NOMINATION OF

MACQUARIE ISLAND

BY THE GOVERNMENT OF AUSTRALIA

FOR INSCRIPTION ON THE

WORLD HERITAGE LIST

Prepared by

DEPARTMENT OF THE ENVIRONMENT,
SPORT AND TERRITORIES

in association with

PARKS AND WILDLIFE SERVICE
TASMANIA

1996

CONTENTS

page

LIST OF APPENDICES

LIST OF FIGURES

1. IDENTIFICATION OF THE PROPERTY

a. Country (and State Party)

AUSTRALIA

b. State, Province or Region

STATE OF TASMANIA

c. Name of Property

MACQUARIE ISLAND

d. Exact location on map and identification of geographical coordinates to the nearest second

The property nominated as Macquarie Island (including the adjacent islets, rocks, reefs and 12 nautical mile wide surrounding marine area is located between latitude 54° 08' 30” S and 55° 18’ 00” S and between longitude 158° 23' 00” E to 159° 07' 30” E.

e. Maps and/or plans showing boundary of area proposed for inscription and of any buffer zone.

A map showing the boundary of the nominated property is enclosed with this nomination.

f. Area of site proposed for inscription (ha.) and proposed buffer zone (ha.) if any.

The land area within the nomination (the Macquarie Island Nature Reserve) is 12,785 hectares. The total area of the nomination is 540,000 hectares (or 5,400 square kilometres). There is no buffer zone.

2. JUSTIFICATION FOR INSCRIPTION

a. Statement of Significance

Even if the Earth were stripped of its atmosphere and hydrosphere, its continents and ocean basins would remain its major surface features. These two principal regions of the Earth's lithosphere differ markedly not just in their elevation but in their structure, their age, their rock types, their chemical composition, their history, and in the ways they form.

The oceanic lithosphere has a life cycle. It is produced by 'sea-floor spreading' at mid-oceanic ridges. In plate tectonic terms, these ridges are 'divergent 'or 'constructive' plate boundaries. The oceanic lithosphere returns to the Earth's interior down subduction zones, which are characteristic of these convergent or destructive plate boundaries. Macquarie Island is the only known locality where the lithosphere of a major ocean basin is exposed above sea-level. Elsewhere, the oceanic lithosphere must be studied by dredge, drill, and submersible. On Macquarie Island, all of the common rock types of the ocean floors are exposed, together with their inter-relationships.

Macquarie Island, therefore, represents an outstanding exposure of the oceanic lithosphere which covers the majority of the Earth's surface, and is thus a natural site of universal significance. Macquarie Island also lies on the boundary between the Australian and Pacific plates, two of the seven large tectonic plates of the Earth. In the Macquarie Island area, this boundary is essentially a 10-45 km wide, strike-slip boundary where faults form a braided zone that encompasses and cuts the island. Plate boundaries where adjacent plates move, horizontally, past one another are termed 'transcurrent plate boundaries', and form the third major boundary type.

Macquarie Island is believed to be the only sub-aerial exposure in the oceanic domain of an active major transcurrent plate boundary. The island is thus doubly significant as the site of active faulting and tectonism caused by an active geological process of global significance.

In summary, the nominated site is of outstanding universal value from a conservation and geoscientific point of view for the following reasons:

- It is the only known locality in the world where oceanic lithosphere formed at a normal mid-ocean spreading ridge environment is being exposed above sea-level within a major ocean basin.
- It provides a unique example of ocean crust uplifted as a result of transpression at a strike-slip plate boundary in an oceanic setting.
- The exposed rock sequence provides a uniquely complete section through the earth’s oceanic crust to upper mantle rocks
- The geological evolution of Macquarie Island began 10 million years ago and continues today with the island experiencing earthquakes and a rapid rate of uplift, all of which are related to active geological processes along the boundary between two plates.
- The island is unique in that its present geomorphology shows features of the marine erosion (raised beaches and benches) that have progressively affected its whole surface during uplift. This unique feature complements, and is a consequence of, its unique geological attribute of being uplifted sea-floor.
- It, therefore, has outstanding universal value in that it provides a unique opportunity to study, in detail, geological features and processes of oceanic crust formation and plate boundary dynamics above sea- level.

b. Comparative analysis

In origin, Macquarie Island is unique. It is the only known exposure above sea-level of the oceanic lithosphere of a major oceanic basin and is therefore of outstanding universal value from a conservation and scientific point of view. The island is also the only known subaerial exposure of a segment of a major active transcurrent plate boundary in an oceanic setting, and is therefore also a unique example of a significant ongoing geological process.

Macquarie Island and associated rock complexes have developed in an entirely oceanic setting. Similar well-developed and well-studied geological complexes (referred to as ophiolites - see Appendix C) include the Semail complex of Oman, which is among the largest and best exposed, the Troodos complex on Cyprus, and the Bay of Islands complex of western Newfoundland (Hall 1987). Almost all exposed ophiolite complexes occur in continental settings and their status as fragments of former oceanic crust is, therefore, a question of interpretation and argument. Neverthless, the only associated rock complexes are those of the oceanic lithosphere which, everywhere else, is underwater. In this respect, ophiolite complexes cannot be compared with Macquarie Island. Macquarie Island is considered exceptional as an example of such a complex in its original geological setting, unlike all of the above examples. It is the only ophiolite complex within a major oceanic basin which is plainly composed of oceanic lithosphere.

From the comparative point of view, it is most important to point out that there is geochemical evidence to question whether any of these other ophiolite complexes were formed at a mid-oceanic spreading ridge in a major ocean setting (Pearce *et.al.* 1984). These complexes may be bigger, but they may not be genuine samples of major ocean lithosphere. This is because volcanic rocks from subduction-zone settings are associated with all of these other ophiolite settings. In addition, Miyashiro (1973) has pointed out the presence, indeed abundance, of island arc volcanics in the Troodos complex. It is now generally accepted that the Troodos complex formed at or near a subduction zone, possibly in a back-arc basin or fore-arc and that it did not form at a spreading ridge in a mid-oceanic setting. There are also subduction volcanics associated with the ophiolite complex in Oman (Alabaster *et.al.* 1982) and Elthon (1991) has demonstrated that the basalts at the Bay of Islands complex, which is already on the World Heritage List, betray a subduction zone signature.

Macquarie Island's tectonic setting, magnetic properties, pillow lavas and deep-sea sediments all show that it is formed of oceanic crust (Williamson 1988). Moreover, the age of the Macquarie Island rocks, the presence of the sheeted dolerite dyke complex, pillow lavas and its structural history and the linear magnetic anomalies of the region, are all consistent with the hypothesis that Macquarie Island has developed by sea-floor spreading at the Australian - Antarctic - Pacific mid-oceanic ridges, since the mid-Tertiary (Duncan & Varne 1988).

In considering the status of ophiolites as oceanic crust, Hall states:

> The components of the ophiolite suite bear a striking resemblance to the assemblage of rocks collected from sea-floor dredging and now believed to constitute the bulk of the oceanic crust. They are also very similar to the assemblage of rocks of Macquarie Island. This has led students of ophiolites to interpret them as segments of oceanic crust tectonically incorporated into the continents and marine geologists, in turn, to construct models of the oceanic crust based on continental ophiolites. This is obviously a somewhat circular line of argument, although it is quite likely that the conclusions are correct (1987, p. 485).

Macquarie Island is the only known connecting link between the ophiolites of continental environments and the *in situ* oceanic crust studied by dredge, drill and submersible.

As Nicolas states:

> The difficulty in reconciling ... (geochemical) data in a simple way with an origin at mid-ocean ridges has led to a quasi-general consensus among geochemists who conclude that most well studied ophiolites around the world represent the crust of small ocean basins adjacent to, or inside, island arc systems, either in fore-arcs, immature island arc or back-arc basins. (1989, p. 199)

In contrast, Macquarie Island is still in the oceanic setting in which it was formed in the Southern Ocean, and there is general acceptance that the rocks of the island were formed at a mid-oceanic spreading ridge in a major ocean basin and that sections through oceanic crust and uppermost mantle are exposed on the island. It is difficult to explain the origin of the rocks in any other way (Griffin & Varne 1980).

The geological importance of Macquarie Island is summarised by Kerr:

> One way to deal with the obvious complexities of most ophiolites would be to find one that has not suffered the bashing and alteration apparently required to put ocean crust onto continents. R. Varne, B. J. Griffin and G. A. Jenner of the University of Tasmania think they have a promising candidate. It forms part of Macquarie Island, the last, lonely outpost south of New Zealand. All of the appropriate crustal layers are there and the island itself seems to have been simply squeezed toward the surface like toothpaste from a tube. Remoteness, foul weather, and rugged terrain make field studies difficult, but researchers hope that Macquarie will provide an even clearer view of at least one section of mid-ocean crust (1983, p. 1309).

As the geological origin of Macquarie Island differs from that of other subantarctic islands, so do its landscape and the processes shaping it. Volcanic islands built up through the ocean's surface have much of their above sea-level mass derived from eruption of ejecta that is not exposed to wave action or submarine erosion, i.e. their above-sea surface may not have been exposed to marine erosion. Rising coasts (eg. Huon Peninsular, New Guinea) do show uplifted geomorphological features of marine erosion, but Macquarie Island's claim to unique status is that its whole surface shows features of the marine erosion. Neither subaerial volcanoes nor glaciers, both features of other subantarctic islands, are to be found on Macquarie Island. Its present landscape results from the interplay of faulting, uplift, sea-level changes, erosion and the cold subantarctic climate.

Its origins are totally oceanic and quite unlike the Auckland Islands or Campbell Island which are volcanic islands built on continental crust, or South Georgia which has resulted from large scale sedimentation. Nor is it an island on which there has been subaerial volcanic activity overlying submarine volcanism leading to further island-building (as on the Prince Edward Islands, Heard Island, the McDonald Islands and lIes Crozet).

In nominating Macquarie Island for World Heritage listing on the basis of its uniqueness as an outstanding example of a major geological process, the emphasis is on the highly significant conservation values associated with the area’s geological make-up. It is clearly a site of great universal value.

There is considerable international scientific interest in investigating the character of the oceanic crust in the area. Investigations of this nature, carried out within the management regime of the responsible government agency, will enhance the World Heritage (that is, geological) values of the area.

In 1995, as part of its assessment of Gough Island, IUCN carried out a “delphi” rating of the southern cool-temperate and subantarctic islands. This process produced a perfect score (15 out of 15) for Macquarie Island in relation to geological character (criterion i). The only other perfect score achieved by any island on any World Heritage criterion (IUCN 1995) was by McDonald Island in relation to impact.

c. Authenticity/Integrity

The nominated property is of sufficient size and contains the necessary elements to demonstrate the key aspects of the geological processes of Macquarie Island and the outlying Bishop & Clerk and Judge & Clerk islets, from Tertiary times to the present, including the structure of the oceanic crust and crustal thickening at the plate boundary (Williamson 1988; Jones and McCue 1988).

Macquarie Island is 5.5 kilometres wide and 34 kilometres long and it displays a variety of structures imposed by plate tectonic processes. These involve varying degrees of tilt and rotation of rock units bounded by faults in the formation and uplift of the island.

All major elements of the Macquarie deformational zone are included in the nominated area (Hayes and Talwani 1972). These onshore and offshore areas include parts of both the Pacific and Australian plates, including the Macquarie Trench, areas of the submarine Macquarie Ridge, and clear regional patterns of sea-floor spreading, detected by sidescan sonar and magnetic anomalies. The transpressional forces between the Australian and Pacific plates, which formed the island, produced a large variety of fault-related structures and these are widespread and well exposed (Williamson 1988).

There are also numerous landscape features on the island that bear witness to its tectonic activity. The major fault contact between extrusive pillow basalts to the south and intrusive rocks to the north at the col between Bauer Bay and Sandy Bay, and numerous fault scarps all over the island, are examples of these features (Adamson *et al.* 1988).

Macquarie Island is the only known subaerial exposure of oceanic crust of a major ocean basin still lying within that basin. The section of oceanic crust exposed in the northern part of the island includes representatives of most rock types dredged from the major ocean basins and unlike dredged samples, rock types from Macquarie Island are preserved in their original crustal context. Importantly, as is seen in the comparison between Macquarie Island and other well-known ophiolite complexes, there are no rock types on Macquarie Island that are not known from the floors of the major ocean basins (Griffin and Varne 1980).

Macquarie Island, therefore. contains the key interrelated and interdependent oceanic crustal elements in their natural relationship - extrusive basaltic rocks and associated sediments; a sheeted dolerite dyke complex; high-level massive (isotropic) gabbros; layered gabbros, troctolites; and upper mantle harzburgites.

d. Criteria under which inscription is proposed (and justification for inscription under these criteria)

Natural Criterion (i) *Be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.*

The nomination property fulfils this criterion in that it is an outstanding example representing major stages of the earth's history, in that it demonstrates significant on-going geological processes in the development of landforms and in that it possesses significant geomorphic or physiographic features.

The nominated property is a globally unique site providing evidence of significant on-going geological processes and is an outstanding site representing major stages in the earth's evolutionary history. It is the only known locality in the world where oceanic lithosphere of a major ocean basin formed underwater is now (and continues to be) exposed via tectonic processes above sea level. It is an outstanding example of the products of sea floor spreading which is an essential and major stage in the geological evolution of the earth's surface and it is also the only place on earth where tectonic forces have brought oceanic mantle-derived rock to the surface within the context of a currently active plate boundary (Duncan and Varne 1988).

It provides a unique exposure of a segment of a major active plate boundary in an oceanic setting and is therefore of major interest not only to the conservation of geological features but also to geoscientific research. The plate boundary represented at Macquarie Ridge, including Macquarie Island, is considered to be highly significant because it is the only place in the world that an ocean-ocean plate boundary of this type occurs above sea level. Typically, plate interactions do not result in oceanic crust being exposed in this way; either they involve more buoyant continental crust, so that oceanic crust sinks into the mantle or they involve subduction of oceanic crust beneath the oceanic crust of another plate leading to the formation of an island arc.

The transpressional forces that formed the Macquarie Ridge and Island during the last 10 million years are ongoing, evidenced by frequent earthquakes, including some of the world's largest, and a dramatic rate of uplift (Adamson *et al*. 1988). This indicates that tectonic and structural processes which uplifted Macquarie Island oceanic crust above sea level are continuing today. This is most important in relation to the understanding of plate tectonics because it provides the only example, globally, of oceanic crust being uplifted as a result of transpression at an ocean-ocean plate boundary.

Macquarie Island is the only oceanic island in the world that undoubtedly consists of rocks formed at a normal submarine mid-oceanic spreading ridge. All rock units were formed on, or below, the sea floor. The island has been uplifted and deformed but has not come in contact with any continental rock types (Duncan and Varne 1988).

The rock complexes represented on Macquarie Island provide excellent examples of a slice of the entire earth's crust and uppermost mantle. Exposures of oceanic crust resulting from plate interactions are usually found at sites on the continents remote from their original ocean setting and their rocks are either highly deformed or eroded. They are commonly older and therefore have a more complex geological history that tends to obliterate or confuse pre-existing structures or features. None of these problems exist at the nominated site.

From a conservation and geoscientific point of view, it is also considered to be a significant site because it has a suite of intrusive and extrusive igneous rocks representative of the oceanic crust, from the ocean floor type pillow lavas to ultrabasic rocks such as harzburgites which are typical of the upper mantle.

It has outstanding universal value in that it provides a unique opportunity to study, in detail, geological processes at a plate boundary. Rocks and geological relationships can be mapped, observed and sampled, in outcrop, and their geological and geophysical parameters can be measured. Such detailed studies are not possible for a similar submarine occurrence.

Natural Criterion (iii) *Contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance.*

> This little island is one of the wonder spots of the world. It is the great focus of the seal and bird life of 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.

So wrote Douglas Mawson in 1919, leader of the 1911-14 Australasian Antarctic Expedition, Antarctic pioneer and subsequently the pre-eminent figure in the battle to conserve the outstanding natural values of Macquarie Island.

Macquarie Island is a small speck thrust up into the vast Southern Ocean by massive forces within the earth. It lies in the latitudes known, since the days of sail, as the “Furious Fifties” because of the frequency of very strong winds and stormy seas.

Around the shoreline there is a coastal terrace formed from a wave-cut platform now raised above sea level. This is best developed in the north-west where it is over a kilometre wide and up to 15 metres above sea level. Vast, waterlogged areas on the coastal platform are heavily vegetated, forming a mire based on deep peat beds and known locally as "featherbed" from the sensation gained when walking over them. Old sea stacks testify to the continual uplifting of the island as they protrude through the peat beds, some of them now being several hundred metres from the existing coastline.

Behind the coastal terrace, steep escarpments rise at angles of up to 80° more than 200 metres to the undulating central plateau which has three peaks over 400 metres, the highest being Mt Hamilton at 433 metres (see Figure 2). The plateau scarps are most spectacular at the southern end of the island and along the west coast where the relentless pounding by the Southern Ocean has cut a myriad of rugged bays and coves, fringed with sea stacks and reefs.

The plateau surface is dotted with innumerable lakes, tarns and pools, mainly of structural origin. Fluctuations in sea level and marine erosion have cut away the original escarpments leaving some lakes now perched on the edge of the plateau, while others have been partially or totally drained. The continual westerly winds, which increase in force as they rise over the barrier of the island, and changes in the topography on the plateau, result in dramatic changes in the vegetation cover which can vary from 100% to less the 10% within a metre or two.

Among the most aesthetically appealing sights of the island are the vast congregations of wildlife, particularly penguins, on suitable parts of the coastal terrace, especially during breeding seasons. The breeding population of royal penguins on Macquarie Island is estimated at over 850,000 pairs – one of the greatest concentrations of sea birds in the world. The enormous Hurd Point royal penguin colony covers 67,000 square metres while the huge Lusitania Bay colony of the stately king penguin exceeds 250,000 birds. As the king penguin chicks do not leave the vicinity of the nest for a year, they survive the rigours of winter standing on the wind and snow-swept beaches.

Four species of albatross nest on steep and rugged cliffs, both on the main island and on Bishop & Clerk Islands. These are majestic birds, easily viewed when nesting.

Elephant seals also form impressive colonies during the breeding season on suitable beaches. These animals can grow to over 4.5 metres in length and to a weight of 3.5 tonnes. Conflicts between the larger bulls are among the more memorable sights that may be witnessed on the island.

3. DESCRIPTION

a. Description of Property

Macquarie Island lies almost 1500 kilometres to the south-south-east of Tasmania, about half-way between Tasmania and Antarctica. The Island has an area of approximately 12,785 hectares. The main island is approximately 34 kilometres long, and 5.5 kilometres wide at its broadest point. Included in the Macquarie Island Nature Reserve are the rocky outcrops of the Judge and Clerk Islets 11 kilometres to the north and the Bishop and Clerk Islets 37 kilometres to the south.

Figure 1 shows the location of Macquarie Island in relation to Australia, New Zealand and Antarctica.

Figure 2 shows the location of the places on the island that are referred to in this nomination.

Figure 3 shows the boundary of the area covered by the nomination, including the 12 nautical mile marine zone surrounding the main island and the Bishop and Clerk and Judge and Clerk Islets.

Macquarie Island lies within and derives many of its characteristics from the subantarctic biogeographical province. This province is a circumpolar body of water dotted with six island groups, all of which lie within a few degrees of latitude of the Antarctic Convergence (the oceanic boundary where cold water from the south meets warmer water from the north). The province is bounded to the north by the cold temperate biogeographical zone of the Southern Ocean and to the south by the maritime antarctic zone. Appendix A contains a definition of these provinces, incorporating geographic, climatic and biotic characteristics.

a.1 Geology

Macquarie Island is part of the Macquarie Ridge Complex, which includes the Hjort Trench to the south and the Puysegur Trench to the North. Continuing further north and onshore New Zealand's South Island, the boundary between the Australian and Pacific plates becomes the Alpine Fault. The development of the Macquarie Ridge Complex as a transform plate boundary probably began in early Miocene times (Appendix B contains a geological time scale). It is the only ocean island in the world that undoubtedly consists of rocks formed at a normal, submarine, mid-ocean spreading ridge. Its origins are neither the result of large-scale sedimentation (as is the case with South Georgia) nor of volcanism built on continental crust (as is the case with the Auckland Islands and Campbell Island). Nor is it an island on which there has been subaerial volcanic activity overlying submarine volcanism leading to further island-building (as on the Prince Edward Islands, Heard Island, the McDonald Islands and the lIes Crozet).

Macquarie Island is totally oceanic in origin, all rock units being formed on or beneath the ocean floor. Following its formation on the ocean floor, the island has been deformed and uplifted but has suffered no collision or other relationship with continental-type rock types. It constitutes a natural site and precisely delineated area of outstanding value from the point of view of conservation geology and plate tectonics.

(I) Regional setting and plate tectonics

The uplifting of a slice of oceanic crust in a mid oceanic tectonic environment is most unusual. Plate tectonics interprets the configuration of the earth in relation to the movement of plates consisting of oceanic or continental lithosphere or a mixture of the two. Oceanic lithosphere is created at mid-ocean ridges by up-welling of partially molten materials from the earth's mantle. These materials solidify into oceanic crust composed of basaltic rocks overlying deeper gabbroic crust and peridotites and move away from the ridges as new crust is created. The oceanic lithosphere is returned into the mantle at the trenches of subduction zones where the leading edges of the oceanic plates are located, until, at depth, the subducted lithosphere again becomes molten and can be redistributed or erupted to form volcanic edifices in island or continental arc regions.

The movement of the plates causes changes in the distribution and configuration of continents, including continental rifting and drifting, and collision of continental masses to form mountain chains such as the Himalayas. The movement is in the order of 5 to 10 centimetres per year but over a time scale of 100 000 years can lead to major local displacements (5 to 10 kilometres) and regions of uplift and subsidence. Over periods of tens or hundreds of millions of years plate movement is the major process reconfiguring and determining the geology, the geomorphology, the distribution of biota and probably the climate of the earth.

The main oceanic plate boundaries occur at mid-ocean spreading ridges, where oceanic plates are formed, and at subducting trenches, where oceanic plates are destroyed. Active mid-ocean spreading ridges can in special circumstances occur above sea-level, as in the case of Iceland, where a plume of hot material rising from deep in the earth's mantle elevates and modifies the spreading ridge. However there the lithosphere is unlike normal oceanic lithosphere both in thickness and in composition. Subducting systems can occur above sea level in the island arc regions, but these areas are greatly modified by island arc volcanism fed by the melt from the down going lithospheric plate and no longer constitute normal oceanic crust. A third type of plate boundary between oceanic plates is a transform boundary, where movement is lateral, with one plate slipping past the other (transcurrent). Where a component of compression also occurs between the plates, the plate boundary is described as transpressional.

This last is the type of plate boundary represented along the Macquarie Ridge Complex, including Macquarie Island. Geologists studying oceanic crust consider the exposure of oceanic crust on Macquarie Island to be unique (Varne and Rubenach 1972). Similar ridges at active transcurrent plate boundaries occur underwater in a small number of places around the world but exposure above water of this plate tectonic environment appears unique to Macquarie Island.

The tectonic and physiographic expression of Macquarie Island and the surrounding region results from transpression between the Australian and Pacific oceanic plates near their common boundary. This boundary, south of New Zealand, lies within the Macquarie Ridge complex, extending from the Macquarie triple junction among the Australian, Pacific and Antarctic plates near 62°S, 160°E to the Alpine Fault of the South Island of New Zealand. The major physiographic element of the complex near Macquarie Island is an arcuate ridge (Macquarie Ridge) with a trench (Macquarie Trench) to the east in the central area near Macquarie Island.

Relative motion along the plate boundary results in earthquake activity (seismicity). The first motion studies of seismic events from the Macquarie Ridge (Frohlich *et al.* submitted) are consistent with modern transcurrent motion near Macquarie Island, although the structure of the Ridge suggests transpression in the geological past. The pole of rotation between the Australian and Pacific plates (DeMets *et al.* 1990) implies transpression of varying degrees for much of the Macquarie Ridge Complex. Figure 2 shows generalised bathymetry and the relative motions between the Australian and Pacific plates in the region.

Past transpression along the Macquarie Ridge Complex near Macquarie Island has resulted in an asymmetric crustal structure, as shown by gravity and bathymetric data. The large scale crustal structure over the Macquarie Ridge near Macquarie Island has been investigated by inversion of gravity data, which shows a progressive thickening of the Australian oceanic crustal layer from approximately 7 to 14 kilometres, over a 200-kilometre distance as Macquarie Ridge is approached from the west (Williamson and Johnson 1974). A root zone, some 30 kilometres wide and comprising an additional crustal thickening of 4 kilometres is displaced from the Macquarie Ridge towards the Macquarie Trench. This asymmetric crustal structure is considered to demonstrate incipient subduction at the Macquarie Trench by comparison with the expressions of progressively more developed subduction in other parts of the world, as exemplified in the Bowers Ridge (in the Bering Sea) and Puerto Rico Trench regions. This interpretation is consistent with SEASAT data collected over the area (Ruff and Cazenave 1985). Thus crustal thickening and isostatic compensation near the plate tectonic boundary have caused Macquarie Island to be uplifted above sea-level.

The spreading of the oceanic crust during the period of reversals of the earth's magnetic field produces the characteristic sea-floor spreading magnetic anomalies associated with oceanic crust. A sea-floor spreading magnetic anomaly is interpreted to the west of Macquarie Island as crossing Macquarie Island (Williamson 1978) and in the oceanic crust to the east of the island. This is consistent with the geological interpretation that Macquarie Island is composed of uplifted oceanic crust (Varne and Rubenach 1972).

(II) Geology of Macquarie and adjacent islands

Macquarie Island represents an ophiolite complex - a slice of oceanic crust (see Appendix C for a fuller definition) - in relatively pristine condition (Selkirk *et al.* 1990, p. 56). Examples of exposed oceanic crust resulting from plate interactions are usually found at sites remote from their original oceanic setting and their rocks are either highly deformed or now highly eroded. The Island is the only known locality where oceanic lithosphere formed in a normal submarine setting within a major ocean basin is now exposed above sea-level. It is therefore of outstanding universal value from the scientific point of view. The basalts and dolerites are compositionally matched with ocean floor basalts from the Mid-Atlantic Ridge (Griffin and Varne 1980). Pillow lavas (see Plates 1 to 4) have magnetic properties that correspond well with those of ocean floor basalts (Levi *et al.* 1984).

Macquarie Island is made up of a series of faulted blocks, representing different crustal levels, tilted with respect to one another and cross-faulted on all scales, providing several partial sections through oceanic crust. A relatively complete section in the northern part of the island passes from basaltic rocks at the top down through a sheeted dolerite dyke complex (see Plate 5) into massive and layered gabbros (see Plates 6 and 7), a complex mixed zone of layered troctolite plagioclase-wehrlite and dunite and, at its base, harzburgite representing the uppermost mantle (see Plate 8). Figure 5 shows an idealised, composite section through a column of the Macquarie Island ophiolite complex (from Griffin and Varne 1980) and illustrates the following sequence:

- an upper volcanic and sedimentary sequence;
- a sheeted dyke complex represented by dyke swarms;
- a sequence of layered troctolites and gabbros;
- gabbroic bodies, the exact position of which within the sequence is difficult to determine;
- harzburgites.

In the section of Macquarie Island north of the Sandy Bay-Bauer Bay col all of these rock types are represented. Figure 6 shows this relationship. Gabbro and serpentinite from the north of the island are indicative of deep oceanic crustal rock from depths of up to 5 kilometres below the pillow lavas. Extrusive rocks and associated sedimentary rocks from the south of the island are characteristic of eruption at the ocean floor at water depths of between 2 and 4 kilometres.

Major ocean basins cover approximately 65 per cent of the earth's surface, but the study of their lithosphere is limited by the tools available. It is known that new oceanic lithosphere is created by spreading at mid oceanic ridges, and the indirect (geophysical) methods of investigation have shown that away from these spreading centres the oceanic lithosphere possesses a layered seismic velocity-depth structure. The geological structure of oceanic lithosphere cannot, however, be deduced directly from its seismic structure: many parameters control seismic velocities in rocks. Direct study of the geological characteristics of the layered oceanic lithosphere is therefore necessary to determine its structure and investigate the processes by which it forms.

Studies by camera, dredge, corer, drill and submersible have shown that, in general, the ocean floor is overlain by a layer of superficial sedimentary cover resting on material that is basaltic in composition. This basaltic material has been sampled mainly by dredging; *in situ* sampling from submersibles has been much more restricted. The composition of these basalts from the ocean floor has proved to be not only remarkably uniform but also unlike that of basalts from other tectonic settings.

By contrast, very little is known of the composition of the deeper layers of the oceanic lithosphere. Although materials thought to be derived from these deeper levels, including serpentinised peridotites, gabbros and dolerites, have been recovered from fracture zones cutting the ocean crust, correlation of these materials with the oceanic lithosphere seismic section has not yet proved possible. So far, most scientific drilling has penetrated only the uppermost parts of the basaltic layer: the deepest hole so far drilled into normal oceanic crust (DSDP Hole 505B) passed through this basaltic layer into underlying dolerite dykes but has not yet penetrated gabbros or peridotites. Macquarie Island, lacking massive deformation, is thus one of the best locations in the world to examine normal oceanic crust and how it was formed. It is difficult to obtain such insight from the ocean floor itself or from active spreading centres such as Iceland, which provides only surface expressions of the process or can be drilled only with difficulty.

The life cycle of ocean basins is an essential element of the tectonic evolution of the earth: new ocean basins develop from young narrow rifts (such as the Red Sea and the Gulf of Aden) into mature ocean basins (such as the Atlantic and Pacific Oceans) then into ocean basins (such as the Mediterranean Sea) that may be in the later stages of disappearance.

Fragments of what is believed to be highly metamorphosed and deformed oceanic crust are found in most fold mountain chains, including the Himalayas, the Urals and the Alps. Perhaps the best known ophiolites that have been subjected to detailed geological study are in the Troodos massif of Cyprus and the Semail nappe of Oman. It is believed that both of these are fragments of ocean floor that have later been emplaced on continental margins and that they have suffered massive deformation in the process. Furthermore, they include volcanic rocks that are not typical of mid-oceanic spreading ridges and are believed to have formed in small basins close to island arcs.

Uplift of deep oceanic crustal rocks by approximately 10 kilometres during crustal thickening is indicated at Macquarie Island, since harzburgites representative of the oceanic upper mantle formed at depths of 5 kilometres (Griffin and Varne 1980) outcrop on the island. The steep dips of lavas on the island and the rotation of the south of the island relative to the central Island block (by 55° clockwise around a vertical axis), which has been demonstrated from palaeomagnetic results, are also associated with past transpression and crustal thickening along the ridge crest. Rotation of rocks on the island is also supported by geological argument (Varne and Rubenach 1972).

Macquarie Island appears to be the only plate tectonic environment above water that is truly representative of normal oceanic crust at an intra-oceanic plate boundary, or anywhere in the ocean basins for that matter. It provides a unique example of oceanic crust uplifted as a result of transpression at a plate boundary and is thus highly significant from a plate tectonic viewpoint. It has outstanding universal value in that it provides a unique opportunity to study in detail the particular structural processes and configurations that result from transpression at an oceanic plate/plate boundary: the rocks and geological relationships can be mapped and sampled in outcrop, and their geological and geophysical parameters can be conveniently measured. Such detailed study would not be possible for a submarine occurrence of a similar plate tectonic environment.

a.2 Geomorphology

Macquarie Island rises steeply from an underwater platform about 100 kilometres long and 10 kilometres wide, extending from Judge and Clerk Islets in the north to Bishop and Clerk Islets in the south. The platform lies in shallow water mostly less than 100 to 150 metres deep, on the crest of Macquarie Ridge, here a submarine mountain range planed off by wave erosion when the world sea level was at its lowest, about 18,000 years ago. Although most of this platform is below the sea, part is now visible as the gently sloping surface between the shore and the foot of the slopes leading up to the plateau. This surface continues underwater, and is best developed around the north western coast. During the present time of relatively stable sea level it is being raised above sea level by tectonic uplift of the island at an average rate of about 0.8 mm per year estimated over a period of several hundred thousand years (Adamson *et al.* 1996).

The whole island has risen above the surface of the seas, as indicated by numerous old ocean beaches from just above present sea level to high on the plateau (Ledingham and Peterson 1984). The island first appeared above the surface of the sea about half a million years ago, an estimate based on dating the raised beaches (Adamson *et al.* in press). Many of the ancient beaches lie on large gently sloping benches up to several kilometres in extent, themselves relics of former sea-cut platforms, comparable to the present platform that is still mostly submerged.

The present topography of the island can be explained by the interplay of erosion (by water, including freeze-thaw, wind and mass rapid movement such as uplift and movements along faults. Both are presently active processes that are superimposed on the older marine-eroded surface.

Glaciation by flowing ice masses is now thought to have been unimportant in sculpturing the landscape as shown by the preservation of numerous raised beaches high on the plateau despite the passage of several global glacial-interglacial cycles. The freshness of scores of sharp escarpments marking fault traces, also shows that flowing ice has been unimportant in carving the landscape. Numerous features identified as cirques, glacial valleys, kame terraces and over deepened lakes formerly attributed to flowing ice (Mawson 1943; Colhoun and Goede 1973; Loeffler and Sullivan 1980; Crohn 1986) can better be explained by fault movement, marine erosion, and extremely active freeze-thaw processes (Ledingham and Peterson 1984; Adamson *et al.* 1988; Selkirk *et al.* 1990). Even cirque-like amphitheatres, such as the Rookery Creek basin, can be accounted for by erosion along curved fault terraces (Selkirk and Adamson 1995).

Wind is an important agent of erosion (Loeffler 1983; Adamson *et al.* 1988) moving gravel, sand and ice pellets at high velocity, causing damage to vegetation. Wind also influences the spectacular terracing that occurs on hill slopes at high altitude on the plateau. On east-facing (lee) slopes terraces have near horizontal gravel treads and high steep well-vegetated risers. On slopes facing to the north or south the long axis of the terraces tilt downwards towards the west at an angle that minimises damage to the vegetation the risers from the westerly gales. On west-facing (windward) slopes well developed treads and risers do not form but the vegetation patches and stripes that do occur are severely eroded on their downslope edges that receive the full force of the westerly gales, but growth occurs on their upslope edges into soil that is being transported downslope from the extensive patches of bare ground.

Lakes and mires are abundant but large areas of the island, especially along stretches of the plateau west of the divide are dry. Also many lakes lack streams to feed them, and some also lack outflowing streams. These peculiarities can be explained by the flow of underground water directed eastwards by dipping rock strata particularly in the southern two thirds of the island.

The island's landscape has been carved primarily by marine erosion over its whole surface. Features of marine erosion, such as raised beach terraces and benches, can be found at altitudes of 270 m above the present sea level. Subsequent to emergence above wave action its geomorphology has been modified by the simultaneous action of wind and water erosion, and by faulting in the environment of the subantarctic Southern Ocean.

a.3 Natural history

Appendix D provides a description of the biota of Macquarie Island and lists of its flora and fauna. Appendix E provides a discussion of the biological status of the island and management measures to conserve its flora and fauna.

b. History and Development

Macquarie Island's recorded history began on 11 July 1810, when Captain Fredrick Hasselburg of the sealing brig Perseverance chanced on the island. The discovery led directly to commercial exploitation of the island's wildlife; this exploitation continued for 110 years (Cumpston 1968).

The first phase of exploitation on Macquarie Island - the harvesting of fur seal pelts - continued until 1820. Fur seals were indiscriminately slaughtered to the point of virtual extirpation; within 10 years the harvest became uneconomic. So thorough was the onslaught that the species of fur seal originally present on the island is now unknown. It is estimated that a total of 179,500 to 193,000 fur seal skins were taken. With the rapid decline of fur seal numbers the sealers increasingly turned to killing elephant seals for their oil and from 1820 to 1830 this was the main industry (Hindell and Burton 1988).

There were few visits to the island from 1830 until 1873 when there was a revival in the exploitation of elephant seals and penguins for oil (Cumpston 1968). The first steam-digester system was introduced to Macquarie Island in 1889. It is estimated that 8,380 tons of elephant seal oil were removed from the island; the original elephant seal population of about 93,000 to 110,000 animals was reduced by 70 per cent as a result of these operations (Hindell and Burton 1988).

In 1820 a Russian expedition led by Thaddeus von Bellingshausen visited the island and made the first known scientific collections of flora and fauna (Debenham 1945). During the next 90 years several other expeditions visited the island and collected specimens. The first attempts at systematic collection and study were made by the New Zealanders Scott (1883) and Hamilton (1895).

Between 1911 and 1914 the Australasian Antarctic Expedition, under Douglas Mawson, established a wireless relay and scientific station on the island (Mawson 1943). The botany, zoology, meteorology and geology of the area were studied, and magnetic observations and detailed mapping were carried out. Due largely to efforts by Mawson (1922), sealing and oil-gathering operations were stopped and the island was declared a Wildlife Sanctuary under Tasmanian legislation in 1933.

Since March 1948 Australian National Antarctic Research Expeditions (ANARE) personnel have continuously operated a scientific research station on Macquarie Island. Research projects have concentrated on the disciplines of biology, geology, upper atmosphere physics, cosmic ray physics and meteorology, although investigations involving other disciplines have been undertaken from time to time. The scientific research conducted on Macquarie Island is of international importance.

Archaeological investigations of the occupation sites of sealers have also become important in recent years (Townrow 1989). Intact examples of land-based tryworks commonly used for rendering oil in the late nineteenth and early twentieth centuries, are found at Hurd Point and Lusitania Bay. Remnants of production works and living quarters are still evident at several sites on Macquarie Island.

The remains of the first radio station established in the Antarctic/subantarctic region are located at Wireless Hill, on the northern tip of the island. This station enabled the first radio communication between Antarctica and the outside world.

The Government of the State of Tasmania began a more active role in the management of the island in 1972 when it raised its status to State Reserve. Research and management programs involving native and introduced flora and fauna on the island are under way. Intensive control programs are also being carried out with considerable success against introduced species, and long-term studies have been instigated to monitor changes in the status of native and alien species. The island was declared a Biosphere Reserve under the UNESCO Man and the Biosphere Program in 1977 and it was inscribed on the (Australian) Register of the National Estate. The State Reserve was extended to low water mark and offshore islands and rocks were included in 1978 and named the Macquarie Island Nature Reserve (Department of Parks, Wildlife and Heritage 1991).

c. Form and date of most recent records of site

An extensive list of publications relating to various elements of the site, and particularly its geology, is given in the bibliography.

The most recent review of the geology of the site is given in Duncan and Varne (1988).

The best general history of the site is Cumpston (1968), while Townrow (1989) provides details of the historic archaeology of the island.

Reviews of many aspects of the site were brought together in the proceedings of a symposium on the island in 1987 (Banks and Smith 1988).

A detailed overview of the environment and biology is given in Selkirk, Seppelt and Selkirk (1990).

Management of the island (and other subantarctic islands) was reviewed in Dingwall (1995a).

d. Present state of conservation

In terms of its overall ecology the nominated area is in a good state of preservation, especially when compared to islands globally. It has suffered the extinction of its indigenous seal and two endemic bird subspecies. As far as is known no species of plant has become extinct. Programs are in hand to control or eliminate exotic vertebrates. The area occupied by the ANARE Station is extensively disturbed, as are small sites around the six field huts. There are local pockets of erosion along some tracks. The offshore islands have not been affected by human activity.

In terms of its geological character (the basis for this nomination) the nominated area retains all of its natural characteristics and qualities. All of the major components of oceanic crust of the region can be identified and these are less deformed than any other example of an ophiolite in the world. The minor areas of human-induced erosion have no significant impact on understanding or interpretation of the geology.

The highly protected reserve status of the island and the active management undertaken by Tasmanian and Australian authorities means that the conservation status of the island is assured and that its natural values will be protected.

4. MANAGEMENT

a. Ownership

The State of Tasmania is the owner of Macquarie Island, Bishop and Clerk Islets, Judge and Clerk Islets, adjacent seastacks and reefs and the surrounding water to 3 nautical miles. The Australian Government has jurisdiction over the marine area from the limit of Tasmania's territorial waters to 12 nautical miles.

b. Legal Status

The nominated property is State-owned ("Crown land"). Macquarie Island itself and the nearby Bishop and Clerk Islets and Judge and Clerk Islets, adjacent seastacks and reefs to the low water mark, have been declared a State Reserve with the name "Macquarie Island Nature Reserve" under Tasmanian legislation *(National Parks and Wildlife Act 1970)* (Statutory Rules 1972, No. 152 and 1978, No. 121).

The marine area to the 3 nautical mile limit is vested in Tasmania under the *Seas and Submerged Lands Act 1972* and that between 3 and 12 nautical miles is vested in the Commonwealth of Australia under the *Seas and Submerged Lands Act 1972*.

c. Protective measures and means of implementing them

In relation to the Nature Reserve and wildlife in the surrounding sea to 3 nautical miles, protection is afforded under the *National Parks and Wildlife Act 1970* and the regulations thereunder *(National Parks and Reserves Regulations 1971* and *Wildlife Regulations 1971).* Under the Act, no statutory power can be exercised within the reserve by any instrumentality of Tasmania (e.g. no mineral exploration rights or mining leases can be issued) without provision for this having been made in an approved management plan and such provisions having been approved by both Houses of the Tasmanian Parliament. No such provisions have been included in the Management Plan for the Nature Reserve. By regulation, the Nature Reserve is a restricted area and can only be visited by "authorised persons" (primarily staff of the Service) or those holding a permit issued by the Director.

The regulations provide a high level of protection to all natural physical and biological (and cultural) elements. For example, the permission of the Director of the Parks and Wildlife Service is required before any person can "interfere with, dig up, cut up, collect, or remove any sand, gravel, clay, rock, mineral, or any timber, firewood, humus, or other natural substance". Permits are required from the Minister administering the *National Parks and Wildlife Act 1970* in order to collect any wildlife or wildlife produce (either plant or animal).

The Act and regulations are enforced through the Parks and Wildlife Service of the Department of Environment and Land Management in Tasmania and, within the Nature Reserve, by officers of the Service and by the ANARE Station Leader (who is authorised by the Director of the Parks and Wildlife Service).

A list of Australian and Tasmanian legislation dealing with environmental matters which relates to the nominated area is given in Appendix F.

d. Agency/agencies with management authority

For Macquarie Island and the adjacent islets: the Government of Tasmania, through the Parks and Wildlife Service of the Department of Environment and Land Management.

For the surrounding water to 3 nautical miles: the Government of Tasmania, through, in relation to

(a) Wildlife (including aquatic mammals): the Parks and Wildlife Service (PWS) of the Department of Environment and Land Management;

(b) Fish: Marine Resources Division, Department of Primary Industry and Fisheries.

For the surrounding water between 3 and 12 nautical miles: the Australian Government.

e. Level at which management is exercised (e.g. on site, regionally) and name and address of responsible person for contact purposes

The PWS usually has between one and three authorised officers working in the Nature Reserve throughout the year. These may be rangers, technical officers or wildlife management officers carrying out research and management programs. The ANARE Station Leader is also made an honorary authorised officer for the duration of her or his stay in the Reserve.

The Macquarie Island Liaison Officer is responsible for overseeing the management of the Reserve and some of the research programs, together with liaising with other organisations, private enterprise and the public regarding visits to or operations within the Reserve.

Responsible person for contact purposes:

Mr. G. Copson
Macquarie Island Liaison Officer
Parks & Wildlife Service
GPO Box 44A
Hobart
Tasmania 7001
AUSTRALIA

f. Agreed plans related to property (e.g. regional, local plan, conservation plan, tourism development plan)

The Macquarie Island Nature Reserve Management Plan 1991 has been in effect for nearly five years and is currently being reviewed as required by the Plan. The Plan is a statutory document, produced through a process which requires wide consultation and public exhibition before approval. The plan, when approved by the Governor, is binding on the Director and all State agencies.

Guidelines for tourist operations at Macquarie Island are reviewed annually, as required by the Management Plan and the policy laid down for tourist visits.

g. Sources and levels of finance

(a) Tasmanian Department of Environment and Land Management:
Through the Parks and Wildlife Service, the State Government provides around A$145,000 per annum in the form of wages and materials for management of the Nature Reserve.

(b) Australian Antarctic Division:
The Australian Antarctic Division provides all logistic support for the Australian National Antarctic Research Expeditions, including that for the Tasmanian Parks and Wildlife Service staff, at Macquarie Island. This includes providing eight over-winter and thirteen over-summer support staff (1993/94) at the island. The cost of this logistic support is approximately A$2.5–3 million per year, paid by the Australian Government.

(c) Other Bodies:
In addition to the above, other agencies, universities and individuals carrying out research programs on the island pay, from their own funds or through grants, the costs of their research projects other than the logistic support provided by the Australian Antarctic Division. It is not possible to obtain an exact figure for this element but it is estimated to be in the order of A$1.25–1.75 million each year.

(d) General:
It is estimated that the combined budgets for research and management for the Macquarie Island Nature Reserve were in excess of A$4.7 million for the period 1 July 1995 to 30 June 1996.

h. Sources of expertise and training in conservation and management techniques

The management of the Macquarie Island Nature Reserve is carried out by the Tasmanian Parks and Wildlife Service. Branches of the Service are staffed by professional officers with expertise in the planning for, and management of, reserves, natural features, public facilities, cultural heritage and wildlife.

Management of that part of the nominated area which extends into the marine zone will require a joint management agreement between statutory authorities of the Australian and Tasmanian Governments.

i. Visitor facilities and statistics

Visitors are provided with a booklet outlining the cultural heritage, geology and natural history of Macquarie Island. Up to date sheets and pamphlets covering research and management programs, minimum impact procedures, recommended reading and checklists of the fauna and vascular flora which they are likely to see are inserted in a loose leaf section of the booklet. Officers of the Parks and Wildlife Service oversee the visits and act as guides/interpreters.

Tourist visits are ship-based and the only facilities ashore are wooden walkways and viewing platforms which provide controlled access to penguin colonies, historic sites and scenic points.

While tourist operators are expected to be self-sufficient, limited medical facilities may be provided by the doctor at the ANARE Station in an emergency. Search and rescue facilities would also have to be provided by ANARE personnel.

The numbers of tourists authorised to visit the island each year since 1988 are set out in the following table:

Tourist Visits to Macquarie Island, 1988 - 1996

Season	Number of ships	Number of passengers
1988/89	1	18
1990/91	4	559
1992/93	4	416
1993/94	3	128
1994/95	4	342
1995/96	8	388

Passenger numbers are for onboard ship and generally not all passengers land at Macquarie Island. There were also two other visits where passengers did not land at all but cruised off-shore in inflatable boats.

j. Site management plan and statement of objectives (copy to be annexed)

A management plan for the Nature Reserve under the *National Parks and Wildlife Act 1970* was adopted in 1991. The plan was prepared by a process involving consultation with all interested parties and public exhibition. Once approved it is binding on the Director of the Parks and Wildlife Service who must ensure that its provisions are complied with.

The plan can only be varied through the same process of consultation and exhibition used in its original preparation. The current plan is under review and is expected to be replaced by a new edition in 1997.

A copy of the 1991 Macquarie Island Nature Reserve Management Plan is annexed as Attachment 1.

The “Objects of Management” as stated in the Management Plan are:

1 To protect and manage the reserve as a natural habitat for its indigenous flora and fauna and in order to achieve ecosystem conservation.

2 To seek to protect and preserve the marine habitat adjacent to the reserve in so far as it provides access and/or feeding grounds for the majority of the indigenous fauna.

3 To conduct, promote and encourage research and studies in so far as they have no permanent detrimental effects into the natural and cultural aspects of the reserve, the surrounding seas and the region.

4 To prevent accidental introductions of alien flora or fauna and, as far as possible, to eradicate or control previously introduced species which affect or endanger native species.

5 To record, protect and/or preserve any historic localities, artefacts or relics found in the reserve or adjacent waters.

6 To permit tourist visits under strictly controlled conditions which allow visitors to experience the natural values of the island without compromising them.

7 To publicise and promote the State’s successful management of the island as a Nature Reserve and internationally-recognised Biosphere Reserve.

(Department of Parks, Wildlife and Heritage 1991)

k. Staffing levels (professional, technical, maintenance)

The Tasmanian Parks and Wildlife Service usually has between one and three authorised officers working in the Nature Reserve throughout the year. These may be rangers, technical officers, scientific officers or wildlife management officers carrying out research and management programs. Maintenance, communication and other back-up staff are provided by the Antarctic Division.

5. FACTORS AFFECTING THE SITE

a. Development Pressures

Because of the reserve status of the island and the terms of its management plan, no commercial or private development onshore can be carried out.

Exploratory commercial fish trawling operations were commenced in the offshore waters (beyond 3 miles) surrounding Macquarie Island in the 1994/95 Austral summer. Further commercial fish trawling operations were undertaken in the following summer period. These have mainly targetted Patagonian Toothfish *(Dissostichus eleginoides)* and have taken up to 1000 tonnes of fish in one season. Limited exploratory trawling operations have also been conducted for deepwater prawns but, to date, have not resulted in commercially viable quantities of prawns being taken. Developmental commercial trawl operations will continue for Patagonian Toothfish during 1996-97 and 1997-98 under a two-year research program to improve the stock assessment advice and understanding of this species. The results of this research will assist in assessing the long-term sustainability of a commercial fishery in the region.

Negotiations between the Parks and Wildlife Service and Tasmanian fisheries authorities in relation to a marine reserve around the island to 3 nautical miles have been commenced.

A geological survey of the island has not indicated the existence of any economic mineral deposit.

b. Environmental Pressures (e.g. pollution, climate change)

The only continuing environmental pressures come from the ANARE Station and the (controlled) visits by tourists (see below). The impact from staff at the station is well-controlled within the station area and is monitored when people go to other parts of the island. Vehicles are only permitted within the defined station area. The possibility exists for pollution through accident from the station, from visiting ships while anchored offshore and from commercial fishing vessels operating in the region. A contingency plan for oil spills is in place. Monitoring sites have been established where checks are made regularly to determine whether any exotic invertebrates or plants have been introduced by visitors.

c. Natural disasters and preparedness (earthquakes, floods, fires, etc.)

The region is subject to frequent low-level earthquakes (in the order of 300 per annum). Of more significant events, Jones and McCue (1988) record:

> Large earthquakes occur frequently on the Macquarie Ridge, with an average return period of one year for an event of magnitude 6.2 or more and 10 years for one of magnitude 7.2 or more.

Tsunamis have never been recorded (probably because of the depth of the surrounding sea).

Increases in size and duration of the "ozone hole" over the region are being monitored constantly. Sea-level rises due to global warming are also being monitored.

Floods and fires are unknown.

d. Visitor/tourism pressures

A maximum figure of 500 tourists per year has been set by the Parks and Wildlife Service. It is considered that this figure is within the carrying capacity of the permitted sites. Tourists are only permitted to land at two locations where structures have been erected to protect the soils, vegetation and wildlife. In fact, since this limit was introduced in 1990-91, it has only been reached on one occasion.

Helicopters are used, under permit, to unload stores and equipment, to re-supply field huts and to carry out controlled scientific work. Tourists boats are not permitted to fly helicopters within 3 nautical miles of the island, except in an emergency.

e. Number of inhabitants within site, buffer zone

The ANARE Station generally has a total staff of no more than 45 during summer; in winter this would rarely exceed 15. Their activities are concentrated within the small area on the Isthmus zoned to provide for the maintenance of the ANARE Station. This is the only permanently-inhabited site; use of the six small field stations is occasional.

f. Other

The remoteness and inhospitable nature of the locality reduces the likelihood of any form of armed conflict. It is well away from shipping lanes and oil production zones, and there are no other known negative impacts on the site.

6. MONITORING / INSPECTION

a. Key indicators for measuring state of conservation

Due to the extensive body of data provided by the research and management programs which have been carried out in the Reserve over the years, there is a solid basis from which to measure the state of conservation of the property. This information includes photographic records of the landscape and historical sites dating from the Australasian Antarctic Expedition 1911-14.

While the introduced rabbits may contribute locally to erosion, it is now considered that most of this is due to the ongoing natural processes which shape the island (Scott 1988; Selkirk *et al.* 1990). The increasing body of data on specific sites in the Reserve, together with the meteorological and seismic data, permit the processes to be measured over time. A number of stations have been established to facilitate photographic recording of sample sites which allows changes to be monitored.

Penguins, albatrosses and seals which breed on the island are key indicators of changes in the Southern Ocean on which they are reliant for food. All species in these groups are being studied on the island. Studies are also being carried out on the flora and vegetation of the Reserve related to such issues as global warming, increased ultra-violet radiation levels and the impacts of introduced species.

b. Administrative arrangements for monitoring property

The responsibility for monitoring the terrestrial part of the property rests with the Tasmanian Parks and Wildlife Service. Monitoring the marine area would be part of the joint management arrangement described above.

c. Results of previous reporting exercises

There have been no previous reporting exercises of the type envisaged but regular environmental reporting will be instigated.

7. DOCUMENTATION

a. Photographs, slides and, where available, film/video

b. Copies of site management plans and extracts of other plans relevant to the site

A copy of the Macquarie Island Nature Reserve Management Plan is annexed as Attachment 1.

c. Bibliography

A comprehensive bibliography is contained in Appendix G.

d. Address where inventory, records and archives are held

The Director
Parks & Wildlife Service
GPO Box 44A
Hobart
Tasmania 7001
AUSTRALIA

8. SIGNATURE ON BEHALF OF THE STATE PARTY

Signed:

....

Full Name: Senator The Hon. Robert Hill

Title: Minister for the Environment

Date: June 1996

APPENDIX A

DEFINITIONS OF THE SUBANTARCTIC PROVINCE AND ADJACENT COLD TEMPERATE AND MARITIME ANTARCTIC PROVINCES

The source of the following material is Smith and Lewis Smith (1987), adapted from Holdgate (1977) and Lewis Smith (1984).

(i) SUBANTARCTIC PROVINCE

Climatic features

Cool oceanic climate; small annual temperature range; mean annual temperature greater than 0°C; mean monthly temperature greater than 0°C for at least six months; strong predominantly westerly wind; annual precipitation greater than 100 centimetres.

Biotic factors

From the southern limit of arborescent vegetation southwards to the southern limit of extensive closed phanerogamic vegetation; vascular plants dominate the vegetation near sea level. Abundant seabirds and seals; some land birds; abundant higher insects, spiders and snails.

Localities

Prince Edward Islands, lIes Crozet, lIes de Kerguelen, Macquarie Island, Heard Island, the McDonald Islands, South Georgia.

(ii) COLD TEMPERATE PROVINCE

Climatic features

Cool temperate oceanic climate; small annual temperature range; monthly mean temperature greater than 10°C for at least three months, rarely greater than 5°C; strong, predominantly westerly wind; annual precipitation greater than 100 centimetres, snow infrequent.

Biotic factors

Vegetation at low altitudes consisting of trees, shrubs, fernbush and tussock grassland. Moss and graminoid dominated mires and swamps at higher altitudes. Abundant seabirds and seals, some landbirds; rich terrestrial invertebrate fauna.

Localities

Tristan da Cunha, Gough Island, Ile St Paul, Ile Amsterdam, Falkland Islands, offshore Fuegian islands, New Zealand shelf islands (Campbell, Auckland, Antipodes, Snares).

(iii) MARITIME ANTARCTIC PROVINCE

Climatic features

Cold maritime climate; mean annual temperature less than 0°C; mean monthly temperatures greater than 0°C for one to three months in summer, rarely below -15°C in winter; annual precipitation generally from 25 to 50 centimetres (water equivalent).

Biotic factors

Small closed stands of the only two antarctic vascular species but mainly cryptogamic vegetation, locally diverse stands near coast; closed moss stands in wetter habitats; lichens predominate in exposed areas and inland. Abundant marine bird and mammal fauna; substantial invertebrate fauna, including the only higher insects (Diptera) in the Antarctic.

Localities

South Sandwich, South Orkney and South Shetland Islands; west coast of Antarctic Peninsula and offshore islands to approximately 70° S; Bouvetøya; Balleny Islands.

APPENDIX B

GEOLOGICAL TIME SCALE

Era	Period	Epoch	Age (millions of years)
CAINOZOIC	Quaternary	Holocene Pleistocene	 0-1.8
	Tertiary	Pliocene	1.8-5
		Miocene	5-24
		Oligocene	24-37
		Eocene	37-52
		Palaeocene	52-66
MESOZOIC		Cretaceous	66-131
		Jurassic	131-204
		Triassic	204-250
PALAEOZOIC		Permian	250-295
		Carboniferous	295-354
		Devonian	354-410
		Silurian	410-434
		Ordovician	434-500
		Cambrian	500-580
PRECAMBRIAN		Proterozoic	580-2500
		Archaean	2500--->

APPENDIX C

CHARACTERISTICS OF OPHIOLITES

Ophiolites are masses of ultramafic and mafic igneous rock, tectonically emplaced on continental margins or within continental collision zones. The most widely accepted definition of 'ophiolite' (Anon. 1972) used by those present at the Geological Society of America Penrose Conference on Ophiolites, states:

Ophiolite refers to a distinctive assemblage of mafic to ultramafic rocks. It should not be used as a rock name or as a lithologic unit in mapping. In a completely developed ophiolite, the rock-types occur in the following sequence, starting from the bottom and working up:

- Ultramafic complex, consisting of variable proportions of harzburgite, dunite, and other ultramafic rocks, usually with a metamorphic tectonite fabric.
- Gabbroic complex, ordinarily with cumulus textures commonly containing cumulus peridotites and pyroxenites and usually less deformed than the ultramafic complex.
- Sheeted mafic dike complex.
- Mafic volcanic complex, commonly pillowed

Associated rock types commonly include:

- An overlying sedimentary section typically containing ribbon cherts, thin shale interbeds and minor limestones.
- Podiform bodies of chromite generally associated with dunite.
- Sodic felsic intrusive and extrusive rocks.

Faulted contacts between mappable units are common. Whole sections may be missing.

An ophiolite may be incomplete, dismembered, or metamorphosed, in which case it should be called a partial, dismembered, or metamorphosed ophiolite.

Although ophiolite generally is interpreted to be oceanic crust and uppermantle, the use of the term should be independent of its supposed origin.

APPENDIX D

BIOTA OF MACQUARIE ISLAND

(i) FLORA AND VEGETATION

Flora

The floras of the subantarctic region have generally been established by the relatively slow processes of immigration and colonisation over large expanses of ocean in an extreme environment and exhibit low diversity. Iles Kerguelen, 700,000 hectares, is the largest island group in the subantarctic region and has a vascular flora of only 36 species. Marion Island (28 000 hectares) has 38 vascular species and Prince Edward Island (4,400 hectares) has 21 vascular species (Clark and Dingwall 1985).

The vascular flora of Macquarie Island (Table D.1) is comprised of 46 species (George *et al.* 1993). There is also a grass, localised at the southern end of the island, which is yet to be identified and may prove to be a second species of *Puccinellia.* Over the past 110 years there have also been several transient aliens (species either accidentally or deliberately introduced and only surviving one or two summers) recorded (Jenkin *et al.* 1981).

Recent taxonomic review indicates that there are three endemic vascular species on Macquarie Island, the cushion plant *Azorella macquariensis,* (Orchard 1989) the coastal grass *Puccinellia macquariensis* and the orchid *Corybas dienemus* (George *et al.* 1993)

Five exotic species are established in the reserve, *Cerastium fontanum, Stellaria media, Anthoxanthum odoratum, Poa annua* and *Rumex crispus*, (Taylor 1955; Copson and Leman 1986; Seppelt *et al.* 1984). *Poa annua* is common and widespread, *Cerastium fontanum* is rare but widespread and the other three taxa *(Stellaria media, Anthoxanthum odoratum and Rumex crispus)* are rare and localised in their distribution, two of these being known from only a single location each (Copson 1984). *Anthoxanthum odoratum* has been removed from the only known site but the area will have to be monitored for several years to know whether eradication was successful.

Bryophytes comprise a significant, and in some cases dominant, component of several plant communities in the reserve (Seppelt 1984a). The known moss flora includes at least 80 species and the hepatic flora at least 50 species. A checklist of the lichen flora contains 141 taxa in 76 genera but, as no taxonomic review has been undertaken, further work is required in this area (Kantvilas and Seppelt 1992). During a recent survey of the fungi over 135 mushrooms, 60 cup fungi, 22 slime moulds and 1 false slime mould were identified (Gary Laursen, unpublished data). There are at least 90 diatoms and 20 other species of freshwater algae known from the reserve Selkirk *et al.* 1990). Undoubtedly the number of algal species identified would increase significantly if further collecting were undertaken for both freshwater and terrestrial species in the reserve.

Radiocarbon dating and pollen analysis of peat samples from several sites shows that vegetation was established and plant remains had begun accumulating at these sites by 8,000 to 10,000 years ago. Many species in the island’s present flora have been present throughout the Holocene (Adamson *et al.* 1996). A small number of pollen grains from exotic species, representing long-distance transport from other land masses, are preserved in peat and lake deposits. There is no evidence for a flora substantially different from that on the island today during the last 10,000 years.

Vegetation

There are four main vegetation formations on Macquarie Island: tall tussock grassland, short tussock grassland, mire and feldmark. Within each formation there are alliances, associations and sub-associations. The associations were greatly modified by rabbit grazing in most areas (Taylor 1955; Copson 1984). However since the commencement of the rabbit control program in 1978 rapid changes in the abundance and distribution of most vascular species have taken place (Copson and Whinam 1994).

The tall tussock grassland association provides the tallest vegetation strata on the island, there being no trees or tall shrubs. It is dominated by *Poa foliosa* either in pure stands or allied with *Stilbocarpa polaris* and/or *P. cookii*. In very dense stands of this association there is little or no understorey (Taylor 1955).

The association occurs on the better drained sections of the coastal terraces, most of the steep coastal slopes and in sheltered and well drained places in many valleys. Heavy rabbit grazing destroys the tall tussock grasslands converting them to either short tussock grassland or mire associations. Isolated patches in areas inaccessible to rabbits, such as cliffs and islands, and increasing numbers of individual tussocks establishing on areas of the plateau supply indirect evidence that the association was much more widespread in the past and is able to re-establish where rabbit grazing has been reduced, (Copson 1984; Copson and Whinam 1994).

Short tussock grassland is the main habitat for the rabbits on Macquarie Island (Copson *et al.* 1981). This association covers areas of raised beach terraces and plateau sites with a moderate to high watertable and/or wind exposure (Taylor 1955). It also occurs on extensive areas of coastal slopes and on the plateau which may previously have been covered by tall tussock grassland associations.

There are indications that, in the past, the megaherb *Pleurophyllum hookeri* was a dominant species in this association but that this species, along with other common short tussock grassland species such as *Festuca*

contracta, Stilbocarpa polaris and *Blechnum penna-marina,* is susceptible to prolonged rabbit grazing and has been greatly reduced or eradicated in many areas (Taylor 1955; Copson and Whinam 1994). Removal or reduction of these species has resulted in more robust and/or less palatable species such as *Agrostis magellanica, Acaena* spp., *Ranunculus crassipes, Luzula crinita* and *Poa annua* becoming dominant (Copson 1984). In very heavily grazed areas bryophytes form the main component of the vegetation with only a few low growing vascular plants present.

The reduction in rabbit numbers has led to a rapid recovery of several species in the short tussock grassland. However some of the major changes, such as the re-establishment of *Pleurophyllum* and *Stilbocarpa* and the reversal of the dominance of *Acaena* spp., may be a slow process. It is also expected that, with prolonged rabbit control, this association will decrease in area as the tall tussock grassland recovers its range (Copson and Whinam 1994).

The feldmark association is the most widespread vegetation formation, covering approximately 50% of the island (Taylor 1955). It occupies the most wind-exposed areas of the plateau region and mountain tops. The vegetation cover varies from over 50% in sheltered areas to less than 5% in extremely windy sites. The transition from either tall tussock grassland or short tussock grassland to feldmark may take place in one or two metres where landforms greatly modify the wind exposure (Selkirk *et al*. 1990)

The endemic, cushion-forming *Azorella macquariensis* is the dominant vascular species in the more sheltered parts of the feldmark. Other common vascular species includes *Pleurophyllum hookeri, Luzula crinita, Agrostis magellanica, Festuca contracta* and *Grammitis poeppigiana,* (Taylor 1955; Selkirk and Seppelt 1984). In the most sheltered sites ecotones are formed with short tussock grassland associations. As the wind exposure increases the percentage cover generally decreases, with mosses such as *Ditrichum strictum* and *Rhacomitrium crispulum* becoming dominant.

Periglacial and wind effects lead to stone sorting and stripes in the surface layers of bare mineral soils and a gradual movement of substrate layers in places. Vegetation terraces are abundant, with *Azorella magellanica* a principle component of the terrace slopes and bryophytes and lichens dominating the steps (Selkirk *et al.* 1990).

The mire formation was previously split into fen and bog associations (Taylor 1955; Selkirk *et al.* 1990). It occurs on areas of the raised beach terrace, valley bottoms and in poorly drained areas inland where the watertable is at or near the surface and the wind exposure is generally moderate.

Several associations are recognised in the mire alliance, three with the rush *Juncus scheuchzerioides* either dominant or co-dominant (Taylor 1955). A fourth association consists of small stands of *Isolepis aucklandicus* and is restricted to patches of up to $2m^2$ around the edge of pools on the raised beach terrace. In recent years *I. aucklandicus* has been found growing in eroded areas on the plateau and is one of the species which has benefited by the presence of rabbits.

In three mire associations mosses are dominant. The watertable forms at or above the surface layer of the bryophytes and the vascular plants are raised above it.

The last association is dominated by cushions of *Colobanthus muscoides* with few other vascular plants or bryophytes. In some places this association covers areas of several hundred square metres on the raised beach terrace. However there are similar *C. muscoides* dominated areas on well drained slopes previously occupied by tall tussock grasses and it appears possible that both types of *C. muscoides* association are formed and maintained by rabbit grazing (Copson 1984).

(ii) FAUNA

Mammals

The indigenous mammals within the nominated area are all marine (Table D2).

The southern elephant seal *(Mirounga leonina)* has recovered rapidly from the exploitation during the 19th century. By the mid 1950s the size of the population using the island was estimated at 155,000 but has declined to approximately 90,000, with approximately 20,000 pups being born annually (Hindell and Burton 1987). Declines have also occurred in most other breeding populations of this species in the Southern Ocean. The adult animals leave the island for several months through autumn and winter the pups do too but may return to the island if there is prolonged stormy weather. Satellite-tracking and instrument packages on adult seals from Macquarie Island has shown they travel as far as the antarctic continental shelf and can submerge for periods of 2 hours feeding at up to 1,300m deep.

The indigenous fur seal (species unknown) was exterminated within ten years of the island being discovered (Cumpston 1968). Since sealing ceased in 1919 the New Zealand fur seal *(Arctocephalus forsteri)* has increasingly used the island. However while there may be over 1,500 individuals of this species at the island in March these are mainly young males. Since the mid 1970s small numbers of subantarctic fur seals *(A. tropicalis)* and Antarctic fur seals *(A. gazella)* have been breeding on the island (Shaughnessy *et al.* 1988. There has been a rapid increase in the number of pups born, from 10 in 1979 to 123 in 1996 (S. Goldworthy, unpublished data), and the relative status of all of the three species of fur seal at Macquarie Island is changing rapidly.

Individual Hooker's sea lion *(Phocarctos hookeri)* and leopard seals *(Hydrurga leptonyx)* visit the island during winter and spring in small numbers. Weddell seals *(Leptonychotes weddelli)* and crabeater seals *(Lobodon carcinophagus)* are very rare vagrants from the south (Department of Parks, Wildlife and Heritage 1991).

Whales were never reported as being common around Macquarie Island and shore-based or pelagic whaling was never based at the island. Table D.2 gives a list of whales that have been recorded within 12 nautical miles of the island and/or have been found stranded on the island (Goodall and Galeazzi 1985; Copson 1994). Killer whales *(Orcinus orca)* are the most common species observed and have been recorded throughout the year. However pods are small and although they have been seen feeding on both penguins and seals they do not appear to be fully exploiting this food source or to have developed specialised feeding methods as has been reported from other areas.

Four species of introduced mammals are now present on the island (Jenkin *et al.* 1981). Their impact is discussed in Appendix E of the nomination. There is no evidence of any introduced fauna species on the Bishop and Clerk Islets, the Judge and Clerk Islets or the marine zone.

Avifauna

More than 70 species of birds, which includes over 40 non-breeding or vagrant species, have been recorded at Macquarie Island (Department of Parks, Wildlife and Heritage 1991). The breeding bird fauna comprises four penguins, four albatrosses, fourteen petrels, one cormorant, two ducks, one skua, one gull, one tern and two passerines (Table D.3). Two endemic subspecies, the Macquarie Island Rail (*Rallus philippensis macquariensis*) and the Macquarie Island Parakeet *(Cyanoramphus novaezelandiae erythrotis)* became extinct late in the 19th century.

Indigenous Birds

Penguins are the most numerous birds breeding on the island at the present day. The king penguin *(Aptenodytes patagonicus)* has recovered dramatically from the slaughter of the last century and the population, estimated at over 400,000 in 1989, is still expanding (Rounsevell and Copson 1982; Scott 1994). Chicks from one season are not fledged until the following spring so many adults re-visit the reserve during the winter to feed chicks. The main diet comprises of two species of myctophid (lantern) fish (Hindell 1988a). These fish are both epipelagic to mesopelagic species that commonly occur at depths down to 150 m.

The gentoo penguin *(Pygoscelis papua papua)* population in the Reserve contains about 5,000 breeding pairs (Robertson 1986). The species remains at the island all year round feeding locally and usually returning ashore each day. Myctophid fish also constitute the major part (59% by weight) of the diet of this penguin species (Hindell 1989).

The royal penguin *(Eudyptes schlegli)* is endemic to Macquarie Island (Woelher 1984). The present population is estimated at approximately 850,000 breeding pairs in 57 colonies with one, the Hurd Point colony, containing approximately 165,000 pairs (Copson and Rounsevell 1987). The adults leave the island in late April returning in mid September. The

diet is mainly euphausiid crustaceans and the myctophid fish *Krefftichthys anderssoni*. Other fish and squid are eaten in small amounts (Hindell 1988b). A second crested penguin, the rockhopper *(Eudyptes chrysocome)*, breeds in medium to large colonies on the west and south coasts and in several small colonies on the east coast (Rounsevell and Brothers,1984). The size of the total population in the reserve is very difficult to estimated but may be as high as 500,000 breeding pairs. Adult euphausiid crustaceans constitute most of their diet but both pelagic and inshore fish species are also eaten occasionally.

Wandering albatrosses *(Diomedea exulans chionoptera)* now breed in very low numbers on the island (Tomkins 1985; Gales 1993). In the mid-1960s there were about 50 breeding pairs but since 1980 there have been less than 10 eggs laid each year. These albatrosses are bi-annual breeders taking about 12 months to rear a chick and if successful do not breed the following year. This breeding population must be considered to be at risk, almost certainly due to the accidental bycatch of albatross by longline fisheries (Brothers 1991). To minimise human disturbance in their main breeding area on the island the southwest corner of the reserve is closed to general entry by expeditioners from November through to April. The only exception to this is limited access granted for personnel to carry out research programs which cannot be carried out elsewhere on the island or at other times.

Black-browed albatrosses *(Diomedea melanophrys melanophrys)* breed at three sites in the reserve, 2-3 pairs on North Head, approximately 40 pairs around South West Point and the third colony on Bishop and Clerk Islets which was estimated at approximately 100 breeding pairs in 1993 (Copson 1988; Gales 1993). Black-browed albatrosses are often seen feeding close inshore through the summer particularly around feeding killer whales. The Grey-headed albatrosses *(Diomedea chrysostoma)* breed only in the South West Point area of Macquarie Island. The estimated population of this biennial breeding species is around 100 pairs.

Light-mantled sooty albatrosses *(Phoebetria palpebrata)* nest on steep slopes all around Macquarie Island with a breeding population estimated at 1,500-2,000 pairs (Gales 1993). Satellite tracking of breeding birds indicated that some feed to the southwest of the island around the Antarctic Convergence (Weimerskirch and Robertson 1994).

Eight species of petrels, the northern and southern giant petrels *(Macronectes halli* and *M. giganteus)*, blue petrels *(Halobeana caerulea)*, Antarctic prions *(Pachyptila desolata)*, fairy prions *(P. turtur)*, sooty-shearwaters *(Puffinus griseus)*, white-headed petrels *(Pterodroma lessonii)* and common diving petrels *(Pelecanoides urinatrix)* breed in the Reserve in moderate (blue petrels 5-600 pairs) to high (Antarctic prions 40,000+ pairs) numbers (Brothers 1984). Six other species, thin billed prions *(P. belcheri)*, grey petrels (*Procellaria cinerea*), soft-plumaged petrels *(Pterodroma mollis)*, grey-backed storm petrels *(Oceanites nereis)*, South Wilson's storm petrels *(O. oceanicus)* and South Georgian diving petrels *(Pelicanoides georgicus)* each have breeding populations in the Reserve estimated at less than 50 pairs. It is thought that alterations to habitats by rabbits and predation by skuas and introduced species such as cats, ship rats and wekas may have greatly reduced or even eliminated populations of some of the smaller species of prions and petrels which once bred in the reserve (Brothers 1984; Brothers and Copson 1988). There has also been an as yet unexplained 50% decline in both giant petrel populations breeding on the island in the past twenty years, in common with most other breeding sites.

The breeding population of the endemic sub-species of the king shag *(Phalacrocorax albiventer purpurascens)* on Macquarie Island is estimated at 660 pairs in nineteen colonies around the island (Brothers 1985). The birds are not strong fliers and this, together with a diving capacity of approximately 40m and the steeply shelving sea bottom, limits their feeding grounds to a quite restricted area close to the island

Great skuas *(Stercorarius skua lonnbergi)* are common on Macquarie Island for nine months of the year but disperse out to sea over the early winter period. Studies carried out in 1974-75 indicated that the skua population was closely correlated with that of the rabbits which provide an added food source (Jones and Skira 1979). Following the commencement of the rabbit control program in 1978 and the subsequent reduction in the rabbit population there has been a decline in the number of skuas breeding on the plateau area (Skira 1984).

Kelp gulls *(Larus dominicanus)* breed in low numbers around the coast and on offshore sea stacks. They are present all year round and flocks of up to fifty birds are often seen feeding in the mire regions along the coast and on the plateau The Antarctic tern *(Sterna vittata bethunei)* breeds in very small numbers (probably 20-50 pairs) on Macquarie Island. It is possible that introduced predators such as cats, wekas and ship rats have greatly reduced its numbers (Garnett 1992).

The only indigenous duck on Macquarie Island is the black duck *(Anas superciliosa superciliosa)* which occurs in small numbers. Recent work has shown that hybrids of black ducks and mallards *(Anas platyrhynchos platyrhynchos)* are also resident in the Reserve (Norman 1987).

Non-indigenous birds

No natives passerines have been recorded from Macquarie Island. The redpoll *(Acanthis flammea)* and common starling *(Sturnus vulgaris)* both became established in the reserve early this century after their introduction into New Zealand, and the starling into Australia also, in the last century (Falla 1937; Copson 1995). Both are widespread and common in the reserve. Other species have been recorded in recent years but all appear to be vagrants.

Mallards were also introduced into New Zealand and Australia in the last century from where they have spread naturally to other islands (Copson 1995).

Wekas *(Gallirallus australis scotti)* were introduced from New Zealand in the mid 1800s as a source of food for the sealers (Cumpston 1968). They probably contributed to the extinction of the endemic sub-species of land rail and parakeet (Taylor 1979).

Reptiles and Amphibians

There are no reptiles or amphibians on Macquarie Island (Department of Parks, Wildlife and Heritage 1991).

Terrestrial Invertebrates

It is estimated that the Macquarie Island fauna has probably less than 300 species. Approximately 10% are endemic with a few others doubtfully so (Greenslade 1990).

It is suggested that a significant proportion of the Macquarie Island insect fauna came from sources to the west of the island rather than Australia or New Zealand. Compared to its two nearest neighbours the number of terrestrial arthropod species, 140+, known from the island is low (Greenslade 1990), the Auckland Islands having 453+ and Campbell Islands 354+.

Although several collections of terrestrial invertebrate fauna have been made on Macquarie Island most have been concentrated on the Arthropoda. The majority of published studies have been taxonomic descriptions although some ecological work has been carried out on a few individual species.

Nine species of terrestrial invertebrates thought to have been introduced by man have been recorded together with another six transient aliens which are not established residents (Greenslade 1990). The European rabbit flea *(Spilopsyllus cuniculi)* has been deliberately introduced onto Macquarie Island several times since 1968, to act as a vector for the *Myxoma* virus being used to control rabbits (Skira *et al.* 1983). The rabbit flea can only breed on rabbits and if the rabbits are eradicated from the Reserve the fleas will also be eliminated.

Fourteen species of nematodes have been recorded plus a further 12 undetermined species (Bunt 1954). Also recorded were an indigenous land snail and three species of slug, two indigenous and one cosmopolitan, the latter probably introduced by the sealers as it is a common European species and was first recorded on the island during the AAE (Selkirk *et al.* 1990). A study of the rotifers identified thirty nine species several of which have also been found on South Georgia and/or Signy Island (Dartnall 1993).

A program to monitor windborne invertebrates has been running for several years at Macquarie Island providing data on the immigration of invertebrate species in the region. It also provides information useful in judging whether newly recorded species may have arrived by natural means or been introduced by human activities. The Antarctic Division undertakes special precautions (inspecting, cleaning and/or fumigating supplies and equipment) in order to reduce this possibility. Contracts for tourist operators visiting the island also stipulate precautions to be taken to prevent accidental introductions . The tourist visitation sites are monitored for possible introductions.

(iii) FLORA AND FAUNA OF THE OFFSHORE ISLETS AND SEASTACKS

Within the nominated area there are two groups of small islets and a large number of offshore seastacks as well as Macquarie Island. The largest group, the Bishop and Clerk Islets, lie 37 kilometres to the south of Macquarie Island while the smaller group of Judge and Clerk Islets lie 14 kilometres to the north of the main island. The seastacks range from a few hundred metres offshore to ones with only narrow tidal channels separating them from the main island. After the establishment of rabbits, cats, wekas and ship rats in the last century, these isolated islets and seastacks have become refuges for some of the smaller burrow-nesting seabirds of the island group (Brothers 1984).

There has been three known landings on the Bishop and Clerk Islets, the last one in 1993 (McKenzie 1968; Lugg 1978). Fur seals have been recorded there but are thought only to use them as a haul out site. Several species of seabirds breed on the islets. The number of black-browed albatrosses breeding on the main Islet approximately 100 breeding pairs, greater than the total in the two colonies on Macquarie Island. *Colobanthus muscoides* is the only vascular plant that has been recorded on the islets. Cushions of it cover the higher central parts of the main Islet and provide the only known breeding site for the South Georgian diving petrel and Wilson's storm petrel in the reserve. Other breeding seabirds are the royal penguin, rockhopper penguin, king shag, kelp gull and great skua. Several invertebrates have been collected, including two species new to the Macquarie Island region (Lugg 1978).

There has been no known landing on the Judge and Clerk Islets. An aerial survey revealed only minimal vegetation cover, probably algae and lichens. The Islets are often washed by waves and heavy spray and it is unlikely that any seabirds or mammals breed on them. Together with the Bishop and Clerk Islets the Judge and Clerk Islets have been designated a separate zone in the Macquarie Island management plan (Department of Parks, Wildlife and Heritage 1991). They may only be visited for biological survey work and no installations are permitted on them.

Many of the seastacks have been visited and some observations have been made on them but none has been the subject of a detailed biological survey. Several species of birds use the stacks for breeding sites. These include such surface breeding species as the king shag, kelp gull and Antarctic tern, the latter now being restricted to breeding on offshore stacks. Many of the seastacks have a good vegetation cover and provide burrow sites for the remnants of the blue petrel, fairy prion and common diving petrel populations in the Reserve (Brothers 1984).

(iv) MARINE ENVIRONMENT

As noted, all the seals and penguins and the majority of the seabirds breeding on the islands derive all their food directly from the sea. The living resources of Macquarie Island are interlocked as part of the fabric of the marine ecosystem (Scott 1994). Twelve species of benthic fishes have been recorded in the limited shallow water area around the Reserve. Six are Antarctic cods (Nototheniidae), five of which have a wide subantarctic distribution, and two of which are also found in waters south of New Zealand (Williams 1988). Another species *(Sanclorhynchus spinifer)* has been recorded only at lIes Kerguelen, Heard Island, lIes Crozet, Prince Edward Islands and Macquarie Island, while two species of toad-fish *(Neophrynichthys magnicirrus* and *N. pschrolutidae)* and *Ebinaria macquariensis* are endemic to waters around the Reserve. Of the 21 pelagic fish recorded around the Reserve, 12 are species of lantern fishes (Myctophidae), well-known from the zone between the Antarctic and Subtropical Convergences. These form the bulk of the diet of king penguins and gentoo penguins and about one quarter of the diet by weight of royal and rockhopper penguins, who mainly eat euphausiid crustaceans (Hindell 1988a, 1988b, 1989). The other nine pelagic fish species are probably at or close to the southern end of their ranges since they belong to a range of families with southern cool temperate distributions. Two of these are also found in antarctic waters (Williams 1988).

Endemism is high among some of the marine and littoral invertebrates recorded from Macquarie Island. Twenty-seven species (64 per cent) of marine molluscs are endemic to the Macquarie Island area, with only another 12 (29 per cent) also found on other subantarctic islands. More work is needed on the taxonomy and biogeography of the benthic fauna. It seems, however that Macquarie Island is a distinct biogeographical unit, with species that have arrived both by long-distance dispersal on Southern Ocean currents and from north and south along the relatively shallow route of the Macquarie Ridge (Dawson 1988).

In general, the seashore is a rich biological environment (Simpson 1988; Richer 1981), dominated by the giant antarctic kelp *(Durvillea antarctica)*, which dampens wave action on the shore and so allows many species of flora and fauna to survive there. Chitons and limpets are conspicuous members of this zone. Of great interest is the distribution among widely separated subantarctic islands of some marine invertebrate species that do not have drifting larval stages.

Recent work by an Australian Museum expedition (Lowry *et al.* 1978) has expanded the number of marine algae known around the Reserve to over one hundred. The geographic origin of this marine flora is particularly interesting: many species may have drifted from other subantarctic islands or the southern tip of South America, or both, providing examples of long-distance dispersal. In doing so they could almost certainly have transported some of the marine invertebrate fauna. This explains how species without planktonic stages in their life cycles are found on widely dispersed islands.

TABLE D.1 VASCULAR PLANTS RECORDED FROM MACQUARIE ISLAND

Family and species	Frequency - Abundance
PTERIDOPHYTES	
Lycopodiacea	
Lycopodium australianum	L - R
Gramitidaceae	
Grammitis poeppigiana	W - R
Aspidiaceae	
Polystichum vestitum	L - R
Blechnaceae	
Blechnum penna-marina	L - R
Hymenophyllaceae	
Hymenophyllum falklandicum	L - R
ANGIOSPERMS, DICOTYLEDONS	
Apiaceae	
Azorella macquariensis	VW - A (E)
Hydrocotyle novae-zeelandiae	L - C
Araliaceae	
Stilbocarpa polaris	VW - A
Asteraceae	
Cotula plurmosa	W - C
Pleurophyllurn hookeri	VW - C
Brassicaceae	
Cardamine corosa	VW - C
Callitrichaceae	
Callitriche antarctica	W - C
Caryophyllaceae	
Cerastiurn fontanurn fontanum	W - R (I)
Colohanthus rnuscoides	W - C
Colobanthus apetalus var. *alpinus*	W - C
Colobanthus affinis	W - R
Stellaria parviflora	W - C
Stellaria media media	L - R (I)
Crassulaceae	
Crassula moschata	W - R
Haloragaceae	
Myriophyllum triphyllum	L - R
Onagraceae	

Epilobium brunnescens brunnescens	VW - R
Epilobium penduncularе	VW - C
Polygonaceae	
Rumex crispus	L - R (I)
Portulacaceae	
Montia fontana fontana	VW - R
Rununculaceae	
Rununculus crassipes	VW - A
Rosaceae	
Acaena magellanica	W - C
Acaena minor	W - C
Rubiaceae	
Coprosma perpusilla subantarctica	L - R
Galium antarcticum	L - R
ANGIOSPERMS, MONOCOTYLEDONS	
Cyperaceae	
Carex trifida	L - R
Isolepis aucklandica	W - R
Uncinia divaricata	W - C
Uncinia hookeri	W - C
Juncaceae	
Juncus scheuchzerioides	W - C
Luzula crinita	VW - A
Orchidaceae	
Corybas dienemus	L - R (E)
Poaceae	
Agrostis magellanica	VW - A
Anthoxanthum odoratum	L - R (I)
Deschampsia caespitosa	L - R
Deschampsia chapmanii	W - C
Festuca contracta	VW - C
Poa annua	W - C (I)
Poa cookii	W - R
Poa foliosa	VW - A
Poa litorosa	L - R
Puccinellia macquariensis	W - R (E)
TOTAL	46

Note: Frequency - L denotes local; W denotes widespread; VW denotes very widespread.
Abundance - R denotes rare; C denotes common; A denotes abundant.

(E) denotes endemic; (I) denotes introduced.

Source: George, Orchard and Hewson (1993); Department of Parks, Wildlife and Heritage (1991)

TABLE D.2 CHECKLIST OF MAMMALS OF MACQUARIE ISLAND

Family and species	Scientific name	Status
Indigenous mammals		
CETACEA		
MYSTICETI		
Southern Right Whale	*Balaena glacialis*	RV ST
Minke Whale	*Balaenoptera acutorostrata*	RV
ODONTOCETI		
Cuvier's Beaked Whale	*Ziphius cavirostris*	ST
Sperm Whale	*Physeter macrocephalus*	RV ST
Longfin Pilot Whale	*Globicephala melaene*	V ST
Killer Whale	*Orcinus orca*	V ST
Southern bottlenosed Whale	*Hyperoodon planifrons*	ST
Strap-toothed Whale	*Mesoplodon layardii*	ST
Blainville's beaked whale	*Mesoplodon densirostris*	ST
Andrew's Beaked Whale	*Mesoplodon bowdoini*	ST
PINNIPEDIA		
OTARIIDAE		
Antarctic Fur Seal	*Arctocephalus gazella*	B
Sub-antarctic Fur Seal	*Arctocephalus tropicalis*	B
New Zealand Fur Seal	*Arctocephalus forsteri*	B
Hooker's sea lion	*Phocarctos hookeri*	V
PHOCIDAE		
Elephant Seal	*Mirounga leonina*	B
Weddell seal	*Leptonychotes weddelli*	RV
Crabeater seal	*Lobodon carcinophagus*	RV
Leopard seal	*Hydrurga leptonyx*	V
Introduced mammals		
LAGOMORPHA		
European Rabbit	*Oryctolagus cuniculus*	B I
CARNIVORA		
Cat	*Felis catus*	B I
RODENTIA		
Ship Rat	*Rattus rattus*	B I
House Mouse	*Mus musculus*	B I

Legend: B breeding; I introduced species; V regular visitor;
RV rare vagrant; ST stranding recorded

All whale sightings were recorded from, or within, 12 nautical miles of the island.

Sources: Department of Parks, Wildlife and Heritage (1991), Copson (1994), Goodall and Galeazzi (1985)

TABLE D.3 CHECKLIST OF BREEDING BIRDS

Family and species	Scientific name	Status
PENGUINS		
King penguin	*Aptenodytes patagonicus*	
Gentoo penguin	*Pygocelis papua papua*	
Rockhopper penguin	*Eudyptes chrysocome*	
Royal penguin	*Eudyptes schlegeli*	E
ALBATROSSES		
Wandering albatross	*Diomedea exulans chionoptera*	
Black-browed albatross	*Diomedea melanophrys melanophrys*	
Grey-headed albatross	*Diomedea chrysostoma*	
Light-mantled Sooty albatross	*Phoebetria palpebrata*	
PETRELS		
Southern giant petrel	*Macronectes giganteus*	
Northern giant petrel	*Macronectes halli*	
Blue petrel	*Halobeana caerulea*	
Antarctic prion	*Pachyptila desolata macquariensis*	
Fairy prion	*Pachyptila turtur subantarctica*	
Thin billed prion	*Pachyptila belcheri*	
Sooty shearwater	*Puffinus griseus*	
Grey petrel	*Procellaria cinerea*	
White-headed petrel	*Pterodroma lessonii*	
Soft-plumaged petrel	*Pterodroma mollis*	
STORM PETRELS		
Wilson's storm petrel	*Oceanites oceanicus*	
Grey-backed storm petrel	*Oceanites nereis*	
DIVING PETRELS		
South Georgian diving petrel	*Pelecanoides georgicus*	
Common diving petrel	*Pelecanoides urinatrix*	
CORMORANTS		
King shag	*Phalacrocorax albiventer purpurascens*	E
DUCKS		
Black duck	*Anas superciliosa superciliosa*	
Mallard	*Anas platyrhynchos platyrhynchos*	I
SKUA		
Great skua	*Stercorarius skua lonnbergi*	
GULLS		
Kelp gull	*Larus dominicanus*	
TERNS		
Antarctic tern	*Sterna vittata bethunei*	
FINCHES		
Redpoll	*Acanthis flammea*	I
STARLINGS		
Common starling	*Sturnus vulgaris*	I
Extinct species		
RAILS		
Macquarie Island rail	*Rallus phillipinensis macquariensis*	E
Stewart Island weka	*Gallirallus australis scotti*	I
PSITTACIFORMES		
Macquarie Island parakeet	*Cyanoramphus novaezelandiae erythrotis*	E

Legend : E - endemic species I - introduced species

Sources: Department of Parks, Wildlife and Heritage (1991), Copson (1995).

APPENDIX E

BIOLOGICAL STATUS AND CONSERVATION MEASURES

Like many other islands the indigenous flora and fauna of Macquarie Island have been affected by the introduction of alien species. In recent years management strategies have been implemented to address these problems and have begun successfully reversing them (Copson 1995). Parts of the nominated area appear to have remained in pristine condition, including Bishop and Clerk Islets, Judge and Clerk Islets and the surrounding marine area (Department of Parks, Wildlife and Heritage 1991; Scott 1994).

Since its discovery several vertebrate fauna species have been introduced to Macquarie Island (Table E1) of which feral cats, European rabbits, ship rats and house mice still remain (Copson 1995). Rabbits have had major effects on the vegetation (Taylor 1955; Copson 1984). Some species such as *Pleurophyllum hookeri* and *Stilbocarpa polaris* may be heavily grazed and have been locally eradicated from some sites on the island. Areas of shorter grassland on the coastal slopes appear to seral communities resulting from heavy grazing of *Poa* sp. and *Stilbocarpa* by rabbits. However the role of rabbits in causing erosion on the island is now considered to have previously been overestimated (Scott 1985).

The presence on Macquarie Island of feral cats since about 1820 (Debenham 1945), has caused a considerable reduction in populations of several species of the smaller seabirds (Jones 1977; Brothers 1984). The white-headed petrel, antarctic prion and sooty shearwater are the only burrow-nesting petrels still found extensively on Macquarie Island. All are summer breeders and do not visit burrows during winter. In contrast, fairy prions, blue petrels and common diving petrels are resident all year and found only in remnant populations on offshore sea stacks (Brothers 1984). The Antarctic Division initiated a study of feral cats on the island in 1974 and this was continued by the Tasmanian Government. It was concluded that there were up to 500 cats on the island, mostly in herbfield or tussock grassland. While their main food item was the introduced rabbits they continued to take significant numbers of burrow-nesting seabirds (Jones 1977; Brothers *et al.* 1985).

Wekas *(Gallirallus australis scotti)*, a flightless rail, were introduced from New Zealand in the mid 1800s as a source of food for the sealers (Cumpston 1968). They probably contributed significantly to the extinction of two endemic subspecies, the Pacific banded rail *(Rallus philippensis macquariensis)* and the Macquarie Island parakeet *(Cyanoramphus novaezelandiae erythrotis)* (Taylor 1979).

Birds exotic to the Australasian region and self-introduced to Macquarie Island include mallards *(Anas platyrhynchos platyrhynchos)* the redpoll *(Acanthis flammea)* and the common starling *(Sturnus vulgaris)* (Falla 1937; Copson 1995). Mallards became established in the Reserve in the 1970s while the redpoll was first recorded in 1912 and starlings in 1930. The latter two species are now widespread and common.

The Tasmanian Parks and Wildlife Service's management of Macquarie Island commenced in 1971. At that time the European rabbit, introduced in the 1870s, was assessed as having caused the greatest modification of the island's ecosystem. A detailed study of the impact and biology of the rabbits on the island, carried out from 1972 to 1978, showed that their numbers could fluctuate between 50,000 and 150,000 individuals, depending on precipitation levels during their breeding season (Copson *et al.* 1981). An integral part of the program was studying other species, particularly other exotics, in order to anticipate responses to any major drop in rabbit numbers (Brothers and Skira 1984; Brothers *et al.* 1985). This lead to the establishment of monitoring programs for the vegetation and burrow-nesting seabirds and the development of control/eradication programs for other exotic species, work which is still continuing (Brothers and Copson 1988; Copson and Whinan 1994; Copson 1995).

While this research phase was under way, progress continued with the establishment of the European rabbit flea *(Spilopsyllus cuniculi)* as a vector for the myxoma virus which was to be used to control the rabbits (Skira *et al.* 1983). The first introduction of the virus was in the summer of 1978/79 and other introductions have been undertaken almost every spring and summer since then (Brothers *et al.* 1982; Brothers and Copson 1988; Copson 1995). By 1986 rabbit numbers had been reduced significantly, to approximately 15,000. The 1996 population is estimated at fewer than 10,000 rabbits and the vegetation monitoring program has shown that there has been quite rapid changes to the distribution and abundance of many of the vascular plants on the island (Copson and Whinam 1994).

With the drop in rabbit numbers it became necessary to commence management programs for feral cats and wekas (Brothers and Copson 1988). By 1984 the number of wekas on the island had dropped significantly, almost certainly due to feral cats using them as an alternative food source (Copson 1995). A high-priority eradication program was commenced in 1985 to take advantage of this decline in their numbers. This was very successful with the last record of a weka being one shot in 1988. As part of the study and general management activities over 300 feral cats were destroyed between 1975 and 1984. The effort was intensified in 1985, when it became apparent that rabbit control was having a noticeable impact on cat abundance. While this work has had a continual high priority since then it is apparent that a greater effort in the field is required if their eradication is to be achieved (Copson 1995). In 1995 a plan was developed aimed at achieving their eradication within five years and it is proposed to commence the field component of this in the 1997/98 summer (Scott 1996).

Studies are being continued into the biology of the introduced house mouse and ship rat on the island. Research has shown that the mice feed mainly on invertebrate material and the ship rats eat mostly plant matter although the rats can have localised seasonal impacts on the smaller breeding seabirds (Copson 1986). Work is also being undertaken into localised control methods for rats which will be applied around vulnerable colonies of burrow-nesting seabirds (Bryant 1994).

Five introduced vascular plant species have become established on Macquarie Island. Of these *Rumex crispus* and *Anthoxanthum odoratum* are each known from only one locality (Copson 1984; Seppelt *et al.* 1984). All *A. odoratum* plants have been cleared from the site which is being monitored. The other three species, *Cerastium fontanum, Stellaria media* and *Poa annua* are cosmopolitan species which have also established on several other subantarctic and cold temperate islands (Greene and Walton 1975). They were all first reported on Macquarie Island in the 1880-90s, almost certainly introduced by sealers and/or oil gatherers Hamilton 1895; Cheeseman 1919). Only one bryophyte species, *Funaria hygrometrica,* could be considered a possible introduction by humans (Selkirk *et al.* 1990).

A part of the Macquarie Island Nature Reserve Management Plan 1991 addresses environmental impacts resulting from the maintenance of the ANARE station on the island and the limited tourist operations permitted there (Department of Parks, Wildlife and Heritage 1991). The Tasmanian PWS together with the Australian Antarctic Division has established management procedures dealing with logistic operations, quarantine procedures, waste disposal, walking tracks and field huts. Research applications are assessed for scientific merit and significance by the Antarctic Division and for conservation impact by Tasmanian authorities, with the PWS issuing permits and supervising compliance.

Tourism is ship-based with a maximum of 500 tourists a year being permitted to land. Access is limited to two sites and then only on designated beach areas, formed tracks on the Isthmus and four walkway constructed to allow the viewing of penguin colonies, digesters and landscapes. The visits are supervised by PWS staff with interpretation material being provided, prior to landings, outlining potential problems of accidental introductions and precautions to be taken, such as boot washing and cleaning clothes and equipment, before landing. The sites are monitored for possible invertebrate and plant introductions and for any adverse impacts on the penguin colonies (Dingwall 1995b). Conditions for allowing tourist visits also cover waste disposal, numbers ashore at any one time and ship to shore operations, helicopter use is not permitted within 3 nautical miles of the Reserve. The operations are reviewed each year, and guidelines modified as necessary.

Species approach	*Date of introduction*	*Current status*	*Current management*
Feral cat	Before 1820	W C	Eradication program
Weka	In 1870s	E ?	Last record December 1988
European rabbit	In 1878	W A	Control program
House mouse	In 1890s	W A	None
Ships rat	In 1890s	W A	Research into impact / local control
Red poll*	Before 1912	W A	Obtaining data on diet, low priority
European starling*	Before1930	W A	Obtaining data on diet, low priority
Mallard*	Before 1950	W C	None

Table E.1. Naturalised vertebrate pests established on Macquarie Island.

Key: W - widespread; A - abundant; C - common; E - eradicated; * - self introduced

Source: Copson (1995)

APPENDIX F

CONSERVATION RELATED LEGISLATION RELEVANT TO MACQUARIE ISLAND

(i) AUSTRALIAN GOVERNMENT LEGISLATION

LEGISLATION	PURPOSE
Quarantine Act 1908	Restricts the import of human, plant and animal samples, and waste material into Australia, including Macquarie Island.
Seas and Submerged Lands Act 1973	Declares that sovereignty in respect of the various maritime zones of Australia, the airspace over it and its bed and subsoil, is vested in the Commonwealth Government. Other legislation provides the management of various apects in the zone.
Environment Protection (Impact of Proposals) Act 1974	This Act aims to ensure that environmental matters are taken into account in actions or decisions of the Commonwealth government. The Act applies to environmentally significant proposals.
National Parks and Wildlife Conservation Act 1975	This Act provides for the protection and conservation of wildlife. The National Parks and Wildlife Regulations, in force under the Act, currently protect all pinnipeds, birds and pelagic algae in or over the waters of the Territory's continental shelf.
Australian Heritage Commission Act 1975	Establishes the Australian Heritage Commission to identify, conserve and protect the National Estate.
Historic Shipwrecks Act 1976	Protects shipwrecks and relics of historic significance (over 75 years old).
Whale Protection Act 1980	Provides for the preservation, conservation and protection of whales and other cetaceans.
Environment Protection (Sea Dumping) Act 1981	This Act regulates dumping into the sea of wastes and other matters from vessels or aircraft, which gives effect to Australia's obligations under the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Dumping Convention).
Wildlife Protection (Regulation of Exports and Imports) Act 1982	This legislation regulates the export, from Australia, of native animals and plants, and products derived from them, and the import of live exotic animals and plants into Australia. It also implements controls on exports and imports of wildlife that are required under international agreements, particularly the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Protection of the Sea (Prevention of Pollution from Ships) Act 1983	Protects the sea from pollution by oil and other harmful substances discharged from ships. This Act implements the International Convention for the Prevention of Pollution from Ships (MARPOL).
World Heritage Properties Conservation Act 1983	Recognises and implements Australia's international obligations to protect and conserve those parts of Australia and its external territories that are of outstanding universal value.
Protection of Movable Cultural Heritage Act 1986	Protects Australia's heritage of moveable cultural objects.
Hazardous Waste (Regulation of Exports and Imports) Act 1982	Provides for the regulation of the export and import of hazardous waste to ensure that such activity does not present a safety risk to human beings or the environment.
Fisheries Management Act 1991	Regulates commercial fishing operations in the Australian Fishing Zone. Extended to waters around Macquarie by Proclamation.
Endangered Species Protection Act 1992	Authorises the Government to promote the recovery of endangered and vulnerable species and endangered ecological communities. Also obliges Commonwealth agencies not to kill, destroy, damage or collect listed species.

(ii) TASMANIAN STATE GOVERNMENT LEGISLATION

LEGISLATION	PURPOSE
Oil Pollution Act 1961	Provides for control of oil discharge from ships.
National Parks and Wildlife Act 1970	Provides for establishment and management of national parks and reserves, and for flora and fauna conservation.
Environment Protection Act 1973	Provides for environmental assessment of projects and enforcement of environmental regulations.
Marine Act 1976	Regulates refuse disposal.
Noxious Weeds Act 1983	Provides for control of noxious weeds.
Whales Protection Act 1988	Provides for protection of whales and other cetaceans.
Animal Welfare Act 1993	Regulates research, experimentation and wildlife management for vertebrate species.
Living Marine Resources Management Act 1995	Regulates the fishing industry and protects fish and their habitat within State waters.
Threatened Species Act 1995	Provides for protection of threatened species.

APPENDIX G

BIBLIOGRAPHY

An asterisk (*) indicates those items cited in this nomination.

*Adamson, D.A., Selkirk, P.M. and Colhoun, E.A. 1988 Landforms of aeolian, tectonic and marine origin in the Bauer Bay - Sandy Bay region of subantarctic Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 65-82

*Adamson, D.A., Selkirk, P.M. Price, D.M., Ward, N. and Selkirk, J.M. 1996 Pleistocene uplift and palaeoenvironments of Macquarie Island: from palaeobeaches and sedimentary deposits. *Pap. Proc. Roy. Soc. Tas.* (in press)

*Alabaster, T., Pearce, J.A. and Malpas, J. 1982. The volcanic stratigraphy and petrogenesis of the Oman Ophiolite Complex. *Contrib. Mineral. Petrol.* 81 :168-183.

*Anon., 1972 Penrose field conference on ophiolites. *Geotimes,* 17:25

*Banks, M.R. and Smith, S.J. (eds.) 1988 Proceedings of the Symposium on Macquarie Island. May 1987. *Pap. Proc. Roy. Soc. Tas.,* 122 (1)

*Brothers, N.P. 1984 Breeding distribution and status of burrow-nesting petrels at Macquarie Island. *Australian Wildlife Research,* 11:113-131

*Brothers, N.P. 1985 Breeding biology, diet and morphometrics of the King Shag, *Phalocrocorax albiventer purpurascens,* at Macquarie Island. *Australian Wildlife Research,* 12:81-94

*Brothers, N.P. 1991. Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. *Biol. Conserv.* 55 :255-268

*Brothers, N.P. and Copson, G.R. 1988 Macquarie Island flora and fauna management - interpreting progress and predictions for the future. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 129-132

*Brothers, N.P., Eberhard, I.E. Copson, G.R. and Skira, I.J. 1982 Control of rabbits on Macquarie Island by myxomatosis. *Australian Wildlife Research,* 9:477-485

*Brothers, N.P. and Skira, I.J. 1984 The Weka on Macquarie Island. *Notornis,* 31:145-154

*Brothers, N.P., Skira, I.J. and Copson, G.R. 1985 Biology of the feral cat, *Felis catus,* (L.), on Macquarie Island. *Australian Wildlife Research,* 12(3)

Brown, G.C. and Mussett, A.E. 1981 *The Inaccessible Earth* George Allen and Unwin, 235pp

*Brown, S. and Townrow, K. 1989 Conservation Plan for Cultural Resources on Macquarie Island, Department of Parks, Wildlife and Heritage, Tasmania

*Bryant, S. 1994 Conservation of the Fairy Prion and other seabirds on Macquarie island, Tasmania. Parks and Wildlife Service, Tasmania.

Buckney, R.T. and Tyler, P.A. 1974 Reconnaissance limnology of subantarctic islands II. Additional features of the chemistry of Macquarie Island lakes and tarns. *Australian Journal Marine and Freshwater Research,* 25:89-95

*Bunt, J.S. 1954 The soil-inhabiting nematodes of Macquarie Island. *Australian Journal Zoology*, 2(2):264-27

Bunt, J.S. 1965 Observations of the fungi of Macquarie Island. *ANARE Scientific Reports,* Series B (II) Botany. ANARE Publication No. 78

Butler, R.F., Banerjee, S.K. and Stout, J.H. 1976 Magnetic properties of oceanic pillow basalts: evidence from Macquarie Island. *The Geophysical Journal of the Royal Astronomical Society,* 47:179-196

Carrick, R. and Ingham, S.E. 1962 Studies on the Southern Elephant Seal, *Mirounga leonina* (L.). V. population dynamics and utilisation. CSIRO *Wildlife Research,* 7:198-206

Chamberlain, N.G. 1952 Observations of terrestrial magnetism at Heard, Kerguelen and Macquarie Islands 1947-48. Bureau of Mineral Resources, *Geology and Geophysics Report* No. 5

*Cheeseman, T.F. 1919. The vascular flora of Macquarie Island. Sci. Rep. Austr. Antarc. Exp. 1911-1914. Ser. C., 7 (3).

Christodoulou, C., Griffin, B.J. and Foden, J. 1984 The geology of Macquarie Island. *ANARE Research Notes*, 21

*Clark, M.R. and Dingwall, P.R. 1985 *Conservation of islands in the Southern Ocean: a review of the protected areas of Insulantarctica*. IUCN: Gland

Cole, K.D. 1962 Magnetic bays at Macquarie Island. *Australian Journal of Physics*, 15:277-281

Cole, K.D. 1988 Importance of Macquarie Island for upper atmosphere physics. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 267-272

Colhoun, E.A. and Goede, A. 1974 A reconnaissance survey of the glaciation of Macquarie Island. *Papers and Proceedings of the Royal Society of Tasmania,* 108:1-19

Colhoun, E.A. and Goede, A. 1973 Fossil penguin bones, C dates and the raised marine terrace of Macquarie Island: some comments. *Search,* 4(11):499-501

*Copson, G.R. 1984 An annotated atlas of the vascular flora of Macquarie Island. *ANARE Research Notes* 18

*Copson, G.R. 1986 The diet of the introduced rodents *Mus musculus* (L.) and *Rattus rattus* (L.) on subantarctic Macquarie Island. *Australian Wildlife Research.* 13: 441-445

*Copson, G.R. 1988 The status of the black-browed and grey-headed albatrosses on Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 137-141

*Copson, G.R. 1994 Cetacean sightings and strandings at subantarctic Macquarie Island, 1968 to 1990. *ANARE Research Notes,* 91:15

*Copson, G.R. 1995 An integrated vertebrate pest strategy for subantarctic Macquarie Island. [In] Proceedings of 10th Vertebrate Pest Control Conference, Hobart, May 1995

*Copson, G.R., Brothers, N.P., Skira, I.J. 1981 Distribution and abundance of the rabbit, *Oryctolagus cuniculus* (L.), at Subantarctic Macquarie Island. *Australian Wildlife Research,* 8: 597-611

*Copson, G.R. and Leaman, E.G. 1981 *Rumex crispus.* (L.) (Polygonaceae) - a new record for Macquarie Island. *N.Z. J. Botany,* 19:401-404

*Copson, G.R. and Rounsevell, D.E. 1987 The abundance of Royal Penguins *(Eudyptes schlegeli,* Finsch) breeding at Macquarie Island. ANARE *Research Notes,* 41

*Copson, G.R. and Whinam, J. 1994. Rabbits and vegetation - Their future on Macquarie Island. Tasmanian Parks and Wildlife Service.

*Crohn, P.W., 1986 The geology and geomorphology of Macquarie Island with special emphasis on heavy metal trace element distribution. *ANARE Research Notes,* 39

*Cumpston, J.S. 1968. Macquarie Island. ANARE *Scientific Reports*, series A(1).

*Dartnall, H.J.G. 1993. The Rotifers of Macquarie Island. *ANARE Research Notes,* 89.

*Dawson, E.W. 1988. The offshore fauna of Macquarie Island: history and biography - results from New Zealand and United States research cruises. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 219-232.

*Debenham, F. (ed.) 1945 *The voyage of Captain Bellinghausen to the Antarctic seas, 1819-1821.* Reprinted by Hakluyt Society

Dell, R.K. 1964. Macquarie and Heard Island's mollusca. *Rec. Dominion Mus.,* 4:267-301

Dell, R.K. 1964. Marine Mollusca from Macquarie and Heard Islands. *Rec. Dominion Mus.,* 4(20):267-301.

*DeMets, C., Gordon, R.G., Argus, D.F. and Stein, S. 1990. Current plate motions. *Geophysical Journal International* 101 :435-478.

*Department of Parks, Wildlife and Heritage 1991 *Macquarie Island Nature Reserve Management Plan 1991* The Department: Hobart 57pp.

*Dingwall, P.R. (Ed). 1995a. Progress in conservation of the Subantarctic Islands. *Proceedings of the SCAR/IUCN Workshop on Protection, Research and Management of Subantarctic Islands,* Paimpont, France, 27-29 April, 1992. Gland: World Conservation Union.

*Dingwall, P.R. 1995b. Subantactic tourism: discussion and recommendations. [In] Dingwall, P.R. (Ed). 1995. Progress in conservation of the Subantarctic Islands. *Proceedings of the SCAR/IUCN Workshop on Protection, Research and Management of Subantarctic Islands,* Paimpont, France, 27-29 April, 1992. Gland: World Conservation Union.

*Duncan, R.A. and Varne, R. 1988 The age and distribution of the igneous rocks of Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 45-50.

*Elthon, D. 1991. Geochemical evidence for formation of the Bay of Islands ophiolite above a subduction zone. Nature 354 :140-143.

Fabricius, A.F. 1957 Climate of the Sub-Antarctic Islands. [In] M.P. van Rooy (ed.). *Meteorology of the Antarctic.* Pretoria, South Africa Weather Bureau, pp.111-135.

*Falla, R.A. 1937 Birds. British, Australian and New Zealand Antarctic Research Expedition (BANZARE) *Reports,* Series B, Vol. 2

Falla, R.A. 1960. Oceanic birds as dispersal agents. *Proc.Royal Society,* London, B, Vol. 152, pp. 655-659.

Francey, R.J., Pearman, G.I. and Beardsmore, D.J. 1988. A southern view of the global atmosphere. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 113-119.

*Frolich, C., Coffin, M.F., Massell, C., Mann, P., Schurr, C.L.,Davis, S.D.,Jones, T., and Karner, G. (submitted). Constraints on Macquarie Ridge tectonics provided by Harvard focal mechanisms and teleseismic earthquake locations. *Journal of Geophysical Research.*

*Garnett, S. 1992. Threatened and extinct birds of Australia. RAOU Report No. 82.

*Gales, R. 1993. Co-operative mechanisms for the conservation of albatrosses. Report for Australian Nature Conservation Agency, Canberra. pp 132.

*George, AS., Orchard, A.E. and Hewn,. (eds.) 1993 *Flora of Australia.* Vol. 50: Oceanic Islands 2. AGPS: Canberra.

Girod, M. and Nougier, J. 1972 Volcanism of sub-Antarctic Islands. [In] Adie, R.J. (ed.) *Antarctic Geology and Geophysics.* Universitetsforlaget, Oslo, pp. 777-788

*Goodall R.N.P. and Galeazzi, A.R. 1985 A review of the food habits of the small cetaceans of the Antarctic and subantarctic. pp. 566-572 [In] W.R.Siefried, P.R. Condy and R.M. Laws (Eds.) *Antarctic Nutrient Cycles and Food Webs.* Springer-Verlag.

*Greene, S.W. and Walton, D.W.H. 1975 An annotated check list of the sub-antarctic and antarctic vascular flora. *Polar Record,* 17(110):473-484

*Greenslade, P.J. 1990 Annotated checklist of the free-living terrestrial invertebrate fauna of Macquarie Island with notes on biogeography. *Pap. Proc. Roy. Soc.Tas.* 124: (in press)

Gressit, J.L. 1962 Insects of Macquarie Island. *Pacific Insects,* 4(4):905-978. (ANARE reprint B2/92).

Gressit, J.L. 1965 Faunal relationships of the more southern Subantarctic Islands (Macquarie, Campbell, Auckland, Heard, South Georgia). [In] Proceedings of the 12th International Congress of Entomology, London, 1964, pp.465-466.

Gressit, J.L. 1970 Subantarctic entomology and biogeography. *Pacific Insects Monograph* 23:295-374.

Griffin, B.J. 1982 Igneous and metamorphic petrology of lavas and dykes of the Macquarie Island ophiolite complex. Ph.D. Thesis, University of Tasmania.

*Griffin, B.J. and Varne, R. 1980 The Macquarie Island ophiolite complex: mid-tertiary oceanic lithosphere from a major ocean basin. *Chemical Geology,* 30:285-308.

*Hall, A. 1987 *Igneous Petrology* Longman, 573pp.

*Hamilton, A. 1895. Notes on a visit to Macquarie Island. *Trans. Proc. of New Zeal. Inst. 1894,* 27 : 559-579.

*Hayes, D.E. and Talwani, M. 1972 Geophysical investigation of the Macquarie Ridge complex [In] Hayes, D.E. (ed.) Antarctic Oceanology II: The Australian - New Zealand sector. *Antarctic Research Service.* Vol.19 pp.211-234. A.G.U. Washington, D.C.

Hayes, D.E., Talwani, M. and Christoffel, D.A. 1972 The Macquarie Ridge complex. [In] Adie, R.J. (ed.) *Antarctic geology and geophysics.* Symposium on Antarctic Geology and Solid Earth Geophysics, Oslo. 6-15 August 1970. Universitetsforlaget, Oslo: 767-771.

*Hindell, M.A. 1988a The diet of the king penguin *Aptenodytes patagonicus* at Macquarie Island. *Ibis,* 130:193-203.

*Hindell, M.A. 1988b The diet of the royal penguin *Eudyptes schlegeli* at Macquarie Island. *Emu,* 88:219-226.

*Hindell, M.A. 1989 The diet of gentoo penguins *Pygoscelis papua* at Macquarie Island: Winter and early breeding season. *Emu*, 89:71-78.

*Hindell, M.A. and Burton, H.R. 1987 The past and present status of the Southern Elephant Seal *Mirounga leonina* (Linn.) at Macquarie Island. *J. Zool. (Lond.)* 213:365-380.

*Hindell, M.A. and Burton, H.R. 1988 The history of the elephant seal industry at Macquarie Island and an estimate of the presealing numbers. *Pap. Proc. Roy. Soc. Tas.,* 122:159-176.

*Holdgate, M.W.1977 Terrestrial ecosystems in the Antarctic. *Philos. Trans. Roy. Soc.London , B*, 279:5-25.

Holdgate, M.W. and Wace, N.M. 1961. The influence of man on the flora and fauna of Southern Islands. *Polar Record*, 10(67):475-494

Horne, R.S.C. 1983 The distribution of penguin breeding colonies on the Australian Antarctic Territory, Heard Island, the McDonald Islands and the Macquarie Island. *ANARE Research Notes*, 9

Houtz, R.E., Hayes, D.E. and Marks, R.G. 1977. Kerguelen Plateau bathymetry, sediment distribution and crustal structure. *Marine Geology*. 25:95-130.

Ingham, S.E. 1960 The status of seals (Pinnipedia) at Australian Antarctic stations. *Mammalia* 24(3):422-438.

*IUCN 1995 World Heritage Nomination - IUCN Technical Evaluation: Gough Island (UK) [In] *Documentation on World Heritage Properties (Natural)* World Heritage Bureau July 1995: Paris

Jacka, F. 1953 Magnetic observations at Heard, Kerguelen and Macquarie Islands, 1947-1951. *ANARE Reports* Series C, I Terrestrial magnetism. ANARE Publication No. 17.

Jacklyn, R.M. 1955 Cosmic rays and air mass effects at Macquarie Island. *Aust. J. Physics,* 8:190-192

Jenkin, J.F. 1975 Macquarie Island, Subantarctic. [In] Rosswall, T. and Heal, O.W. (Eds) Structure and function of tundra ecosystems. *Ecological Bulletins* (Stockholm) 20:375-397

*Jenkin, J.F., Johnstone C.W. and Copson, G.R. 1981 Introduced animal and plant species on Macquarie Island. *Colloque Sur Les Ecosystemes Subantarctique, Paimpont, 1981, C.N.F.R.A.,* 51:301-313

Jenner, G.A., Griffin, B.J. and Varne, R. 1982 Macquarie Island basalts: geochemistry and nature of their source. Abstract only. [In] Abstracts - Generation of major basalt types. IAVEI - IAGC Scientific Assembly, Reykjavik, Iceland - August 15-22, 1982

Johnstone, G.W. 1985 Threats to birds on subantarctic islands. [In] Moors, P.J. (ed.) Conservation of island birds: case studies for the management of threatened island species. Proceedings of a symposium held at XVIII ICBP World Conference in Cambridge, England, in August 1982

*Jones, E. 1977 Ecology of the feral cat, *Felis catus* (L.), (Carnivora: Felidae), on Macquarie Island. *Australian Wildlife Research*, 4:249-262

*Jones, E. and Skira, I.J. 1979 Breeding distribution of the Great Skua at Macquarie Island in relation to numbers of rabbits *Emu,* 79:19-23

*Jones, T.D. and McCue, K.F. 1988 The seismicity and tectonics of the Macquarie Ridge. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 51-57

*Kantvilas, G. and Seppelt, R.D. 1992 The lichen flora of Macquarie Island: introduction and an annotated checklist of species. *ANARE Research Notes*, 87.

Kenny, R. and Haysom, N. 1962 Ecology of rocky shore organisms at Macquarie Island. *Pacific Science,* XVI (3)

*Kerr, R.A. 1983 Ophiolites: windows on which ocean crust? *Science,* 219:1307-1309

Kerry, E. 1984 The fungal flora of Macquarie Island. *Tasmanian Naturalist,* 78:16-21

Ledingham, R. 1981 Macquarie shakes again. *Aurora,* 2:6-8

Ledingham, R.B. 1978 Report on some aspects of erosion on Macquarie Island - 1977. *Antarctic Division Technical Memorandum* , 72

*Ledingham, R. and Peterson, J.A. 1984 Raised beach deposits and the distribution of structural lineaments on Macquarie Island. *Pap. Proc. Roy. Soc. Tas.,*118

*Levi, S., Banerjee, S.K., Beske-Diehl, S. and Moskowitz, B. 1978 Limitations of ophiolite complexes as models for the magnetic layer of the oceanic lithosphere. *Geophys. Res.* Zett. 5:473-476

*Lewis Smith, R.I. 1984, Terrestrial plant biology of the sub-Antarctic and Antarctic [In] *Antarctic Ecology,* R.M.Laws, (ed.)Vol. 1, pp. 61-162

*Loffler, E. 1983. Macquarie Island - eine vom wind gepragte naturlandschaft in der sub-antarktis. *Polarforschung* 53 :59-74.

Loffler, E. and Sullivan, M.E. 1980 The extent of former glaciation on Macquarie Island. *Search,* II, (7-8):246-247

Loffler, E., Sullivan, M.E. and Gillison, A.N. 1983 Periglacial landforms on Macquarie Island, Subantarctic. *Zietschrift fur Geomorphologie* N.F., 27(2):223-236

*Lowry, J.K. and Horning, D.S. Poore, G.C.B. and Ricker, R.W. 1978 *The Australian Museum Macquarie Island expedition, summer 1977- 78.* The Australian Museum Trust, Nov. 1978

Lucas, P.H.C. and Dingwall, P.R. 1987 Protected areas and environmental conservation in Antarctica and the Southern Ocean. [In] Nelson, J.G., Needham, R. and Norton, L (eds.) *Arctic Heritage: proceedings of a symposium* August 24-28, 1985, Banff, Alberta, Canada.

*Lugg, D.J. Johnstone, G.W. and Griffin, B.J. 1978 The outlying islands of Macquarie Island. *Geogr. J.,* 144:277-87

*Mackenzie, D. 1968 The birds and seals of the Bishop and Clerk Islets, Macquarie Island. *Emu,* 67(3-4):241-45

Mallis, M. 1988 Total ozone fluctuations observed at Macquarie Island: 1981-82. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 289-302

*Mawson, D. 1919 Macquarie Island - A sanctuary for Australasian subantarctic fauna. *Proc. Roy. Geogr. Soc. Aust. S. Aust. Branch,* 1918-19:71-85

*Mawson, D. 1922 Macquarie Island and its future. *Pap. Proc. Roy. Soc. Tas.,* 1922:39-54

*Mawson, D. 1943 Macquarie Island: its geography and geology. *Australasian Antarctic Expedition (1911-1914) Scientific Reports,* Series A, Vol. V

McCann, T.S. 1980 Population structure and social organization of Southern Elephant Seals, Mirounga leonina (L). [In] Bonner, W.N. and Berry, R.J. (eds.) *Ecology in the Antarctic.* Papers presented at a meeting held on 11 October 1979 organised by the Linnean Society of London. Academic Press: London: pp. 133-150

McEvey, A.R. and Vestjens, W.J.M. 1973 Fossil penguin bones from Macquarie Island, southern ocean. *Proc. Roy. Soc. Vict.,* 86(2):151-174

*Minster, J.B. and Jordan, T.H. 1978 Present-day plate motions. *J. Geophys. Res.,* 83:5311-5354.

*Miyashiro, A. 1973. The Troodos Ophiolite probably formed in an island arc. *Earth Planet. Sci. Lett.* 19 :218-224.

*Moores, E.M., and Jackson, E.D. 1974 Ophiolites and oceanic crust. *Nature,* 250, 136-139

*Nicholas, A., 1989 *Structures of ophiolites and dynamics of oceanic lithosphere.* Kluwer, 367 pp

*Norman, F.l. 1987 The ducks of Macquarie Island. *ANARE Research Notes,* 42

*Orchard, A.E. 1989 *Azorella lamarck* (Apiaceae) on Heard and Macquarie Islands, with description of a new species *A. macquariensis. Muelleria,* 7:15-20

*Pearce, J.A., Lippard, S.J. and Roberts, S. 1984. Characteristics and tectonic significance of supra-subduction zone ophiolites. In Kokelaar, B.P. and Howells, M.F. (eds.) *Marginal Basin Geology*. *Spec. Publ.* Geol. Soc. Lond. 16 :77-94.

Peterson, J.R. and Scott, J.J. 1988 Interrelationships between wind exposure, vegetation distribution and pollen fallout between Bauer Bay and Sandy Bay, Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart

*Peterson, J.R., Scott, J.J. and Derbyshire, E. 1983 Australian landform example No. 43. Sorted stripes of periglacial origin. *Australian Geographer*, 15(5):325-328

Pickard, J., Selkirk, P.M. and Selkirk, D.R. 1984 Holocene climates of the Vestfold Hills, Antarctica and Macquarie Island. [In] Vogel, J.C. (ed.) Late Cainozoic Palaeoclimates of the Southern Hemisphere. Proceedings of an International Symposium held by the South African Society for Quaternary Research, Swaziland, 29 August - 2 September 1983. Balkema, Rotterdam: pp.173-182

Prescott, G.W. 1979 A contribution to a bibliography of Antarctic and subantarctic algae together with a checklist of freshwater taxa reported to 1977. *Bibliotheca Phyclogica*, 45

Quilty, P.G.J., Rubenach M. and Wilcoxon, J.R. 1973 Miocene ooze from Macquarie Island. *Search,* 4:163-164

*Ricker, R.W. 1981 Macquarie Island: a blend of cold temperate, subantarctic and Antarctic seaweeds. *Eighth International Biological Congress Abstracts: 186*

*Robertson, G.R. 1986. Population Size and breeding success of the gentoo penguin *Pygoscelis papua* at Macquarie Island. *Aust. Wildl. Res.* 13(4) :583-587

Rounsevell, D. 1988 Periodic irruptions of itinerant leopard seals within the Australasian sector of the Southern Ocean, 1976-86. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 189-191

*Rounsevell, D.E. and Brothers, N.P. 1984 The status and conservation of seabirds at Macquarie Island [in] Cropxall, J.P., Evans, P.G.H. and Schreiber, R.W. (eds.). *Status and conservation of the world's seabirds.* I.C.B.P.: Cambridge

*Rounsevell, D.E. and Copson, G.R. 1982 Growth rate and recovery of a King Penguin, *Aptenodytes patagonicus*, population after exploitation *Australian Wildlife Research,* 9:519-525

Rounsevell, D.E. and Eberhard, I.H. 1980 Leopard seals, *Hydrurga leptonyx* (Pinnipedia) at Macquarie Island 1949-1979. *Australian Wildlife Research,* 7:403-415

*Ruff, L.J. and Cazenave, A. 1985 SEASAT geoid anomalies and the Macquarie Ridge Complex. *Phys. Earth Planet Interiore,* 38:59-69

*Ruff, L.J., Given, G. and Sanders, C. 1982 The tectonics of the Macquarie Ridge, New Zealand: new evidence of strikeslip motion from the earthquake of May 25, 1981 Mw = 7.7. *EOS,* 63(18):384

*Ruff, L.J., 1990 The Great Macquarie Island earthquake of 1989; Introduction. *Geophys. Research Letters,* 17:989-992.

Salas, M.R. 1983 Long-distance pollen transport over the southern Tasman Sea: evidence from Macquarie Island. *New Zealand J. Botany*, 21:285-292

*Scott, J.H. 1883. Macquarie Island. *Trans. & Proc. of the New Zealand Inst. 1881*, 15 : 484-493.

Scott, J.J. 1983 Landslip revegetation and rabbits, Subantarctic Macquarie Island. *Proc. Ecological Soc. Aust.*, 12:170-171

*Scott, J.J. 1985 Effects of feral rabbits on the revegetation of disturbed coastal slope sites, Macquarie Island. M.A. thesis, Monash University, Melbourne

Scott, J.J. 1988 Rabbit distribution history and related land disturbance, Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 255-266

*Scott, J.J. 1994 Marine conservation at Macquarie Island. Parks and Wildlife Service, Tasmania.

*Scott, J.J. 1996. A feral cat threat abatement plan for Macquarie Island. *Tasmanian Parks and Wildlife Service*

Selkirk, D.R. and Selkirk, P.M. 1983 Preliminary report on some peats from Macquarie Island. [In] *Proceedings of First CLI~Z Conference, February 1981*. Department of Biogeography and Geomorphology, Research School of Pacific Studies, Australian National University, Canberra: pp.115- 117

Selkirk, D.R., Selkirk, P.M., Bergstrom, D.M. and Adamson, D.A. 1988 Ridge top peats and paleolake deposits on Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 83-90

Selkirk, D.R., Selkirk, P.M. and Griffin, K. 1983 Palynological evidence for - Holocene environmental change and uplift on Wireless Hill, Macquarie Island. *Proc. Linnean Soc. New South Wales,* 107:1-17

Selkirk, D.R., Selkirk, P.M. and Seppelt, R.D. 1986 An annotated bibliography of Macquarie Island. *ANARE Research Notes,* No 38.

*Selkirk, P.M. and Adamson, D. 1995. Mapping Macquarie Island. *The Globe Journal of the Australian Map Circle* No. 41 :53-67.

*Selkirk, P.M., Adamson, D.A. and Seppelt, R.D. 1988 Terrace types and vegetation dynamics on Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 59-64

Selkirk, P.M., Costin, A.B., Seppelt, R.D. and Scott, J.J.1983 Rabbits, vegetation and erosion on Macquarie Island. *Proc. Linnean Soc. New South Wales,* 106(4):337-346

Selkirk, P.M., Edgecombe, A.J. and Seppelt, R.D. 1986 Distribution of bryophytes on subantarctic Macquarie Island. *Acta Botanica*

Selkirk, P.M., and Selkirk, D.R. 1982 Late Quaternary mosses from Macquarie Island. *Journal of the Hattori Botanical Laboratory,* 52:167-169

*Selkirk, P.M., Seppelt, R.D. and Selkirk, D.R. 1990. *Subantarctic Macquarie Island: environment and biology.* Cambridge University Press

Seppelt, R.D. 1977 Studies on the bryoflora of Macquarie Island. I. Introduction and checklist of species. *The Bryologist*, 80:167-170

Seppelt, R.D. 1978 Studies on the bryoflora of Macquarie Island. II. Ulota phyllantha Brid. *New Zealand J. Botany,* 16:21-23

* Seppelt, R.D. 1984a. Bryoflora of Macquarie Island. *Tasmanian Naturalist,* Vol. 78 :12-14

*Seppelt, R.D., Copson G.R. and Brown, M.J. 1984 Vascular flora and vegetation of Macquarie Island. *Tasmanian Naturalist,* 78:7-12

Seppelt, R.D. and Hughes, J.M.R. 1987 Contrasts in vegetation patterns: Heard Island and Macquarie Island. *CNFRA* , 58:171-175

Serventy, D.L., Serventy, V. and Warham, J. 1971, *The Handbook of Australian Seabirds.* Sydney: A.H. & A.W. Reed

*Shaughnessy, P.D., Shaughnessy, G.L. and Fletcher, L. 1988 Recovery of the fur seal population at Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 177-187

Shields, O. 1976 A summary of the oldest ages for the World's islands. *Pap. Proc. Roy. Soc. Tas.,* 110:35-53

Simpson, R.D. 1976a The shore environment of Macquarie Island. *ANARE Science Report Series B(1)* Zoology, 125:1-41

*Simpson, R.D. 1988 Developments in the studies of subantarctic shores, with particular reference to Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp 177-187

*Skira, I.J., 1984 Breeding distribution of the Brown Skua on Macquarie Island. *Emu,* 84(4):248

*Skira, I.J., Brothers, N.P., Copson, G.R. 1983 Establishment of the European Rabbit flea on Macquarie Island. *Australian Wildlife Research,* 10:121-127

*Smith, V.R. and Lewis Smith, R.I. 1987 The Biota and Conservation Status of Sub-Antarctic Islands. *Environment International,* 13:95-104

Sobey, W.R., Adams, K.M., Johnston, G.C., Gould, L.R., Simpson, K.N.G. and Keith, K. 1923 Macquarie Island: the introduction of the European rabbit flea Spilospsyllus cuniculi (Dale) as a possible vector for myxomatosis. *Journal of Hygiene.* (Cambridge), 71:299-308

Solem, A. 1968 The subantarctic land snail, *Notodiscus hookeri* (Reeve, 1854) (Pulmonata, Endodontidae). *Proc. Malacological Soc. Lond.,* 38(3):251-266

Streten, N.A. 1988 The climate of Macquarie Island and its role in atmospheric monitoring. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 91-106

Summerhayes, C.P. 1967 Macquarie Bathymetry. *New Zealand Oceanographic Institute Chart,* Oceanic Series, 1:1 000 000

*Taylor, B.W. 1955. The flora, vegetation to soils of Macquarie Island. *ANARE Repts*. B(2) No. 19, Botany, 190pp.

*Taylor, R.H. 1979 How the Macquarie Island parakeet became extinct. *New Zealand J. Ecology,* 2:42-45

Tomkins, R.J. 1984 Some aspects of the morphology of Wandering Albatrosses on Macquarie Island. *The Emu,* 84:29-32

*Tomkins, R.J. 1985 Reproduction and mortality of Wandering Albatrosses on Macquarie Island. *The Emu,* 85:40-42

*Townrow, K. 1989. Survey and excavation of historical sites on Macquarie Island. *Lands, Parks and Wildlife, Tasmania, Occasional Paper* No. 20

Tyler, P.A. 1972 Reconnaissance limnology of sub-Antarctic islands. I. Chemistry of lake waters from Macquarie Island and the lIes Kerguelen. *International Revue der gesamten Hydrobiologie und Hydrographie.* 57(5):759-778

Van Loon, H. 1972 Cloudiness and precipitation in the Southern Hemisphere. Meteorology of the Southern Hemisphere. *American Meteorological Society monograph,* 13:101-112

van Zinderen Bakker, E.M. 1969 Quaternary pollen analytical studies in the Southern Hemisphere with special reference to the sub-Antarctic. [In] van Zinderen Bakker, E.M. (ed.) *Palaeoecology of Africa, the surrounding islands and Antarctica,* vol.5, pp.175-212

van Zinderen Bakker, E.M. 1970 Quaternary climates and Antarctic biogeography. [In] Holdgate, M.W. (ed.) *Antarctic Ecology.* Academic Press, London, pp. 31-40

Varne, R., Gee, R.D. and Quilty, P.G.J. 1969 Macquarie Island and the Cause of Oceanic Linear Magnetic Anomalies.*Science,* 166:230-233

Varne, R., Thomson, J.W. 1988 Macquarie Island. [In] Le Masurier, W.E. et al (eds.) 1990, Volcanoes of the Antarctic Plate and Southern Oceans. *Antarctic Research Series,* 48:476-481

*Varne, R. and Rubenach. M.J. 1972 Macquarie Island and its relationship to oceanic crust. in D.E. Hayes (ed.) *Antarctic Research Series.* Vol. 19, American Geophysical Union, Washington, D.C., pp. 251-266

Varne, R. and Rubenach, M.J. 1973 Geology of Macquarie Island in relation to tectonic environment. [In] Coleman P.J. (ed.) *The Western Pacific - Island Arcs, Marginal Seas, Geochemistry.* University of Western Australia Press pp. 535-541

Vestjens, W.J.M. 1963 Remains of the extinct banded rail at Macquarie Island. *The Emu,* 62:249-250

Wace, N.M. 1960 The botany of the southern oceanic islands. *Proceedings of the Royal Society* B, 152:475-490

Walton, D.W.H. 1986 Conservation of subantarctic islands. The biological basis for conservation of subantarctic islands. *Report of SCAR/IUCN Workshop.* 12-14 September 1986. Painport, France

Warham, J. 1962 The biology of the giant petrel, *Macronectes giganteus. Auk,* 79:139-160

Warham, J. 1963 The rockhopper penguin, *Eudyptes chrysocome,* at Macquarie Island. *Auk,* 80:229-256

Warham, J. 1967 The White-headed petrel, *Pterodroma lessoni* at Macquarie Island. *The Emu,* 67(1):1-22

Watkins, N.D. 1975 Subantactic islands in the Indian Ocean. *Antarctic Journal of the United States,* 10(5):252-253

Watson, G.E. 1975 *Birds of the Antarctic and sub-Antarctic.* American Geophysical Union, Washington

*Weimerskirch, H. and Robertson, G.R. 1994. A satellite tracking study of the light-mantled sooty albatross at Macquarie Island. *Polar Biology* 14 :123-126

Williams, A.J. 1980 Aspects of the breeding biology of the gentoo penguin, *Pygoscelis papua. Gerfaut,* 70(3):283-295

*Williams, R. 1988 The near-shore fishes of Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 233-245

Williamson, P. 1974 a Recent studies of Macquarie Island and the Macquarie Ridge complex. *Bulletin of the Australian Society of Exploration Geophysicists,* 5:19-22

Williamson, P. 1974 b The structural evolution of the Macquarie Island region and its relation to oceanic crust. Ph.D thesis, University of New South Wales, Sydney

*Williamson, P. 1978 The palaeomagnetism of outcropping oceanic crust on Macquarie Island. *J. Geol. Soc. Aust.,* 27(7)387-394

*Williamson, P.E., 1988 Origin, structural and tectonic history of the Macquarie Island region. *Pap. Proc. Roy. Soc. Tas.,* 122:27-43

*Williamson P. and Johnson. B.D. 1974 Crustal structure of the central region of the Macquarie Ridge Complex from gravity studies. *Mar. Geophys. Res.,* 11(2):127-132

*Williamson, P.E., Jones, T.D., and McCue, K.F., 1989 Evidence for crustal thickening and shortening of the overriding plate during incipient plate/plate subduction. *Journal of Geodynamics,* 11:1-15

Wilson, G.J. 1983 Distribution and abundance of Antarctic and Sub-Antarctic penguins: a synthesis of current knowledge. Cambridge: SCAR

Wilson, J.T. 1963 A resume of the geology of islands in the main ocean basins. Volume 1. Atlantic and Indian Oceans. *Toronto University Institute of Earth Sciences, Scientific Report* No. 4

Wilson, J.T. 1963 A resume of the geology of islands in the main ocean basins. Volume 2. Pacific Ocean. *Toronto, University Institute of Earth Sciences, Scientific Report* No.4

Wilson, J.T. 1963 A resume of the geology of islands in the main ocean basins. Volume 3. Paper summarising results *Toronto, University Institute of Earth Sciences, Scientific Report* No. 4

*Woehler, E. 1984 Morphology of the Royal Penguin *Eudyptes schlegeli* at Macquarie Island. *Tasmanian Naturalist,* 79:2-4

Woehler, E.J. and Johnstone, G.W. 1988 Banding studies of giant petrels, *Macronectes spp.,* at Macquarie Island. [In] M.R. Banks and S.J. Smith (eds.) *Proceedings of the Symposium on Macquarie Island.* The Royal Society of Tasmania: Hobart pp. 143-152

INDEX FOR SLIDES CONTAINED IN BACK OF FOLDER

Slide Number	Description	Photographer
1	Heavy cloud over the Red River Valley	G Copson
2	Only a narrow beach lies between the sea and the steep coastal slopes at Caroline Cove	G Copson
3	Elephant seals rest ashore during a storm	G Copson
4	Reefs, bays and rugged coastal slopes, typical of the southern section of the west coast	G Copson
5	Surrounded by *Pleurophyllum hookeri herbfield* Emerald Lake perches on the plateau edge above Bauer Bay	G Copson
6	Royal and king penguins rest and moult on the beach at Caroline Cove	G Copson
7	Old sea stacks now stranded on the raised beach terrace by the uplift of Macquarie Ridge	G Copson
8	The colony of endemic royal penguins at Hurd Point covers 67,000 m^2 and contains 160,000 breeding pairs	G Copson
9	Old sea stacks rise above tall-tussock grassland at Mawson Point	A Everett
10	The plateau, eroded by wave action as it rose above sea level, now lies 200-300 metres above the present sea level	
11	At Half Moon Bay the raised beach terrace is covered by up to six metres of peat in places	A Jackson
12	Gales and storms frequently deposit antarctic kelp well above sea level	D Rasch
13	The king penguins have recovered from the exploitation of the last century and the Lusitania Bay colony now contains over 120,000 pairs each year as compared to an estimated 600 pairs in 1930	
14	King penguins surround the old digesters in which their predecessors were boiled down for oil	M Lambert
15	Tall-tussock grassland fringes mires on the better drained sections of the raised beach terrace	G Copson
16	The Red River Valley runs along the Brothers fault line, one of the major structural lineaments on Macquarie Island	D Rasch
17	Stagnant pools form in the mire communities between old sea stacks	D Rasch
18	The steep coastal slopes continue under the sea dropping 5,000 metres in to the Macquarie Trench within 12 nautical miles of the east coast	G Copson
19	Wind erosion modifies the landscape in a high plateau valley south of Mount Haswell	G Copson
20	Moulting elephant seals relax in a peat wallow on the west coast raised beach terrace	G Copson

96

In 1996, Macquarie Island was nominated by the Australian Government for inscription on the World Heritage Register, mainly for its unique geological features. The island is the exposed crest of the undersea Macquarie Ridge, raised to its present position where the Indo-Australian tectonic plate meets the Pacific plate. It is the only place on Earth where rocks from the Earth's mantle are exposed above sea level. These unique exposures include excellent examples of pillow basalts and other extrusive rocks. For more than 50 years, Australia has operated a research and Antarctic support sta Nomination by Australia of Heard Island and McDonaid Islands for inscription on the World Heritaae List 58. World heritage nomination - IUCN technical evaluation macquarie island (australia). The Bureau referred this nomination to Australia for additional information. IUCN received a substantial new file on 16 Septemberwhich will be reviewed over the next several months. A report will be available for the next meeting of the Bureau.