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The place of the Antarctic in biological sciences

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The Antarctic offers a number of special features and opportunities for biological science. The dominating marine ecosystem is rich in nutrients and biologically very productive. The relatively few species of plants and animals are highly adapted to the rigorous climatic conditions and to the extreme annual pattern of day length and light intensity. The terrestrial and freshwater communities are even more restricted in species composition and are adapted to an even more rigorous climate. The understanding of ecological processes and trophic relations in such systems is of fundamental importance, and is essential before technology is developed to exploit the vast biological resources of the Southern Ocean.

Special environmental features of the Antarctic have led to the development of remarkable adaptations in plants and animals, and there is opportunity for detailed study at the levels of the life cycle, behaviour, physiology and biochemistry. Further, with the recent developments in the understanding of plate tectonics, and the increasing acceptance of the concept of continental drift there is now an increasing need for knowledge about the biological history of this area.

I have been asked to talk on the place of the Antarctic in biological sciences. This is a daunting topic which can be tackled only at the general level. Indeed, it has been difficult to find something new to say. Since 1962 there have been three international conferences on Antarctic biology organized by the Scientific Committee for Antarctic Research (Carrick, Holdgate & Prévost 1964; Holdgate 1970; S.C.A.R. 1977), a large volume on biogeography and ecology in the Antarctic was published by Miegham & van Oye (1965), and the I.B.P. tundra biome studies included work in the Antarctic (Rosswall & Heal 1975). These indicate the rate at which the subject is progressing and the importance that has been attached to it. I will not, therefore, attempt to assess in detail progress in Antarctic biology, about some of which we have heard today, but will try to identify some important aspects of biology which for one reason or another may be most appropriately undertaken in the Antarctic. Since all scientific studies carried on in the Antarctic depend greatly on logistic support I will also say a few words about the relevance of this in the context of biological science.

Cook circumnavigated the Antarctic 200 years ago and wrote, in his account of the voyage of the *Resolution*, about the large numbers of whales, seals and seabirds which he encountered in high southern latitudes. This was of great interest to the whaling and sealing industry of the Northern Hemisphere where already catches were beginning to diminish. The impact of man on the southern whales and seals in the following 50 years or so will never be known but it was undoubtedly vast. Virtually nothing was left that could be easily and profitably killed. Alan Moorhead (1966) gives a dramatic account of this in his book *The fatal impact*, in the chapter headed appropriately enough 'The blood-stained ice'. For example, as early as 1820 Bellingshausen found that the fur seal stocks of Macquarie Island, discovered only 10 years earlier, had been exterminated by sealers from Tasmania and New Zealand, who had already turned their attention to the then abundant elephant seals for their blubber. By 1834 they had further to augment their catch by killing penguins. This pattern of reckless over-exploitation was widespread in subantarctic seas well over a century ago. Only in the last 25 years or so has there been a substantial recovery of stocks of elephant seals and fur seals in several parts of the sub-Antarctic as we have heard today from Mr Payne.

Thus, although man first set foot on the Antarctic continent only 80 years ago, the biological resources of the subantarctic seas and islands have been exploited by man often ruthlessly and unwisely for at least a century and a half. However remote the area, the situation in marine systems now is often far from natural. Freshwater and terrestrial communities are very much less directly interfered with, but are affected indirectly by those marine animals, the seabirds and seals, which come ashore to breed and moult.

Explorers and voyagers in the nineteenth century and in the early years of this century all contributed to our knowledge of the general natural history of the Antarctic, often through naturalists, such as Edward Wilson, on their expeditions. Thus science generally remained at the level of the collection of specimens for identification and biogeographic interpretation and the recording of field observations.

The first serious *in situ* science was carried out on board the *Challenger* on its oceanographic cruise of 1872–6. This was followed by the notable series of cruises by the *Discovery I* in 1925–7 and by the *Discovery II* from 1929 until 1951. These cruises were concerned with oceanography and pelagic marine biology, and much of the biological investigations were directed at an understanding of the populations of whales and their food supplies, mainly krill. On-shore bases were established for exploration and research on the subantarctic islands and the Antarctic continent from about the end of the last war, and from that time onward research programmes have been developed and carried out at numerous points around the continent by many countries. These bases provided an opportunity for continuous study which was previously impossible owing to the intermittent and short-term opportunities presented by expeditions. Oceanographic cruises are still carried out for a variety of research purposes, some of them biological, and frequently in relation to potentially exploitable resources.

It is clear then that biological research in the Antarctic has been highly developed only for the last 30 or so years. Before that, apart from oceanographic and pelagic studies, much of the work was the product of expeditions. Several important studies were carried out in this way, for example Brian Roberts' study of Wilson's petrel during the British Graham Land Expedition of 1934–7 (Roberts 1940), and many scientific collections were made for study back home. The emphasis was on taxonomy, systematics, distribution and general biology.

The first international attempt to take stock of biological research in the Antarctic was organized by S.C.A.R. which held its first international symposium in Paris in 1962 (Carrick *et al.* 1964). This symposium was designed to cover every aspect of biological research in the Antarctic, and it is interesting to look at the range of subject matter discussed. The main sections covered the following topics: human physiology and psychology; microbiology; biogeography, and systematics of plants, marine animals, and terrestrial animals; marine productivity; ecology of invertebrates; ecology of vertebrates; ethology of vertebrates; conservation; animal physiology; and future work. Scientists from 15 countries participated.

In summing up the 1962 programme, and considering the future of biological research in Antarctica, Dr Eric Smith drew attention to problems that seemed then to be most in need of investigation. In the marine environment he emphasized the need for additional work on hydrography, on the plankton and nekton of the open seas, on the benthos of the deep sea and

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coastal shelf and studies of seashores and coastal fringes. He emphasized the need for a study of what he called 'the economy of the Antarctic seas in terms of capital and revenue' – i.e. the study of trophic relations and ecosystem processes. In the freshwater field, he pointed to the need for the study of the species composition of the restricted biological communities of freshwaters, and drew attention to problems of geographical isolation and speciation, and the differentiation of distinctive floras and faunas in the very small and often scattered habitats. Once again he called for further detailed examination of ecosystem organization and function in these habitats. Dealing with the terrestrial flora mainly of lichens and mosses, with some liverworts, fungi and flowering plants, he again referred to the need for the establishment of a sound taxonomy, and recommended cytological studies of chromosomes and experimental work. Phytosociology of the vegetation of the varied and rather specialized terrestrial habitat was also recommended for study, and also the terrestrial ecosystems. He also felt that the unparalleled opportunities for studies of social behaviour and social organization of the breeding colonies of seabirds and seals, marine animals coming ashore only to breed, surely justified the development of work in this area.

Dr Smith's predictions have very largely come true. The present emphasis on ecological processes and on adaptation in the plants and animals of all Antarctic habitats is clear from today's symposium. In all habitats studies of the physiology and behaviour of selected species go ahead to establish the precise nature of the physiological and other adaptations of animals and plants to their very exacting environments. However, aspects of taxonomy and systematics have not developed to fill the needs seen in 1962 and it seems likely that this will require new emphasis in the future. In today's programme on scientific research in the life sciences in Antarctica, admittedly drawn very largely from the work of the British Antarctic Survey and associated scientists, the range of topics is apparently substantially smaller, and similar to that reflected in the programme of the 3rd S.C.A.R. symposium held in 1974. There is a strong concentration of interest into ecosystem processes, mainly of energy transfer and storage, in terrestrial freshwater and marine habitats. There is no reference to studies of the taxonomy and systematics of plants and animals in the Antarctic (though I know this is going on in the British Antarctic Survey) – topics which were very substantial in the symposium 14 years ago.

How can we account for this surprising concentration on synecological studies? Is it because the inventory of plants and animals of the Antarctic is now more or less complete, and their systematic and biogeographic relationships fully understood? or has such work become less fashionable? In general, in temperate and tropical as well as polar areas, ecological science (and most Antarctic biology is ecology in some sense) has moved away from the cataloguing and descriptive phase associated with establishing an inventory of species and a description of their associations, to the study of population, community and ecosystem processes. Work in the Antarctic is no exception, and it is prudent to consider whether or not the studies carried out at such a distance and at such a relative cost should simply be fashionable, or whether they should have some special orientation of their own. In view of the recent impetus to our thinking provided by theories of the timing and geography of continental drift and sea-floor spreading, especially in the southern hemisphere (Jardine & McKenzie 1972), I think there is still a need for studies on taxonomy, systematics and distribution in the Antarctic.

Ecosystem ecology

The Antarctic areas have relatively few species of highly specialized plants and animals, often occurring in great abundance. This has given rise to the idea that ecosystems in the Antarctic are relatively simple, and therefore especially suitable for fundamental ecological study. This simplicity is most evident in terms of species diversity, and is particularly the case in the very restricted areas of terrestrial and freshwater habitats. It is not nearly so obviously the case in the marine field where many more groups and species are represented and where it is difficult to put limits between inshore and offshore situations. Though Antarctic ecosystems may be relatively simple in terms of numbers of species we must not be deluded into thinking that they are in any other sense simple: detailed studies of temperate systems have revealed very great complexity and very great variability.

In the Antarctic there is obviously great opportunity for making substantial progress in the understanding of the highly specialized ecosystems of the freshwater lakes and terrestrial habitats, and valuable data are being obtained for comparison with temperate and tropical systems. It is much less clear to me that an all-embracing study of inshore marine ecosystems is a profitable objective in the Antarctic at the present time. Such studies call for the deployment in the field of well coordinated teams of specialists from several diverse fields working together, preferably contemporaneously, with compatible aims and elaborate equipment. This is very difficult to achieve even in large laboratories at home and it may not be appropriate to attempt it from shore bases in the Antarctic with limited facilities for work at sea. There is in any event a great deal of preliminary work still to be done at the inventory stage, and in order to understand life cycles and general adaptations of component species. I am not sure that a selection of key organisms, relationships, and processes could yet be identified with confidence to provide an understanding of the functioning of the inshore ecosystem.

Studies of the offshore pelagic ecosystem with short food chains from phytoplankton through krill to fish and squids, whales, seals and birds are important and relevant for different reasons. While perhaps even more difficult to study comprehensively as an ecosystem, owing to huge logistic and organizational problems, it is likely to be of great significance to man. A preliminary model of this system was prepared by Holdgate 10 years ago (Holdgate 1967). Recently, it has been estimated that as a result of the reduction in the numbers of seals and whales the potential yield of krill (*Euphausia superba*) to man may be between 100–200 million tonnes per year, from a standing crop in the order of 800–5000 million tonnes. This figure should be seen in relation to the present total annual world catch from aquatic resources which, in 1972, was slightly over 65 million tonnes (F.A.O. 1975). This is a resource in which man is bound to become more and more interested, and experiments are already under way to develop suitable techniques for catching, processing, utilizing and marketing krill. There is already an active fishery for the pelagic krill-eating *Notothenia rossii* – the Antarctic 'cod', and the Americans are contemplating the introduction of Pacific salmon into this system (Joyner, Mahnken & Clark 1974). It is a matter for concern, or indeed alarm, to biologists that plans for the further exploitation of these resources should be developing in advance of fundamental biological knowledge of key features of the biology of the main species of this community, e.g. the annual cycle and distribution of the krill, the significance of its extreme patchiness in terms of distinct stocks, and of the qualitative and quantitative relationships between krill and its other predators, notably species of whales, seals, fish and seabirds which are probably utterly dependent on it. It is clear that with

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commercial interests in this resource so imminent, high priority must be given to the necessary oceanographic and biological research to fill in these gaps. Clearly this will call for considerable expenditure of money and the deployment of men, ships and other resources. It is important not only commercially, but also for science and for conservation (Roberts, this symposium). For too long biologists have been diffident about seeking appropriate financial support for their research, and it is essential that the importance of this work, which can hardly be exaggerated, be recognized before it is again too late.

With the recovery of some stocks of seals, and hopefully in the future of whales, exploitation of these resources by man may again become possible and commercially attractive (Laws 1977). Studies such as that described by Mr Payne this afternoon are essential if such harvesting is going to continue at a sustainable level, and there is clearly a need for further work in this area.

Adaptation

The study of ecosystems so that their functioning can be understood, or so that man can channel some of the biological production to his own ends, necessitates a thorough knowledge of at least the main species of plants and animals. Such knowledge must include an understanding of adaptations to their particular environments. These adaptations may be spectacular and may bring about dramatic modifications of structure, physiology, reproductive strategy, behaviour and annual cycles. Basic processes, such as the biochemistry and function of enzyme systems are clearly important, and genetic aspects may be important too in relation to patchiness and variation in local conditions. Classical ideas of cold-adaptedness in poikilotherms may have to be revised at least in marine situations (Everson, this volume). Students of all groups of plants and animals can find much to challenge and interest in the study of these adaptations. To me one of the most spectacularly adapted of all animals is the Emperor Penguin *Aptenodytes forsteri*. Structurally it is modified in many ways, and a special feature is the flap of skin on the lower belly. This covers the egg which rests on the feet, thereby dispensing with the need for a nest of any kind. This feature is associated with the absence of individual distance or territorial tendencies (common in other penguins) enabling these birds to gather together in tight bunches during severe blizzard conditions in winter when the males are incubating the egg. Huddling in this way brings about a dramatic saving in the amount of stored fat which otherwise has to be metabolized to maintain body temperature. The metabolism of the species is highly adapted in numerous ways. It is capable of dropping its temperature temporarily in severe cold thereby reducing heat loss and saving fuel; the male can fast for a period of up to 5 months and the females for a period of 3 or 4 months; the male is able to produce food for the young as a secretion from its crop, after months of fasting, if the female has not returned at the time at which the egg hatches. Much of the study of the Emperor has been carried out by French biologists at Point Géologie in Adélie Land (Prévost & Sapin-Jaloustre 1964), and recent studies by Le Maho & Delclitte (1974*a*, *b*) have drawn attention to the distinction between the acceptable and normal physiological fasting, and the point at which the bird enters a phase of dangerous starvation. Body mass and condition is of crucial importance to other species of penguins too, and Carrick (1972) has demonstrated the significance of achieving a minimum body weight before breeding in the Royal Penguin. It may be that the long period of adolescence is associated with the ability to put on condition at the right time of year.

Many Antarctic seabirds are long-lived, having a very long adolescent period and often a remarkably long adult life. Little is known about the biological efficiency of birds at great ages and there are opportunities for such work in the Antarctic stemming from the large amount of ringing, often done as much for recreation as for research, which has taken place at several of the permanent bases over the last 20 years. In general birds cannot be aged alive once they have become adult and the only source of information on very old birds comes from those which have been ringed as nestlings. These adaptations are clearly worthy of further study for scientific reasons.

Surely we must not become too 'modern' in our approach to ecology, and so fail to understand the nice complexities of the adaptations of individual species of plants and animals. Since Darwin's time it has been of interest to compare the ecology of closely related species which coexist in the same area. In studying the Antarctic fauna, whether from the point of view of adaptation of individual species or of the relationships within biological communities this is clearly important. Among the birds there are many pairs of similar species and current work is directed at these problems. So far such studies are concentrated on those aspects of biology which can be tackled on land, but it is clearly important for the proper understanding of seabirds and seals to extend observations to their pelagic phase. In the past few years there has been a number of research programmes directed at determining the feasibility of studying seabirds at sea and while there are obvious limitations in what can be done I would strongly urge that when biological work develops on the open sea ecosystem of the Antarctic, the opportunity is taken for ornithologists to carry out detailed ecological studies of birds at sea.

As I suggested earlier there is still a need for work on taxonomy, systematics, biogeography and general survey and inventory. There are still few definite accounts of the flora and fauna of different parts of the Antarctic and sub-Antarctic. The biogeographical relationships of Antarctica have been a subject of great interest and much controversy in the past. Recent dispersal around the Southern Ocean by ocean currents or by seabirds on the one hand and ancient continental connections on the other have offered explanations of distributions and relationships. The recent paper by Jardine & McKenzie (1972) confirming southern connections between the southern continents and Antarctica and giving dates of great biological significance for the separation of their land masses, gives impetus to further work in this field. My own interest in antarctic fleas is relevant. The flea genus *Parapsyllus*, a Rhopalopsyllid derived from South American rodent fleas, is now widely distributed on seabirds, including penguins, throughout the Southern Ocean and has speciated dramatically among subantarctic islands of New Zealand where it occurs on many species of birds including flightless and flying parrots (Dunnet 1964). It is clearly a relatively recent dispersal brought about by seabird transport. The other common genus of subantarctic fleas, *Notiopsylla*, derived from pygiopsyllid fleas and occurring mainly on Australian marsupials and rodents, likewise is distributed around the Southern Ocean on flying seabirds (Dunnet 1964). It was therefore a considerable surprise to find that fleas collected from the Snow Petrel (*Pagodroma nivea*) and the Silver Grey Fulmar (*Fulmarus glacialoides*) from Davis and Wilkes in Antarctica belong to neither of these genera, but to quite a separate family, the Ceratophyllidae, which is widely represented on birds throughout the Northern Hemisphere, and in South America. Its closest relatives appear to be the genus *Dasypsyllus* which is represented in South America and elsewhere. It is not possible to explain at present why this monotypic genus – *Glaciopsyllus antarcticus* – should be distributed only on the Antarctic continental margins, and has not been recorded from the same hosts in lower latitudes. There are no Antarctic or sub-Antarctic representatives of the family of fleas – the Stephanocircidae – which is shared by the marsupials of Australia and South America. Stephanocircids are quite unknown from the Northern Hemisphere, which supports the view that marsupials have always been a southern stock, possibly occupying Antarctica in mesosoic times (Traub 1972).

Logistics

Well equipped biological bases have now been established by several countries at a number of points around the Antarctic Continent. The British Antarctic Survey have their main biological bases at Signy Island in the South Orkneys and are now developing a second on South Georgia which has the great advantage of being accessible all the year round. The Americans have important biological bases at Palmer on the Antarctic Peninsula and at McMurdo in the Ross Sea. The French, Australians, Japanese, Russians, New Zealanders and others have also biological bases on the Antarctic Continent and subantarctic islands. With these well equipped modern scientific laboratories the opportunity exists for a wide range of physiological and biochemical studies to be developed in support of studies of adaptation, behaviour, and ecological aspects of energy relationships in antarctic communities. It is clearly important that such facilities should be developed and fully supported.

Pelagic expeditions are extremely expensive and research ships spending all of their working time in Antarctic waters are now rather few. Currently several such ships are carrying out cruises to investigate some aspects of the biology of krill and relevant fishing technology, but the main British effort is directed at studies of geophysics and other aspects of physical science. In my view there is a need for the recognition of the urgent international requirement for detailed biological investigations of the pelagic ecosystem in Antarctic waters.

In view of the high costs, international collaboration between countries with active research programmes in the Antarctic continues to be essential. The great value of the S.C.A.R. organization is readily apparent from the series of symposia that it has organized to chart and plan the progress of Antarctic biological science. Clearly, such international coordination and cooperation must continue in research and conservation (Roberts, this volume).

In conclusion, it is perhaps relevant to say in the context of biological research in the Antarctic that the opportunities for high quality work are quite outstanding. Young scientists are not only exposed to a challenging and stimulating physical and social environment for a period of months or years, but are given the opportunity of seeing some of the most spectacular biological systems in the world. Given well prepared programmes and, where appropriate, good supervision they have almost complete freedom from distractions to get on with the work. This makes the Antarctic a most effective training ground, and as we can see here today many young men starting off in this way have become eminent in their fields of study.

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