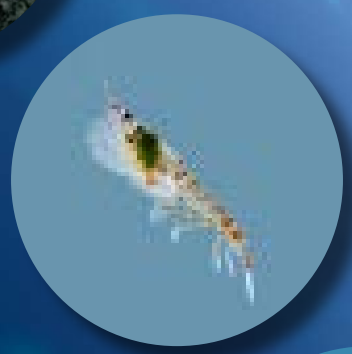
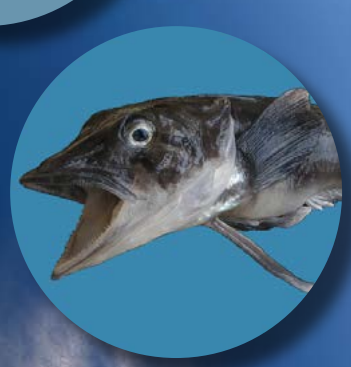
Census of Antarctic Marine Life
SCAR-Marine Biodiversity Information Network

BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN





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Claude DE BROYER & Philippe KOUBBI (chief editors)

with Huw GRIFFITHS, Ben RAYMOND, Cédric d'UDEKEM d'ACOZ, Anton VAN DE PUTTE, Bruno DANIS, Bruno DAVID, Susie GRANT, Julian GUTT, Christoph HELD, Graham HOSIE, Falk HUETTMANN, Alix POST & Yan ROPERT-COUDERT

SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

Census of Antarctic Marine Life (CAML)

SCAR Marine Biodiversity Information Network (SCAR-MarBIN)

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The “Biogeographic Atlas of the Southern Ocean” is a legacy of the International Polar Year 2007-2009 (www.ipy.org) and of the Census of Marine Life 2000-2010 (www.coml.org), contributed by the Census of Antarctic Marine Life (www.caml.aq) and the SCAR Marine Biodiversity Information Network (www.scarmarbin.be; www.biodiversity.aq).

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Contents

Preface

Famous lines from the diary of explorer Robert F. Scott, 17 January, 1912: "*Great God! This is an awful place, and terrible enough for us to have labored to it without the reward of priority. Now for the run home, and a desperate struggle*." Scott and his companions would starve, freeze, and die ten weeks later in an Antarctic blizzard, disheartened by the knowledge that Roald Amundsen had reached the South Pole a month before them. A century later, we know in much greater detail the gigantic ferocity of Antarctica. But, as the Biogeographic Atlas of the Southern Ocean proves, we also know the unpredicted diversity and fecundity of the waters around it, and that rewards of priority from Antarctic exploration are far from exhaustion.

Still, Antarctica does not yield secrets easily. To modernize our knowledge of the diversity and distribution of its marine life required five years of field work and then three years of analysis by about 140 researchers from all the other six continents. About equally men and women, they looked from the sea birds and the sea surface to the sea floor as deep as six thousand meters and into the sediments. They looked on and under the ice. They looked from the microplankton to the macroalgae, from the sponges and corals to the molluscs and the crustaceans, from the sea spiders and sea stars to the seals and the fish. They looked at animals living off heat and gases coming from the crust beneath the ocean as well as those that bask in the seasonal sun above and enjoy its photosynthesis. They looked at the uniquely Antarctic and the cosmopolitan.

To perceive the patterns and processes emerging from studying more than one million records of about ten thousand species, the fourteen editors of the Atlas organized knowledge on the evolutionary and environmental settings, and finally prepared the way for a gratifying chapter that synthesizes knowledge on the realms and regions of the Southern Ocean. Wizardly cartographers present the information in colorful maps that allow us to understand at a glance the grand carousel that whirls around Antarctica.

Meanwhile, wizardly geneticists using molecular clocks allow us to explore deep time as well as space. We learn about Antarctic ancestors, their kinships, and how past changes in the Southern Oceans may have sent species such as octopods venturing forth into the Pacific, Indian, and Atlantic oceans.

We also learn modesty, as do all who encounter high latitudes. We learn of regions still little explored, such as the sea named for Amundsen below the South Pacific, and taxa, such as the sea squirts (tunicates) and roundworms (nematodes). We also learn of threats to the life of the Southern Ocean, from fishing, tourism, pollution, and climate change, and proposals for new marine protected areas matching the richness of our hard-won knowledge.

This magnificent scholarly achievement comes to us because of organizations as well as individuals. The Census of Antarctic Marine Life (CAML) program of the global Census of Marine Life (2000-2010) fostered many expeditions that have provided observations, and the Scientific Committee on Antarctic Research Marine Biodiversity Information Network (SCAR-MarBIN) has carefully filtered and archived the data and made them accessible. Founded in 1958, SCAR initiates, develops, and coordinates research in the Antarctic region, and adds to its lustrous history with this volume. National organizations such as the such as the Australian Antarctic Division and the Royal Belgian Institute of Natural Sciences in turn make possible cooperative international efforts such as CAML and SCAR-MarBIN.

Finally, only the truly visionary and persistent succeed in Antarctica, and here we salute Claude De Broyer and Philippe Koubbi, chief editors. They together with their 140 co-authors prove conclusively that the Southern Ocean is not monotonously blank but a shining, stirring, diving world of anemone and albatross, jelly and whale, revealing Earth's history and nature and still rich with rewards for the hard labor of future explorers.

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Foreword

Many people unfamiliar with the Southern Ocean regard this ice-bound region as still largely unexplored biologically. This is far from the truth, for the study of the diversity and distribution of organisms in the Southern Ocean has a long and distinguished history. James Cook got close to the Antarctic continent in 1774 aboard HMS *Resolution*, although he never saw it. His reports of the abundant wildlife led to an explosion of commercial sealing activity, but sadly none of this contributed much to a wider understanding of Southern Ocean biology as the knowledge gained was of powerful commercial interest and largely remained within the community of fisherman to whom it was valuable economically.

Some Antarctic marine species were, however, described as early as the 19th century, reflecting how even the earliest voyages of exploration contributed something to science. The initial exploration of Antarctica was dominated by political, geographical and economic considerations, but even so many of the expeditions undertook biological collections and observations. These were typically fairly limited in scope and often undertaken by participants whose primary role was elsewhere. This early work was dominated by collection of shallow-water benthos and fish, although Bellingshausen did undertake some plankton tows.

Although these early collections were valuable, we can trace the dedicated scientific investigation of the Southern Ocean fauna and flora to the seminal voyages of HMS *Challenger* (1872-1876), which penetrated to the Antarctic Circle off Queen Maud Land in the Southern Indian Ocean whilst sailing eastwards in 1874. The concept of a purely scientific voyage was novel at that time and although the equipment and approach were perhaps somewhat conservative, this voyage revolutionised our understanding of the biology and chemistry of the oceans. Working up the material took a great many years, but in the end some fifty volumes of scientific findings were published, all beautifully illustrated, and these remain an important scientific resource to this day.

During the Heroic Era of Antarctic exploration, many national expeditions included biologists in their complement and these added incrementally to our knowledge. For some expeditions science was a minor component, whereas for others it was integral to the enterprise as a whole. The next significant contribution to our knowledge of Southern Ocean marine diversity, however, came from the *Discovery* Investigations. Fieldwork was initiated in 1925, based at South Georgia, and the work was intended to provide an understanding of the biology of the great whales on which the whaling industry depended. In doing so, these extensive voyages of biological oceanography covered the entire Southern Ocean and provided the single greatest advance in our understanding of the system since the voyage of HMS *Challenger*.

The legacy of this important early work can be seen in the sharp increase in the rate of description of new marine species from the Southern Ocean during the early half of the 20th century. At this time ecology as a discipline was developing rapidly, and the attention of many biologists was moving away from the documentation of new species to understanding how species interacted with each other and with their environment. Although the description of new taxa continued to be important in museums, university researchers were busy exploring this new field of ecology and the rate of description of new Antarctic taxa slowed markedly.

The later decades of the 20th century were a time when Antarctic science started to flourish and many new young researchers starting their careers in Antarctic research at this time rapidly became aware of the importance of this early work. When I started my first Antarctic work in 1970, I decided to explore aspects of the biology and physiology of the caridean decapod *Chorismus antarcticus* in the shallow waters of South Georgia. In those days there was no easy way to identify Antarctic marine invertebrates, and so to be certain I was working on the animal I thought I was, I had to find a copy of the original description by Georg Johann Pfeffer, from specimens collected by the German South Georgia expedition which was based at Moltke Harbour for the first International Polar Year in 1882/83.

In the late 20th century many funding agencies became less interested in funding primary taxonomy, but the documentation of Antarctic marine diversity remained important for many national Antarctic programmes. The next important phase in the study of Southern Ocean diversity and biogeography was the support of Antarctic marine biology by the Scientific Committee on Antarctic Research (SCAR), and in particular the EASIZ (Ecology of the Antarctic Sea Ice Zone) programme which ran for ten years from 1994. Whilst this international programme was focussed primarily on ecology, it also stimulated a considerable volume of primary taxonomic work and prompted the first comprehensive assessments of marine diversity for all of Antarctica. Whilst these assessments were valuable in themselves, they were also important in directing attention at gaps in our knowledge. In particular they identified how little was known of the fauna of the continental slope and the deep-sea around Antarctica. Other important features of the EASIZ programme were the emphasis placed on understanding the relationship between marine organisms and the oceanographic environment within which they lived, and also the evolutionary context in respect of the climatic and tectonic history of the Southern Ocean.

After the EASIZ programme had drawn to a close, the ANDEEP (Antarctic Deep-Sea Biodiversity) programme undertook a series of cruises directed specifically at improving our knowledge of the Antarctic deep-sea fauna. At about this time another significant development was the initiation, under the auspices of SCAR and hosted by Royal Belgian Institute of Natural Sciences, of an interactive database for Antarctic marine diversity, MarBIN (Marine Biodiversity Information Network). As science becomes ever more reliant on information being available on-line, SCAR-MarBIN has been instrumental in improving the quality of marine diversity data for Antarctica, and in disseminating this information to those who need it. The Southern Ocean is now part of the global information network, and no longer an isolated region of the world.

These important developments meant that when the Census of Antarctic Marine Life (CAML) was initiated, and fieldwork undertaken in conjunction with the second International Polar Year (2007/08), the stage was set for a major step forward in our knowledge and understanding of Southern Ocean marine diversity. This volume shows the extent to which this opportunity has been taken and the potential realised. CAML has delivered the single largest step in our knowledge of Antarctic marine diversity and biogeography since the first half of the 20th century. The Biogeographic Atlas has sections devoted to every major taxonomic group, with detailed maps of distribution, as well as chapters documenting the environmental background and evolutionary history, and synthetic analyses. This is a magnificent achievement and testament to the vision of those who planned and developed the programme. It will undoubtedly remain an important resource for many years to come.

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THE BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

Scope

Biogeographic information is of fundamental importance for discovering marine biodiversity hotspots, detecting and understanding impacts of environmental changes, predicting future distributions, monitoring biodiversity, or supporting conservation and sustainable management strategies.

The recent extensive exploration and assessment of biodiversity by the Census of Antarctic Marine Life (CAML), and the intense compilation and validation efforts of Southern Ocean biogeographic data by the SCAR Marine Biodiversity Information Network (SCAR-MarBIN / OBIS) provided a unique opportunity to assess and synthesise the current knowledge on Southern Ocean biogeography.

The scope of the Biogeographic Atlas of the Southern Ocean is to present a concise synopsis of the present state of knowledge of the distributional patterns of the major benthic and pelagic taxa and of the key communities, in the light of biotic and abiotic factors operating within an evolutionary framework. Each chapter has been written by the most pertinent experts in their field, relying on vastly improved occurrence datasets from recent decades, as well as on new insights provided by molecular and phylogeographic approaches, and new methods of analysis, visualisation, modelling and prediction of biogeographic distributions.

A dynamic online version of the Biogeographic Atlas will be hosted on www.biodiversity.aq.

The Census of Antarctic Marine Life (CAML)

CAML (www.caml.aq) was a 5-year project that aimed at assessing the nature, distribution and abundance of all living organisms of the Southern Ocean. In this time of environmental change, CAML provided a comprehensive baseline information on the Antarctic marine biodiversity as a sound benchmark against which future change can reliably be assessed. CAML was initiated in 2005 as the regional Antarctic project of the worldwide programme Census of Marine Life (2000-2010) and was the most important biology project of the International Polar Year 2007-2009.

The SCAR Marine Biodiversity Information Network (SCAR-MarBIN)

In close connection with CAML, SCAR-MarBIN (www.scarmarbin.be, integrated into www.biodiversity.aq) compiled and managed the historic, current and new information (i.a. generated by CAML) on Antarctic marine biodiversity by establishing and supporting a distributed system of interoperable databases, forming the Antarctic regional node of the Ocean Biogeographic Information System (OBIS, www.iobis.org), under the aegis of SCAR (Scientific Committee on Antarctic Research, www.scar.org). SCAR-MarBIN established a comprehensive register of Antarctic marine species and, with biodiversity.aq provided free access to more than 2.9 million Antarctic georeferenced biodiversity data, which allowed more than 60 million downloads.

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Alexandra POST is a marine geoscientist, with expertise in benthic habitat mapping, sedimentology and geomorphic characterisation of the seafloor. She has worked at Geoscience Australia since 2002, with a primary focus on understanding seafloor processes and habitats on the East Antarctic margin. Most recently she has led work to understand the biophysical environment beneath the Amery Ice Shelf, and to characterise the habitats on the George V Shelf and slope following the successful CAML voyages in that region.

Yan ROPERT COUDERT spent 10 years at the Japanese National Institute of Polar Research, where he graduated as a Doctor in Polar Sciences in 2001. Since 2007, he is a permanent researcher at the CNRS in France and the director of a polar research programme (since 2011) that examines the ecological response of Adélie penguins to environmental changes. He is also the secretary of the Expert Group on Birds and Marine Mammals and of the Life Science Group of the Scientific Committee on Antarctic Research.