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MACQUARIE ISLAND — A WONDER SPOT OF THE WORLD

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The geographical position, and geological and cultural history of Macquarie Island render it an imponant site for continued observations in upper atmosphere physics, meteorology, geology and many aspects of biology, especially those concerned with the Southern Ocean ecosystem and the control of introduced species. (Ed.)

Key Words: Macquarie Island, Southern Ocean, population studies, island flora and fauna, meteorology, aurora, mid-ocean ridge.

INTRODUCTION AND HISTORICAL COMMENTS

The title of this address reflects the sentiment of Sir Douglas Mawson, who, in a paper read to the South Australian branch of the Royal Geographical Society of Australasia in 1919, stated:

> "This little island is one of the wonder spots of the world. It is the great focus of the seal and bird life in the Australasian sub-Antarctic regions, and is consequently of far greater significance and importance in the economy of that great area than its small dimensions suggest."

This contrasts sharply with earlier statements (see Cumpston 1968, pp.60, 66) by Captain Douglass, master of the ship *Mariner* that visited Macquarie Island in 1822:

> "As to the island, it is the most wretched place of involuntary and slavish exilium that can possibly be conceived; nothing could warrant any civilized creature living on such a spot, were it not the certainty of industry being handsomely rewarded...",

and the *Hobart Town Gazette* of 4 February 1826, commenting on the advisability of establishing a penal settlement there:

> "The remote and stormy region in which Macquarie Island is placed, is a strong reason against the adoption of that sterile place as a penal settlement."

Macquarie Island, at latitude 54°30'S and longitude 158°57'E, lies just to the north of the Antarctic Convergence, 1466 km (833 nautical miles) southeast of Hobart, and 1294 km (735 nautical miles) from the antarctic continent. It is an exposed fragment of the crust of the Macquarie Ridge Complex which runs south from New Zealand, towards the Balleny Islands. The island is 34 km long and up to 5 km wide (120 km^2), its long axis running roughly northeast, and comprises a long narrow plateau, 250–350 m above sea level, bounded on all sides by steep slopes (20°–40°) or cliffs rising either directly from the coast or from a raised beach terrace.

Cumpston (1968) saw it as

> "standing like a signpost pointing the way to the frozen lands and seas of the antarctic region ... the last vestige of land to be found in the vast expanse of the Southern Ocean to the south of Australia."

Since the earliest days of visits and temporary occupation, Macquarie Island has been attached as a dependency to Tasmania. It is within the Municipality of Esperance. In 1890 an endeavour was made by the New Zealand Government to annex it, but this was unsuccessful (Mawson 1922). Subsequently, representations were made to transfer jurisdiction over the island to the Commonwealth Government, but that was never effected.

Early scientists to visit the island commented particularly on the abundance of wildlife, and its scientific interest. Prior to the Australasian Antarctic Expedition 1911–14, the only important contributions to the natural history of Macquarie Island were those of Scott (1883) and Hamilton (1895). Sir Douglas Mawson devoted the greater part of his paper "Macquarie Island and Its Future", read to the Royal Society of Tasmania (Mawson 1922), to a discussion of the animal life of the island. It is clear that he saw that as scientifically the most interesting aspect of Macquarie:

"... the island is quadruply unique in the Australasian seas. Firstly, for the abundance of its life; secondly, for the variety of species frequenting its shores ...; thirdly, for the fact that it is the ... only possible breeding place for such life in those seas; finally, for the fortunate circumstance that up to the present man has not completely wrecked nature's handiwork, though certain spheres of life formerly abundant are now extinct, and others so greatly reduced that they are in danger of complete extermination."

This gives me some comfort in delivering the present address; although much has changed in the 65 years since Mawson's address, I perceive biology at Macquarie Island as being most important still. However, the fact that I accentuate biology in this address reflects my knowledge and special interests, and not necessarily the relative importance of the various scientific disciplines. I have had lengthy discussions with a number of people in other scientific areas, and their opinions and advice have been most valuable to me in composing this address.

One might expect that Mawson would have emphasised the geology of Macquarie Island more than he did, instead of its biological significance. However, it is as a result of concepts developed in recent years, especially the concepts of plate tectonics, that the great geological importance of Macquarie Island has been realised.

The Australian National Antarctic Research Expeditions personnel have maintained a scientific station on Macquarie Island continuously since 1948. Research projects have concentrated in the disciplines of biology, geology, upper atmosphere physics, cosmic ray physics, and meteorology, although other disciplines have been represented from time to time.

CONTRIBUTIONS OF RESEARCH AT MACQUARIE ISLAND

As I see it, the contributions to these different scientific disciplines of research at Macquarie Island fall into three major categories: (1) those involving collection of data at Macquarie Island, to be added to those gathered elsewhere, thereby providing a broader picture; (2) intrinsic studies, largely descriptive, that reflect the geological history and natural history of the island itself; (3) those that exploit the unique position or features of the island, and potentially provide new scientific insights.

Broad Picture

I place in this category the fields of seismology, cosmic ray physics, and certain aspects of geology, meteorology and biology. Because the island is so far from any other land mass, meteorological, seismological and cosmic ray information collected there provides a body of data in what would otherwise be a large void. This contribution is becoming less important in certain respects now, with access to advanced technology, but, nonetheless, local observations do provide detailed information not obtainable by other means.

For historical reasons, the island has presented an opportunity to examine several general questions in biology: for example, the extensive depletion and subsequent recovery of populations of animals (royal and king penguins), colonisation or recolonisation (fur seals), and the effects of introduced species (rats, mice, cats, rabbits, wekas) on the ecology of the island. Further, the results of control or eradication of introduced species on the fauna and flora of the island could provide valuable insights. Ecological investigations of animal populations at Macquarie Island and antarctic stations have provided further information on which to base ecological concepts (see Carrick 1964, Carrick & Ingham 1967).

Descriptive Studies

The structure and ecology of Macquarie Island have been examined from many points of view. There is a substantial body of knowledge relating to its climate, geology, lakes and streams, flora, fauna and littoral zone; some oceanographic investigations have been conducted in the region. (For a comprehensive list of publications, see Selkirk *et al.* 1986.) A very brief summary is presented here, much of the information having been drawn from Jenkin's excellent descriptions (Jenkin 1975).

The dominant influence on the climate of the island, associated with its location, is the surface temperature of the surrounding ocean. This, in turn, is influenced strongly by ocean currents. As a result of this and of the position of the island, to the north of the Antarctic Convergence, the climate is extremely oceanic with a uniform temperature regime. Precipitation occurs in some form on most days of the year (in excess of 300 days). This resultant excess of precipitation over evaporation and consistently high humidity result in a moist, drought-free environment.

The rocks of Macquarie Island form an almost unaltered ophiolite complex of mid-Tertiary age, upthrust in association with tectonic activity along the margin of the Indian–Australian plate. Evidence of apparent glacial activity exists, but there is debate about whether, in fact, the island was glaciated during the last glacial maximum. It has been suggested that supposedly glacial features can be explained in terms of structural control, by faulting and rapid uplift.

The soils in areas of maximum exposure, as on the plateaux, are mainly gravelly loams. Elsewhere acid peats predominate, differentiated into various types according to drainage. The organic matter generally masks the effects of different parent materials.

Drainage of water from the plateaux is either directly via streams, or into the numerous lakes, some of which in turn are drained by streams, others by subterranean seepage. Periods of heavy rain usually result in increased erosion of the steep coastal slopes. Although it has been assumed that grazing by rabbits has denuded the slopes, causing extensive erosion, there is recent evidence that rabbit activity has had minimal effect on overall rates of erosion, even though it appears significant in localised areas (Griffin 1980, Selkirk *et al.* 1983).

The chemistry of the island lake waters is influenced by the surrounding sea: salinity of lake waters depends on distance from the west coast, that is, in the direction of the prevailing westerly winds.

The flora comprises vascular species, mosses, liverworts and lichens. Broadly, grassland occurs on the coastal slopes, herbfield, fen and bog on the beach terraces and relatively flat, sheltered upland areas, and fellfield on the plateaux. With increasing altitude or exposure, the vegetation in all formations shows a progressive reduction in size and vigour.

Because the island always has been isolated from other land masses, the establishment of its non-marine flora must have been by long-distance transoceanic dispersal. Numerous exotic pollen and spore types occur in Holocene lake deposits.

The fauna of Macquarie Island has received considerable attention. There are many publications describing the species of invertebrates, including arthropods (more than 100 species), annelids, platyhelminths and a land mollusc on the island; littoral molluscs, echinoderms, brachiopods and chordates (ascidians); and marine bacteria and other micro-organisms, echinoderms, molluscs, nemerteans and arthropods (crustaceans). The vertebrates are spectacular, and large in numbers but not in variety. In the seas surrounding the island, several species of fishes and certain cetaceans have been identified. Macquarie Island is a breeding ground for very large populations of seabirds and seals. A few species of non-marine birds have been recorded. The vertebrate wildlife was exploited for more than a century from the time of discovery of the island in 1810, and this inevitably modified the original biota. The specific identity of the original fur seal, which was exterminated within a few years after 1810, is not known. An endemic rail and a parakeet became extinct, and rats, mice, wekas, cats, rabbits, a slug and a mite became established. Predation by cats probably has affected bird populations, particularly burrow-nesting species; burrowing and grazing by rabbits have modified vegetation to some extent and contribute locally to erosion.

Studies Exploiting the Unique Position or Features of the Island

Meteorology

The Australasian Antarctic Expedition in 1911–14 established the value of Macquarie Island as a meteorological station. F.M.B. Fisher, Minister in Charge of the Meteorological Department in New Zealand in 1913, stated, among other things, that he attached great importance and much value to the daily messages from Macquarie Island. A committee of the Australasian Association for the Advancement of Science stressed the importance of maintaining the wireless station at Macquarie Island in that

> "(1) in the matter of meteorological forecasts and warnings to shipping, the station has already proved its value, (2) important general results are to be obtained by the scientific study of the weather conditions of the far south, as those conditions are related to those in the temperate regions." (For sources see Cumpston 1968.)

These points are still valid as I understand it. When the antarctic station of Mawson was established, it was necessary to close one of the other stations. A major reason for retaining the station at Macquarie Island rather than Heard Island was that the former is more valuable as a meteorological station in relation to Australasian meteorological studies: Heard Island contributes only indirectly.

Overall, the benefits of Macquarie Island as a weather station for short-term forecasting in southern Australia and New Zealand have diminished in importance as improved records from satellites have become available. However, at the same time the importance of Macquarie Island as a ground-truthing station has increased. It is a most valuable platform from which to monitor long-term changes or trends in the climatic record.

Upper Atmosphere Physics

Camps were established at the isthmus and Hurd Point, near the northern and southern ends of the island respectively, during the International Geophysical Year, 1956. Simultaneous observations enabled accurate estimates to be made of the distance of the aurora, obtained by triangulation, a measurement that is surprisingly difficult to obtain.

Macquarie Island lies towards the equator from the southern auroral zone, forming a conjugate pair with Kotzebue in Alaska. It has been suggested that this conjugate pair is well positioned to investigate the characteristics of auroral substorms on the global scale. These regions are particularly suitable for conjugate investigations, because they lie within the closed magnetic field line region; in addition, post-breakup pulsating auroras, associated with strong absorption increases, occur most frequently equator-wards of the auroral zone (Hajkowicz 1969).

Investigations of the visible aurora are made difficult at Macquarie Island because of the prevalence of cloud cover. The interrelationship of the auroral phenomenon and other events in the upper atmosphere at Macquarie Island are somewhat similar to that in parts of New Zealand and southern Australia.

Geology

The Macquarie Ridge runs south from New Zealand, Macquarie Island itself being an exposed portion of the ridge. The entire ridge formed as a result of interactions along the congruent margins of the Indian–Australian and Pacific plates. The island is a rare example of uplifted oceanic crust, detailed examination of which provides insight into how the oceanic crust was formed. Such insight is difficult, if not impossible, to obtain from studies of the ocean floor itself. Macquarie Island is, therefore, a critical area for the study of the oceanic crust and ocean tectonics.

Zoology

Macquarie Island has been recognised as being important zoologically for a long time, as we have seen already. Because of its position, the only speck of land in the vast expanse of ocean to the south of Australia and New Zealand between latitude 52°S and the Antarctic Circle, it is an important place to examine critical aspects of the ecosystem of the Southern Ocean.

Some descriptions and species lists resulted from the activities of members of the Australasian Antarctic Expedition 1911–14 and the British, Australian and New Zealand Research Expedition 1919–31, and in the early days of the Australian National Antarctic Research Expeditions (see references in Selkirk *et al.* 1986). A major upturn in biological research at Macquarie Island occurred in the 1950's and 1960's, when long-term investigations of elephant seals and royal penguins, supervised by Dr R. Carrick of the CSIRO Division of Wildlife Research, were undertaken. A series of papers by Carrick and others was published in *CSIRO Wildlife Research*, volume 7, in 1962. As an adjunct to those projects several more restricted but related investigations involving anatomy, physiology and ethology of seals and penguins were undertaken (see Bryden 1964 *et seq.*, Ling 1965 *et seq.*, Shaughnessy 1970a, 1974, 1975, Smith 1974), and studies of certain other species, particularly birds, were made (see for example Mackenzie 1968, Purchase 1980, Shaughnessy 1970b, c, 1971, Simpson 1965a, b).

In the 1970's the emphasis of zoology, by then supervised within the Antarctic Division, shifted to the antarctic continent, where extensive studies were centred at Davis. The major thrust was in limnology at that time. Monitoring of populations continued at Macquarie Island, and an intensive investigation of the control of the annual cycle of elephant seals was conducted (see Griffiths *et al.* 1979, Griffiths & Bryden 1981, Griffiths 1984 *et seq.*). At the end of that decade the emphasis shifted again, when marine biological investigations began. This was an important development and was seen as a valuable contribution by Australia to the BIOMASS Programme (Biological Investigations of Marine Antarctic Systems and Stocks).

In the last three or four years the importance of Macquarie Island zoologically, mainly as a result of its location, has been re-emphasised. The knowledge now that certain animal populations are undergoing dynamic change in the Southern Ocean has pointed up the need for major zoological studies at Macquarie Island to supplement the marine biology programmes. There is solid evidence that the elephant seal population at Macquarie Island has declined by 50% in the last 30-odd years (Hindell & Burton 1987), and some preliminary investigations of factors associated with that decline have been undertaken (Little *et al.* 1987).

Throughout the 1970's and early 1980's other aspects of biology continued. These included

- making collections of biota for selected studies of flora and fauna, in particular algae and aquatic invertebrates;
- continuation of long-term population studies of seabirds, particularly the wandering albatross, the light-mantled sooty albatross and the giant petrels; more recently, the black-browed albatross and the grey-headed albatross have been included;
- control programmes: initial surveys and experimental control of rabbits and cats were conducted as early as the 1960's, and control procedures have been employed since then; control of rodents and wekas has been attempted more recently;
- monitoring seabirds: this represented an involvement in an International Survey of Antarctic Seabirds; photographic censuses of all the major penguin colonies on the island were carried out;
- making a census of fur seals: general study of the fur seals at Macquarie Island was conducted as early as the 1950's (Csordas & Ingham 1965); recently it has been recognised that there are three species of fur seal at the island, the New Zealand fur seal which is a visitor only, the antarctic fur seal and the subantarctic fur seal;
- recording and tagging leopard seals;
- studies of diet of the four species of penguin, gentoo, royal, king and rockhopper.

The Commission for the Conservation of Antarctic Marine Living Resources, now established in Hobart, has recognised for several years that high-level consumers, such as seals, penguins and other seabirds, may be valuable "biological indicators" of the condition of the Southern Ocean ecosystem. The long-term censuses and population studies that have been conducted over several years will continue to be most valuable in this regard.

THE FUTURE

There is little doubt that Macquarie Island continues to be an important meteorological station and presents opportunities to conduct unique investigations of the aurora and other aspects of the upper atmosphere. Exciting geological work is currently being conducted at the island. All these aspects will be addressed elsewhere in this volume.

The recognition by Mawson and some before him that the fauna of Macquarie Island is of principal importance is as true today as it was early this century. However, our perception of what constitutes its importance could hardly be more different from that of Mawson. In this regard it is interesting to reflect on the future management of the fauna of Macquarie Island put forward by Mawson (1919):

(1) ensure that only redundant bull elephant seals and decrepit animals are killed;
(2) kill any sea leopards that come ashore;
(3) reduce the number of skua gulls;
(4) investigate the possibility of a penguin egg industry;
(5) reduce, and if possible exterminate, the wild cats;
(6) breed a few sheep in a restricted area on North Head;
(7) introduce the fur seal and possibly other fur-bearing animals.

The potential value of seals and seabirds as biological indicators of the status of the ecosystem of the Southern Ocean has been mentioned above; censuses of these species should continue, in particular the penguins and elephant seals. Detailed ecological investigations of these species may shed valuable light on the factors responsible for fluctuations in population size. Technology is being developed, and in some cases is available now, to examine their range, short-term and long-term movements, energetics, diving and foraging behaviour. It will be possible to compare these factors among age and sex classes.

The fur seals at Macquarie Island present an excellent opportunity to examine ecology and behaviour in an apparently developing population that may be unique. The interrelationships among New Zealand, antarctic and subantarctic fur seals, and possible interbreeding between subantarctic and antarctic species, potentially are a fertile field for ecological study.

Hitherto, physiological investigations of the fauna at Macquarie Island have been few. The opportunity for such studies provided by the island fauna is not unique on a world scale, but it does present the only practicable opportunity for such work by Australians in Australia. Recent investigations have been aimed at examining the role of the pineal gland in southern seals (Griffiths & Bryden 1981, Bryden *et al.* 1986, Griffiths *et al.* 1986), and mechanisms of body temperature control in newborn seals (Little & Bryden, work in progress). It appears that changes in day length, which are marked in polar regions, are monitored by a mechanism involving the pineal gland, and are particularly important in controlling at least some annual cycles in the southern seals. It is likely that light, upon which most phytoplankton are dependent, has a significant influence on the marine fauna of the Southern Ocean at many trophic levels. The physiology of energy transfer within species is potentially extremely important to our understanding of the mechanisms of shifts in the Southern Ocean system.

CONCLUDING REMARKS

In summary, Macquarie Island is as fascinating today as it was 70 and more years ago when scientists first visited it. The animal life is of particular interest, as it was when Sir Douglas Mawson visited the island earlier this century; the strategic importance of the island in the Southern Ocean has a different and even greater significance in this regard than was foreseen earlier. The declaration of the island as a fauna and flora reserve and, more recently, placing it under the control of the National Parks and Wildlife Service, Tasmania, have been vital. The introduction of measures to control feral species and ensure the continued well-being of natural populations have contributed significantly to improving the value of the island's populations of animals as monitors of the Southern Ocean ecosystem.

As a result of investigations in a number of scientific disciplines, we have an appreciation of the geological history of the island and its flora and fauna.

Macquarie Island continues to be an important meteorological station. Largely as a result of its geographic position, useful data in a number of scientific spheres continue to be recorded there.

In the 1980's we are reaping the benefits of wise planning and execution of scientific programmes at Macquarie Island by the Australian National Antarctic Research Expeditions over the past 39 years.

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