

MARINE BIOLOGY IN ANTARCTICA

-

THEN AND NOW



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INTRODUCTION

Marine life around Antarctica, dictated by its extreme climate, has always been a fascinating topic for biologists. In the 19th century, first documentations of the abundant marine life were revealed through the eyes of the first sealers. Those expeditions further contributed significant information on the diversity and distribution of Antarctic marine life (McClintock, Amsler *et al.* 2001). But despite several expeditions, Antarctica was regarded as a 'terra incognita' at the end of the 19th century. The beginning of the 20th century, however, brought a change with the departure of several scientific expeditions into Antarctic regions. While geographical exploration and magnetic studies were of major importance, biologists were eager to discover and study the marine life and its adaptations to the Antarctic climate (McClintock, Amsler *et al.* 2001; Lüdecke 2003). Until today, Antarctic marine biology has undergone major changes, but is still of major interests for marine biologists, due to its extreme environments and importance in the world's ocean cycles (Hempel 2007).

Six expeditions (Table 1), leaving into Antarctic regions at the turn of the 19th century, were selected for this report and will be investigated for methods and research areas of marine biology. These methods will further be compared to and reviewed for their influence on modern studies in marine biology. A further aspect includes international collaboration of scientific studies during early expeditions and today.

Table 1. Scientific Antarctic expeditions at the turn of the 19th century.

Expedition	Year	Country	Leader
Belgica Expedition	1897 - 1899	Belgium	A. de Gerlache
Southern Cross Expedition	1898-1900	England	C.E. Borchgrevink
Discovery Expedition	1901-1904	England	R.F. Scott
Gauss Expedition	1901-1903	Germany	E. von Drygalski
Swedish Antarctic Expedition	1901-1903	Sweden	O. Nordenskjöld
Scottish National Antarctic Expedition	1902-1904	Scotland	W.S Bruce

SCIENTIFIC EXPLORATION OF ANTARCTICA

Polar exploration at the end of the 19th century had covered most of the Arctic and despite several expeditions into the Antarctic, such as in 1823-24 by Weddell, by Ross in 1839-43, or by Charles Wyville Thomson in 1872-1876, Antarctica was still a 'terra incognita'. This, however, was about to change with the beginning of the 20th century. According to climatic periods discovered by E. Brückner, the end of the 19th century was supposed to be a period of warmer temperatures. This should result in unusually advantageous ice conditions in following years, allowing ships to proceed far to the south (Lüdecke 2003). Plans for Antarctic expeditions arose in several countries, but the strongest promoters of Antarctic research came from Germany (G. von Neumeyer) and Britain (C. Markham) (Lüdecke 2003).

At the Sixth International Geographical Congress in London in 1895, a general scientific agreement decided that an Antarctic research programme should be established:

“[...] the Congress records its opinion that the exploration of the Antarctic Regions is the greatest piece of geographic exploration still to be undertaken. That, in the view of the additions to knowledge in almost every branch of science which would result from such a scientific exploration, the Congress recommends that the scientific societies throughout the world should urge [...] that this work should be undertaken [...].”

after Lüdecke 2003

The first of such scientific expeditions was launched from Belgium under the direction of A. de Gerlache (1897-1899) and was the first to winter in Antarctic waters (for this report defined as south of 60°S) (Decleir and Broyer 2001). The Southern Cross Expedition by C.E. Borchgrevink followed one year later (1898-1900) and was the first to winter on the Antarctic continent (Crawford 1998).

INTERNATIONAL COLLABORATION DURING THE EARLY EXPEDITIONS

At the Seventh International Geographical Congress in Berlin in 1899, E. Drygalski (the later leader of the Gauss Expedition) proposed an international collaboration for Antarctic research with Britain. C. Markham subsequently defined research areas for Germany and Britain and separated Antarctica into four quadrants assigning Britain the Ross and Victoria Quadrant, and Germany the Enderby and Weddell Quadrant (Fig. 1). W. Bruce from Scotland and O. Nordenskjöld from Sweden also attended the Congress and finally joined the collaboration. Final geographical areas of research are depicted in Table 2.

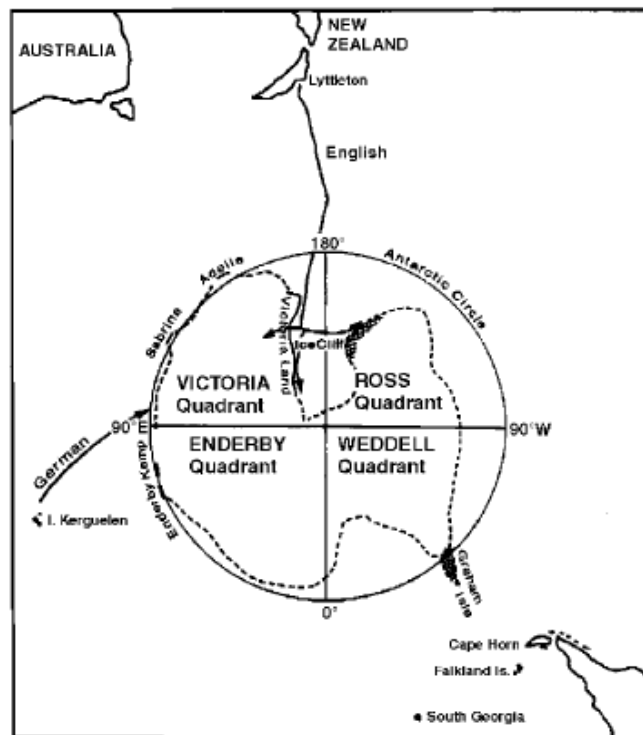


Figure 1. Map of Antarctica's four quadrants as divided by C. Markham (after Lüdecke 2003).

Table 2. Expeditions of international collaboration (Lüdecke 2003).

Expedition	Research area
Discovery Expedition	Kaiser Wilhelm II Land
Gauss Expedition	Graham Land
Swedish Antarctic Expedition	Victoria Land
Scottish National Antarctic Expedition	Laurie Island (South Orkney Island), Coats Land (eastern Weddell Sea)

Geographical exploration was a major focus of all four expeditions, but additionally to general routine measurements, each expedition focused on slightly different areas. The Swedish concentrated on geological research of Terre Louis Philip, the Scottish on deep sea investigations and meteorology, and Germany as well as Britain focused on magnetism. Collaboration was given in terms of magnetic and meteorological measurements, which were taken simultaneously by all four members throughout the duration of the expeditions. Germany and Britain further used the same instrumentation (Lüdecke 2003).

The early expeditions consisted of a mixture of scientists, typically one for each field. The “naturalist” was in charge of all types of biological studies, which were ultimately influenced by his educational background. Methods used to explore the Antarctic marine life during those above mentioned six expeditions will be discussed in further detail in the following.

METHODOLOGIES AND APPROACHES BY THE EARLY EXPLORERS

Information on Antarctic life and life strategies were widely unknown. Various sealing trips (predominantly from 1780-1892) had, however, reported on the existence, abundance and distribution of various seal species. A major was thus to gather as much information as possible. All six expeditions spent one or more winters in the Antarctic region and were able to collect extensive information about the marine life throughout the cycle of a whole year. This information was predominantly gathered in the form of observations and descriptions. For this purpose the Scottish National expedition kept a zoological log and each encounter with a marine species was entered together with a geographical reference. To keep observations as comprehensive as possible, everyone on board the Scotia was familiar with the names of Antarctic birds and seals (Bruce and Speak 1992). Observations were often conducted in a very detailed and structured manner and illustrated by drawings and photographs. They were further complemented by the establishment of zoological museum collections, as well as physiological and anatomical examinations.

Next to the studies on marine life, various oceanographic experiments were conducted as well. These included extensive soundings, analyses of seawater characteristics, such as temperature, conductivity or gravity, speed and direction of ocean currents, tidal measurements and sediment samples (Wilson 1966; Mossman, Pirie *et al.* 1978; Drygalski 1989). As these studies were rather of physical character and observed not in context of marine life, they were excluded from this report.

Seals and seabirds were easily observable and often the major focus of marine biological research. Detailed research methods will be discussed separately for seals, seabirds and the remaining oceanic flora and fauna in the following section.

Seals

"Very little is known on the domestic economy of these southern seals, and everything is interesting."

Discovery Expedition (Scott 1907) Vol II, p 44

Observational studies on seals were extensive and recorded e.g. general behaviour of seals on land, different colour stages during life, geographical and seasonal abundance and distribution, and population structure (Appendix 1). These observations were also compared between the four different species that were known (Crabeater Seal, Ross Seal, Leopard Seal, Weddell Seal). E.O. Wilson created highly valuable and comprehensive illustrations of those observations on seals (Fig. 2).

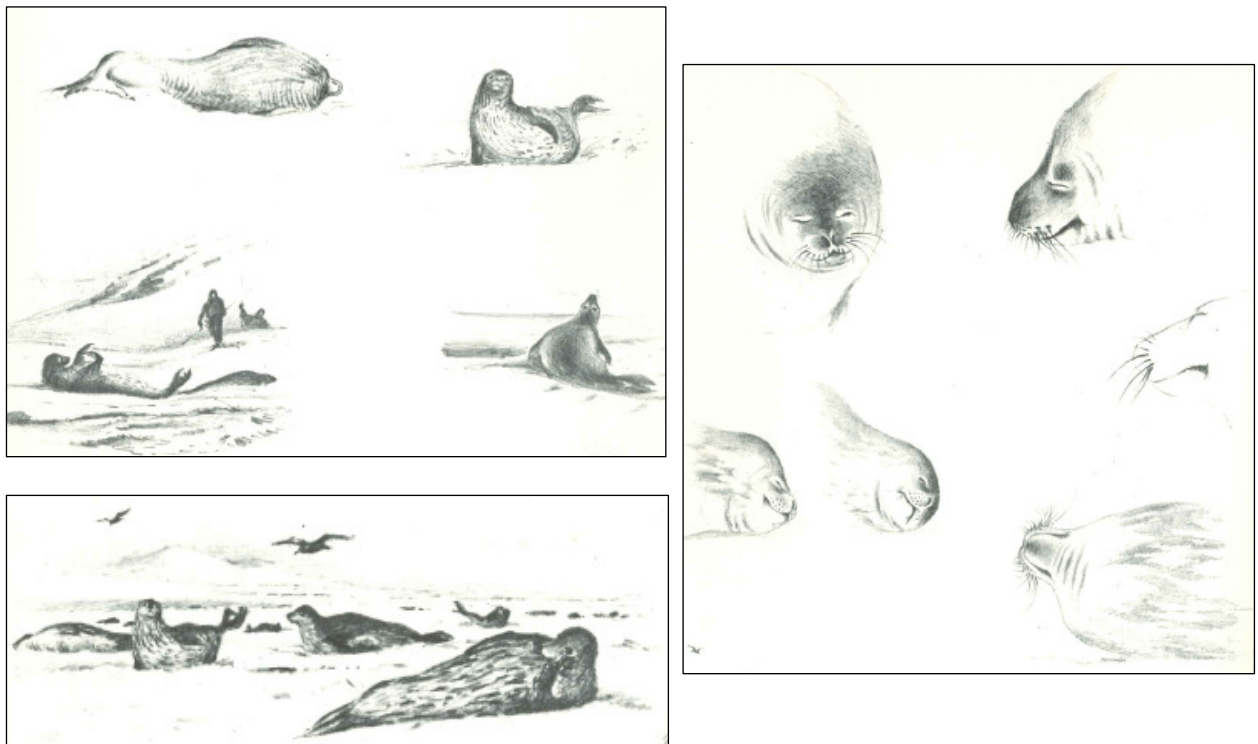


Figure 2. Seal sketches by E.O. Wilson (Wilson 1966).

Seals were usually approached by foot, on ski or in boats and then "collected" by shooting, clubbing or stabbing them. Subsequently they were skinned and skins as well as skeletons were prepared for zoological museum collections e.g. (Wilson

1966; Drygalski 1989; Crawford 1998) (Fig. 3). A rather interesting method to clean the skeletons was used by the Scottish National Antarctic Expedition, where roughly cleaned skeletons were lowered through holes in the ice and then left in the water for up to a week until the skeleton was precisely cleaned by amphipods.

"...we visited several "skeleton holes" - that is to say, places where we had cut a hole in the ice and lowered to the bottom a roughly cleaned seal skeleton with the object of allowing the little sea-lice (or amphipoda) to complete the work. These sea-lice swarmed in myriads in parts of the bay, and ate voraciously off any carcass lowered amongst them, thus very obligingly preparing beautiful skeletons for us in a week or thereabout."

Scottish National Antarctic Expedition (Mossman, Pirie *et al.* 1978), p92



Figure 3. Seal hunting (Nordenskjöld, Andersson *et al.* 1904).

A very good example of how structured and detailed studies on seals were conducted is given by Emil Racovitza, the naturalist on board the *Belgica*. He sorted and classified his samples and also included abundant and accurate data on their place and date of collection, distribution and their integration in the natural environment, complemented by the colour drawings he made on the spot. His final list to describe a seal species included the following aspects: denomination, history, external features (dimension; general aspect; colour in adults, pre-adults,

juveniles and foetus; fur and hair in the embryonic and adult state; whiskers; claws). Then followed notes on anatomy (teeth, bladder, genitals, fatty layers) as well as notes on physiology (sexual differences, size of both sexes, reproduction, growth, foetal envelopes). Finally, he included a very comprehensive discussion on ethology (voice, feeding behaviour, sociability, pathologies, parasites, predators, scars, causes of death and hunting) resulting from observations of these species' behaviour. He also conducted the first embryological studies on seals and the resulting embryological collection was of great value to scientists. Combined with breeding observations (i.e. the time pups were born), studies on seal foetuses were used for a detailed investigation of the breeding cycle of seals (Declair and Broyer 2001).

Various anatomical and physiological studies were conducted during the Gauss Expedition. They measured the amount of blood contained in a seal, the structure of the blood-vessels for a better understanding of the diving behaviour of seals, as well as the blood composition:

"Certain vessels have subsidiary branches, which serve to some extent as reservoirs of oxygenated blood so that the animals can remain longer under water. We also confirmed a particularly high haemoglobin content, with a separation of very little serum."

Gauss Expedition (Drygalski 1989), p 135

Freezing points of blood and urine were investigated, the latter to clarify if seals were actively drinking freshwater, or whether the uptake of seawater ingested along with their diet was sufficient. Further physiological tests included the measurement of pulse rates and blood temperature of resting seals. Therefore, an approached seal was observed until it had calmed down before it was shot. The "fountain of blood" coming out of the shot-wound could then be used to measure the blood temperature (Drygalski 1989).

Stomach contents of seals were examined for diet composition. Skull preparations further revealed feeding strategies, e.g. in the case of the crabeater seal, which showed that its teeth had developed to hold back krill (Drygalski 1989).

Seabirds

Observational studies of penguins were again extensively illustrated by E.O. Wilson and described e.g. breeding behaviour - nest building strategies (which materials were used), methods of egg incubation - population dynamics within a rookery, feeding strategies, predator-prey relationships between penguins and skuas preying on penguin eggs and young chicks, as well as estimations about chick survival rates (Wilson 1966) (Fig 4 -6, Appendix 2).

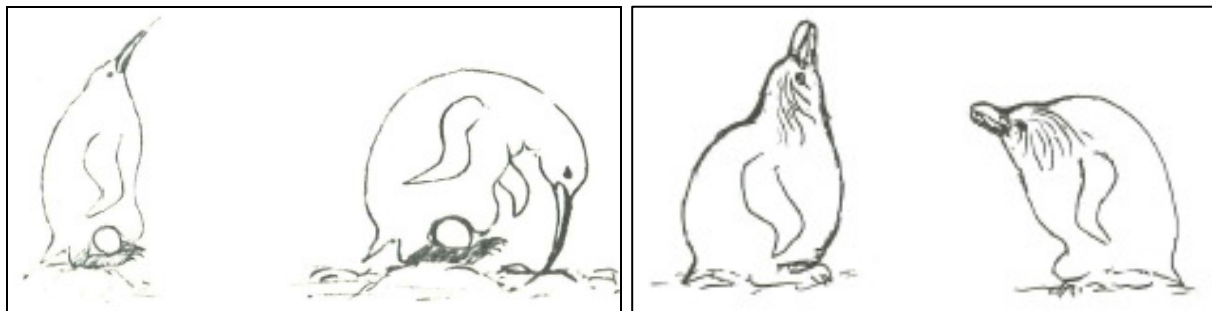


Figure 4. Egg incubation of penguins. The King Penguin (left side) keeps its egg kept off the ground by resting it on its insteps, protected by a loose lappet of skin and feathers, whereas the crested penguin (right side) is sting hunched up over its egg, which is lying in the nest (Wilson 1966).

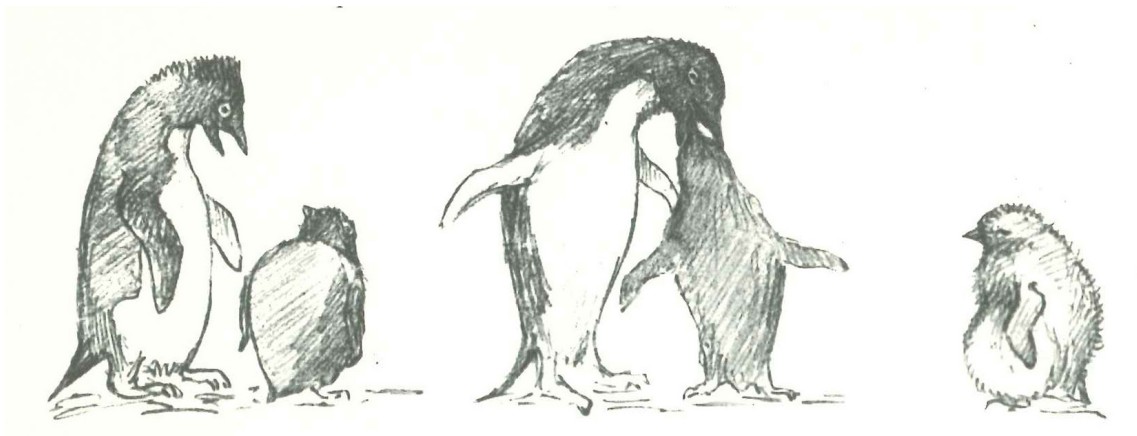


Figure 5. Feeding of young Adélie penguins (Wilson 1966).

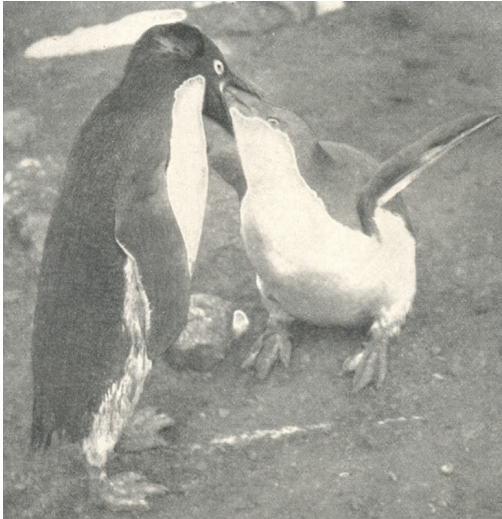




Figure 6. Feeding of young Adélie penguins (Nordenskjöld, Andersson *et al.* 1904).

In the same manner as seals, seabirds were killed for skin and skeleton collections. The Scottish National Antarctic Expedition established a comprehensive embryo collection of penguins by collecting eggs from the day they were laid until the day they were hatching. Additionally eggs were collected from the rookeries, blown out and prepared for museum purposes (Wilson 1966; Mossman, Pirie *et al.* 1978).

In order to capture seabirds at sea, E.O. Wilson adopted the methods devised by ancient mariners (shooting was impracticable as the ship couldn't stop to pick the birds up) (Wilson 1967): black cotton strands were either streamed aft from the peak halyards to entangle the smaller petrels, or a special designed triangle, which proved more successful with the larger petrel and albatrosses was used (Fig. 7). This latter method is described in more detail in a note from Wilson's diary (Wilson 1966; Wilson 1967) (Fig. 8)



Figure 7. Mechanisms to capture seabirds in open waters (Wilson 1967).

A dull cold drizzly gray day - no sun - no wind
 no sea + strongest of all no perceptible roll. Very few
 birds - Spent the morning on deck - + an hour's painting
 in my cabin - Afternoon skinned a Shearwater - After tea
 painting + again on deck for an hour till dinner, where the
 skipper was trying a new trap for Albatross - without
 much success. We have had very bad luck in
 catching Albatross - The general method is to cut out
 a tin triangle  so, with a triangular hole in
 the middle. This  is floated by attaching a piece of wood
 to it so. + then into the vacant space of the
 hole in the tin a piece of salt pork is tied so
 and the whole thing is played by a long
 line from the stern of the ship. The Albatross
 has a long hook to his upper beak which hooks
 into the tin triangle + you just pull him in by his
 beak so - Only of course the
 moment the strain is off, his
 beak slips out - so you have to haul in very fast.

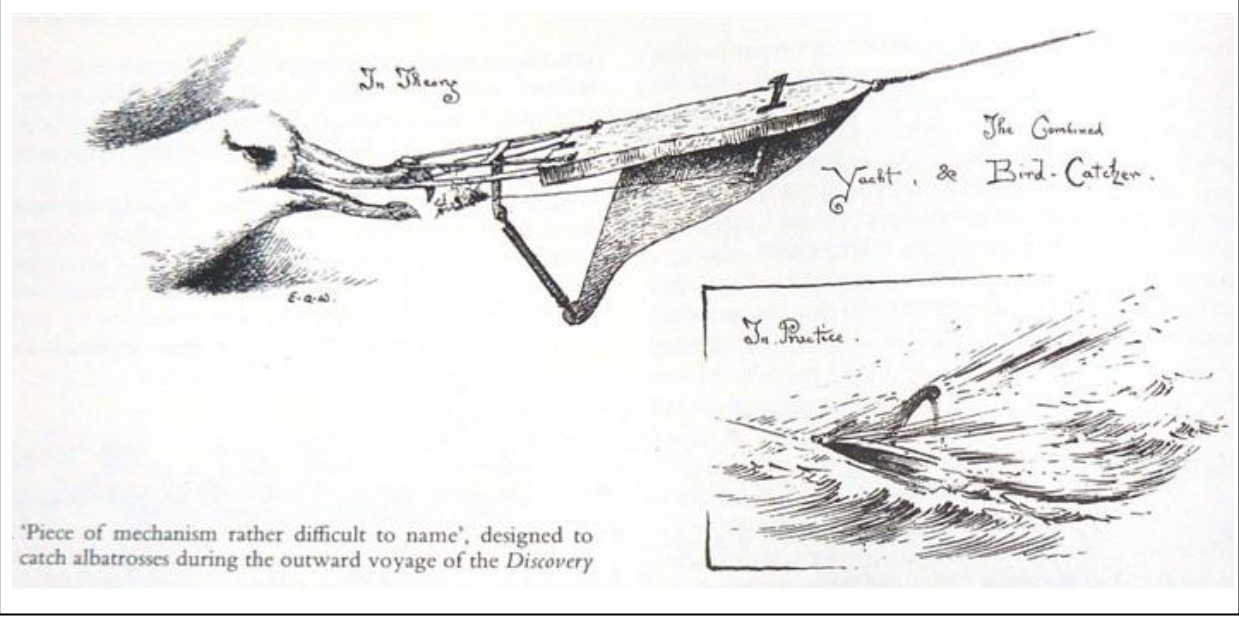


Figure 8. Methods used by E.O. Wilson to catch seabirds during the voyage (Wilson 1967).

E.O. Wilson had a very structured method in sketching birds, overall producing 8 pictures for each bird species aiming to create an easy identification guide for the future:

"Each new bird I get I paint the head, profile and from above, and the foot and leg, and two full views of the bird, front and back, and one of a wing fully outstretched. The object is to be able to enlarge and paint up correctly rough sketches I make in a pocket book of all the birds we see in various positions in life, so that in winter I hope to be able to work up all these notes into a series of pictures with sea and ice and birds in characteristic positions, which will enable anyone to recognize the birds at sight, instead of ploughing through descriptions each time, as I have to do whenever we strike a new bird."

Discovery Expedition (Wilson 1967), p 13

At the ice edge birds could then be "collected" by using a shotgun and penguins were killed by a hit on the head, knocking them against rocks or with chloroform (Wilson 1967; Drygalski 1989)(Fig. 9).

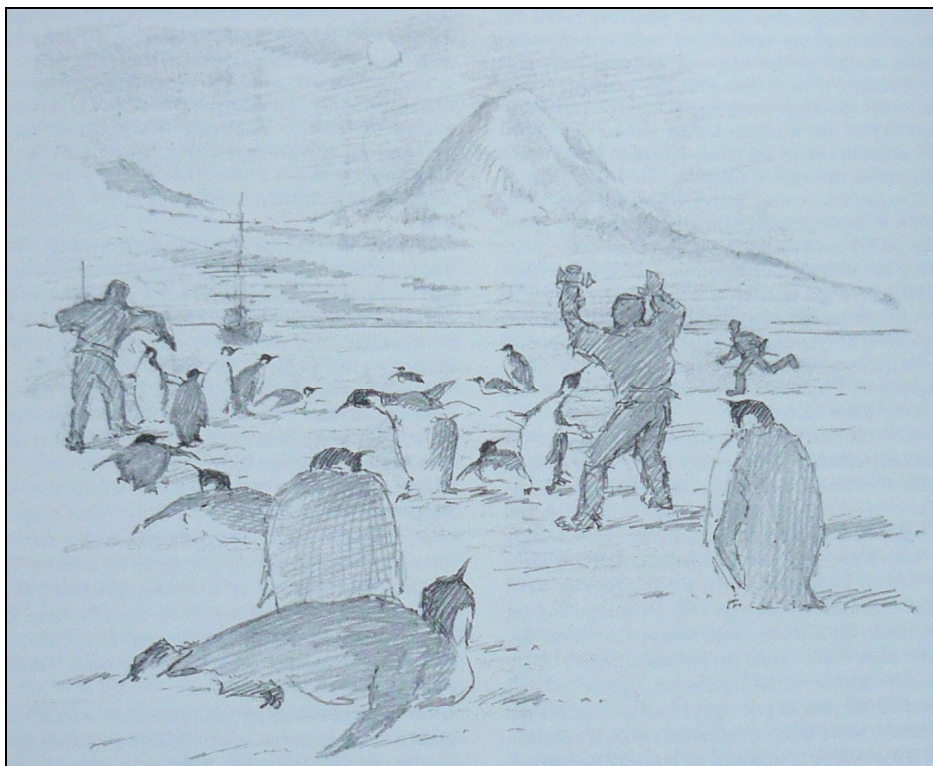


Figure 9. Penguin hunt (Wilson 1966).

Stomach contents of penguin were also investigated, as was the amount of blood contained in a penguin (Drygalski 1989).

Other rather interesting studies by the Scottish included the effect of music on Emperor Penguins (Fig. 10), tested by playing bagpipes to a penguin and observing its reaction as well as playing an "amusing trick" on nesting skuas by replacing of one of its two eggs with a penguin egg (Mossman, Pirie *et al.* 1978):

"The deception was not at first discovered, for the bird was seen sitting happily on the egg afterwards; but in the course of a few says the change was found out, and doubtless the egg was eaten: at all events, no trace of it could be seen on our return visit."

Scottish National Antarctic Expedition (Mossman, Pirie *et al.* 1978), p 223

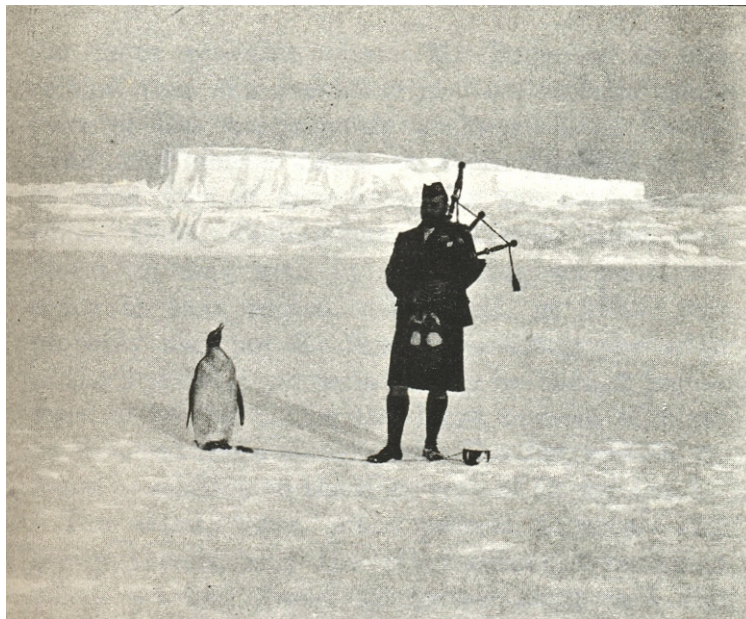


Figure 10. Experiment to test the effects of music on Emperor Penguins (Mossman, Pirie *et al.* 1978).

Submerged oceanic fauna and flora

Marine life, such as fish, invertebrates, plankton or other algae were more difficult to observe. Studies generally recorded whatever species was caught and samples of those were stored in containers filled with methylated spirits (Mossman, Pirie *et al.* 1978).

Gale winds washed up marine life from time to time, which could then be collected from the shore (Crawford 1998). In shallow coastal areas observations on the life at the seafloor could be made from boats due to the clearness of the water (Crawford 1998). Species were also often found and taken from seal or seabird stomachs, but generally the marine life was caught by trawling, dredging, using traps or fishing.

During the journey through Antarctic waters, marine life was collected by trawling and dredging. A variety of nets ranging from vertical nets, hand-held surface nets, self closing nets to tow-nets was used (Fig 11, 12).

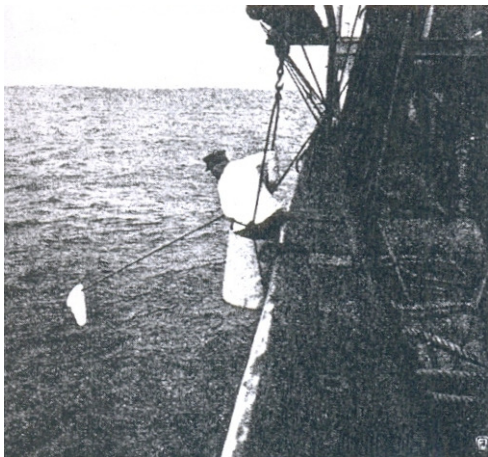


Figure 11. Net used to collect samples from the water surface (Drygalski 1989).

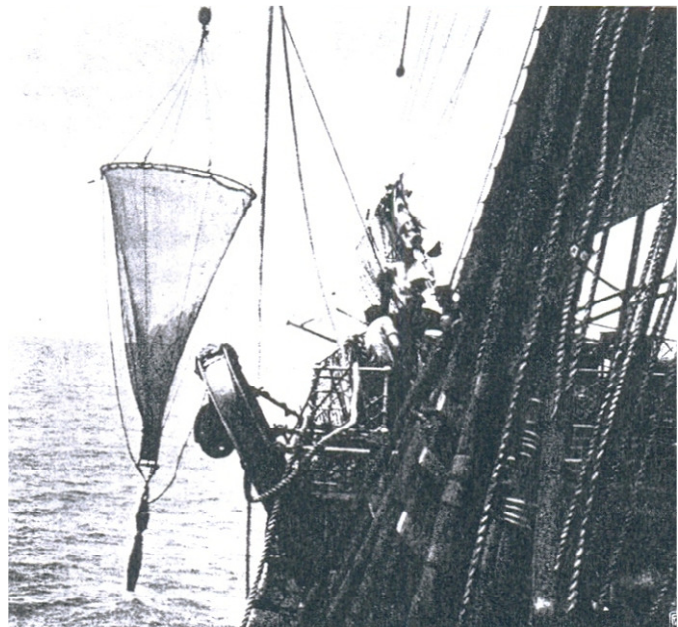


Figure 12. Vertical net (Drygalski 1989).

They varied in dimension and mesh size and appropriate nets were selected depending on the depth of trawling. A precise description of tow-nets is available from the Scottish National Antarctic Expedition:

The tow-nets [...] were of various types, both as regards dimensions and material. The coarser ones were made of muslin or coarse butter-cloth, but the finer ones were made of different meshed silk gauzes: the finest of these [...] was No. 20 miller's gauze, which has 5926 meshes to a square centimetre, with the side of each mesh 0.05 mm long. It is very regularly made and extremely strong, while the fineness of the mesh ensures that hardly anything can pass through; but it naturally becomes choked very soon, particularly where diatoms are abundant, and has often to be renewed. As the greater part of the tow-netting had to be done without slowing down the ship, it was essential that the net used should have a small diameter to offer as little resistance as possible to the water. With this in view, Brown devised a form of net 4 to 5 feet long, with a mouth 4 inches in diameter, and the tail-end narrowing to 2 inches. [...] there was a device by which the terminal six inches, clamped into a brass ring, could be unscrewed from the body of the net, which ended in a similar brass ring. The catch could then be carried into the laboratory and quickly preserved. [...] Other nets of similar shape, but with a 6-inch mouth, were also used, as well as larger nets (8 inches to 12 inches across) for slow speeds of for boat work. The larger the net the coarser the mesh, was naturally the case [...].”

Scottish National Antarctic Expedition (Mossman, Pirie *et al.* 1978), p 13

Those nets were generally deployed either from the side of the ship or dragged behind the ship. They were then lifted back onto the vessel with the aid of power-steamed winched (Fig 13, 14).



Figure 13. Self-closing net (Nordenskjöld, *et al.* 1978).
Andersson *et al.* 1904).

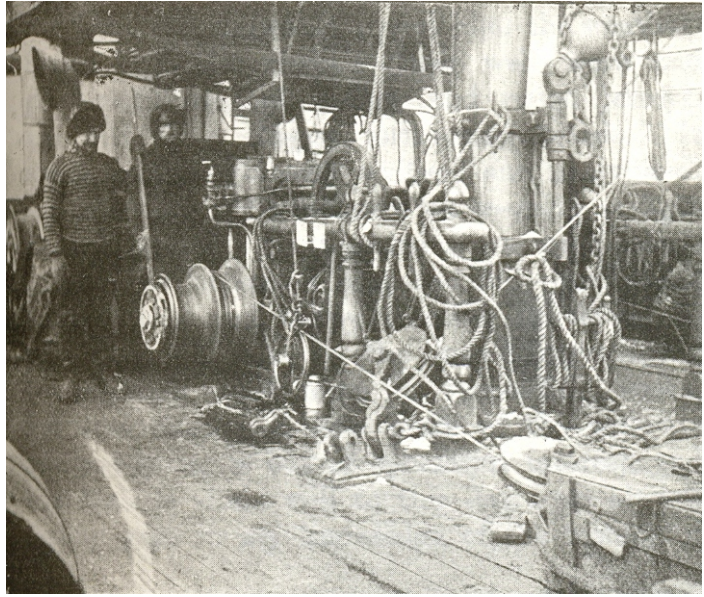


Figure 14. At the winch-trawling (Mossman, Pirie *et al.* 1904).

Winter trawling revealed highly valuable information about the annual composition of the marine fauna. However, as nearly all ships were frozen into the ice and thus stationary during winter, a different technique was used. A tow-net was set up on a line, which was dragged between two holes in the ice that were kept open during winter. An illustrative description was found in Wilson's Diary (Fig. 15):

"I helped [...] to draw up the D net which he has on a line between to holes in the ice. It is a dredge net and one drags it some few hundred yards. The line and the net were put in position when the floe was cracked by a storm. This crack has since frozen over of course, but the holes at each end are kept open, and so the net can be dragged periodically over the sea bottom backwards and forwards, catching anything there may be there."

Discovery Expedition (Wilson 1966), p 148

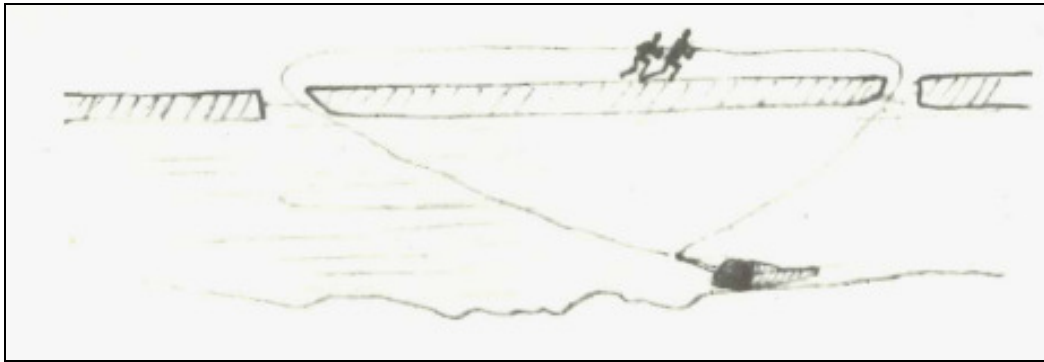


Figure 15. The trawling net ("D net") used by the British during winter (Wilson 1966).

The German Gauss Expedition was leading the line lengthwise under the ship, instead of between two holes in the ice. After the line had snapped an Emperor Penguin was sent down one hole with the line attached to its leg in the hope that he would swim towards the other hole and repair the dredging set-up.

"As there were many of these birds to be found around the ship, a suitable specimen was soon chosen and, with a cord tied round its leg, was dropped into a small hole in the ice near the bow of the ship. The poor creature tried at first to scramble out again, but as we had other ideas it was ducked again, until it eventually gave up, dived, and resurfaced about 50 m away in another hole by the stern. Unfortunately, it had lost the line on the way, so the procedure had to be repeated twice more (the bird having been attain careless the second time), until at the third attempt it came up at the stern of the ship with the line still attached. The bird was recaptured, praised for its good work and then released at last."

Gauss Expedition (Drygalski 1989), p 161

During the Southern Cross Expedition fishing during winter was practised through a hole in the ice using the "Norwegian pilk, a method of fishing, which depends upon knowledge of the layers of the temperature in the water and where fish are likely to be found" (Crawford 1998). Other expeditions set up fishing lines and lowered small fishing nets through the ice to the bottom, where they were left overnight (Fig.16, 17) (Mossman, Pirie *et al.* 1978; Drygalski 1989; Crawford 1998).

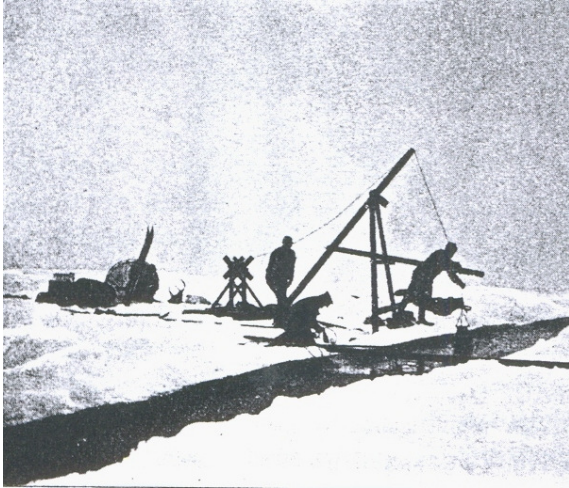


Figure 16. Fishing (right side) (Drygalski 1989).



Figure 17. Setting of fishing lines (Mossman, Pirie *et al.* 1978).

Additionally, traps were widely used to catch marine life. They varied in sizes and were deployed in various depth ranges (Scottish, German). The Scottish traps were a type of lobster pot. Smaller traps had the shape of a skeleton box and were covered with a 1-inch herring netting. They had a funnel on either end and an opening door at the top through which the catch could be retrieved. This type of trap ranged from one to two feet in height, and two to four feet in length. Additionally, a larger trap was developed, which was in a triangular shape, but with similar funnels and a door then the smaller traps (Fig. 18). Traps were designed based on previous experience in higher latitude areas and penguin carcasses were used as bait (Mossman, Pirie *et al.* 1978). The Germans used next to traps hemp swabs, which were "*tassels of tow formed from unlayed rope ends 1.5 m long, sent down five at a time fixed to a weighted transverse bar.*" These swabs were then moving in the tidal currents and collecting benthic species (Drygalski 1989).



Figure 18. The large trap used by the Scottish National (Mossman, Pirie *et al.* 1978).

HOW DOES MODERN MARINE BIOLOGY DIFFER FROM THE EARLY DAYS?

Early marine biology was often done en route during the expeditions and science for the “pure sake of science’ was not always the only interest. Borchgrevink, e.g. stated that even though the collection on scientific data was important, *“full attention will also be given to further investigations of the commercial possibilities”* of Antarctic areas (after Crawford 1998). Until today, Antarctic marine biological research has undergone major changes. Hempel (2007) defines three driving forces in the 20th century that dictated research: sealing and whaling until the 1950s, fishing for krill and fish in the 1960s - 1980s, and worries about global climate change and biodiversity loss since the 1990s. Each of these drivers was related to global demand (e.g. seals and whales for candlelight, whale blubber for margarine, the hope for a CO₂ sink of the Southern Ocean) and have influenced specific research on mammals, krill and plankton, biogeochemistry, sea ice and benthos (Hempel 2007).

Various new disciplines have evolved, many of which the "naturalists" were pioneers, e.g. Racovitza is considered a pioneer of ethology, nowadays a discipline in full expansion but at the end of the 19th century only vaguely defined (Declerq and Broyer 2001). Disciplines, such as microbiology, genetics, ecology, integrative ecophysiology, or biological oceanography are only few examples of the wide range of marine biological studies today. This development has led to highly specialised marine biologists today, compared to the versatile nature of the early biologist.

This development in the field of marine biology was strongly influenced by the studies and results of the early expeditions. An extensive amount of first discoveries and observations was made during that time, e.g.:

- the discovery of many undescribed oceanic species,
- basic observations on the geographical and seasonal distribution of seals and seabirds,
- the location of many seabird and penguin rookeries
- first observations on the composition of oceanic species (plankton, fish) throughout the year

- first observations on adaptations to life in the Antarctic

As little information about Antarctic species was known, a major aspect of marine biological studies (esp. for seals and seabirds) during the early expeditions was the collection and preparation of skins, skeletons, but also embryo and egg specimens. Several members of the early expeditions regretted the killing of animals in the “name of science”:

“It seems a horrible intrusion slaughtering these harmless beasts [when they are] sleeping upon the ice under the peaceful silence of the Antarctic sky.”

Southern Cross Expedition (Crawford 1998), p.60

“[...] but an opportunity not to be missed, for no one has ever seen this bird [Emperor Penguin] in any numbers before, and it is our duty to bring back as good a collection as we can”

Discovery Expedition (Wilson 1966), p.17

“I had to superintend this beastly butcher’s job, a duty much against the grain”

Discovery Expedition (Seaver 1946),
p.88

These studies, however, gave important results about the basic organisation of an organism and made it possible that much of today’s research on seals and seabirds can focus on non-lethal methods. The latter are further influenced by the need to consider the conservation status of different species as well as the aspect of animal ethics in modern research.

Nevertheless, a variety of the methods and the general research ideas of the early biologists are still used today. E.g. studies about the seasonal and geographical distribution, about feeding behaviour, such as diet composition and feeding grounds, and studies about diving behaviour of seals and seabirds are still conducted. Advances in technology, however, such as the use of “biologgers”, which are satellite transmitters attached to an animal, or surgically implanted

loggers, have added more detail and expanded on the data collected in early times (Fig. 19). Species can be followed on their distributional ranges for up to one year, habitat preferences, feeding strategies, as well as specific diving behaviour (duration, depths, 3-D profiles) can now be observed (Bornemann, Kreyscher *et al.* 2000; Green, Wilson *et al.* 2008).



Figure 19. Young Emperor Penguin with satellite tracker (www.aad.gov.au).

Nets of various types and sizes are still used to catch and study submerged marine flora and fauna, such as plankton, fish or benthos (e.g. Barrera-Oro and Winter 2008; Ward, Meredith *et al.* 2008) (Fig. 20, 21). Researchers continue to discover new species, which are then described in a structured way similar to that used by the early explorers, i.e. size, outer appearance, anatomy and illustrated by drawings and photographs, etc. (Matallanas 2009).



Figure 20. Plankton net (compare to Fig. 12) (www.esf.edu)



Figure 21. Tow-net (<http://images.aad.gov.au>)

New research areas have additionally developed due to human impacts on the Antarctic ecosystem. The effects of UV radiation on marine life, the effects of fishing on ecosystem dynamics or the impacts of climate change due to elevated CO₂ emissions were non-existing areas of research back then.

Research has also moved away from the sole study of individual species. The importance of understanding food web dynamics and ecosystem processes further promotes interdisciplinary research, e.g. with marine chemistry and physical oceanography.

Some of the biological research is also still used for commercial purposes, just like during the early expeditions. Bioprospecting, which involves the search for genetic or biochemical resource for commercial purposes, is currently thought to be one of the world's most important growing industries likely to affect Antarctica and the Southern Ocean (Weber 2006).

INTERNATIONAL COLLABORATION TODAY

Modern research in Antarctic marine biology is dominated by international collaboration. Organisations such as the Scientific Committee on Antarctic Research (SCAR), the Scientific Committee on Oceanographic Research (SCOR), or the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) bring together joint international programmes for marine biological research. Various large research programmes have been conducted. The Biological Investigations of Marine Antarctic Systems (BIOMASS), directed to understand the structure and functioning of the Southern Ocean ecosystem, from 1976-1991 was probably one of the largest and most comprehensive biological projects conducted (Hempel 2007). Other large collaborations include the Southern Ocean Global Ocean Ecosystem Dynamics (GLOBEC) project, which focused on the year-round life cycle of Antarctic zooplankton, particularly krill, or the Southern Ocean Iron Experiment (SOFeX), which aimed to investigate the effects of iron fertilization on the productivity of the Southern Ocean (Hempel 2007, www.mbari.org). Particular focus on international collaboration is further given through the International Polar Year (IPY), which operates on a 50-year cycle and represents an *"intensive burst of internationally coordinated, interdisciplinary, scientific research and observations focused on the Earth's polar regions"* (Rapley, Bell *et al.* 2004). International joint research is, however, not restricted to large projects. Even though many nations have established their own (smaller) national research programmes, biologist from various nations are often partaking in those due to logistical constraints that greatly dictate research in Antarctica. Collaboration is additionally enforced within the Antarctic Treaty that states in Article III that *"to the greatest extent feasible and practicable ... scientific observations and results from Antarctica shall be exchanged and made freely available"* (Antarctic Treaty, 1959).

CONCLUSION

Antarctic marine biology has developed since the early expeditions from being a science conducted in the background of other interests (esp. geographical exploration) to a science of global scope. Today there is widespread scientific interest in old and new questions in Antarctic biology: How are organisms defending themselves against the extreme cold? Where do they go to? How are they interlinked within the Antarctic food web? How will they react to climate change? But Antarctic marine biology is also increasingly focusing to explore more dynamic global issues including the flow of carbon, nutrients and energy through marine food webs, the effects of ozone depletion on planktonic and benthic organisms, and global change processes. International collaboration continues to be a major factor in successful research due to Antarctica's remote and harsh environment (Hempel 2007) and various research platforms operate either from research vessels or bases established on the continent.

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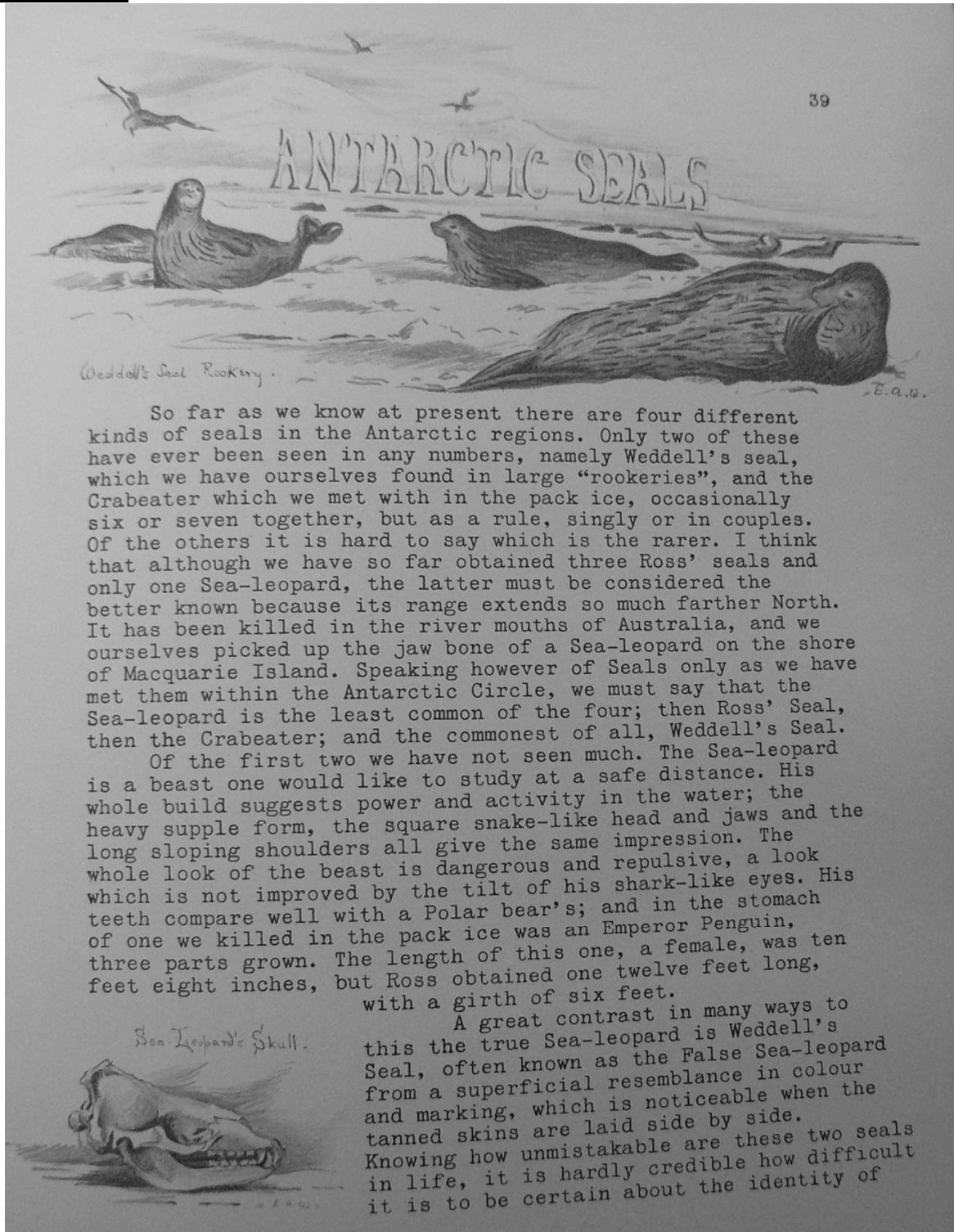
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ANTARCTIC SEALS

Weddell's Seal Rookery.

E.A.W.

So far as we know at present there are four different kinds of seals in the Antarctic regions. Only two of these have ever been seen in any numbers, namely Weddell's seal, which we have ourselves found in large "rookeries", and the Crabeater which we met with in the pack ice, occasionally six or seven together, but as a rule, singly or in couples. Of the others it is hard to say which is the rarer. I think that although we have so far obtained three Ross' seals and only one Sea-leopard, the latter must be considered the better known because its range extends so much farther North. It has been killed in the river mouths of Australia, and we ourselves picked up the jaw bone of a Sea-leopard on the shore of Macquarie Island. Speaking however of Seals only as we have met them within the Antarctic Circle, we must say that the Sea-leopard is the least common of the four; then Ross' Seal, then the Crabeater; and the commonest of all, Weddell's Seal.

Of the first two we have not seen much. The Sea-leopard is a beast one would like to study at a safe distance. His whole build suggests power and activity in the water; the heavy supple form, the square snake-like head and jaws and the long sloping shoulders all give the same impression. The whole look of the beast is dangerous and repulsive, a look which is not improved by the tilt of his shark-like eyes. His teeth compare well with a Polar bear's; and in the stomach of one we killed in the pack ice was an Emperor Penguin, three parts grown. The length of this one, a female, was ten feet eight inches, but Ross obtained one twelve feet long, with a girth of six feet.

Sea-Leopard's Skull.



A great contrast in many ways to this the true Sea-leopard is Weddell's Seal, often known as the False Sea-leopard from a superficial resemblance in colour and marking, which is noticeable when the tanned skins are laid side by side. Knowing how unmistakable are these two seals in life, it is hardly credible how difficult it is to be certain about the identity of

two skins when the skulls and bodies have been removed.

Weddell's Seal is truly gregarious in the summer months. What its habits are in the winter we hope to discover. Along the Barrier edge of MacMurdo Strait we found thousands of these seals in companies of two or three hundred together, lying on the ice edge as far as the eye could see; but as the open water froze during April these companies broke up and seals began to appear more frequently at the tide cracks and at various holes kept open near the ship for fish-traps, tide measurement, and so forth. Some, we hope, will remain with us throughout the winter and give us an opportunity of seeing their nursery in September.

Ever since our arrival here, in MacMurdo Strait, the "Seal Crack" rookery has been a source of interest, a kind of "Zoo" where the species are certainly limited in number, but the individuals are numerous and grotesque. A seal scratching his nose with the fore finger-nail of his front flipper, or twisting himself into knots to scratch the small of his back, or sleepily stretching himself in a prolonged yawn; the expression of open-eyed surprise and bewilderment when roused from his slumbers by any of our party, as though awaking from a bad dream to a worse reality; the weird noises, bubbling, gurgling, snorting, whistling, sighing and sometimes roaring, with a sound which, at a distance, forcibly reminds one of a herd of cows in an English meadow; all these little characteristics afford one interest and amusement in walking through this sleepy community of handsome Weddell's Seals. Later on the coat gets rusty and at the beginning of Spring is shed. They feed on shrimps and fish and swallow an immense amount of mud in getting them. During the summer, when the temperature is seldom very low, they seem to keep irregular hours, and may be found asleep, or feeding, at any hour of the twenty four; but as the days go on and the temperature of the air gets lower

and lower they feed more regularly during the colder hours of twilight and never miss an opportunity of basking at midday in the sunshine. And now that there is no sunshine and the temperature falls still lower, there seems to be a great reluctance on the part of any of them to put more than a nose out of the warmer water; and how and where



they sleep in the winter, and for how many hours a day, is a problem full of interest. Now and again as we walk among the Weddell's Seals we find a Crab-eater, seldom more than one or two, asleep with the rest.

When we were in the pack ice these were our daily food, for we saw some every day, and often ate them. Here they are a rarity, and an interesting one, as they have hitherto been considered the peculiar property of the pack ice. The "Southern Cross" expedition found one on the Great Ice Barrier, and we saw several as we sailed along it, but here we have them still farther South, and prospect of our from time to

there seems every seeing them time during the winter and perhaps even something of their family arrangements in the Spring.

I think the general admiration of our party is divided somewhat between the Crab-eater and Ross' Seal. We have had but few opportunities of getting to know the latter, though both are very interesting. No one has ever met with Ross' Seal except in the pack ice, and possibly his coat would be found to vary much if seen at other seasons of the year, but he has only been seen in summer when all have had a roughish hair

Sea Leopard
chasing Emperor Penguins

E. A. W.

of grey, generally pure grey, occasionally brown, which is perhaps the older unshed coat of the previous year. Along the sides from the shoulder to the flank are a few long whitish streaks and lines, and the chin is sometimes black, though generally silver-grey, the same colour as the under parts.

Very different to this is the slim and active long-snouted Crab-eater, well known to Sealers as the White Antarctic Seal, and changeable enough in colour and in marking. Sometimes he is silvery-white with creamy dapple-marks on the flanks and neck and shoulders; sometimes, before the shedding of the winter coat, creamy white all over with the dark chocolate of the Spring coat appearing along the back and on the flippers; sometimes chocolate brown all over shading into silver grey below with rich dark dapple-marks on flank and shoulder, the handsomest coat of all, for summer wear, which gradually but surely bleaches once again to the silvery coat of

the white Antarctic winter. Why all this routine, and to what purpose? What enemies have these seals? How come they to be scarred and wounded as they so often are, lightly on the shoulders and the neck and back, but viciously with deep angular rents on the lower parts? In some way this change of coat must be a protection to them, but from what? Is it from the intense cold? Perhaps



the dark summer coat has some power of helping the beast to absorb the sun's warmth and more quickly clothe itself with blubber for the coming winter, the only fuel he has, with which to supply the demand of the tissue-change which must needs be faster as the temperatures go down. Or possibly he alters colour to protect himself from some enemy. If we but knew what enemies he has, we might perhaps guess how. One beast there is which we see here again and again, in large herds, the Killer whale or Grampus, and I rather think he is responsible for the bigger wounds about the abdomen of these seals. The smaller tears and scratches may quite well, I think, be due to other things, scratches against the sharp ice edges, which cut like steel when the temperatures run low; or they may be due to mutual caresses in love or anger, quarrelsome or kindly; or again they may be torn at the bottom of the sea in fishing among ragged rocks and stones. Perhaps the white coat of Winter is less conspicuous when the seal lives chiefly under water and runs less chance of being seen by Killer whales. Perhaps the darker

coat, conspicuous enough on the floe as the owner sleeps away his time in safety from all enemies, is useful chiefly in absorbing every ray of summer sunshine.

One thing is certain, they are very noticeable, these changes, and not a little beautiful, and governed not by vanity but by reason and hard necessity.

Whether all these four seals change their coats as the Crab-eater does is uncertain; certainly the Weddell does not do so to the same degree. But they all have points of striking similarity, family characteristics common to them all. A little trick of Weddell's Seal and the Crab-eater is seen ridiculously exaggerated in Ross' Seal, who draws in his head until it almost disappears among the folds of thick blubber and skin around the neck. He then reminds one strangely of the little pig that Alice nursed in "Wonderland". Three of these we met in the pack ice, our entrance into Wonderland: they ran from seven feet to seven feet nine inches, while the Crab-eaters were a little bigger as a rule.

The food of these seals is interesting, because in their general build and character and teeth we can see how well they are adapted to procure it. The Sea-Leopard is built for catching and holding not only fish but penguins, and those of the largest and most active kind, themselves quick enough to catch the fish they live on. The Crab-eater built for speed and agility, lives on small fish and shrimps; his stomach is often full of mud and gravel swallowed no doubt in routing for the shrimps with his long snout at the bottom of the sea or round the edges of an iceberg or a floe. In goes a large mouthful, the sieve-like teeth are clenched and out squirts all but the food and mud which cannot pass the teeth.

How came this tidy little seal to have such a unique set of teeth? I think it must have been a spark of genius which first led him to do the best he could with the teeth he had, and then as usual "Nature" helped him because he helped himself. Ross' Seal on the other hand is fast losing all but his front teeth; as often as not the back ones are gone, or if not gone they are mere loose pegs hardly appearing through the gums at all; but the front teeth are sharp as needles and turn backwards like a snake's, evidently for holding something soft and slippery, perhaps octopus, remains of which were found in two of the Ross' Seals taken by the "Southern Cross". This seal is not a very active looking animal, but at the same time he has a far more compact figure than the

cow-like Weddell's Seal whose skin appears always a size or more too large for it. The Weddell's teeth have some resemblance to the teeth of Ross' Seal, though the back ones have not yet become quite so useless. There are the same needle points and recurved form to the front teeth, which in this case I think are chiefly for seizing slippery fish.

All these are "Hair Seals", not "Fur Seals", and their skins are of value only as leather. True "Sealskin" is the inner thick coat which is left when all the longer hairs are pulled out of the skin of the true Sea-bear. All our seals are called earless, because although a small hole can be found leading through the skin from each internal ear, no outer ear is visible. The Fur Seals all have external ears. All the seals we find here sleeping on the ice are very hard to wake by shouting. Their hearing then is certainly not acute, but quite possibly when they are swimming under water their ears are useful in some way we cannot understand.

These are a few of the questions we can all help to answer.

Very little is known of the domestic economy of these southern seals, and everything is interesting. How often, for example, are they seen outside the water in the winter, and at what temperatures? How often are they found breathing in air spaces under unbroken ice as one was heard to do a short time since? How often are they found really sleeping with the head alone appearing outside a seal hole?

We have been fortunate so far in meeting with examples of all the known seals of this region; we may not find a new one, but we can all do something towards filling up a chapter on the natural history of those that are already known.

ZINGIBER.



APPENDIX 2

For the place where we had seen the White Giant Petrels as the ship rounded the Cape - we found them there standing on the shore ice & I killed four white ones & one dark one as they made off for the ice floating on the sea. One I lost & it floated away on the tide. I also shot two MacComick's Skuas, and Shackleton two, there were any number of them flying over the Penguins ready to pounce on the first nestling found unprotected. The Penguins as usual were very amusing. They had eggs some of them, carefully laid in a nest made of pebbles. Some had just hatched out, and some had big downy or woolly young ones more than half as big as they were themselves. These they tried to sit on but all they could cover was the head so it looked very absurd. Although



the bird lays two eggs. Hardly ever more than one young one survives. Then they had a strange way of flying at one's feet - a big penguin would start running towards one from some considerable distance, and without a moment's hesitation would seize one's trousers & begin battering one's shoes with its very bony flippers. The

number of these birds was simply incredible. They covered the 200 odd acres - they covered the sides of the mountain, ft. high, & they spread in small colonies over the top. There was a constant stream of them up & down the side of the mountain & their paths were very useful to us in getting up the steep snow & rocky slopes. We found several Skuas on the way up, with their fledglings - pretty little grayish white fluffy things with pale blue bills & feet - but the old birds kept up a continual attack on us when we were anywhere near their young, chattering excitedly & dashing at our heads so boldly & persistently that we had to protect ourselves with a stick & one of the

Figure XX. Extract from E. O. Wilson's diary about observational studies on penguin (Wilson 1966).