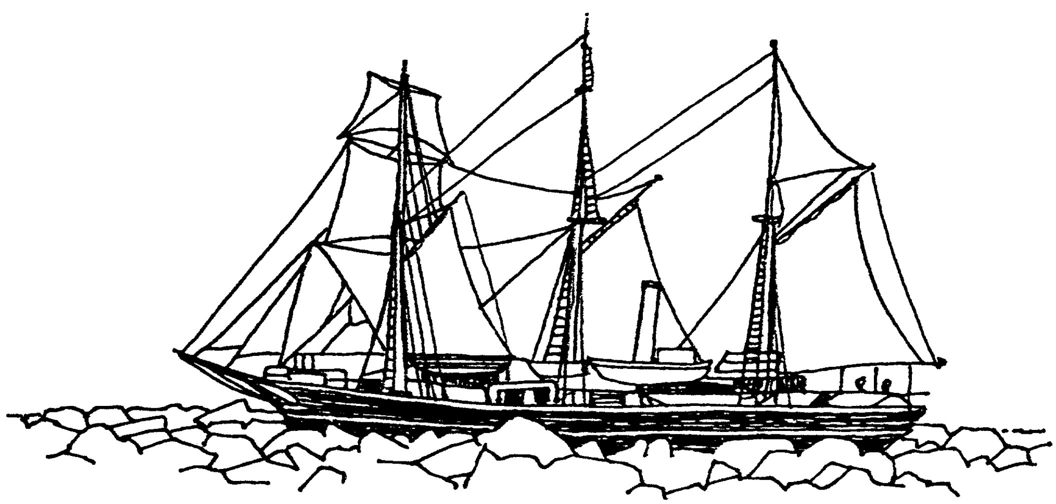


FIGURE 33. *HMS ENDURANCE* trapped in the ice of the Weddell Sea in 1915.

The disasters suffered between 1911 and 1917 emphasized the difficulties of exploring on land. Mawson had earlier stated he thought airplanes could be useful in Antarctica, and in fact had planned to use one during his 1912 expedition, but it was damaged before he had a chance to use it. The time of airplanes in Antarctica had arrived.

The Age of Science (1917-): The first sustained scientific research in Antarctica began in 1925, and was a follow-up to the formation of a committee in the British Government of 1917 to review the excesses of commercial whaling in the Antarctic. The Marine Biological Station was set up on South Georgia Island, and was operated by the Discovery Committee primarily to collect information on Antarctic whale populations. The purpose of all this was to make recommendations regarding a policy of conservation, because it had become increasingly obvious the whales were in danger of being hunted to extinction. Between 1925 and 1939, there were 13 scientific voyages; the first five were on Scott's old ship *DISCOVERY*, and the rest were on *DISCOVERY II*. Studies needed to be carried out in order to learn about breeding seasons, gestation periods, growth rates, etc. Some aspects of whale conservation soon began to take shape. In 1929, the Norwegian Government enacted legislation which prohibited its whaling fleet (which was the biggest in the world at the time) from taking calves and nursing mothers. Minimum size limits were imposed in 1930, and in the following year 26 countries agreed to form the International Convention to regulate the industry. Six years later, nine member nations agreed to new minimum size limits and to the placement of inspectors on each factory ship. All these regulations really had little effect on declining populations, but in 1946 the International Whaling Convention was set up in Washington, D.C., and far-reaching policies began to be applied. It was the extensive work accomplished by the Discovery Committee which made possible the conservation of whales as we know it.

Many people had already talked of using airplanes to explore Antarctica, but it was a British adventurer, Sir Hubert Wilkins (sponsored by the American Geographical Society and backed partly by William Randolph Hearst), who was the first to do so. He organized two expeditions, the first in 1928 followed by a second in 1929, and succeeded in exploring nearly 2,100 km (1,300 mi) of the Antarctic Peninsula by air. Much of this terrain had never been seen before, and Wilkins obtained many photographs and information (much of which was incorrectly interpreted). Unfortunately, he not only suffered bad weather during much of his time in Antarctica, he also encountered some of the warmest temperatures ever recorded in the peninsular region. This caused many problems because the sea ice he used as launching and landing platforms began to melt.

Even with Wilkins' limited success, few people believed airplanes could actually be flown to the South Pole. Richard Evelyn Byrd (United States Navy) was already an accomplished polar pilot because he had made the first flight over the North Pole in 1926. He was determined to do the same with the South Pole, and discussed the project with Roald Amundsen who had plenty of advice to give. He arrived in Antarctica at the Bay of Whales on Christmas Day, 1928, with three airplanes (a Ford Trimotor, a Fokker Universal, and a Fairchild monoplane with folding wings), 95 dogs, and more than 50 men. Their base was built on the Ross Ice Shelf 14 km (9 mi) in from the edge of the ice, and was named Little America. Several test flights were made in the ensuing months resulting in numerous discoveries, and accompanying parties were sent on geological studies and charting missions. In November, 1929, a geological party made the startling discovery that the interior mountains consisted of sandstone (and coal), and were therefore part of the Earth's buckled crust rather than volcanic extrusions. At the same time, a fuel dump was organized at the foot of the Axel Heiberg Glacier in preparation for the upcoming flight to the pole. On November 29, four men, with Byrd navigating, took off from Little America in the Ford Trimotor and flew nonstop to a position over the South Pole, and then returned by way of the fuel dump 18 hours 41 minutes later (the flight time was 15 hours 51 minutes). The same trip had taken Amundsen three months to complete 18 years earlier. Although several explorers had previously field-tested various types of mechanized transport, Byrd was foremost in experimentation with transport, as well as communications and dietary innovations. In 1934, he returned with sledges, tracked vehicles, and airplanes to continue his work in Antarctica, making sledge trips and aerial surveys from Little America. This expedition added a great deal of scientific knowledge about Antarctica, and proved for the first time that there was no strait connecting the Ross Sea with the Weddell Sea, thus confirming Antarctica as a single continent. They measured the depth of the continental ice cap, they discovered and mapped vast new land areas, made in-depth weather studies, found and catalogued new life forms, and much more. Byrd spent the winter alone, 200 km (124 mi) away from base in a small hut sunk in the ice, making meteorological studies. He was there for four months, but was nearly killed when the chimney froze without his realization and stopped the ventilation. Fumes from the radio generator and faulty stove affected his judgement and could have proved lethal, but his peculiar radio messages alerted the men at the main base and they came and rescued him. Byrd returned again in 1939 with the largest Antarctic expedition yet, and accomplished much more important mapping work. He brought with him this time more experimental vehicles, including the infamous Snow Cruiser- it was 17 m (55 ft) long, and had wheels which were 3 m (10 ft) in diameter and weighed 2,700 kg (3 tons) each. It was diesel-powered, had a small airplane perched on top, living quarters, a laboratory, machine shop, and darkroom. Supposedly, it could cross crevasses up to 4.5 m (15 ft) in width, and could carry the airplane 8,000 km (5,000 mi). He planned to drive it to the pole, using the airplane to scout the route ahead. Unfortunately, the tires provided too little traction and the electric motors were too weak to move the vehicle in snow. The farthest it got was 5 km (3 mi) from the landing site to the base.

Another noteworthy milestone in the history of Antarctic exploration was the first flight across the continent made in 1935 by Lincoln Ellsworth, an American millionaire. He had already flown over the North Pole in 1926, in an airship with Roald Amundsen (after Byrd's flight), and had been beaten again by Byrd in flight to the South Pole. This project, like so many other Antarctic expeditions before it, was wrought with bad weather and numerous setbacks. He first came to the Bay of Whales in January, 1934, and set up camp on the ice. He planned to fly from the Ross Sea to the Weddell Sea, and back (a distance of nearly 5,500 km, or 3,400 mi). Four days later, just before he was to take off on his epic flight, severe ice movements destroyed the camp and nearly destroyed the aircraft (it fell between two separating ice floes and was hanging, half submerged, by its wings). He was forced to take his expedition back to the United States to repair the aircraft. He returned later that same year, only this time he planned to fly the route in the opposite direction. Bad weather conditions and a contrary partner pilot prevented the flight on this, his second attempt. His ship became trapped by ice and he had to remain at Snow Hill Island until March, 1935, before the ship escaped the ice. Ellsworth returned in November, 1935, and set up camp at Dundee Island at the tip of the Antarctic Peninsula. On November 23, he and his new pilot, Herbert Hollick-Kenyon (British), finally took off in their plane, the Polar Star, on what was to be a successful flight to Little America in the Ross Sea. The total flight time was 14 hours, but they had to make four stops along the way, and on one occasion were trapped in their tent for eight days by a blizzard. Unfortunately, they ran out of fuel just 26 km (16 mi) short of their goal and were forced to walk the last distance to Byrd's base.

In 1946, the United States Navy conducted the largest Antarctic expedition ever attempted, using 13 ships, 23 aircraft, and more than 4,700 men. Byrd was placed in charge of the operations. The main group set up a base on the Ross Ice Shelf in the Bay of Whales, and two other groups sailed respectively east and west conducting surveys around the continent. Icebreakers and helicopters were used for the first time in Antarctica, and nearly four million sq km (1.6 million sq mi) of the continent had been sighted. Some 70,000 aerial photographs were taken, covering 60% of the coastline. Byrd was onboard one of two aircraft that together made a flight to the pole on February 15, 1947. A follow-up expedition named Operation Windmill used ship borne helicopters to place survey markers to accurately fix positions of landmarks shown on the photographs taken during Operation Highjump. This enabled the construction of accurate maps.

It was not until 1958 that the first overland trans-continental expedition was made. The Commonwealth Trans-Antarctic Expedition, led by Vivian Fuchs and Sir Edmund Hillary (the New Zealander of Mount Everest fame), was designed along the same lines as Shackleton's expedition of 1914. Hillary left from Scott Base on Ross Island with four tracked vehicles and four sledges to drive to the pole and set out supply and fuel depots along the way. Fuchs' group, which was the one to actually make the complete crossing, left from Shackleton Base on the Ronne Ice Shelf in the Weddell Sea with eight vehicles, and two dog sledges to scout a route. He had many problems with glacial crevasses and bad weather, and had to abandon three of the vehicles along the way. The two parties met at the South Pole on January 19, 1958, and proceeded to Scott Base via Hillary's route.

The first International Polar Year was held in 1882-83, during which 12 nations established 14 bases in polar regions to observe and study the Earth's climate and magnetism. It was such a success the decision was made to repeat the process every 50 years. The second International Polar Year was held in 1932-33. Scientific techniques were advancing so rapidly, however, many felt 50 year intervals were too long. Dr. Lloyd Berkner, an American scientist, put forth an idea in 1950 for the International Geophysical Year (Geophysics is the application of physics to Earthly processes, such as meteorology, oceanography, seismology, geodesy, orogeny, volcanology, glaciology, geo-magnetism, upper-air studies, etc.). It was enthusiastically received, and twelve countries (Argentina, Australia, Belgium, Chile, France, Great Britain, Japan, New Zealand, Norway, South Africa, the United States, and the Soviet Union) agreed to take part in a program which would conduct research in Antarctica, as well as outer space. June, 1957, to December, 1958, was chosen for the timing because solar activity was at a minimum, and this time period was even termed "the year of the quiet sun". Forty scientific stations were established on the continent and another twenty were set up on various Antarctic islands. The United States established the Amundsen-Scott Base at the South Pole (called Operation Deepfreeze), and the Soviet Union established a base at the Pole of Inaccessibility. Needless to say, much of this work became long-term studies, and continues today. Most of the earlier research stations were set up to simply collect meteorological data, and many of these have since been abandoned. Antarctica seems to be littered with such stations, because they were usually built in the most accessible areas. Many of the modern stations are much more sophisticated, however, and are used to house scientists involved with varied subjects of study, and support teams.

COMPARISON OF POLAR REGIONS

There is some disagreement as to how to properly qualify the two polar regions. One proposal uses plant life as the defining factor, such as the northern limit of trees in the Arctic, but this does not work for Antarctica. Another method uses average climatic conditions, such as temperature or precipitation, but these vary considerably over time. Another method to determine polar boundaries is a natural one based upon sunlight, e.g. the polar circles, but there are several problems with this method, too.

The Earth is tilted on its rotating axis by 23° 27' 8.26" (or about 23.5°) relative to the vertical plane of its orbit around the sun. On the day of each solstice, one pole is facing away from the sun at an angle of about 23.5° and the other is facing toward the sun at an angle of about 23.5° . The two poles switch angled positions relative to the sun on sequential solstices. Because the Earth is a sphere, a person located less than about 23.5° from the North Pole on the day of the northern winter solstice would not see the sun rise above the horizon. Conversely, a person located less than about 23.5° from the South Pole on that same day (the southern summer solstice) would not see the sun set. These relative positions correspond exactly to 66° 32' 51.74" (or about 66.5°) latitudes both North and South and delineate the polar circles. The Arctic and Antarctic Circles therefore demarcate the territories which experience at least one complete day of direct sunlight, as well as at least one complete day of no direct sunlight, each year. Unfortunately, a significant portion of the Greenland Ice Cap is located south of the Arctic Circle. It would be ludicrous to claim that this section of the great ice sheet, which stretches nearly 400 miles south of the Arctic Circle, is not part of the Arctic. Likewise, a significant portion of the Antarctic Peninsula is located north of the Antarctic Circle. It seems the two polar regions require different criteria to define them properly. Generally, ecologists and geographers prefer using the northern treeline (the northern limit of arborescent growth) as the Arctic boundary and the Antarctic Convergence as the Antarctic boundary.

Most people mistakenly assume the two polar regions are very similar. It is true that the two areas both experience cold temperatures because of their relative positions on the Earth, but a closer comparison brings out many differences. It is interesting to note that the Arctic Ocean, covering about 14 million sq km, is nearly the same size as the Antarctic continent, which has an area of about 13 million sq km. They are even roughly the same shape, with the Antarctic Peninsula corresponding to the deep Arctic outlet located east of Greenland. But, the Arctic is an ocean surrounded by land, while the Antarctic is a continent surrounded by ocean. It is as if a core of the Earth has been depressed at the North Pole, forcing a corresponding bulge at the South Pole.

The Arctic Ocean has an average depth of 1,400 m (4,600 ft) and a maximum depth of 5,300 m (17,500 ft), while the Antarctic continent has an average height of 2,200 m (7,300 ft) and a maximum height of 5,100 m (16,800 ft). Antarctica is basically one great ice sheet surrounded by extensive sea ice, whereas the Arctic is mostly sea ice (although Greenland also has a significant ice sheet). Antarctica contains nearly 10 times the amount of ice that is found in the ice store of the Arctic. Ice bergs, broken off from glaciers, are common in both polar region, but only in the Antarctic can one encounter the huge tabular bergs…some as large as 2,600 sq km (1,000 sq mi) in surface area by 300 m (1,000 ft) thick.

The North Pole is located at sea level, in pack ice, while the South Pole is located at an elevation of 2,800 m (9,200 ft) on the top of a great continental ice sheet. The weather in the Arctic is much milder than that of Antarctica. Temperatures at the North Pole vary from above 0° C to -50° C (32° F to -58° F), while at the South Pole temperatures vary from -20° C to -80° C (-4° F to -112° F). The relatively milder climate of the Arctic is much more conducive to life than that of Antarctica, as evidenced by a comparison of life forms of the two regions. In the Arctic there are more than 900 species of flowering plants, 500 species of mosses, and 2,000 species of lichens. In Antarctica there are only two species of flowering plants, 75 species of mosses, and 400 species of lichens. It is important, also, to remember that more than two million people live within the Arctic Circle, but there are no permanent residents within the Antarctic Circle. The enormous reservoir of cold and unequaled fierce winds of the Antarctic frozen continent, combined with the far reaching Antarctic ocean currents, have a worldwide influence on weather patterns (the Greenland ice sheet produces somewhat similar effects in the Northern Hemisphere on a much smaller and more localized scale). However, 90% of the human population lives on continents surrounding the Arctic, and it has become important as a source of petroleum, food, and minerals. Modern air travel routinely moves across the Arctic polar basin, because it is often the shortest route between intercontinental destinations. For these reasons the Arctic is much more important to humankind and better known than the remote continent of Antarctica. This has allowed the very fragile ecosystem of Antarctica to endure to this day. Great efforts are now being made in hopes that the incredible wilderness of Antarctica may be saved from humankind's relentless encroachment.

GLOBAL WARMING

As radiant energy from the sun reaches the Earth, most of it is reflected or re-radiated back into space. Certain gases in the lower atmosphere, such as water vapor, carbon dioxide (CO2), methane (CH4), chlorofluorocarbons (CFCs), and others, trap some of the heat before it escapes completely. The effect of these gases is analogous to glass windows surrounding a greenhouse, and is in fact often referred to as the Greenhouse Effect. This trapped heat is necessary to keep the Earth's climate warm enough for life to exist. There must, therefore, be some kind of a balance to insure the Earth neither cools nor warms too much.

The greenhouse gases were discussed in an earlier chapter, but are covered in more detail here. They have been steadily increasing for the past 200 years, since the beginning of the Industrial Revolution. Carbon dioxide, the most abundant trace gas in our atmosphere, has increased by 25% during this time period. It is produced through the burning of wood and fossil fuels, such as coal and petroleum products. It is also released by volcanoes, oceans, decaying plants, and respiration. It is interesting to note that more than 11% of this increase in atmospheric CO2 has come about in only the last 30 years. It stands to reason that the massive clearing and burning of tropical rainforests occurring today is releasing an increasingly significant amount of CO2 to the atmosphere.

Methane, the second most abundant greenhouse gas, is produced as a by-product of the decomposition of organic material. The most common known sources are swamps, rice paddies, livestock (especially cud-chewing animals), termites, and the use of natural gas. Unstable natural sources of methane hydrates in permafrost regions and oceanic continental slopes are a potential source of atmospheric methane. The level of atmospheric methane is growing at about one percent per year. The level of CFCs in the atmosphere is small by comparison, but these compounds are thousands of times more potent in absorbing heat. They are man-made chemicals and are also implicated in another potentially serious climatic problem- the depletion of the ozone layer. It has been estimated that the present level of greenhouse gases may double in the next century, and could raise the average temperature of the Earth by perhaps as much as 5° C (9° F).

The interaction of climatic forces is not completely understood, so it is as yet impossible to determine the overall effect of increasing the greenhouse gases. Statistics show that the average Earthly temperature has indeed increased 0.5° C (1° F) during the past 100 years, and that nine of the warmest years yet recorded were in the 1980s and 1990s. It is, however, much more complicated than these figures indicate, because there have been warming trends followed by cooling trends in the past. It also should be noted that several of the recent localized warm years were probably somehow associated with the aberrant and disruptive El Niño current in the central Pacific Ocean. Antarctic scientists are at the forefront of this research. It has been suggested that the dramatic increases in populations of chinstrap penguins and fur seals in the last couple decades may be due in part to the possibility that there is now less sea ice (or rather, more open water). Both of these species may act as indicator species regarding global warming because they spend the winters primarily in the water, not on the ice.

Most scientists do believe human activities now contribute significantly to the heat budget of the Earth. It is important to consider that worldwide climatic variations have been monitored for only a relatively short period of time, and it is difficult to draw solid conclusions and make absolute predictions. Nonetheless, the information we do have indicates to many scientists we may well have started a global warming trend which is irreversible- at least not without drastic changes in our present way of life. One study, published in 1990, concluded that in order to halt the rise in CO2 levels in our atmosphere we must halt the net deforestation worldwide by the year 2000, and reduce the energy-related emissions of CO2 by 70% of today's production before the year 2030.

Venus, a neighboring planet similar to our own in many respects, has 60,000 times more CO2 in its atmosphere than does Earth. Greenhouse gases keep the average Venusian temperature above 400° C (800° F), which is hot enough to melt lead. If the average Earthly temperature were raised just a few degrees, both the Greenland and Antarctic ice sheets would certainly be affected. If the Antarctic Ice Cap were to melt completely, the sea levels worldwide would rise as much as 100 m (330 ft), thereby flooding most coastal cities and displacing about half the world's human population.

OZONE DEPLETION OVER ANTARCTICA

Atmospheric studies have shown there are regional vortices above both poles that become relatively isolated from the rest of the Earth's atmosphere during the winter months. This isolation is most complete when the vortices are at their coldest. At the North Pole, the vortex lasts about two months, but at the South Pole (which is considerably colder during its winter) the vortex typically lasts twice as long. In 1985, the British Antarctic Survey published the results of an ongoing study of Antarctic atmospheric conditions begun in 1957. Each year since records have been kept there has been a dramatic depletion of ozone (a tri-atomic form of oxygen which is rare in the lower atmosphere) above Antarctica beginning in late August or early September and then gradually replenishing itself by early December. The Cambridge-based organization reported that the thinning of the ozone above Antarctica has increased each year since about 1976. In 1993, the ozone layer had reached its lowest concentration yet recorded, but subsequent years have remained relatively constant. At its maximum, the "ozone hole" above Antarctica covered an area equal in size to the United States of America.

Ozone is found in small amounts in the stratosphere (that part of the atmosphere from 10 to 48 km, or 6 to 30 mi, above the Earth's surface). It is, however, very important to life because ozone shields the Earth from most solar ultraviolet, or UV, radiation. This radiation can be further divided into UV-A radiation and UV-B radiation, based upon their respective wavelengths (with UV-B composed of shorter wavelengths). UV-B appears to be the more injurious of the two types with regards to life on Earth. In humans it causes sunburn and skin cancer, and has been linked to cataract formation. It is also harmful to plants, ranging from bacteria to food crops. Studies carried out at the American Palmer Station on Anvers Island, Antarctica, have indicated increased UV-B radiation at the ocean's surface reduces the photosynthetic productivity of phytoplankton. Smaller species (diatoms) within the phytoplankton may be killed by enhanced UV-B radiation, which consequently causes a shift in the algal community makeup of the phytoplankton. Any effect upon the base of the simple Antarctic food chain could obviously have far-reaching effects upon the entire ecosystem. Similar studies have shown increased UV-B radiation kills at least some species of copepods (tiny planktonic crustaceans), but it is not yet known what long-term effect it may have upon krill.

It has been found that a variety of gases affect the abundance of ozone, either directly or indirectly, but chlorine is thought to be the major contributor to the breakdown of ozone. Most of this chlorine probably reaches the stratosphere from the release of man-made CFC chemicals used as coolants in refrigerators and air conditioners, and as propellants in aerosol sprays. Steps have been taken to end the production of these chemicals, but they are still produced in some countries, and stockpiles still exist. When CFC molecules come into contact with UV radiation in the stratosphere, they are broken down into smaller components, giving off chlorine. It was discovered in 1979 that thin clouds of ice and concentrated nitric acid form in polar regions where temperatures reach -200° C (-130° F). Chlorine molecules on the surface of these clouds are changed chemically into reactive chlorine catalysts, which in turn break down ozone molecules. Nitrogen compounds can convert reactive chlorine back into the non-reactive form, but the nitric acid clouds reduce this process because they remove nitrogen from the stratosphere. Reactive chlorine levels above Antarctica during the winter of 1988 were about 1,000 times more concentrated than the rest of the stratosphere, and led to a 50% reduction in ozone. The yearly fluctuation has been fairly consistent since then.

THE ANTARCTIC TREATY

Many countries have made territorial claims to Antarctica over the years based upon discoveries, occupations, and hypothetical geographical continuities. Today, seven countries still maintain official claims upon the continent: Argentina, Australia, Chile, France, New Zealand, Norway, and the United Kingdom. Other countries have registered official interest in various parts of the Antarctic Peninsula. The claims have been made in accordance with the sector principle established in the Arctic which delineates wedge-shaped pieces extending to the South Pole. The United Kingdom, Argentina, and Chile overlap in their claims, and have had a long period of sovereignty dispute and even open conflict between the U.K. and Argentina in 1982. The United States of America, through the actions of its citizens, has made numerous claims upon Antarctica, but its official policy is to recognize neither the sector principle of sovereignty, nor any claims in any form in Antarctica.

In 1948, the USA proposed to the seven claimant nations that Antarctica be made an international trust territory. The scientific operations, beginning with the first International Polar Year of 1882-83, helped greatly to establish cooperation among nations in Antarctica. During the International Geophysical Year (IGY), the USSR moved into Australian Antarctica, and the USA moved into New Zealand's territory and the Antarctic Peninsula to build scientific stations. The fact that both the USSR and the USA intended to stay in Antarctica after the finish of the IGY helped convince the nations involved to continue cooperation beyond IGY. A 12-month extension was agreed upon. In April, 1958, President Eisenhower of the USA convened a conference to discuss the future of Antarctica, and proposed the continent be left open to all nations for the pursuit of scientific and other peaceful activities. It took over a year to draft an acceptable treaty, and on December 1, 1959, the treaty was signed by the 12 nations that had taken part in the IGY. The treaty was ratified on June 23, 1961, and since that time the list of signatory countries has grown to more than 40.

The treaty was so designed that after a period of 30 years (ending in 1991), any desired amendments to the treaty must be agreed upon by a majority of the members. However, if any amendment is not acceptable to the members within a period of two years after being proposed, any member may withdraw after giving two years notice. Territorial sovereignty claims, however, still must be dealt with. This problem may well lead to the eventual failure of the treaty, but the close cooperation and agreement witnessed in Antarctica during the last few decades indicate good intentions and give hope that the treaty will continue to work. The Treaty consists of 14 Articles, and simply put, they are as follows:

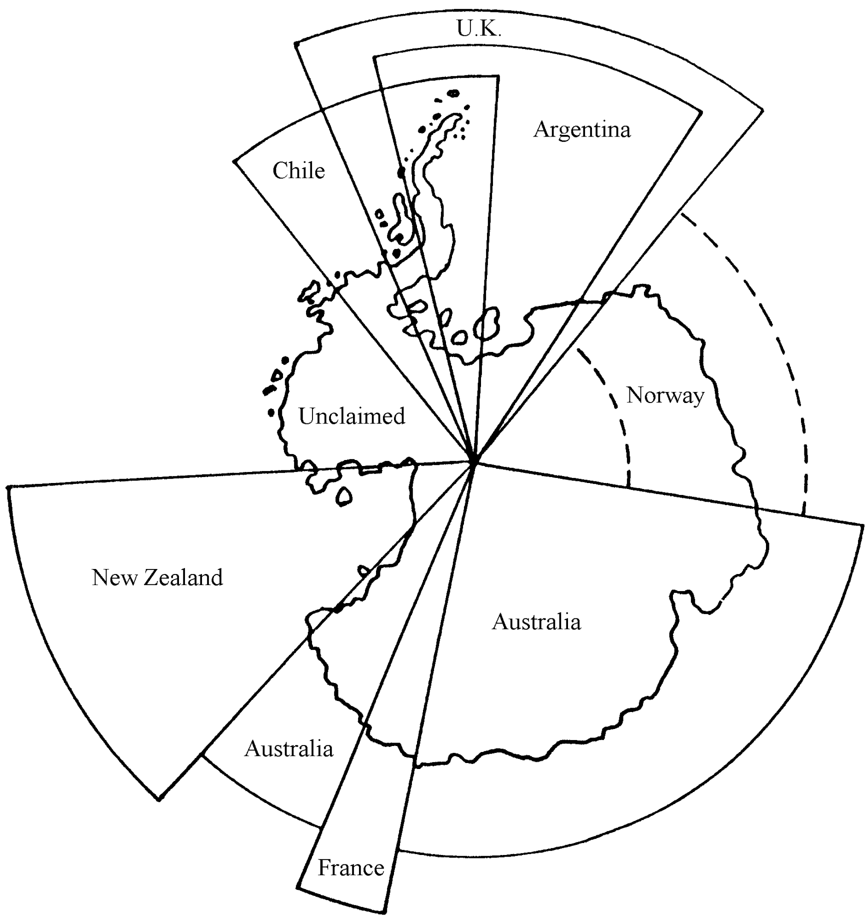


FIGURE 34. Modern-day national claims to the Antarctic continent.

1. Antarctica shall be used for peaceful purposes only (no military bases, fortifications, maneuvers, or weapons testing are permitted), but military equipment and personnel may be used to assist in scientific and other peaceful projects.
2. There is to be a freedom of scientific investigation, and any international cooperation which may be needed toward that end.
3. Information regarding Antarctic scientific programs, as well as scientific personnel, and the results of scientific work will be exchanged to permit maximum cooperation, efficiency, and economy of operations.
4. This treaty is not to be interpreted as a renunciation by any signatory nation of previously asserted rights or territorial claims, and no new claims may be made while the treaty is in force.
5. Nuclear explosions and the disposal of nuclear wastes are prohibited in Antarctica.

6. The provisions of this treaty apply to the area south of 60° South Latitude (except where precluded by international law of the high seas).
7. Any signatory may designate observers to inspect the activities, stations, equipment, etc., of any other signatory.
8. Designated observers and scientific personnel in exchange programs come under the jurisdiction of their respective governments.
9. Representatives of all signatories shall meet at suitable intervals and places to exchange information, consult upon matters of common interest regarding Antarctica, and make recommendations concerning those matters to their respective governments.
10. Appropriate efforts will be made to insure no one engages in activities contrary to the principles or purposes of this treaty.
11. It is the responsibility of any signatories involved in a dispute regarding this treaty to consult among themselves peacefully in an attempt to resolve said dispute, and if this is not possible the matter is to be referred to the International Court of Justice for arbitration.
12. This treaty may be modified or amended at any time by unanimous agreement of signatories. After 30 years from the time this treaty takes force any signatory may request an amendment to be voted upon by all member nations. A simple majority is needed to pass the amendment, but if it fails to pass within two years any signatory may withdraw from the treaty after an additional two years.
13. This treaty is subject to the ratification by all signatories, and is open for accession by any state which is a member of the United Nations, or any other state only by consent of all signatories.
14. This treaty is written in English, French, Russian, and Spanish, and these equally authentic versions are to be deposited in the Archives of the Government of the United States of America (each signatory is to be given a duly certified copy of the treaty).

In recent years, a number of important additional measures have been agreed upon to help ensure adequate protection of the environment. Tourism and other non-governmental activities are now subject to legal obligations (as are all governmental activities), and passage of the Protocol on Environmental Protection to the Antarctic Treaty is pending.

ANTARCTIC TOURISM

Antarctica is certainly one of the ultimate tour destinations of the world. However, for more than 150 years after its discovery, Antarctica was too far, too remote, too extreme, too dangerous, and too expensive for all but the most stout-hearted explorers and adventurers...those people willing to risk everything for the tasks at hand and fortunate enough to have the financial backing of governments or wealthy organizations. Few simple travelers could dare venture into this domain. To go there meant outfitting an expedition, and necessitated making preparations for all kinds of contingencies. These contingencies occurred all too commonly, often with disastrous results. The human history of Antarctica contains some of the most exciting stories of endeavor and persistence imaginable, and includes many survival tales of people overcoming almost unimaginable odds. It is also wrought with many heart-wrenching tragedies. The reasons for people going there varied tremendously, such as the desire to conduct important exploration of an unknown land, promote the furtherment of science, seek the thrill and personal recognition of new discoveries, profit from the exploitation of resources (e.g. fur seal pelts and whale products), etc. But, whatever their reasons for going to Antarctica, these people were first and foremost adventurers at heart. It has taken the efforts of these many expeditions and fearless explorers to reduce much of the Antarctic mystery and danger.

The relative ease and safety of modern travel to Antarctica is a direct consequence of the dedication of these forerunners. A new breed of traveler came on the Antarctic scene in 1964. This was the real beginning of the age of tourism in Antarctica, and like so many other remote and exotic reaches of the globe, the first tourists went there with Lars Eric Lindblad. The late Mr. Lindblad founded the prestigious, world-famous Lindblad Travel company in 1952, and has been called the Marco Polo of the 20th century. He was the ultimate traveler of our day and almost single-handedly originated a new type of tourism, now known as expedition travel. Those of us privileged to have known him and traveled with him have had our lives enriched tremendously. Lindblad’s lifelong dream of reaching Antarctica was finally realized in 1965, when he chartered the *LAPATAIA*, a converted Argentinian naval ship, and take a group of fellow enthusiasts to the Antarctic Peninsula. A year later, he also chartered the Chilean naval vessel

NAVARINO to continue his passenger expeditions to the peninsular region. Lindblad soon realized these ships were inadequate for his needs, so he decided to have a vessel built to his specifications which would not only be capable of taking passengers to Antarctica, but could sail throughout all the world's oceans. It had to be of moderate size, have a reinforced hull to withstand sea ice conditions, have a long cruising range, and be able to transport her passengers in both comfort and safety. The result was the famous *LINDBLAD EXPLORER*, a ship of some 2,500 tons, measuring 76 m (250 ft) in length. The emphasis aboard was on education and among other amenities she contained a dedicated lecture hall. The ship could carry 92 passengers along with about 60 crew members, naturalists, and lecturers. She had a cruising range of nearly 6,000 nautical miles, a top speed of about 14 knots, and a bow thruster with which she could turn around almost within her own length. Lindblad's ingenious use of small, inflatable boats called Zodiacs provided the means for his passengers to get ashore almost anywhere, under a multitude of conditions. The *LINDBLAD EXPLORER* set the standard for all expedition-styled passenger ships to follow. Her maiden voyage was in 1969, and the first expedition cruise to Antarctica was in 1970.

Sven Olof Lindblad (Lars Eric's son) founded an expedition travel company in 1979 called Special Expeditions, now called Lindblad Expeditions, and has continued the family tradition. Among the company's fleet is the ice class expedition ship *M.S. ENDEAVOUR*, named in honor of Captain James Cook's famous expedition ship of the 18^{th} century. The *ENDEAVOUR* was designed and built specifically for operations within cold, ice-filled polar waters, and is the company's primary Antarctic expedition vessel. Lindblad Expeditions strongly promotes environmental awareness and education on its voyages and operates all over the globe, including Antarctica. This style of operations has been so successful, virtually all the ship borne tour companies working in Antarctica today follow what is known simply as...the Lindblad Model.

FIGURE 35. The versatile Zodiac inflatable boat is the preferred craft for making safe landings in Antarctica.

In 1990, several of the tour companies operating in Antarctica took it upon themselves to create an organization known as IAATO (International Association of Antarctic Tour Operators). The purpose of IAATO is to insure safe, responsible, environmentally sensitive tourism in the fragile ecosystem of Antarctica. It is a self-regulating organization with strict bylaws and codes of conduct, and has grown to nearly 30 members and associates. The number of tourists visiting Antarctica each year has grown from about 300 in the early 1970s to about 12,000 in the early 2000s. The vast majority of these tourists are ship borne passengers who are carried by organizers who voluntarily abide by the IAATO guidelines, and this has been very successful in keeping visitor impacts to a minimum and promoting a real sense of Antarctic conservation.

ANTARCTIC CONSERVATION

Until the middle of this century, there was a virtual free-for-all in the taking of fur seals, elephant seals, and whales. The fur seals, harvested for their luxuriant pelts, were virtually annihilated throughout their entire range within 25 years, so that by 1840 most efforts were aimed toward the taking of elephant seals and whales primarily for their oil. With the development of fast, steam-powered ships and exploding harpoon heads in the 1860s, even the large, speedy rorqual whales could be taken. Unlike the slow-swimming right whales that were killed only for their oil and baleen, the rorquals provided not only oil, but also huge quantities of meat, bone meal, and other byproducts. Over the next 100 years, the whale populations were reduced to just a small fraction of their original numbers. Although people began protesting the slaughters even in the early 20th century, there was no real control or means of implementing conservation measures until just after World War II, when the International Whaling Convention was established in 1946. The Antarctic Treaty was initiated 15 years later and the important Agreed Measures for the Conservation of Antarctic Fauna and Flora was adopted in 1964 as an annex to the treaty. It covered the area south of 60° S latitude, and gave protection to all native plants, birds, and mammals (with the glaring exception of whales). The United States followed this up with its Antarctic Conservation Act of 1978, which pertains to all U.S. citizens as well as non-U.S. citizens travelling to Antarctica with U.S. operators. The Antarctic Conservation Act regulations are as follows:

Section 1: It is unlawful to take native mammals or birds (without a permit).
It is unlawful to enter specially designated areas (without a permit).
It is unlawful to introduce non-indigenous species to Antarctica.
It is unlawful to use or discharge pollutants.
It is unlawful to discharge wastes.
It is unlawful to import certain Antarctic items into the United States.

Section 2: Specially Protected Areas require a permit to be entered.

Section 3: Sites of Special Scientific Interest require a permit to be entered.

Section 4: Historic monuments have special provisions to insure their protection.

Section 5: Individuals or groups travelling to Antarctica must obtain required permits.

In 1991, the Antarctic Treaty Consultative Parties adopted the Protocol on Environmental Protection to the Antarctic Treaty (including its five annexes). Many of the original rules and regulations imposed by IAATO upon its members are now incorporated into the Protocol. It designates Antarctica as a natural reserve and was designed to protect the Antarctic environment and its dependent and associated ecosystems. In 1994, the Antarctic Treaty Consultative Parties adopted Recommendation XVIII-I: Guidance for Visitors to the Antarctic.

That Guidance is as follows:

Keep Antarctica Pristine:

Do not disturb or pollute lakes or streams. Do not dispose of litter or garbage from ships or on land. Do not bring non-native plants or animals into Antarctica. Wash your boots before and after each landing. Do not collect souvenirs or remove anything-including rocks, feathers, bones, eggs, fossils, and parts or contents of buildings. Leave no evidence of your visit ashore. Do not paint or engrave anything on rocks or buildings.

Protect Antarctic wildlife:

Do not use aircraft, vessels, small boats, or other means of transport in any ways that disturb wildlife-either at sea or on land. Be alert to the presence of wildlife-and monitor its reaction to you. Take special care around animals that are breeding or molting. Be aware of the periphery of a rookery-and remain outside of it. Never harass wildlife. It is illegal and can be dangerous. Do not feed, touch, or handle birds or seals, or approach them in ways that cause them to alter their behavior. Do not damage plants. Avoid stepping, walking, driving, or landing on extensive moss beds or lichen-covered scree slopes.

Respect Protected Areas:

Know the locations of specially protected areas-and take note of any restrictions regarding them. Do not disturb, remove, or damage anything associated with a historic site or monument. Historic huts may be entered only when accompanied by a proper authority.

Respect Scientific Research:

Do not interfere with scientific research, facilities, or equipment. Take care not to disturb study sites, field camps, or supplies. Obtain permission before visiting science and support facilities.

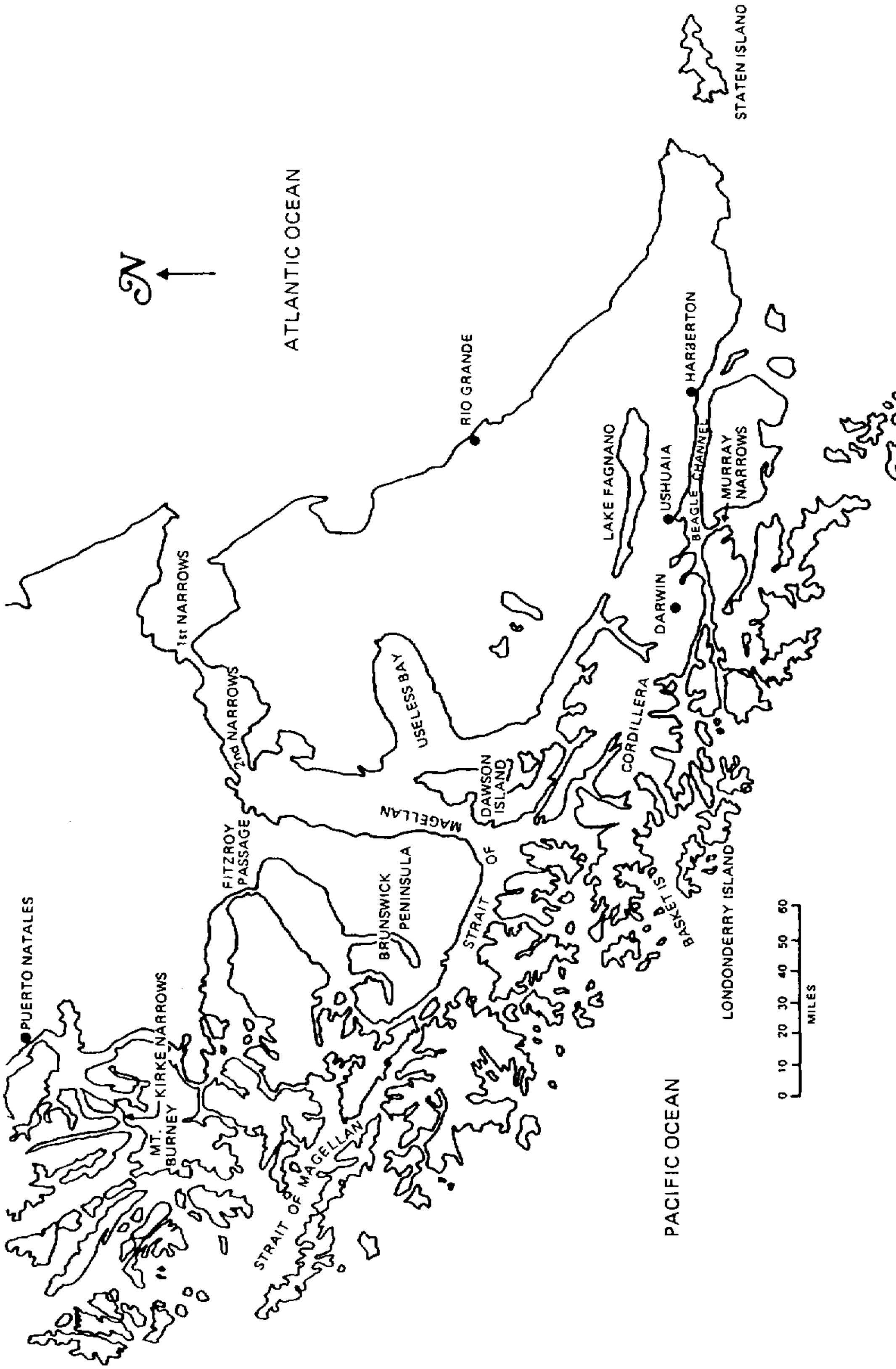
Be Safe:

Be prepared for severe and changeable weather-and insure that your equipment and clothing meet Antarctic standards. Take special care at the Zodiac platform. Accept help getting in and out of the boats. Expect slippery, uneven terrain. Respect any smoking restrictions, particularly around buildings. Do not walk onto glaciers or large snow fields without the proper equipment and experience. Take note and heed the advice of your leaders. Yield right of way to wildlife. Keep your distance. Keep noise to a minimum around wildlife. Do not stray from your group, or wander off alone.

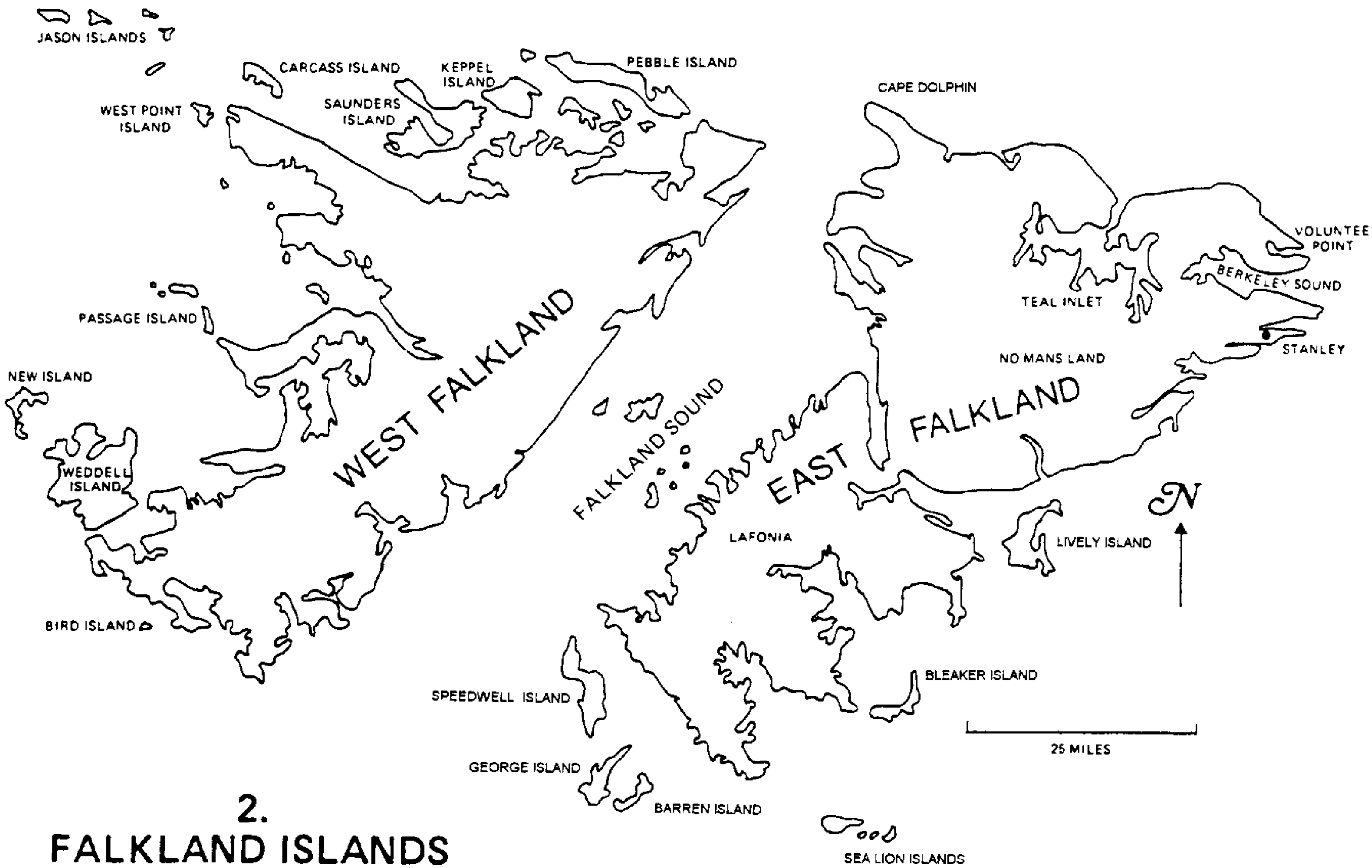
Following these guidelines should insure a safe and enjoyable Antarctic experience for all visitors, resident scientists and other Antarctic personnel, as well as the wildlife. Keeping this in mind, it will be possible for Antarctic visitors to become the new ambassadors to the Great White Continent.

MAP PORTFOLIO

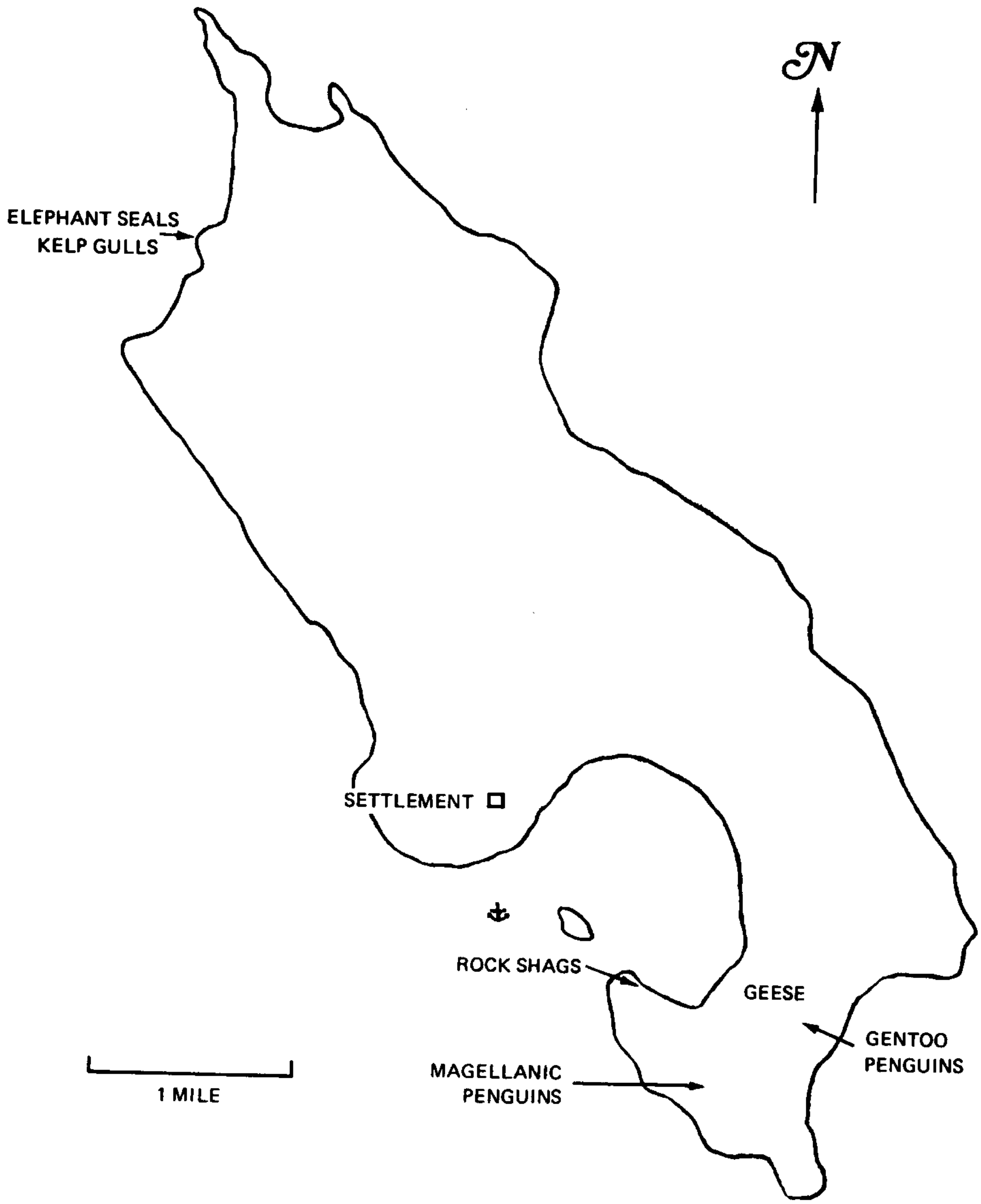
Included here are maps made by Lindblad personnel covering many of the regions and places in Antarctica, the Sub-Antarctic islands, the Falkland Islands (Islas Malvinas), and Tierra del Fuego that are commonly explored during our expeditions. Over several decades, we have found many exciting and wildlife-rich sites throughout the Southern Continent and surrounding areas. It is hoped these simple maps will help the traveler follow along with the course of any particular expedition and get a better understanding of the relationship concerning various site locations and the fascinating natural history and human history of that region.



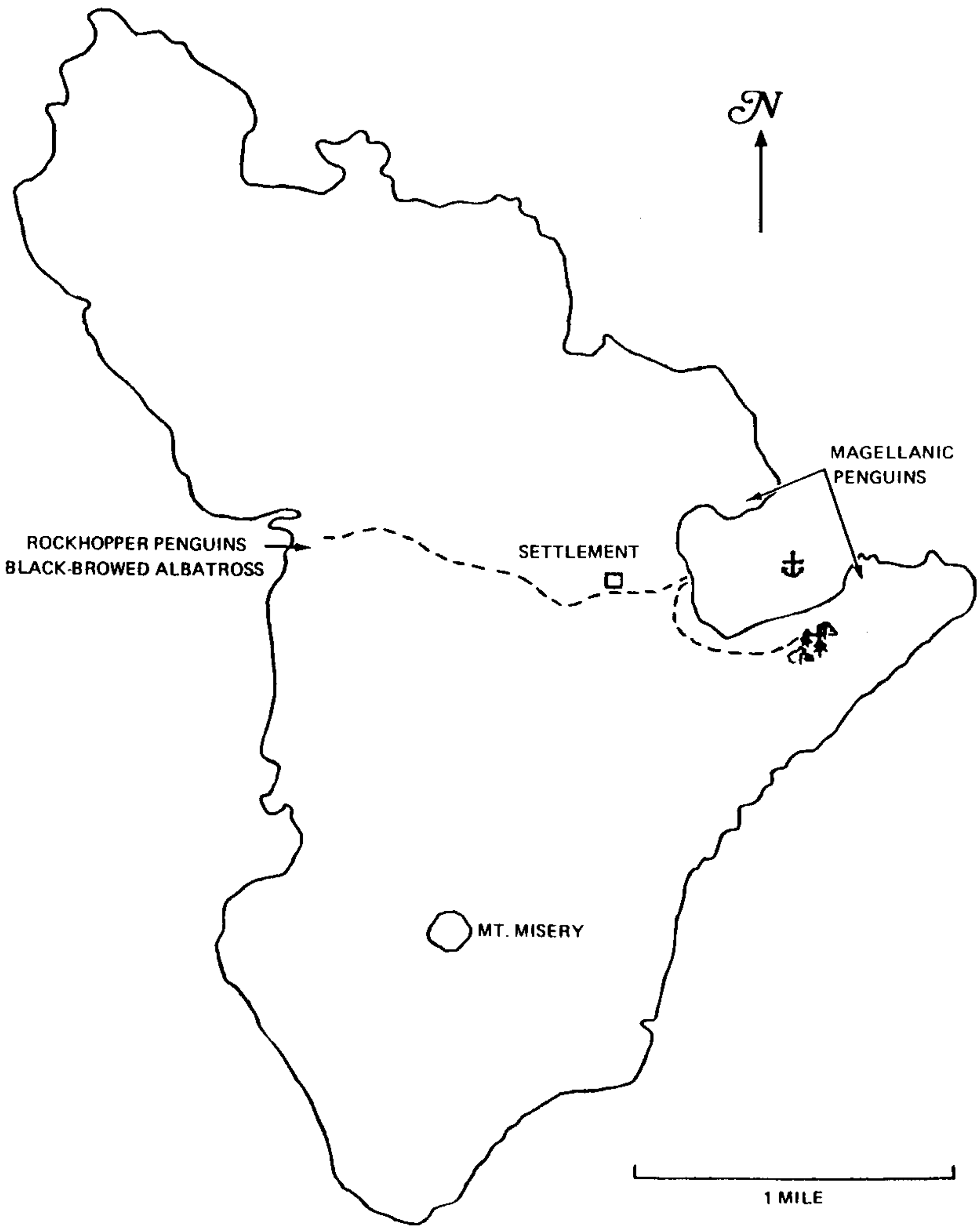
1. TIERRA DEL FUEGO



2.
FALKLAND ISLANDS
(ISLAS MALVINAS)



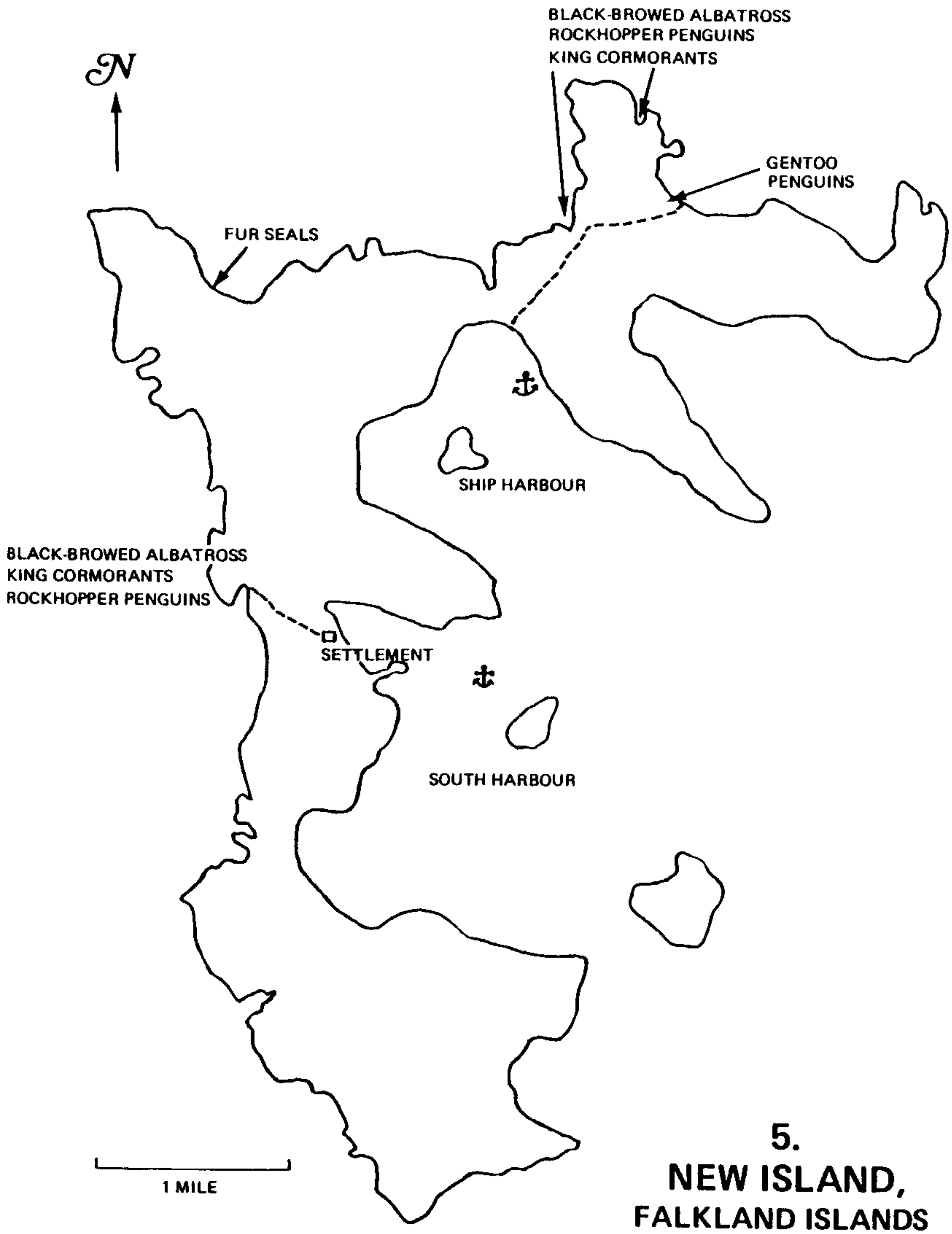
3.
CARCASS ISLAND,
FALKLAND ISLANDS (ISLAS MALVINAS)



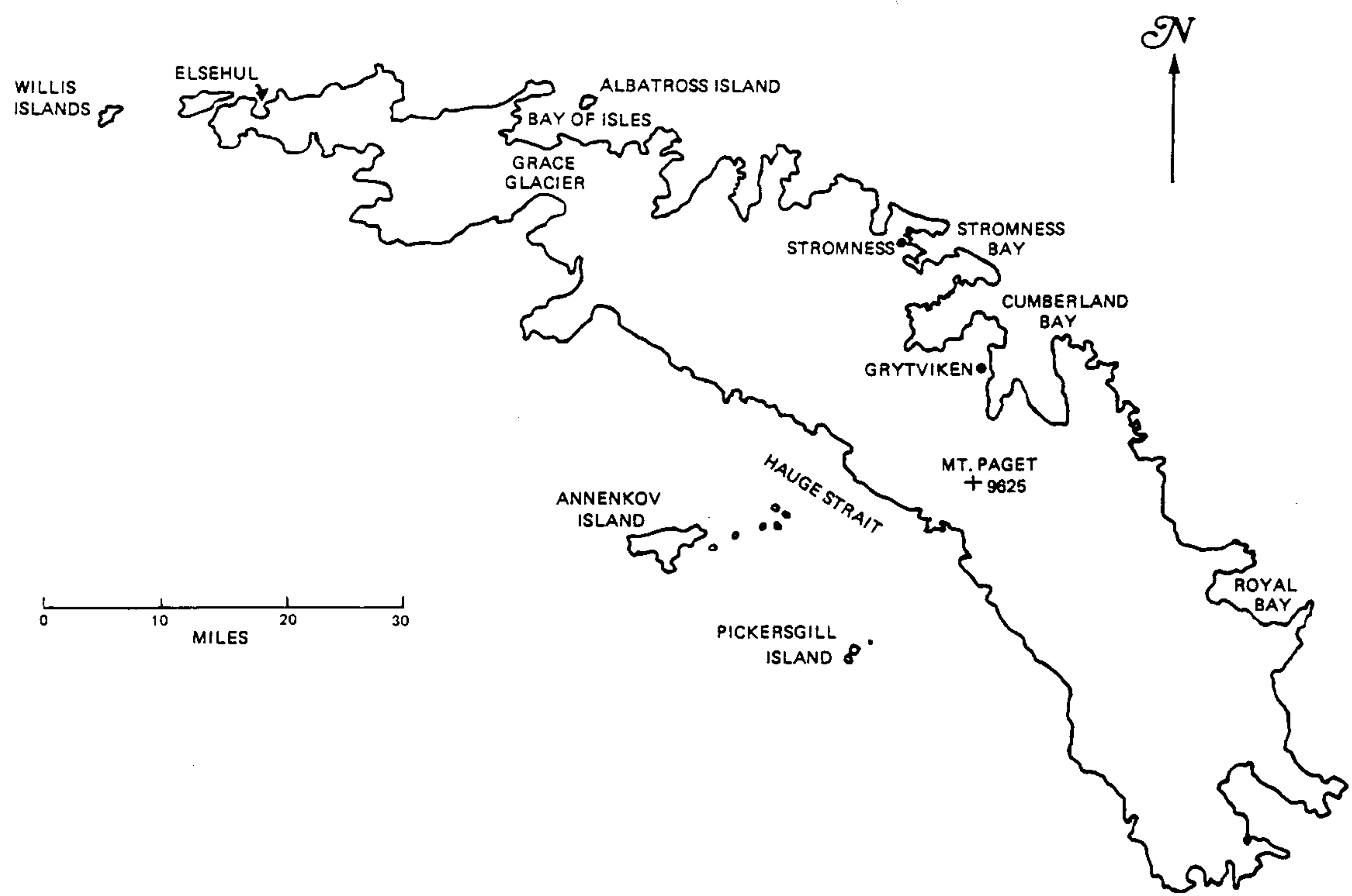
4.

WEST POINT ISLAND,

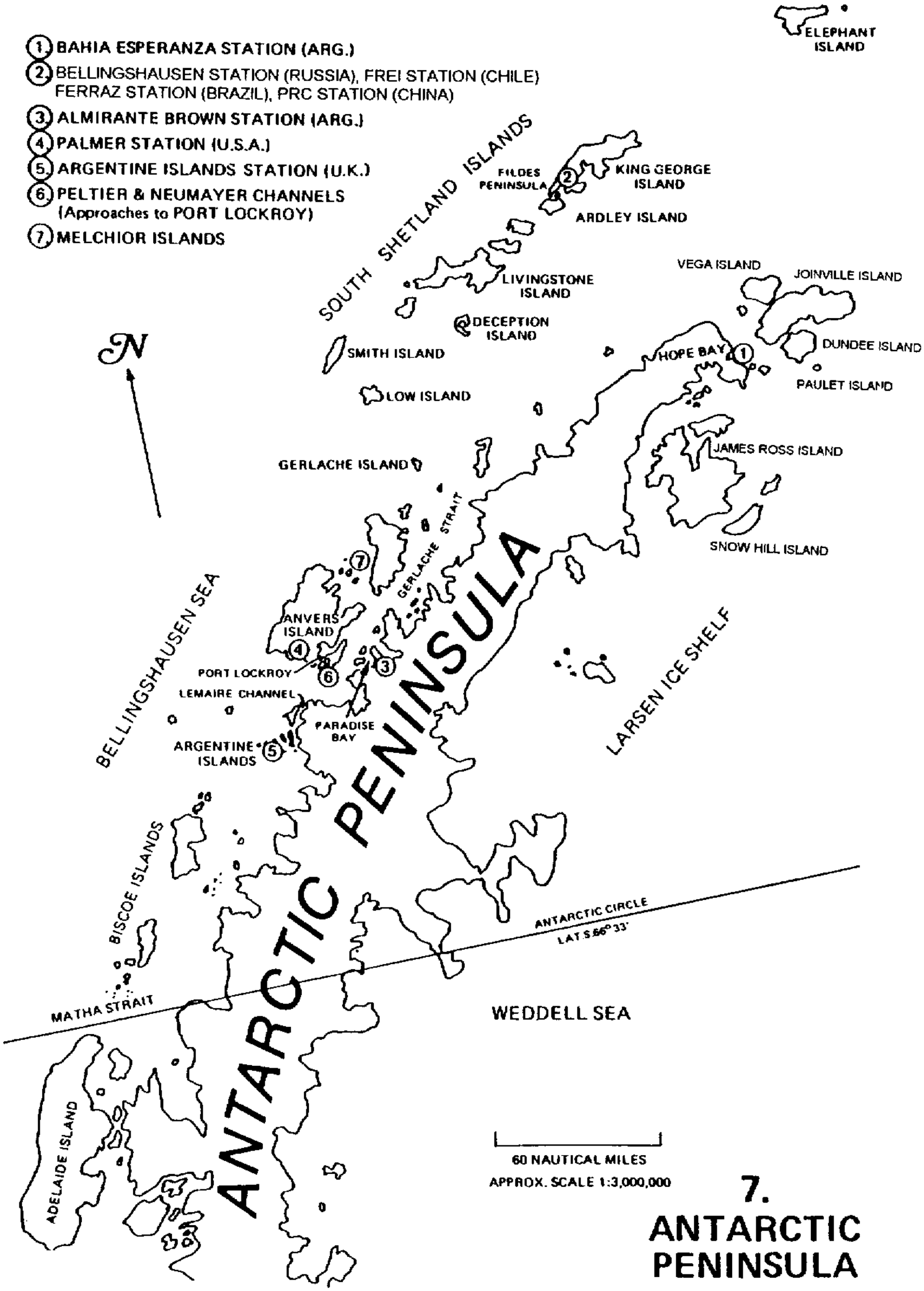
FALKLAND ISLANDS (ISLAS MALVINAS)



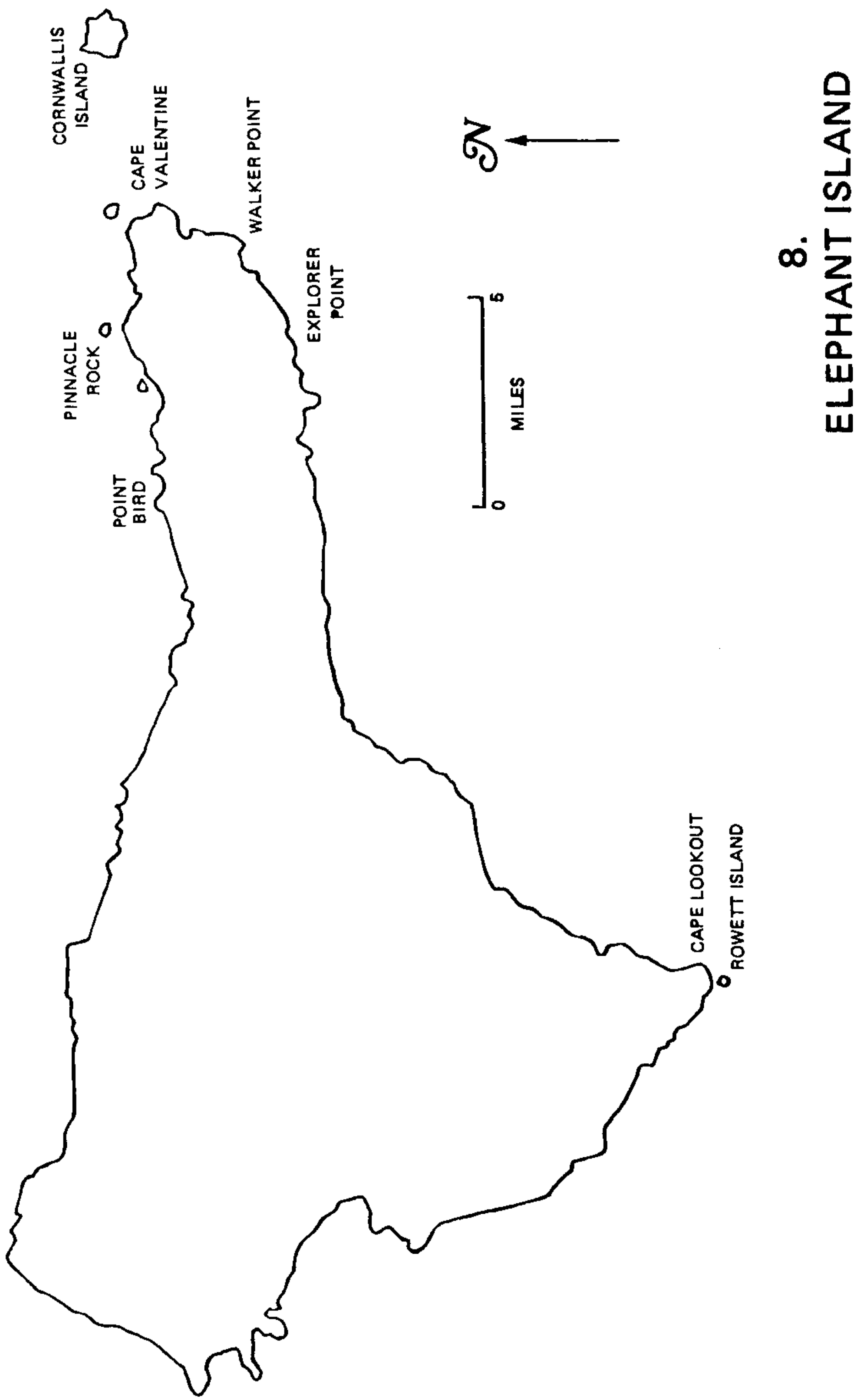
5.
NEW ISLAND,
FALKLAND ISLANDS
(ISLAS MALVINAS)

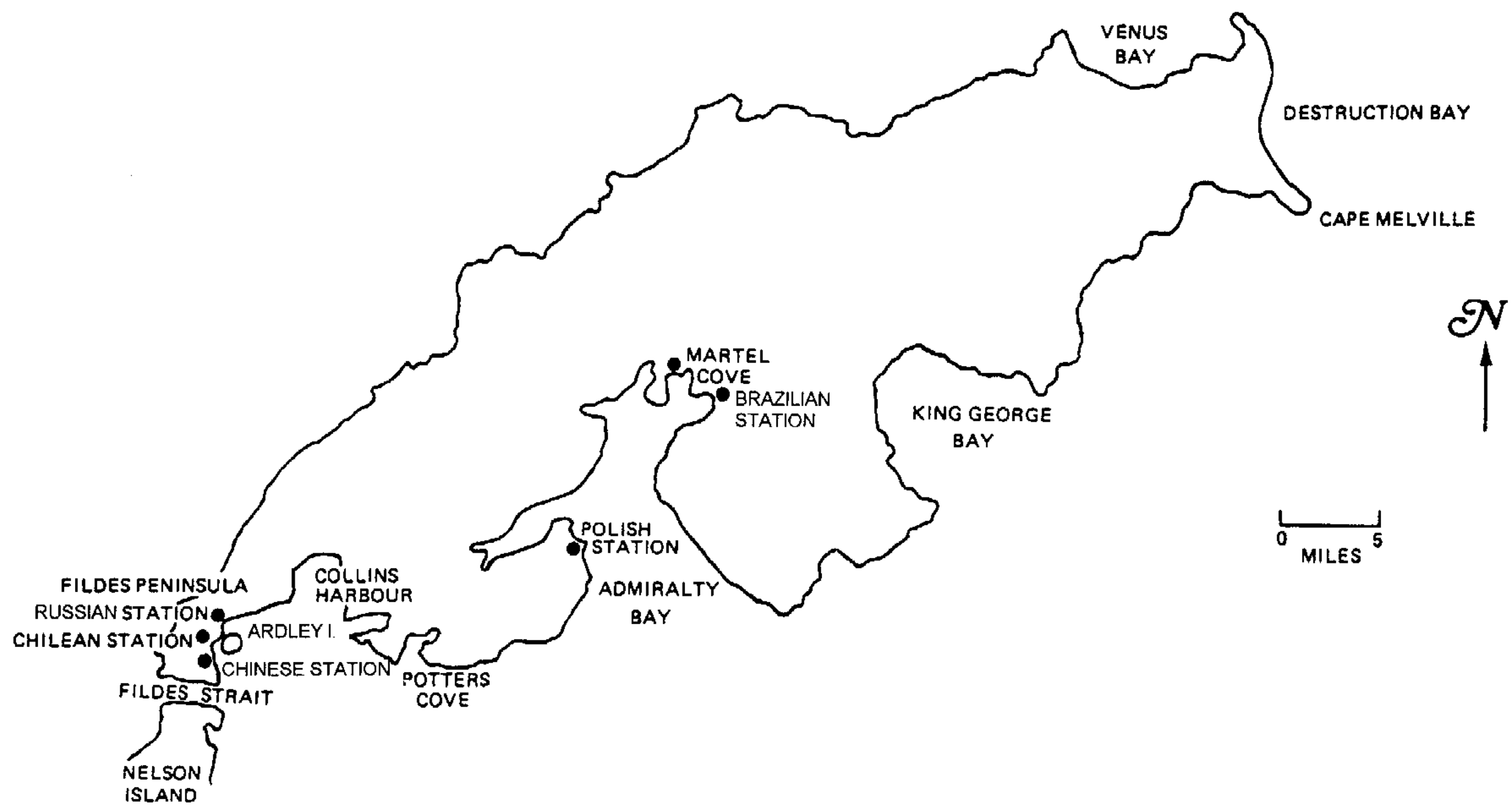


6. SOUTH GEORGIA

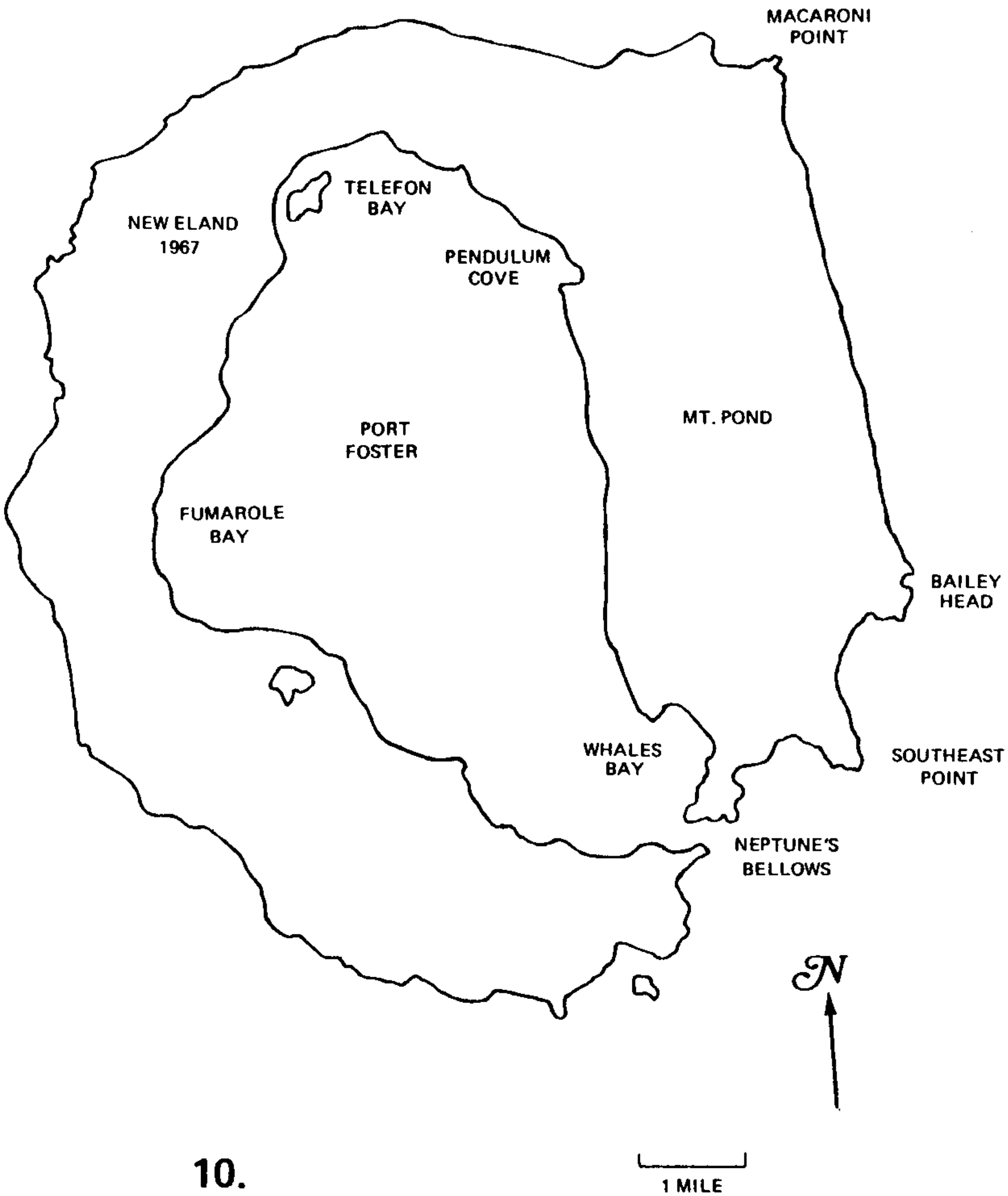


7. ANTARCTIC PENINSULA

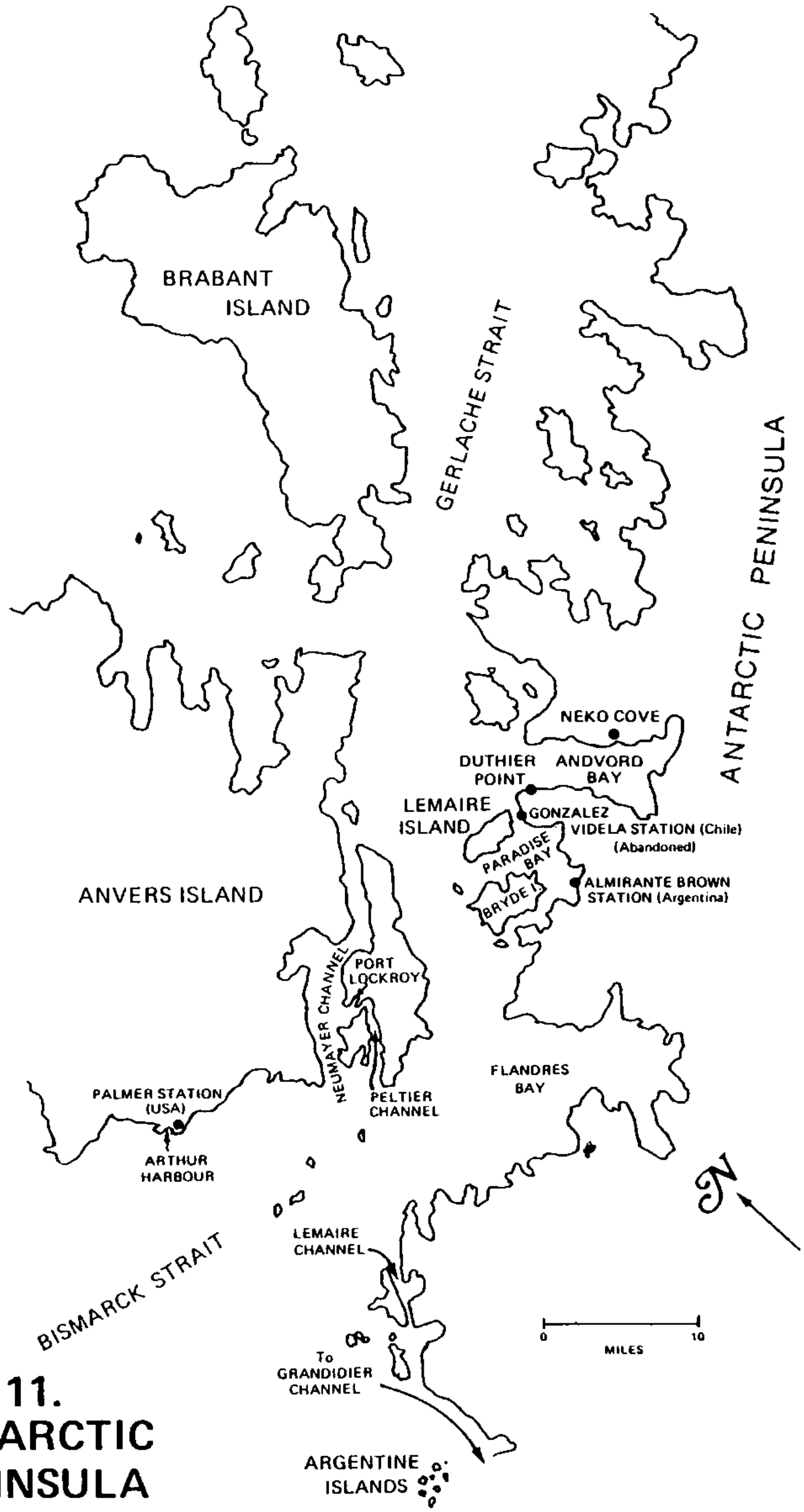

CORNWALLIS ISLAND
CAPE VALENTINE
WALKER POINT
EXPLORER POINT
PINNACLE ROCK
POINT BIRD
0
MILES
5
N
CAPE LOOKOUT
ROWETT ISLAND
8.
ELEPHANT ISLAND



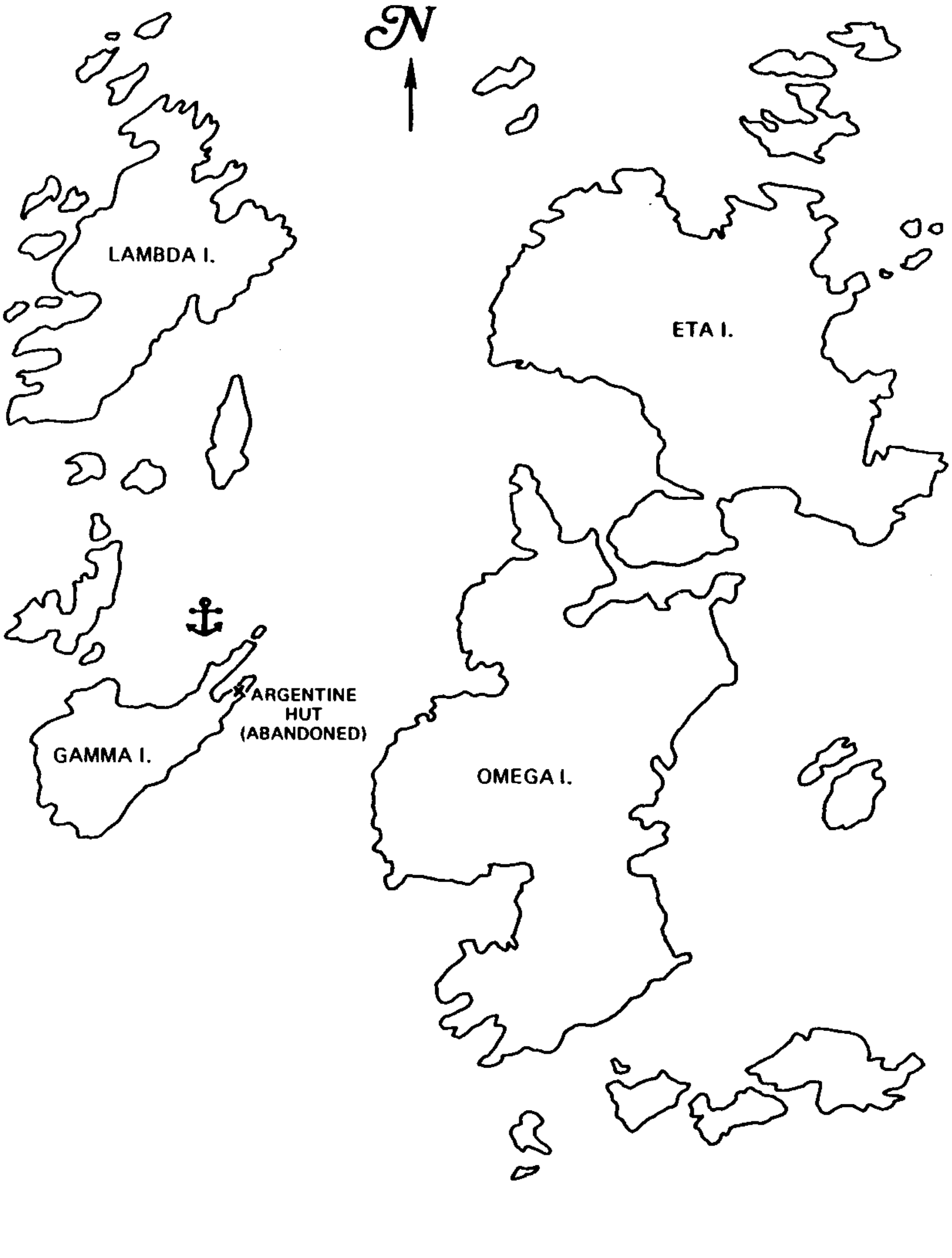
9.
KING GEORGE ISLAND



10.
DECEPTION ISLAND

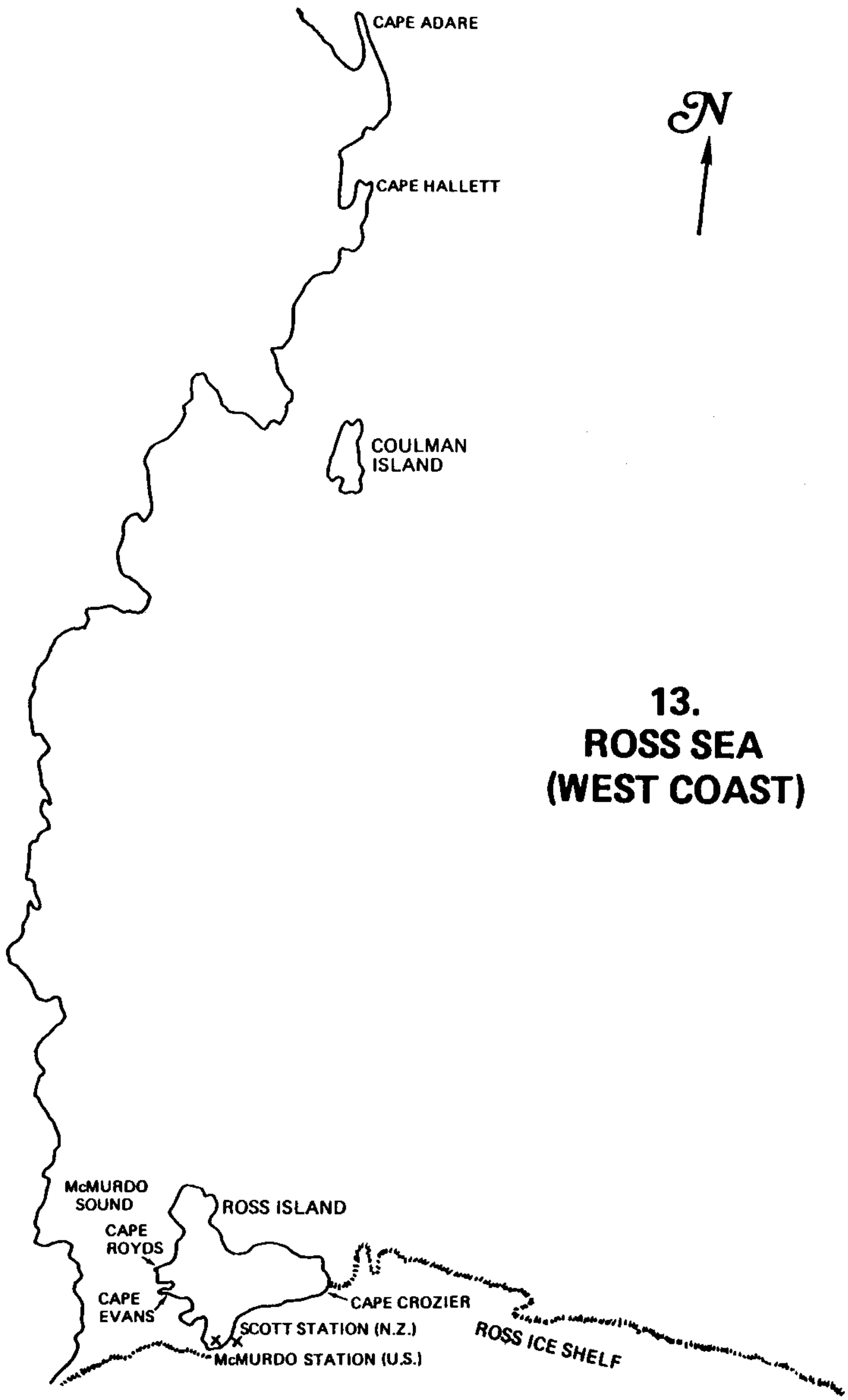


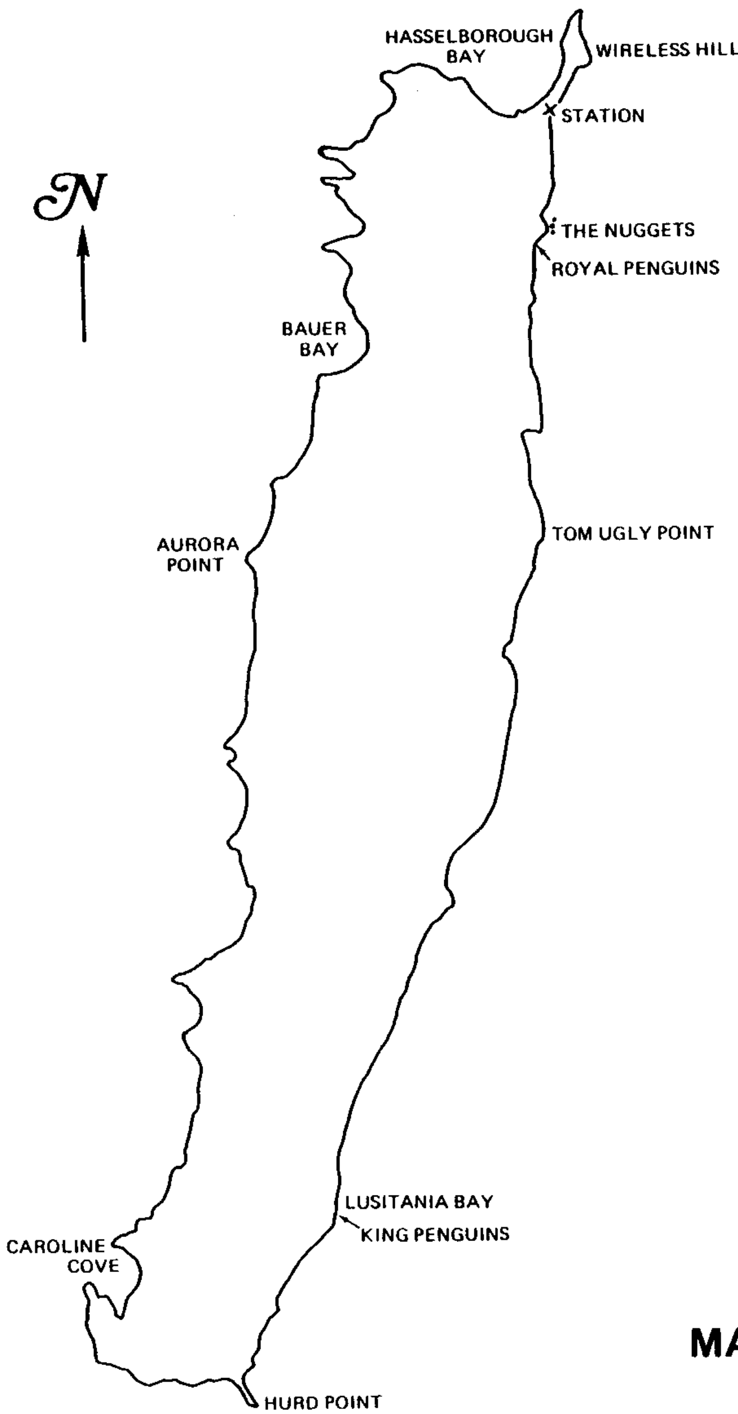
11. ANTARCTIC PENINSULA



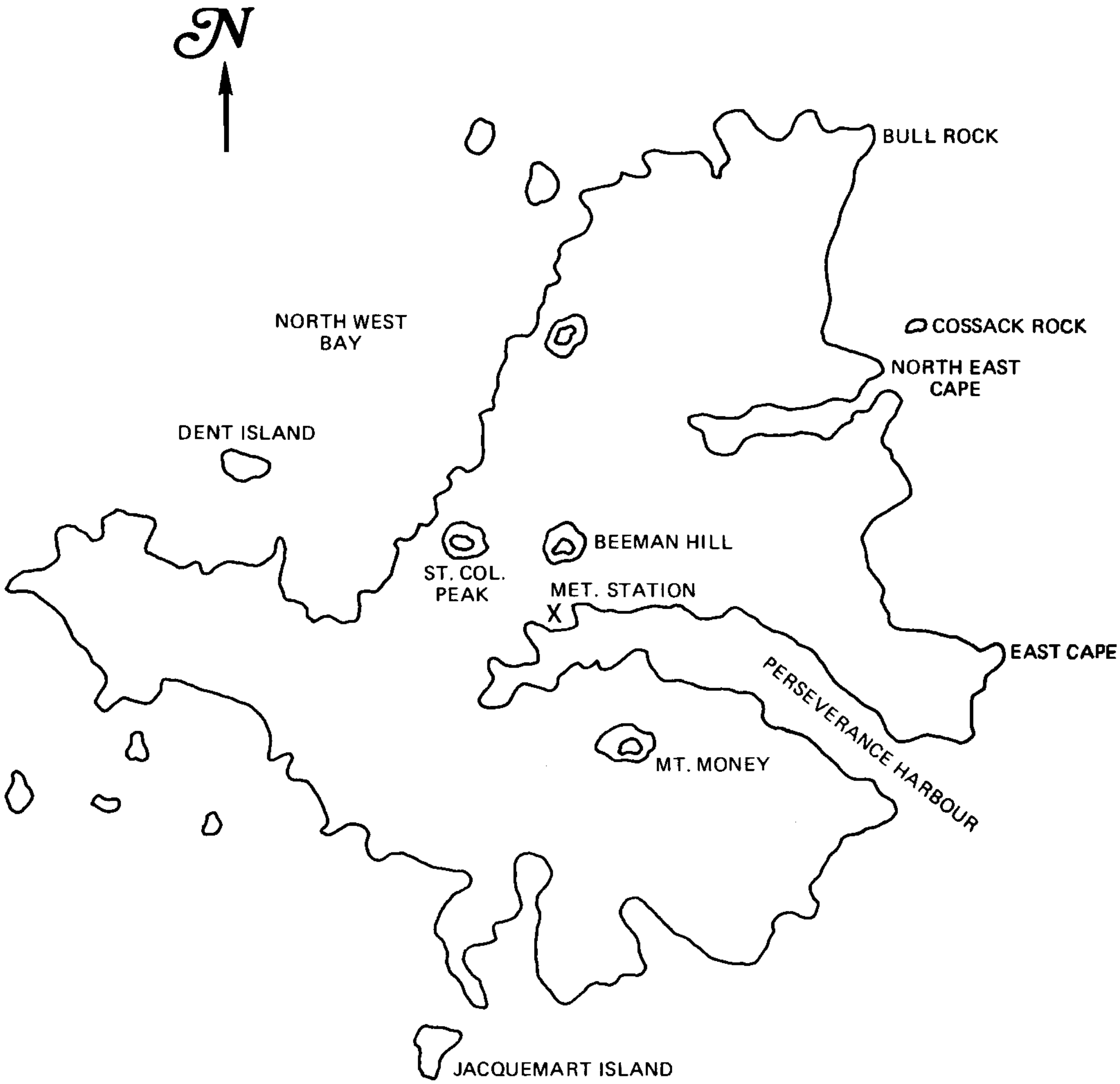
12.
MELCHIOR ISLANDS

13. ROSS SEA (WEST COAST)

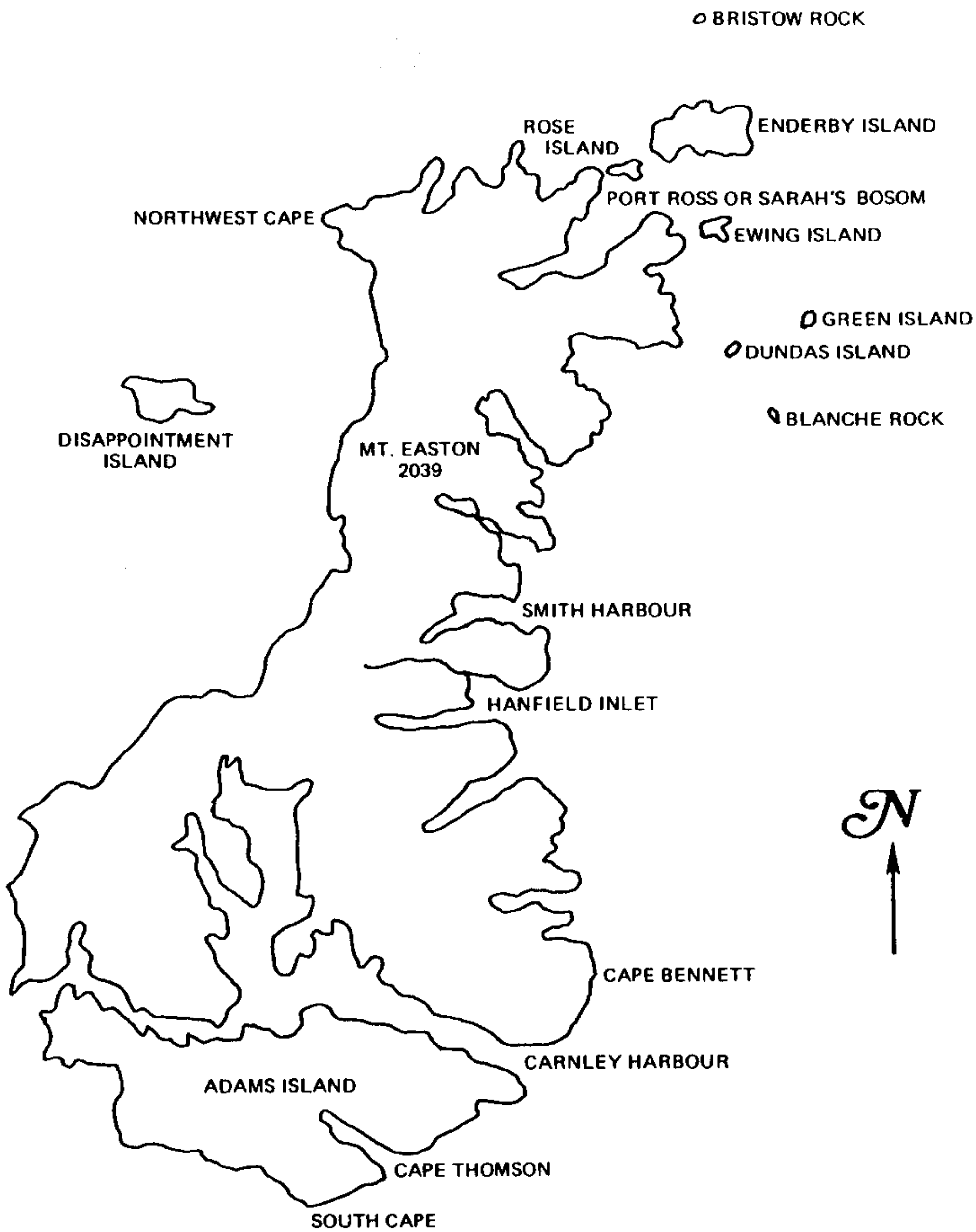




14. MACQUARIE ISLAND



15.
CAMPBELL ISLAND



16. AUCKLAND ISLANDS