Conservation of marine habitats in the region of Heard Island and McDonald Islands

ANZAC Peak, Heard Island
Australian Antarctic Division photo by G.W.Johnstone

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EXECUTIVE SUMMARY

This report aims to review the status of information in the region of Heard Island and McDonald Islands (HIMI), to determine the future work that may enhance our understanding of the conservation values, and to determine a possible approach to protecting the conservation values of the HIMI region.

Heard Island and McDonald Islands form Australia's most remote sovereign territory. They are situated in the south Indian Ocean, about 4100 km southwest from the coast of Western Australia, a similar distance southeast of South Africa and 1700 km north of Antarctica. The closest land is the French territory of Îles Kerguelen, situated about 380 km to the northwest. Arising from the northern half of the Kerguelen Plateau, Heard Island, McDonald Islands and Îles Kerguelen form the only exposed peaks of the plateau. The plateau forms one of the largest oceanic ridges, extending 2100 km in a northwesterly direction from continental Antarctica into the Indian Ocean. These islands have severe climates. They lie directly in the path of a convergence zone where cold-temperate oceans meet polar waters. Heard Island is directly in the path of the Antarctic Circumpolar Current and is in close proximity to, and south of, the Polar Front.

Australia has two exclusive economic zones (EEZ) distant from the continental EEZ in temperate and sub-Antarctic waters: around Macquarie Island (MI) to the southeast of Australia and around Heard Island and McDonald Islands to the southwest (HIMI). These regions are different in their morphology and proximity to the Polar Front, MI to the north and HIMI to the south. They are considered different in the recent Interim Marine and Coastal Regionalisation for Australia (IMCRA) in which they are known as the Macquarie Province and Kerguelen Province respectively.

The Physical Environment

The Kerguelen Plateau region has been divided into five distinct domains: northern (including Îles Kerguelen and Rogers Seamount), central (including Heard Island and the McDonald Islands) and southern portions; Elan Bank and the Labuan Basin.

The primary surface sediments in the HIMI region comprise siliceous diatom mud or ooze with some stations revealing quantities of calcareous sediments and foraminifera. Around HIMI itself, the surface is a mosaic of basaltic sand, mud, cobbles and reefs with Shell Bank being covered in a layer of shell grit. On the basis of computer modelling of regional scale wave dynamics, the bottom area shallower than 200m around Heard Island (in the territorial sea) is considered to be potentially influenced by wave action during major storms.

The Kerguelen Plateau is a major barrier to the eastward flow of the Antarctic Circumpolar Current (ACC). The PF is thought to move in a north, northeasterly direction as it passes around the south of Îles Kerguelen up to latitude 48ºS. From there it travels in a southeastern direction back down to about 50ºS. Directly north of Heard Island it is estimated to be between 48ºS and 49ºS.

In the Heard Island region, most water is thought to move in an easterly direction across the plateau to the north and south of the island. However, there is a passage of water that moves in a northwesterly direction up through the trough between the relatively shallow central plateau and west of Shell Bank. Water is also known to eddy around the east of Shell Bank in an anticlockwise direction.

The region of the plateau within the Australian EEZ can be divided into a number of physiographic local units, which are described in this report as Shell Bank, Eastern Trough,

Northeast Plateau, Southern Plateau (shallow), Northern Plateau (deeper), Discovery Bank, Pike Bank, Western Trough, Coral and Aurora Banks, and the area around HIMI in the territorial sea. In addition, a deep-water local unit is recognised in the remaining areas for waters deeper than 1000 m.

The Biological Environment

Information on the distribution of benthic invertebrates and fish were mostly obtained from three extensive trawl surveys of fish in the early 1990s. The data on invertebrates was mostly qualitative with samples mostly sorted to Class level and, within each class, into morphologically similar groups of specimens. All fish samples had been identified to species and quantitative data were available. The echinoderms from the two later fish surveys were also identified to species.

Analyses of the benthic invertebrates showed that the invertebrate assemblages could be separated based on the physiographic classification, with the exception that the Southern Plateau should be split into two, an inner and outer area. The inner area has a greater affinity with the benthos in the territorial sea, while the outer area has an affinity with the adjacent Eastern Trough. There is a general east-west division in the fauna with a number of taxa restricted in their distributions.

The Kerguelen-Heard ichthyofauna is dominated by the sub-Antarctic nototheniids (*Notothenia rossi, Lepidonotothen squamifrons, Dissostichus eleginoides*) and the channichthyids (icefish) (*Champsocephalus gunnari, Channichthys rhinoceratus*). The inshore fish fauna of Heard Island is similar to that found at Îles Kerguelen and it is believed that the Kerguelen-Heard region is a single unit with regard to the fish. Four fish species (*Muranolepis marmouratus, Gobionotothen acuta, N. cyanobrancha* and *C. rhinoceratus*) are endemic to the Kerguelen-Heard region.

In general, the fish fauna is distributed widely across the plateau around HIMI. However, the fauna does vary from shallow to deep water and between the Shell Bank in the west and the remainder of the banks and plateau areas. Two species are able to support commercial fisheries: the mackerel icefish, *C. gunnari*, and the Patagonian toothfish, *D. eleginoides*. The stocks of mackerel icefish on Shell Bank and on the Southern Plateau are separate stocks with the former area having a stock unlikely to be able to support a sustainable commercial harvest.

Three species of seals are known to breed on Heard Island: southern elephant seals, Antarctic and Sub-Antarctic fur seals. There are four species of breeding penguins, three species of non-breeding penguins and 15 species of breeding flying birds and nine species of non-breeding flying birds that have been recorded at HIMI

Land-based marine predators from Heard Island feed predominantly on mesopelagic fish, most of which are myctophids, and squid. Commercial fish species appear in the diet of some of the predators. The mackerel icefish is known to occur in the diet of fur seals and king and gentoo penguins and seems to be important for these species during winter. The juvenile Patagonian toothfish occurs in the diet of southern elephant seals but observations indicate only low numbers of these fish are taken.

The important foraging areas for land-based marine predators in the HIMI region appear to be to the north-east of the island on the shelf break to the north of Shell Bank or further north towards the Polar Front. This is consistent with the foraging areas of many predators from Îles Kerguelen, which forage to the east and south east of this island in the Polar Frontal zone.

Current Commercial and Other Activities

Australian commercial fishing, within the AFZ around HIMI, began in April 1997 and continues to concentrate on *C. gunnari* and *D. eleginoides.* Fishing occurs in two main areas, rather than being disperrsed over the whole plateau region. The northern and central parts of the Kerguelen Plateau have been the target of illegal longline fishing for Patagonian toothfish in recent years. The northeastern area of the HIMI AFZ is the main area where illegal fishers have poached toothfish from the Australian EEZ.

Opportunities exist for recreation and tourist activities in the Territory. Few tourist visits have been made to the island due to geographical and climatic difficulties. Three Visitor Access Areas exist on Heard Island; Atlas Cove, Spit Bay and Long Beach.

Existing Management Regimes

Heard Island, McDonald Islands and the surrounding territorial sea (12 n.m. from shore) comprise a Wilderness Reserve, which is managed by the Australian Antarctic Division according to the Heard Island Wilderness Reserve Management Plan (AAD, 1995) and the *Territory of Heard Island and McDonald Islands Environment Protection and Management Ordinance 1987*. To reduce the possibility of interaction between the Wilderness Reserve and commercial fishing activities, there is a further 1 n.m. buffer zone surrounding the Wilderness Reserve, where fishing is prohibited (AFMA, 1998). The Territory is surrounded by the Australian Fishing Zone (AFZ) and the Australian Exclusive Economic Zone (AEEZ), which both extend from 12 to 200 n.m. from the islands, except for an area to the northwest which is separated by the Australia France Maritime Delimitation Agreement boundary.

Internationally, the Territory is subject to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). HIMI falls within the CCAMLR Statistical Division 58.5.2.

No fishing is permitted within the 12 n.m. territorial sea. Fishing boats may enter the 1 n.m. buffer zone, extending from the 12 n.m. territorial sea, but are not permitted to engage in any fishing in that zone. The Wilderness Reserve and the surrounding buffer zone comprises 6488 km^2 in which fishing is prohibited.

Subdivision of the HIMI region into biophysical local units

The analysis of the physical and biological environments at HIMI coupled with consideration of the ecology of these areas identifies thirteen potentially different local units (*sensu* IMCRA; spatial scale of 10s – 100s of km). The characteristics of these units are described in the report. The units are:

1. Aurora Bank
2. Coral Bank
3. Discovery Bank
4. Pike Bank
5. Shell Bank
6. near to Heard Island and McDonald Islands (territorial sea)
7. inner Southern Plateau
8. outer Southern Plateau
9. Northern Plateau
10. Northeastern Plateau
11. Eastern Trough
12. Western Trough
13. South of HIMI

Other Factors to Consider for Conservation of Benthic Habitats in the HIMI Region

A discussion of the potential ecology of the benthic assemblages is provided, based on available literature on deep-sea and Antarctic benthic communities.

Currently, bottom trawling for Patagonian toothfish and mackerel icefish is the primary threat to the benthic environment. The effects of bottom trawling generally are described. The toothfish fishery concentrates on a number of localised grounds. However, the Patagonian toothfish is widespread in the HIMI region. Thus, all benthic zones identified in this report are potentially vulnerable to disturbance by trawling. It is unlikely this fishery will compete with predators of toothfish because the level of predation of toothfish is low and the escapement of juvenile fish from this fishery is sufficient to sustain predators according to the current rules for setting catch limits on major prey species in CCAMLR. There is potential for some overlap between the icefish fishery at Shell Bank and the foraging activities of icefish predators. Shell Bank has a separate stock of icefish, which is much smaller than that on the Southern Plateau. The Shell Bank stock is likely to have only a low long-term annual yield and this stock is currently protected under CCAMLR Conservation Measure 159/XVII. Records from AFMA observers to date indicate that these trawl fisheries have few direct interactions with land-based marine predators.

Future threats may include the development of a longline fishery for Patagonian toothfish in the region and the development of a pelagic trawl fishery for mesopelagic fish (myctophids). A pelagic trawl fishery for mesopelagic fish has similar ramifications around HIMI as a trawl fishery for Antarctic krill has in higher latitudes. There is potential for overlap in the foraging range of land-based marine predators reliant on these fish and the activities of the trawl fishery because of the concentrations of these fish to the northeast of the island and, potentially, to the west in the Western Trough.

Recommendations for a Marine Protected Area (MPA)

It is recommended that an MPA be established to protect unique features of the HIMI benthic environment, representative portions of the different types of habitat in the region and the pelagic area in which land-based marine predators concentrate their local foraging activities.

The EEZ surrounding HIMI is managed already according to the obligations that Australia has to CCAMLR. A number of areas are recommended to be given IUCN Category 1 protection in addition to the existing protection given to the territorial sea. Additional areas are considered necessary because this report has identified that not all attributes of the HIMI environment are represented in the currently protected area of the territorial sea. The recommended areas and their purpose are:

- Territorial Sea. The existing 12 n.m. zone around HIMI provides for the protection of nearshore marine species as well as foraging areas for many flying birds, including the endemic Heard Island shag.
- South of HIMI. The inclusion of this area would provide a more complete representative section of the steep sloping margins of the Southern Plateau. Few data are available concerning this and other deep-water areas. However, as it is likely to be highly productive with a diverse assemblage in the depths between 500 and 1000 m, the inclusion of this area would be a precautionary approach to protecting some deep-water habitats.

- Discovery Bank and portions of Southern Plateau Inner, Southern Plateau Outer and the Northern Plateau. The inclusion of a strip encompassing Discovery Bank and portions of the inner and outer Southern Plateau and the Northern Plateau would provide representative habitats from these zones. These areas contain long-lived glass and other erect sponge habitats vulnerable to disturbance from bottom trawling, areas where juvenile Patagonian toothfish are abundant and an area where very small mackerel icefish have been found (in the Inner Southern Plateau, but outside the territorial sea). Thus, such a strip would provide important refuges for young fish that migrate to adjacent commercial fishing grounds.
- Coral and Aurora Banks and portions of the Western Trough. Coral and Aurora Banks are areas with diverse assemblages of benthic invertebrates, in particular, gorgonian corals, barnacles and other species that are vulnerable to disturbance from bottom trawling. The adjacent deeper water habitats are representative of the Western Trough and are thought to be highly productive.
- Shell Bank, deep waters to the north, and portions of the Eastern Trough and Northeastern Plateau. Shell Bank maintains a separate stock of mackerel icefish, which is considered by the CCAMLR Working Group on Fish Stock Assessment to be insufficient to support a commercial fishery (SC-CAMLR, 1997; SC-CAMLR, 1998). Australia has elected to close this area to the icefish fishery in the last two years. In addition, this bank maintains small aggregations of a variety of other fish species, including species that can be caught as by-catch to commercial trawling. Protection of Shell Bank will provide refuge for these small stocks as well as protecting the diverse echinoderm assemblage and other locally distributed species present on the bank. This area will also protect the unique shell grit habitat, which differs from the basaltic sand and cobbles of the greater HIMI area. The inclusion of the deep water habitats north of Shell Bank would protect the main foraging area around HIMI for land-based marine predators. These areas and the inclusion of portions of the Eastern Trough and Northeastern Plateau would provide a cross-section of habitats identified to be locally important as well as providing a representative area encompassing the eastern HIMI fauna.

An assessment is given in the report of how the recommended MPA areas meet the criteria for identification and selection of MPAs as part of the National Representative System of Marine Protected Areas.

Steps to the Implementation of an MPA in the HIMI region

The primary interest groups in the conservation and management of the HIMI region will be environment groups and commercial fishing interests. In the case of the latter, two permits are currently provided for fishing in the HIMI region. A fisheries management plan is currently being developed by AFMA for implementation by the end of 2000. The existing companies as well as the fishing industry generally are likely to wish to comment on conservation initiatives in the region.

The HIMI AEEZ is part of the CCAMLR area. Australia has obligations to abide by the principles of the convention and CCAMLR Conservation Measures set down each year by the Commission of CAMLR. A representative MPA at HIMI will not jeopardise our obligations under CCAMLR and is unlikely to cause conflict between Australia and other members of CCAMLR.

Future Work towards a successful long-term MPA in the HIMI region

The further development of an MPA will require some research to address the following questions:

1. What are the small- and large-scale effects of the current and expected future activities in the area?
2. Does the current MPA provide sufficient representation of the different kinds of marine habitats in the HIMI region, including deep-water habitats?
3. Is the protection of land-based marine predator foraging locations sufficient for the conservation of those species?
4. How well does the MPA configuration protect the features it is designed to protect?

A brief discussion is provided to indicate how each of these questions might be addressed in the future.

INTRODUCTION

Heard Island and McDonald Islands (HIMI) form Australia's most remote sovereign territory. They are situated in the south Indian Ocean, about 4100 km southwest from the coast of Western Australia, a similar distance southeast of South Africa and 1700 km north of Antarctica (Fig 1). The closest land is the French territory of Îles Kerguelen, situated about 480 km to the northwest. Arising from the northern half of the Kerguelen Plateau, Heard Island, McDonald Islands and Îles Kerguelen form the only exposed peaks of the plateau. The plateau forms one of the largest oceanic ridges, extending 2100 km in a northwesterly direction from Antarctica into the Indian Ocean. It is located between 45ºS to 63ºS and 65ºE to 83ºE. It is about 500 km across and rises 3 to 4 km above the surrounding ocean floor to within a kilometre of the sea surface. Water depths on the southern half of the plateau are as shallow as 700 m, but are mostly between 1500 and 2500 m (Harris, 1998). These islands have severe climates. They lie directly in the path of a convergence zone where cold-temperate oceans meet polar waters. Heard Island is directly in the path of the Antarctic Circumpolar Current and is in close proximity to the Polar Front.

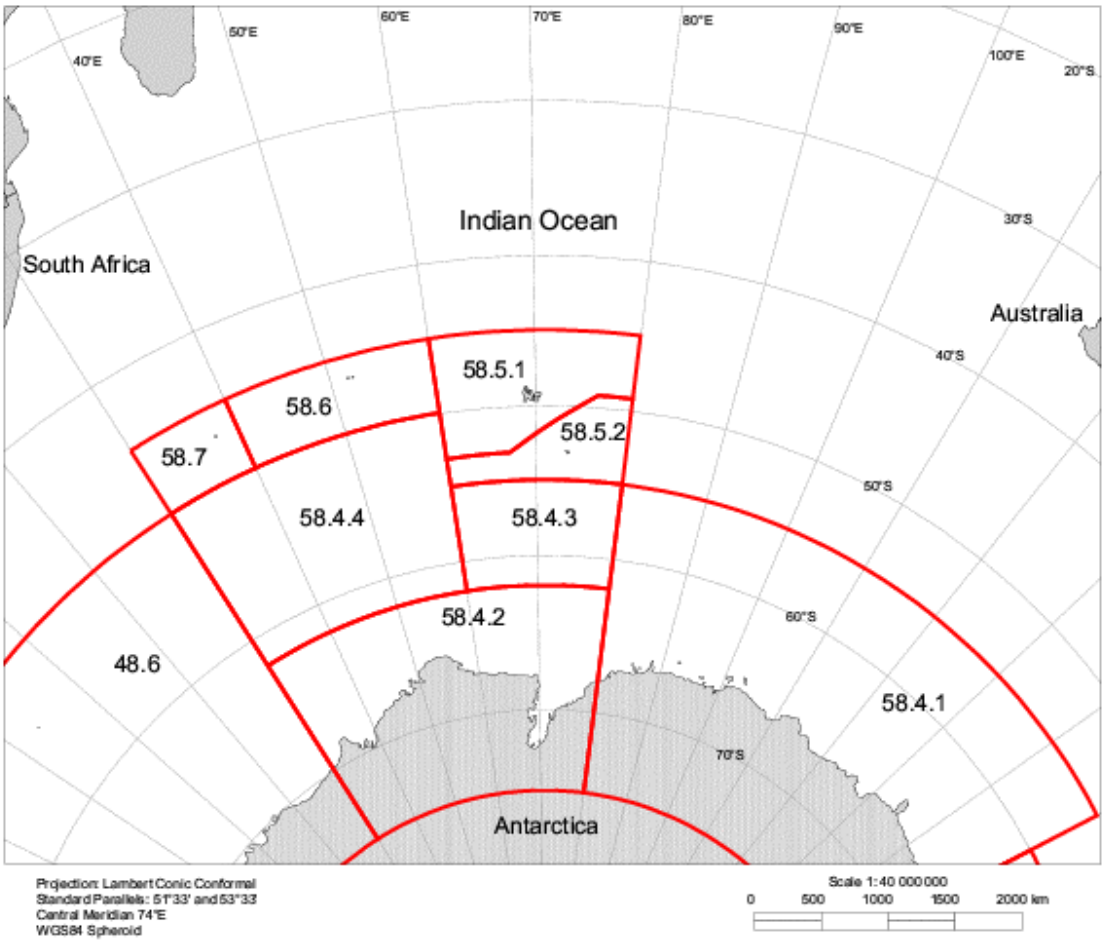
Australia has two exclusive economic zones (AEEZ) distant from the continental AEEZ in temperate and subantarctic waters: around Macquarie Island to the southeast of Australia and around HIMI to the southwest (Fig. 2). These regions are different in both proximity to the Polar Front and morphology. They are considered different in the recent Interim Marine and Coastal Regionalisation for Australia (IMCRA) (IMCRA Technical Group, 1998), in which they are known as the Macquarie Province and Kerguelen Province respectively.

Macquarie Island is well known for its land-based marine predators - albatross, petrels, penguins, elephant and fur seals, and has recently been recognised for its geological significance through its listing on the World Heritage register. Land-based marine predators use Macquarie Island for breeding as well as a place to haul out. Despite this, the foraging range of many of these predators usually extends beyond the limits of the AEEZ around the island, e.g. elephant seals seem to forage mostly around Antarctica, although some species such as gentoo penguins and fur seals feed closer to the island. The Commonwealth has recently declared a Macquarie Island Marine Park (MIMP) in this area, which is Stage 1 in the development of the MIMP and seeks to protect foraging areas of land-based marine predators and some benthic habitats to the east of the island. Currently, very little is known of the benthic habitats in this region, which will be considered in Stage 2 of the MIMP development.

The environmental values of the region of Heard Island and McDonald Islands, have been recognised in the listing of these islands and the territorial waters surrounding them (out to 12 n.m.) on the National Estate and World Heritage registers. The territorial waters have been declared as a Wilderness Reserve (equivalent to an IUCN Category 1a, which is an area managed mainly for science – see Appendix 1) under the *Territory of Heard Island and McDonald Islands Environment Protection and Management Ordinance 1987*. A number of domestic and international laws govern Australia's obligations beyond the 12 n.m. limit in the remainder of its AEEZ but there is no explicit reference as to how the area is to be managed. Notably, the World Heritage and National Estate registrations recognise the limitation of declaring only 12 n.m. as a wilderness reserve.

Trawl fisheries for Patagonian toothfish and mackerel icefish, *Champsocephalus gunnari*, have been established at Heard Island in recent years. Research in the area has focussed on these fisheries and on the biology of higher predators, including seabirds and marine mammals. Future work is aimed at understanding the linkages between predators and the commercial fish species.

Fig. 1 Location of Heard Island and the McDonald Islands in the southern Indian Ocean. Lines in bold mark the boundaries of the numbered CCAMLR statistical reporting areas in the Indian Ocean. Heard Island and the McDonald Islands lie within Statistical Division 58.5.2.



Trawling is favoured over longlining around HIMI because of the high levels of incidental mortality of seabirds reported for longline activities. However, trawling is recognised to have potentially considerable effects on the composition of benthic communities (Jennings & Kaiser, 1998). Together, these issues form the core of a project proposed to examine the impacts of fishing in the HIMI region being addressed by the Australian Antarctic Division.

This region has been the subject of three extensive benthic trawl surveys for fish in the last 10 years. As a result of these surveys and other smaller-scale surveys previously, some limited data are available on habitat types. However, no research has provided quantitative information on habitats and their biodiversity or on the effects of trawling on these habitats. With the advent of fishing in the area and the potential for other commercial activities on the shelf area surrounding these islands, the vulnerability of marine biodiversity on the shelf and appropriate strategies for conservation of marine biota (including potential configuration of marine protected areas) need to be assessed. In particular, an assessment needs to be made as to the strategies required to provide a suitable representative sample of marine biodiversity in the region, including whether the 12 n.m. territorial sea provides sufficient representation.

AIMS

This report aims to review the status of information on the HIMI region, to determine the future work that may enhance our understanding of the conservation values, and to determine a possible approach to protecting the conservation values of the HIMI region. It also will provide a structure for future work, which aims

- To further examine the distribution of different types of benthic habitats around Heard Island, including an evaluation of the differences between the benthic habitats in the territorial waters and those habitats in the remainder of the greater Australian EEZ,
- To examine the effects of trawling on these types of habitats, and
- To further develop management options for protecting the benthic environment.

STRUCTURE OF THE REPORT

This report is broken down into the following major sections:

Background

1. The Physical Environment
2. The Biological Environment
3. Current Commercial and Other Activities
4. Existing Management Regimes

Recommendations for a Marine Protected Area in the HIMI Region

5. Subdivision of the HIMI Region into Biophysical Local Units
6. Other Factors to Consider for Conservation of Benthic Habitats in the HIMI Region
7. Recommendations for a MPA
8. Steps to the Implementation of an MPA in the HIMI Region
9. Future Work Towards a Successful long-term MPA in the HIMI Region

BACKGROUND

THE PHYSICAL ENVIRONMENT

Bathymetry

Bathymetric maps of the Kerguelen Plateau and of the AEEZ surrounding Heard Island are shown in Figs. 2 and 3, respectively.

Bathymetric data for the Kerguelen Plateau region is available from GEBCO (1997) and Sandwell and Smith (1996). A number of institutions contribute to the GEBCO dataset, which is derived from ship echo-soundings. The isobaths are compiled and digitised on Mercator sheets at a scale of four inches per degree longitude (about 1:1 000 000). The Sandwell and Smith dataset provides seafloor topography from echo-soundings and satellite altimetry, with depth values on a 2 x 2 minute grid. This dataset is to be updated to an increased resolution of 1 x 1 minute grid in 1999. It is unlikely that the presently available Sandwell and Smith dataset will provide better bathymetric coverage than GEBCO around Heard Island because both datasets are derived from echo-soundings. The Australian Geological Survey Organisation (AGSO) also compiles bathymetric data using a combination of ship depth soundings and foreign multibeam surveys. This provides a more accurate estimation of the seafloor than soundings alone. However, this data is currently unavailable for the Kerguelen Plateau, but may be available some time in 2000.

Currently, the GEBCO dataset is being used to map the Kerguelen Plateau (Fig. 2) and data from the published 1 : 1 000 000 "Heard Island Bathymetric Map" is being used to map the area within the 200 n.m. AEEZ around Heard Island (Fig. 3). Data from the latter were provided by the Royal Australian Navy Hydrographic Service and include definite and approximate contours that were compiled from data acquired up to and including 1993. Soundings have been corrected using echo-sounding correction tables based on a speed of sound in water of 1 500 m/s.

Geomorphology

Geology

The region of the Kerguelen Plateau has been divided into five distinct domains: northern, central and southern portions, Elan Bank and the Labuan Basin (ODP, 1998) (Fig. 2). The predominant crustal structure of the Kerguelen Plateau is believed to be basaltic, but there are differences throughout the plateau. The crustal structure of the Northern Kerguelen Plateau (NKP), about 46ºS to 50ºS (including Îles Kerguelen and Rogers Seamount), differs significantly from that of the Central Kerguelen Plateau (CKP), about 50ºS to 55ºS (including Heard Island and the McDonald Islands). Igneous crust of the NKP is 17-19 km thick and composed of two layers, whereas the CKP is 19-21 km thick and is composed of three layers. On the Southern Kerguelen Plateau (SKP), about 55ºS to 63ºS, igneous crust can be divided into three layers, but their composition is significantly different from the NKP and CKP, suggesting that parts of the SKP are fragments of a volcanic passive margin (ODP, 1998).

Heard Island and the McDonald Islands were formed by volcanic activity. The McDonald Islands consist of three separate islands: Meyer Rock, Flat Island and McDonald Island; the latter being the largest with a maximum elevation of 186 m (Quilty *et al.*, 1983). Heard

Island is dominated by Laurens Peninsula and Big Ben; a conical volcano whose apex, Mawson Peak, is 2 745 m high and displays minor sporadic activity (Quilty *et al.*, 1983). Eighty percent of Heard Island is covered by permanent ice and snow. Heard Island was built up by three main phases of volcanic activity. Geologically, three basic units have been recognised on the island:

1) basal pelagic limestones and mafic intrusions (gabbros and dolerites, Palaeogene in age) on the Laurens Peninsula,
2) 'Drygalski Formation' or 'Agglomerate', consisting of sub-horizontal conglomerate sandstone mudstone and basalt flows, with trachyandesite intrusions, probably Late Miocene or Pliocene in age, and
3) massive basaltic lavas associated with Big Ben and the smaller volcanic centres of Mt Olsen-Anzac Peak of the Laurens Peninsula (this unit forms the bulk of the island); all formed in the last one million years (Clarke *et al.*, 1983; Colwell *et al.*, 1984).

The Ocean Drilling Program (ODP) has conducted three research cruises on the Kerguelen Plateau: Legs 119 (1987/1988), 120 (1988), and 183 (1998/1999). The purpose of the drilling was to determine the formation and evolution of the plateau. Legs 120 and 183 have drilled one site each into the Australian sector of the plateau. Collectively, the ODP have drilled seventeen sites on the plateau with most being situated in the southern part (Fig. 4). The results of Legs 119 and 120 have been published in the Initial Reports and Scientific Results volumes of the ODP. The results of Leg 183 are yet to be fully analysed and published, but the preliminary report is available at the following World Wide Web URL:

http://www-odp.tamu.edu/publications/prelim/183_prel/183toc.html

There are collectively 618 cores/grabs/dredges/drill samples for the Kerguelen Plateau region (within 60ºE to 90ºE, 45ºS to 65ºS), consisting of samples collected during cruises on the research vessels *Eltanin*, *JOIDES Resolution*, and the *Robert Conrad* between 1964 and 1988. Samples taken directly on the Kerguelen Plateau are shown in Fig. 4. Samples are archived and managed by Florida State University Antarctic Research Facility, Lamont-Doherty Earth Observatory and the Ocean Drilling Program, depending upon sample origin. Lengths of core samples range from 0 to 299 m. The descriptive results of these core samples can be found by searching in the 'Index to marine geological samples' at the following URL:

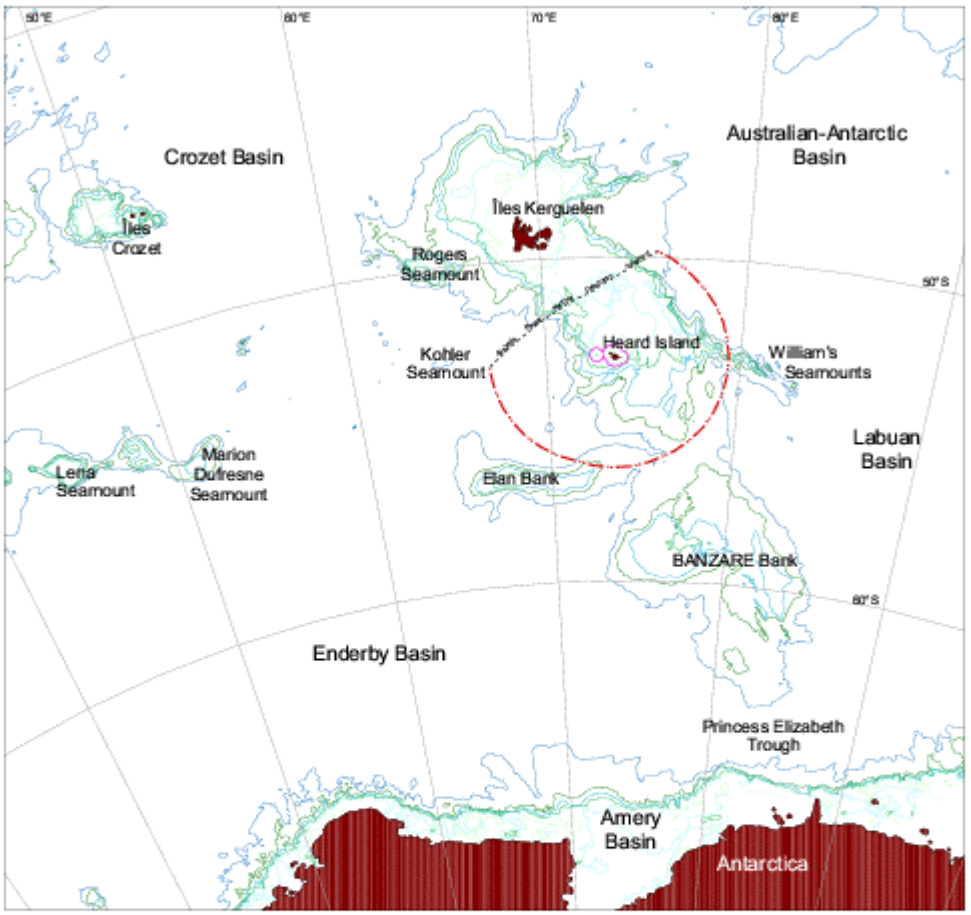
http://www.ngdc.noaa.gov/mgg/geology/seadas.html

The position data and primary lithology of surface sediment samples taken within the Heard Island region are summarised in Table 1. The primary surface sediments in the HIMI region comprise siliceous diatom mud or ooze with some stations revealing quantities of calcareous sediments and foraminifera.

Table 1: Descriptive results of core samples around Heard Island, from *Eltanin* cruises 47 (1971) and 54 (1972), and *Robert Conrad* cruise 008 (1964).

Research vessel and cruise	Sample code	Sample device	Latitude	Longitude	Water depth (m)	Primary lithology/texture	Components
Eltanin 47	002-BD	Dredge (old fmt)	51º09.5 S	75º46.5 E	1564	Siliceous, diatoms mud or ooze	Calcareous, foraminifera
	003-CG	Dredge (old fmt)	51º14.0 S	76º44.9 E	3293	Siliceous, diatoms mud or ooze	Volcanics Terrigenous
	005-CG	Grab	51º05.5 S	76º35.3 E	1408	Calcareous, foraminifera mud or ooze	Terrigenous
	006-CG	Grab	51º09.5 S	75º46.5 E	1757	Siliceous, diatoms mud or ooze	Calcareous, foraminifera Terrigenous
	007-CG	Grab	51º08.9 S	76º03.8 E	2328	Calcareous, foraminifera mud or ooze	Siliceous
	012-CG	Grab	53º59.1 S	70º45.0 E	3605	Siliceous, diatoms mud or ooze	Calcareous, foraminifera
	013-CG	Grab	53º21.0 S	70º55.8 E	3096	Siliceous mud or ooze	Calcareous, foraminifera
	014-CG	Grab	53º21.3 S	70º58.5 E	2722	Siliceous, diatoms mud or ooze	Calcareous, foraminifera
	015-CG	Grab	53º21.2 S	71º06.0 E	2295	Siliceous diatoms mud or ooze	
	016-CG	Grab	53º21.1 S	71º06.0 E	1924	Siliceous diatoms mud or ooze	Calcareous, foraminifera
	017-CG	Grab	53º20.4 S	71º39.4 E	1692	Siliceous diatoms mud or ooze	
	017-PC	Piston core	53º21.1 S	72º10.9 E	958	Siliceous diatoms mud or ooze	Calcareous, foraminifera Siliceous, radoilaria
	018-CG	Grab	53º17.9 S	71º43.1 E	1472	Siliceous diatoms mud or ooze	
	018-PC	Piston core	52º57.9 S	72º51.1 E	215	Volcanics ash	Siliceous, diatoms
	019-CG	Grab	53º17.8 S	71º48.1 E	1312	Siliceous diatoms mud or ooze	
	020-CG	Grab	53º17.6 S	71º55.0 E	1121	Terrigenous, siliceous, diatoms	
	021-CG	Grab	53º20.0 S	72º14.4 E	929	Terrigenous, siliceous, diatoms	
	022-CG	Grab	53º19.8 S	72º56.6 E	757	Calcareous, foraminifera mud or ooze, sandy	
	023-CG	Grab	52º56.9 S	72º54.9 E	215	Siliceous diatoms mud or ooze	Volcanics and terrigenous
	024-CG	Grab	52º56.0 S	72º55.0 E	218	Calcareous shells	Siliceous, sponge spicules
	025-CG	Grab	52º47.2 S	72º24.2 E	440	Siliceous diatoms mud or ooze, sandy	Calcareous, foraminifera
	026-CG	Grab	52º46.6 S	72º22.7 E	546	Terrigenous sand	Siliceous, diatoms Volcanics
	039A-PH	Gravity core	53º59.1 S	70º45.0 E	3681	Siliceous diatoms mud or ooze	Calcareous, foraminifera Siliceous, radiolaria
	041A-PH	Gravity core	53º21.0 S	70º55.8 E	3114	Siliceous diatoms mud or ooze	Calcareous, foraminifera Siliceous, radiolaria
	056A-PH	Gravity core	51º22.8 S	73º09.0 E	277	Volcanics ash	Siliceous, diatoms Calcareous, foraminifera
Eltanin 54	005-PC	Piston core	56º52.6 S	74º33.3 E	2959	Calcareous, foraminifera mud or ooze	Siliceous, diatoms
	006-PC	Piston core	55º28.1 S	76º01.0 E	2163	Siliceous diatoms mud or ooze	Calcareous, foraminifera Siliceous, radiolaria
	006-TC		55º28.1 S	76º01.0 E	2163	Siliceous diatoms mud or ooze	Calcareous, foraminifera
Robert Conrad 008	047	Piston core	55º03.0 S	71º47.0 E	3502	Laminated shell hash Silt dominant	Volcanic sand
	048	Piston core	53º16.0 S	76º55.0 E	1099	Interbedded foraminiferal marl ooze	

Fig. 2 Bathymetry of the Kerguelen Plateau and the location of surrounding deep ocean basins.



Legend

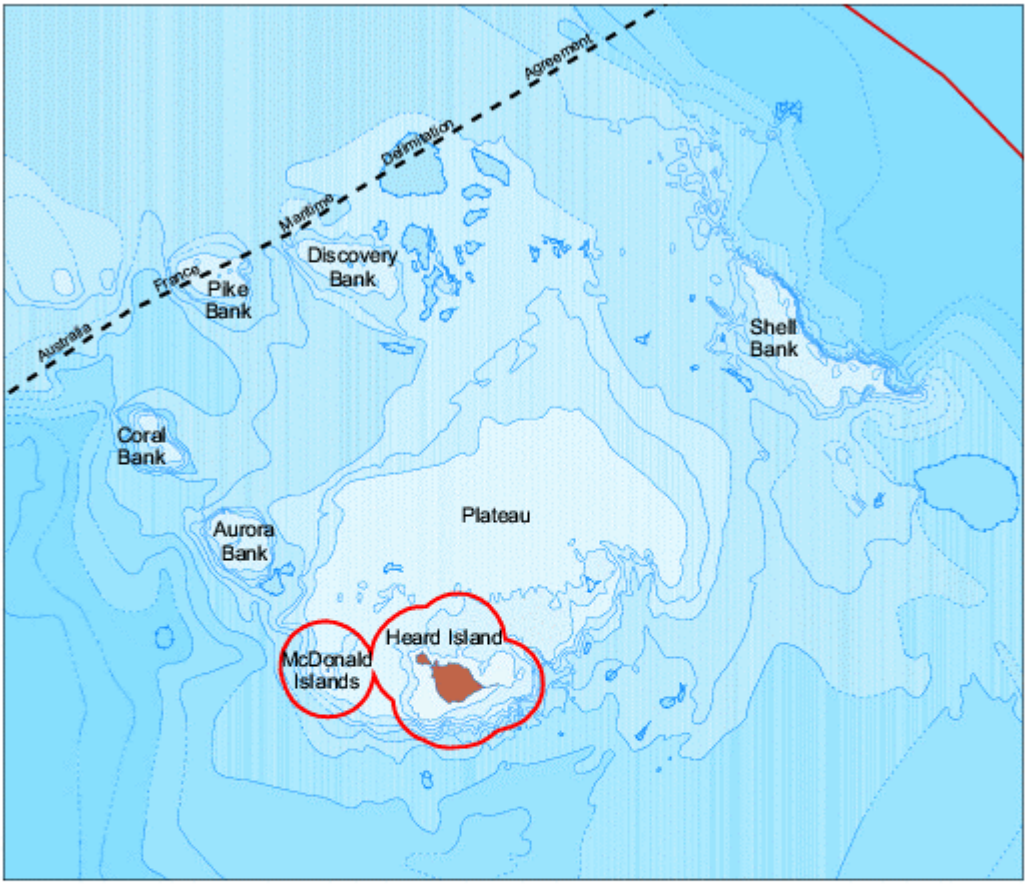
Maritime Boundaries
- 12 n.m. territorial sea
- 200 n.m. AEEZ
- AFMDA

Bathymetry
- 200 m
- 500 m
- 1000 m
- 1500 m
- 2000 m
- 3000 m

Scale 1: 19 000 000
0 300 600 900 1200 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33
Central Meridian 74°E
WGS84 Spheroid

Fig. 3 Regional bathymetry surrounding Heard Island and the McDonald Islands. Isobaths are shown every 100 m to 500 m, then at 750 m and 1000 m, followed by 500 m intervals after the 1000 m isobath.



Legend

Maritime Boundaries
- 12 n.m. territorial sea
- 200 n.m AEEZ
- AFMDA

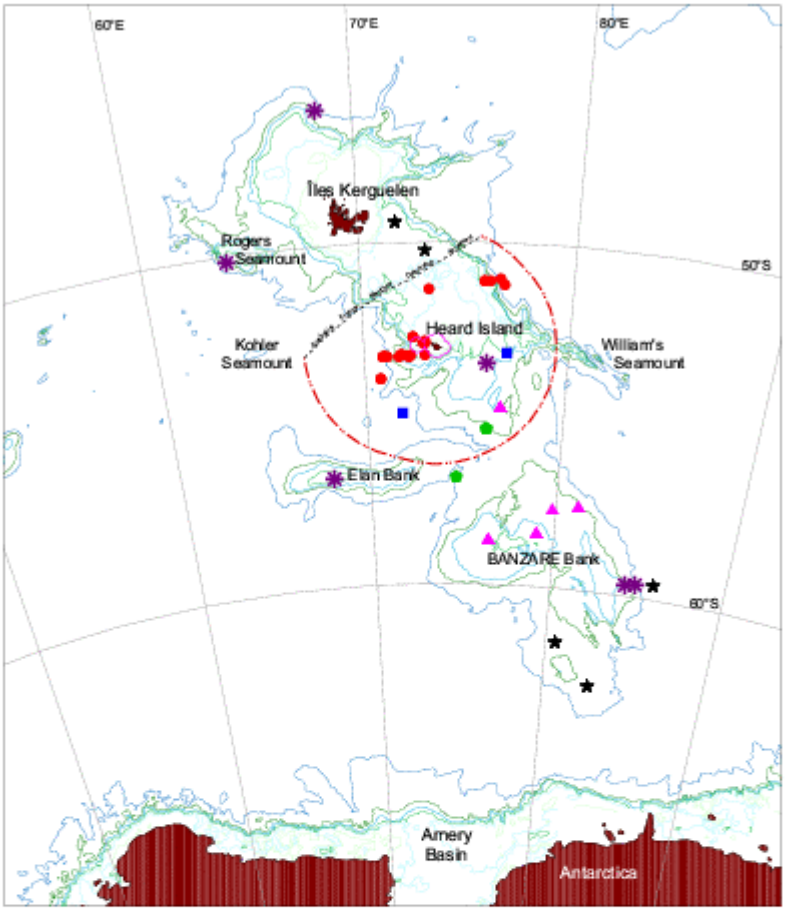
Bathymetric Contours
- Definite
- Approximate
- Depression Contour

Bathymetric Tints
- land
- 0 - 100 m
- 100 - 300 m
- 300 - 500 m
- 500 - 1000 m
- 1000 - 2500 m
- > 2500 m

Scale 1 : 2 750 000
0 50 100 150 200 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33'
Central Meridian 47°E
WGS84 Spheroid

Fig. 4 Location of geological sampling sites on the Kerguelen Plateau.



Legend

Cruise Details

- Robert Conrad cruise 008 (1964) (n = 2)
- Eltanin cruise 47 (1971) (n = 25)
- Eltanin cruise 54 (1972) (n = 3)
- ODP Leg 119 (1987/88) (n = 6)
- ODP Leg 120 (1988) (n = 5)
- ODP Leg 183 (1998/99) (n = 6)

Maritime Boundaries

- 12 n.m. territorial sea
- 200 n.m. AEEZ
- AFMDA

Bathymetry

- 200 m
- 500 m
- 1000 m
- 1500 m
- 2000 m
- 3000 m

Scale 1: 18 000 000

0 300 600 900 1200 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33'
Central Meridian 74°E
WGS84 Spheroid

Sedimentation and mobility

Sedimentation rates for the Kerguelen Plateau have been estimated to be 3 to 10 Bubnoff (mm per 1000 years). Directly around Îles Kerguelen and Heard Island rates have been estimated to be 10-30 Bubnoff. The thickness of the sedimentary cover is estimated to be between 0.5 and 1.0 km for the Kerguelen Plateau (NOAA, 1999).

Harris and Coleman (1998) used wave models to estimate global shelf sediment mobility (fine sand grains of 0.1 mm diameter) due to swell waves. Their model assumes the shelf area is comprised of cohesionless quartz spheroids and also ignores the frictional drag of bedforms and local currents and eddies. However, without actual data on shelf grain size distributions and wave and tidal output, it does provide some indication of the areas that are most likely to be affected by waves. The area around Heard Island, approximately out to the 200 m isobath (6 350 km^2), was estimated as an area of varying disturbance (Harris, 1998). Table 2 lists the percentage of time sediments may be mobilised and the amount of area where this was estimated to occur. To the north, northeast, and east of Heard Island, sediments become progressively less mobilised at increasing distances away from the island. This also occurs to the south of the island, but sediment mobilisation is less pronounced than to the north.

Table 2: Amount of time (%) and area (km^2) that sediments may be mobilised by wave action around Heard Island approximately out to the 200 m isobath (P. Harris, 1998

Sediment mobility time (%)	Area (km^2)
1	1 350
1 to <10	1 600
>10 to <50	1 350
>50 to <100	1 100
100	950

Oceanography

Oceanographic Setting

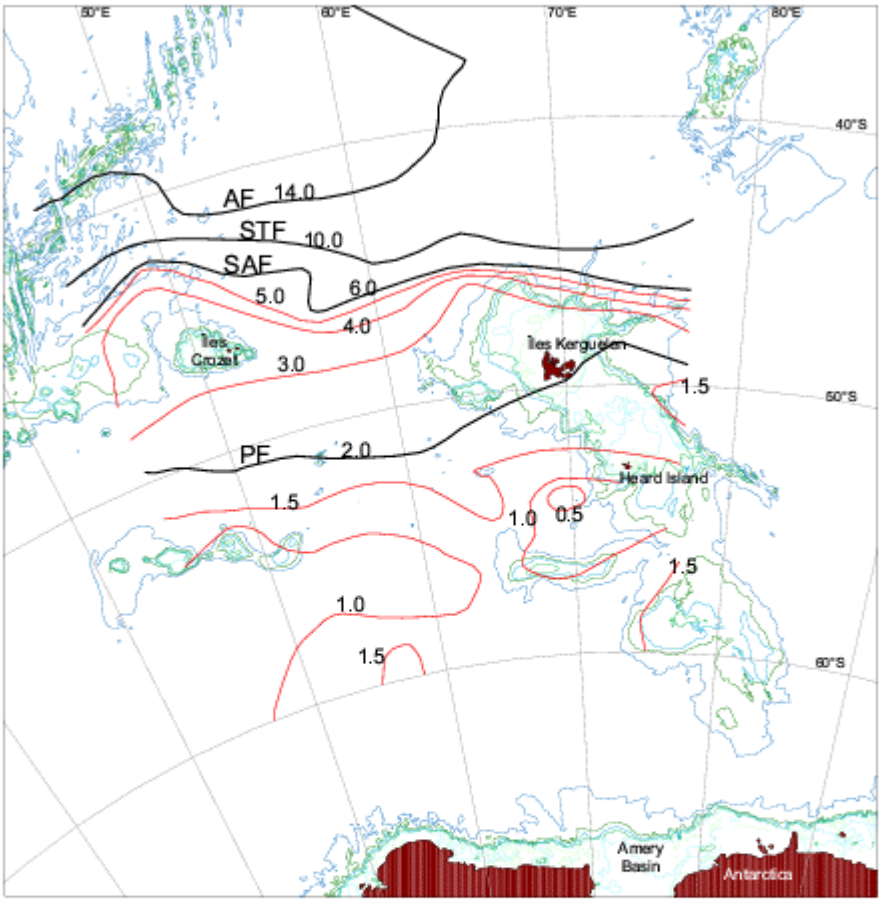
The Kerguelen Plateau is surrounded by deep ocean basins: to the northwest is the Crozet Basin; to the northeast is the Australian-Antarctic Basin; to the east is is the Labuan Basin; to the south is the 3500m deep Princess Elizabeth Trough; and to the southwest is the Enderby Basin (ODP, 1998) (see Fig. 2).

The northern and central parts of the plateau (NKP and CKP) have shallow water depths (<1000 m) and contain a major sedimentary basin (Kerguelen-Heard Basin). The southern plateau (SKP) is characterised by deep water, from 1500 to 2500 m (ODP, 1998) (see Fig. 2).

Currents

Several frontal systems exist in the southern Indian Ocean, the largest of which forms the Antarctic Circumpolar Current (ACC) (Sparrow *et al.*, 1996). The ACC links all the major oceans and it's eastward flow is driven by the world's strongest westerly winds, found between about 45ºS and 55ºS (Orsi *et al.*, 1995). The Kerguelen Plateau is a major barrier to this eastward flow, preventing direct mass transport of the deep-reaching waters of the ACC. The fronts are identified by sharp boundaries of temperature, salinity and density between different water masses, especially in the upper few hundred metres. These fronts are, from north to south, the Agulhas Return Current Front (AF), Subtropical Front (STF), Subantarctic Front (SAF) and Polar Front (PF) (Park & Gamberoni, 1997) (Figs. 5 and 6). The most important front in the Kerguelen Plateau region is the PF. It should be noted that 'Antarctic Convergence' and 'Antarctic Polar Front' are occasionally used in the literature but PF is more widely accepted and is used in this report.

Fig. 5 Water temperature values (°C) at 200 m depth from recent and historical hydrographic data. Lines in bold correspond to major oceanic fronts for this region (adapted from Park and Gamberoni, 1997).



Legend

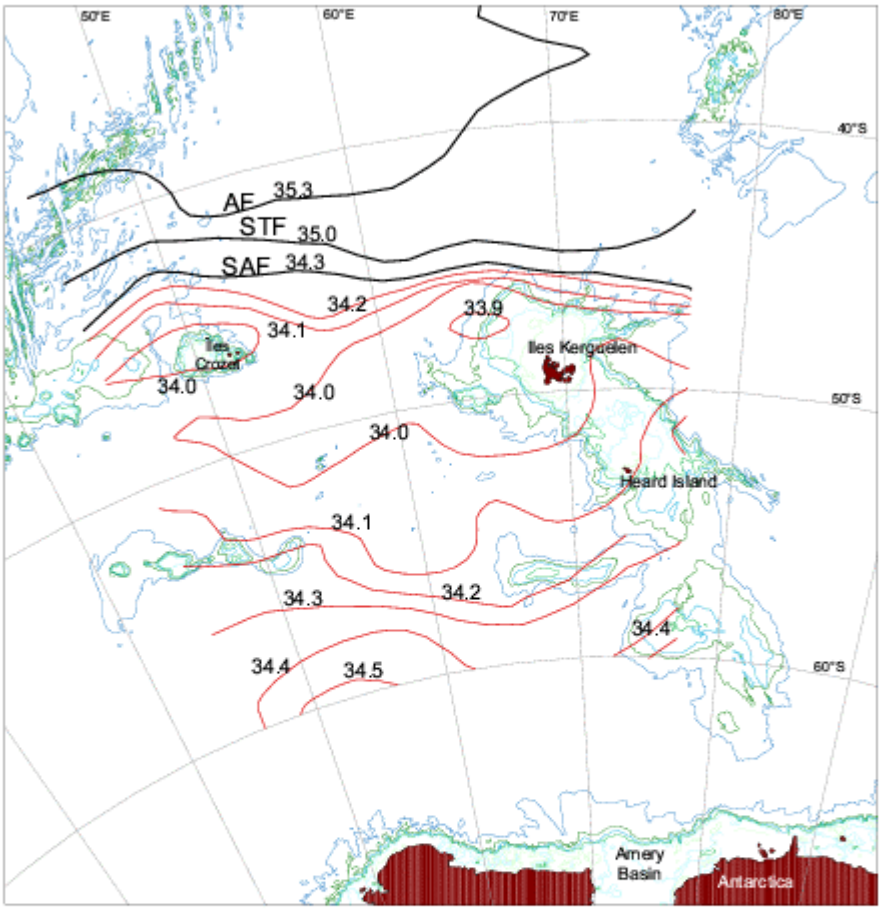
Fronts
AF = Agulhas Return Current Front
STF = Sub-Tropical Front
SAF = Sub-Antarctic Front
PF = Polar Front

Bathymetry
200 m
500 m
1000 m
1500 m
2000 m
3000 m

Scale 1: 23 000 000
0 300 600 900 1200 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33'
Central Meridian 74°E
WGS84 Spheroid

Fig. 6 Salinity values (‰) at 200 m depth from recent and historical hydrographic data. Lines in bold correspond to properties of major oceanic fronts for this region (adapted from Park and Gamberoni, 1997).



Legend

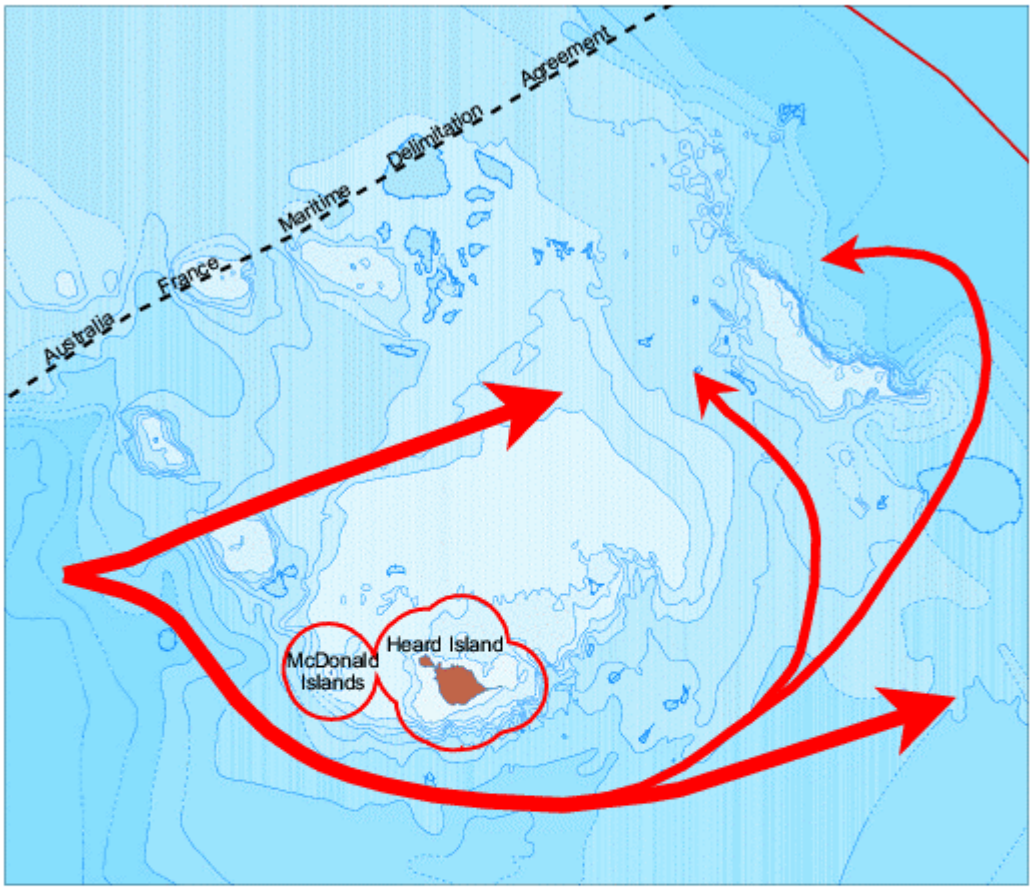
Fronts
AF = Agulhas Return Current Front
STF = Sub-Tropical Front
SAF = Sub-Antarctic Front

Bathymetry
200 m
500 m
1000 m
1500 m
2000 m
3000 m

Scale 1: 23 000 000
0 300 600 900 1200 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33'
Central Meridian 74°E
WGS84 Spheroid

Fig. 7 Heard Island and the McDonald Islands regional oceanography. Arrows show the inferred surface currents from local oceanographic data and observations.



Legend

Maritime Boundaries
- 12 n.m. territorial sea
- 200 n.m AEEZ
- AFMDA

Bathymetric Contours
- Definite
- Approximate
- Depression Contour

Bathymetric Tints
- land
- 0 - 100 m
- 100 - 300 m
- 300 - 500 m
- 500 - 1000 m
- 1000 - 2500 m
- > 2500 m

Scale 1 : 2 750 000

0 50 100 150 200 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33'
Central Meridian 47°E
WGS84 Spheroid

The Polar Front has been reported to exhibit considerable spatial and temporal variability, especially near the Kerguelen Plateau. This may be partly attributable to inconsistencies in the definition of the boundary characteristics of the PF (e.g. the northern limit of 2ºC; an isotherm at 200 m; or the northern boundary of antarctic waters) (Nagata *et al.*, 1988; Sparrow *et al.*, 1996). This report uses the more widely accepted definition of the PF as the northern limit of a temperature minimum of 2ºC at the 100 to 300 m depth range (Park *et al.*, 1993; Belkin & Gordon, 1996; Park & Gamberoni, 1997). Reported positions of the PF, in the Kerguelen Plateau region, are across the shallow plateau north of Îles Kerguelen (e.g. Gamberoni *et al.*, 1982; Belkin & Gordon, 1996), south of Îles Kerguelen (e.g. Park *et al.*, 1993; Orsi *et al.*, 1995), between Îles Kerguelen and Heard Island (e.g. Macintosh, 1946), and south of Heard Island (Sparrow *et al.*, 1996). A recent analysis of new and historical hydrographic data suggests the PF is located at or just south of 51ºS at 62ºE (Fig. 5) (Park & Gamberoni, 1997). This position can only be used as an approximation because of the relatively large distance between sampling stations (1º or 2º in latitude), but it is the accepted position used in this report. Park and Gamberoni (1997) suggest the PF varies by 0.5 to 1.0 degree from the 2ºC boundary represented in Fig. 5. At this latitude the PF is not associated with any strong baroclinic sheer, which is regarded as an unusual characteristic of the PF in this region of the Southern Ocean and is believed to result from the effect of the Kerguelen Plateau as a topographic barrier (Park *et al.*, 1998a). The PF is thought to move in a north, northeasterly direction as it passes around the south of Îles Kerguelen up to latitude 48ºS. From there it travels in a southeasterly direction back down to about 50ºS. Directly north of Heard Island it is estimated to be between 48ºS and 49ºS (Park *et al.*, 1993).

North of the PF there is a high contrast in the salinity of surface waters between the west and east of the Kerguelen Plateau. Relatively fresher water (<33.9) is found to the west and it is speculated that this decreased salinity is a product of atmospheric precipitation, resulting from the confluence of subantarctic and subtropical waters (Park *et al.*, 1998a). Similar low-salinity surface waters are also found in the western Enderby Basin. This surface salinity minimum (<33.8) extends to the east and is thought to be due to the eastward movement of meltwater from Antarctica (Park *et al.*, 1998a).

As previously mentioned, the plateau creates a topographic barrier to the eastward flow of the ACC and water in the deep basin to the west of the Kerguelen Plateau is believed to be relatively stagnant (Park *et al.*, 1998a). Most of the ACC is thought to be deflected in a northeasterly direction and travel over the shallow section of the plateau, north of Îles Kerguelen (Sparrow *et al.*, 1996). The ACC then travels down the eastern side of the plateau (Sparrow *et al.*, 1996), where a relatively warm inflow of bottom water occurs as part of the ACC, between the plateau and the mid-ocean ridge (Speer & Forbes, 1994). The temperature of this inflowing water may be greater than about 0ºC (Speer & Forbes, 1994). In the Heard Island region, most water is thought to move in an easterly direction across the north and south of the island (see Fig. 7). However, there is a passage of water that moves in a northwesterly direction up through the trough between the relatively shallow central plateau and west of Shell Bank (R. Williams, AAD, pers. comm.). Water is also known to eddy around the east of Shell Bank in an anticlockwise direction (R. Williams, AAD, pers. comm.). South of Heard Island, surface water currents move in a northeasterly direction, whereas water currents at about 800 m move in a northwesterly direction up the slope to Heard Island (Forbes, unpublished manuscript). In 1993, winter sea surface temperatures within this region were found to gradually decrease by at least 1ºC from west to east. Temperatures at 73ºE (west of Heard Island) were recorded at >1.5ºC, whereas temperatures at 77ºE (near Shell Bank) were <0.5ºC (R. Williams, AAD, unpublished data).

To the south of the PF towards the southernmost part of the Kerguelen Plateau, water temperatures drop from 2ºC at the PF to less than –1.7ºC near the coast of Antarctica. In the Heard Island region two water masses commonly occupy the top 1000 m of the water column;

Antarctic Surface Water (AASW) uppermost and upper Circumpolar Deep Water (uCDW) below (Forbes, unpublished manuscript). The local characteristics of these water masses (Table 3) are typical of the Kerguelen Plateau and may differ from water masses of the same names found in other areas of the Southern Ocean (Forbes, unpublished manuscript). For example, AASW is typically colder (~ 0ºC) and fresher (~ 34.0) towards Antarctica.

Table 3: Characteristics of Antarctic Surface Water (AASW) and upper Circumpolar Deep Water (uCDW).
(from Forbes, unpublished document)

Water Mass	Temperature	Salinity	Oxygen
AASW	<1.0	<34.4	6.0 – 8.0
UCDW	1.5 – 2.0	34.5 – 34.7	4.0 – 5.5

Subdivision of the HIMI region into local units based on physical characteristics

The region of the Kerguelen Plateau within the AEEZ has been divided into 12 local units (*sensu* IMCRA Technical Group, 1998; spatial scale of 10s – 100s of km), based on the benthic environment and oceanographic conditions (Fig. 8). The division of the local units is based on the information above, coupled with observations made during the three AAD research cruises to the area in 1990, 1992 and 1993. There are five banks (Aurora, Coral, Pike, Discovery and Shell banks) that are geographically isolated and possess different physical characteristics. The plateau area, outside of the territorial sea, has been divided from the north and northeast of the plateau. The last three local units are the deep troughs on the western and eastern sides of the main plateau area and the remaining areas in water deeper than 1000m, which are predominantly to the south of the island. The physical characteristics of each of the units are described below, other than the southern "deep-water" local unit.

The Territorial Sea has a mostly smooth substratum with medium-grain black basaltic sand, with basaltic cobbles and boulders common in the nearshore area. Water depths range from 0 to 300 m deep, except the southern margins are steep slopes descending to 1000 m depth. The substratum in this area is more disturbed by wave action than other areas in the AEEZ. This occurs mostly in water shallower than 200 m, particularly in the north, northeast and eastern areas.

Aurora Bank is a mesa-like bank rising steeply from deep water. Water depths in the area range from 300 to 500 m deep. The bank has a relatively large and flat top, but the top is rugged with pinnacles, boulders and a covering of sand. It is locally highly productive in relatively warm, nutrient-rich waters as it is one of two banks that first intercepts the ACC.

Coral Bank is a 300 to 500 m deep mesa-like bank that rises steeply from deep water. It has a flat but rugged top with pinnacles, boulders and a covering of sand. It is locally highly productive in relatively warm, nutrient-rich waters as it is influenced by relatively warm water of the ACC.

Discovery Bank is a 300 to 400 m deep whale-backed bank rising from the Northern Plateau. The bank is reasonably flat with basaltic sand, but can be pebbly and craggy in places. It is influenced by relatively warm water of the ACC.

Pike Bank is a 300 to 500 m deep bank that is flat on top but pebbly and gnarly on the slopes. The eastern slopes are relatively steep.

Shell Bank is a 180 m to 350 m-deep, isolated mesa-like bank with a flat, even top. The bank has steep craggy slopes with a craggy rim. It has white sand and is uniquely covered with a thick deposit of shell grit. There is relatively cool water around the bank and an eddy of productive water influences it.

The Southern Plateau has a broad, flat and even substratum with the east and west margins generally steep and undulating to craggy slopes. Water depths range from 200 to 500 m deep. The ground is mostly smooth, medium-grain black basaltic sand and grey silt. The area is influenced by cooler water from the Eastern Trough and the relatively warm water of the ACC in the west and north of this unit.

The Northern Plateau is the relatively narrow region of the main plateau. The area is deeper than the Southern Plateau, averaging about 500 m depth. It has a very uneven topography, with a hard substratum of basaltic cobbles, small pinnacles, black sand and grey silt. Cooler water from the Eastern Trough and the relatively warm water of the ACC in the west and central part of this unit influence the area.

The Northeastern Plateau has a hard substratum with cobbles, yellow sand and grey silt. Water depths range from 500 to 700 m deep, sloping into deeper water in the east.

The Eastern Trough is wide in the southern part and water depths average 750m. The substratum is composed of fine grey sand and silt. The area contains cooler water from either the eddy in the lee of the plateau and/or of antarctic origin.

The Western Trough is topographically similar to the Eastern Trough but it is deeper and more open to the influence of the ACC. Water depths are from 500 m to greater than 1500 m deep. The area experiences the warmest waters, as this is the first location where the ACC encounters the plateau around HIMI.

Fig. 8 Local units within the HIMI AEEZ based on substratum characteristics and features of the physical environment.

The deep water southern unit is not shown but comprises all of the deep areas to the south of the local units indicated.

THE BIOLOGICAL ENVIRONMENT

Distribution of fauna

Lists of benthic invertebrates and fish found in the territorial sea surrounding HIMI have been published previously (AAD, 1995) and are given in Appendices 2 and 3 respectively. Recent identifications by the Museum of Victoria of echinoderm fauna described below are also included in Appendix 2.

The distribution of benthos in the greater HIMI region was examined using samples from five different voyages to the area (Table 4). Fig. 9 shows the location of the biological sampling sites within the HIMI AEEZ. All surveys obtained samples from areas shallower than 1000m.

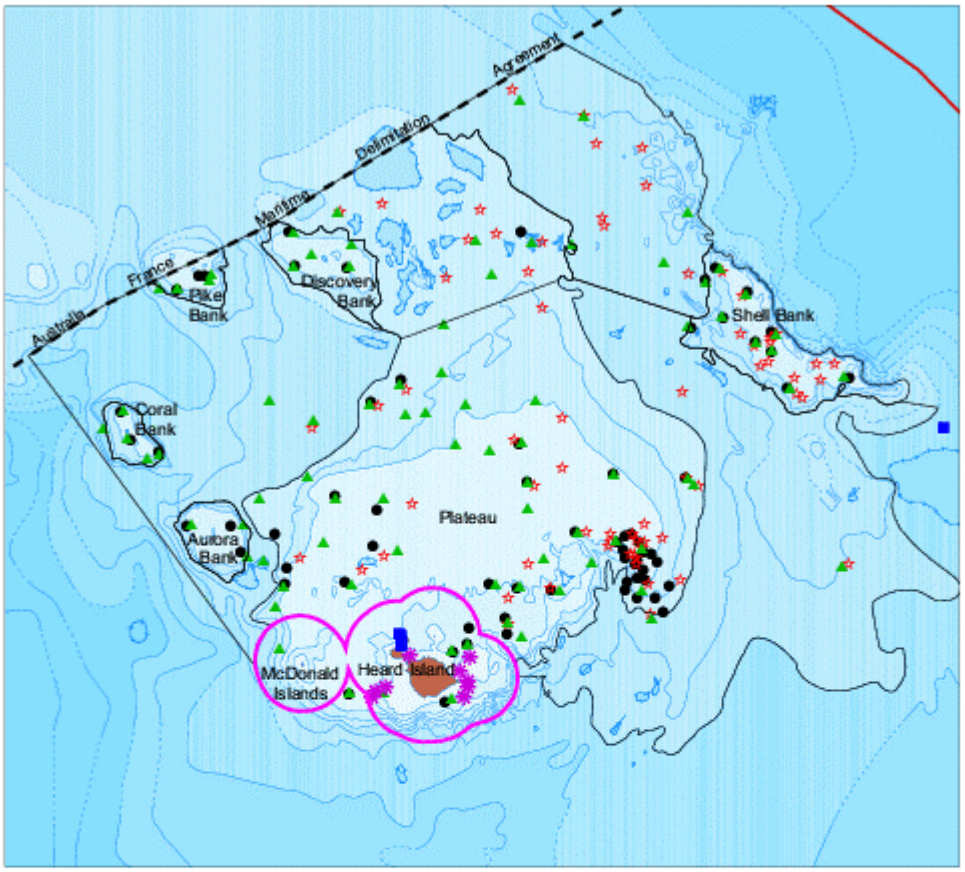
Three of these surveys (1990-1993) were undertaken by Dick Williams and the AAD using bottom trawl gear, and were undertaken to assess the distribution and abundance of the dominant fish species in the region (see Williams & de la Mare, 1995 for details). These were the most comprehensive surveys of the five available. Data arising from these surveys were used to analyse the distribution of fish in the HIMI region. Benthic invertebrates obtained during these surveys were caught as incidental by-catch in the operation to trawl for fish; i.e. invertebrates were retrieved as a result of entanglement in the nets or captured with the fish. Thus, this sampling provides a qualitative indication of the types of fauna found in these areas rather than quantitative measures of abundance. These analyses were supplemented by general observations by Dick Williams during these fish surveys and from participation as an observer during some commercial fishing operations from 1996 to the present.

Table 4: Details of the samples available for analysing the distribution of fish and benthic invertebrates in the HIMI region.

Year	Vessel	Sampling purpose	Sampling equipment	Number of stations sampled	Number of stations at which benthos was collected	Status of the benthos samples	Benthos samples lodged at
1964	*Umitaka Maru*	Geology	Dredge / Trawl	5	5	Mostly unsorted	Museum of Victoria
1985	*Nella Dan*	Geology / Biology	Beam trawl	9	9	Mostly unsorted	Museum of Victoria
1990	*Aurora Australis*	Benthic Fish	Otter Trawl	84	80	Mostly sorted but identifications need to be verified	South Australia Museum
1992	*Aurora Australis*	Benthic Fish	Otter Trawl	68	39	Mostly unsorted	Museum of Victoria
1993	*Aurora Australis*	Benthic Fish	Otter Trawl	68	49	Mostly unsorted	Museum of Victoria

All material was preserved on board the research vessels and later stored in ethanol.

Fig. 9 Trawl survey station positions within the HIMI AEEZ.



Legend

Cruise Details

- Umitaka Maru (1967) dredge and trawl sites (n = 4)
- Nella Dan (1985) trawl sites (n = 9)
- Aurora Australis (1990) Otter trawl sites (n = 83)
- Aurora Australis (1992) Otter trawl sites (n = 33)
- Aurora Australis (1993) Otter trawl sites (n = 35)

Maritime Boundaries

- 12 n.m. territorial sea
- 200 n.m. AEEZ
- AFMDA

Bathymetric Contours

- Definite
- Approximate
- Depression Contour

Bathymetric Tints

- land
- 0 - 100 m
- 100 - 300 m
- 300 - 500 m
- 500 - 1000 m
- 1000 - 2500 m
- > 2500 m

Scale: 1: 2 750 000

0 50 100 150 200 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33'
Central Meridian 74°E
WGS84 Spheroid

Benthic invertebrates

Material from four voyages is held by the Museum of Victoria while the material from the 1990 voyage of the Aurora Australis is held by the South Australia Museum. Some material had been separated to species but most of the material remained unsorted. There was only sufficient time during this study to separate the Museum of Victoria samples to morphotypes. The samples from the South Australia Museum had already been separated in this way. Morphotypes are groups of specimens that have the same or similar external morphologies and general characteristics. These could be classified formally to at least the taxonomic level of Class. However, further subdivision would require specialist taxonomic expertise. Summaries of the material held at both museums are given in Tables 5a and 5b.

The echinoderms were the most ubiquitous animals in the samples. These fauna in the samples from the Museum of Victoria were identified to species by Tim O'Hara, Mark O'Loughlin and Peter Tutera of the Museum of Victoria. Many echinoderms in the South Australia Museum collection had been identifed to species. However, confirmation of these identifications needs to be undertaken in light of recent syntheses of subantarctic fauna (e.g. O'Hara, 1998). This was unable to be completed in the time available. Thus, the echinoderm data from 1990 were not included in this analysis. The echinoderm data from 1992 and 1993 were analysed separately.

For the remaining taxa (morphotypes), the results presented here are based on the lowest level of classification possible in the time available, including further refinement to morphotypes where such morphotypes were clearly separate taxa. Data from all voyages were analysed together.

A number of points arose out of the initial summary of the specimens available:

1. Few stations were sampled in 1964 and in 1985 and all of these stations occurred within the 12 n.m. territorial sea. Also, the nature of this sampling using combinations of dredges and beam trawls was likely to yield different results to the qualitative sampling of benthos arising from the fish surveys using otter trawls in the 1990s. These results are included in the analysis below but are biased towards smaller infauna and epibenthic fauna. In contrast, the fish survey trawls were more likely to retain larger epibenthic fauna and less fragile fauna. Consequently, taxa such as bryozoans, gorgonians and polychaetes are likely to be underrepresented in the trawl surveys.
2. The echinoderm fauna was the most prevalent invertebrate fauna to be sampled in the HIMI region during the fish surveys and the detailed identification by the Museum of Victoria provides the best opportunity for determining differences in assemblages between areas.
3. Analyses of the distribution of taxa and the types of assemblages that may be present in different parts of the HIMI region must be qualitative because of the qualitative nature of the benthos sampling, which was primarily done as an incidental activity to the fish surveys. This type of sampling enables a qualitative examination of the prevalence of individual species from stations within particular strata. However, it is difficult to undertake community level analyses, which endeavour to identify important associations between species. This is because the trawls will not necessarily have collected specimens of all species present at the respective sampling stations, particularly smaller specimens, unlike sampling gear that can be used to target invertebrate assemblages. The presence of habitat-forming species, such as corals and sponges, indicate the potential for some types of assemblages to be present in different areas but more detailed sampling would be required generally to confirm the specific characteristics of those assemblages.

Table 5a: List of the number of species/morphotypes within the major taxonomic groups of benthic invertebrates held at the Museum of Victoria, for each of two periods of sampling, 1964/85 and 1992/93.
The number of morphotypes and the number of specimens within the each major taxonomic group are given. For echinoderms the number of species are shown (identified by the Museum of Victoria).

Phylum	Class / Subclass / Order	Group	1964-1985 morphs/ species	1964-1985 n	1992-1993 morphs/ species	1992-1993 n	**Total morphs/ species**	**Total n**
Porifera		sponges	2	6	6	9	**6**	**15**
Cnidaria	Corals		1	1	2	3	**3**	**4**
	Anemones				1	31	**1**	**31**
Annelida	Hirudinea	leeches	1	1	0	0	**1**	**1**
	Polychaeta	worms	3	96	4	70	**4**	**166**
Mollusca	Cephalopoda	squid and octopus			2	4	**2**	**4**
Bryozoa			6	36	4	8	**6**	**44**
Crustacea	Amphipoda		4	37	1	14	**4**	**51**
	Prawns/shrimps				4	41	**4**	**41**
	Isopoda		3	49	4	191	**6**	**240**
	Other		1	1			**1**	**1**
Chelicerata	Pycnogonida	Sea spiders	2	5	2	4	**3**	**9**
Brachiopoda					1	17	**1**	**17**
Echinodermata	Asteroidea	Asteriidae	4	89	3	67	**4**	**156**
		Asterinidae			1	8	**1**	**8**
		Astropectinidae	1	2	3	19	**3**	**21**
		Benthopectinidae			1	10	**1**	**10**
		Echinasteridae			3	6	**3**	**6**
		Ganeriidae	1	9	1	2	**2**	**11**
		Goniasteridae			1	2	**1**	**2**
		Labidiasteridae	1	8	1	12	**1**	**20**
		Odontasteridae	2	13	3	10	**3**	**23**
		Poraniidae	1	10	1	25	**1**	**35**
		Pterasteridae	1	7	1	7	**1**	**14**
		Solasteridae	2	2	2	16	**2**	**18**
	Crinoidea	Antedonidae	2	50	2	12	**2**	**62**
	Echinoidea	Cidaridae	1	12	2	64	**2**	**76**
		Echinidae	3	32	3	22	**3**	**54**
		Schizasteridae	2	97			**2**	**97**
	Holothuroidea	Chiridotidae			1	3	**1**	**3**
		Cucumariidae	6	39	7	244	**7**	**283**
		Molpadiidae	1	1			**1**	**1**
		Psolidae	1	3	4	26	**4**	**29**
	Ophiuroidea	Amphiuridae			3	15	**4**	**15**
		Asteronychidae			1	9	**1**	**9**
		Gorgonocephalidae	1	8	2	25	**2**	**33**
		Ophiacanthidae	2	16	4	20	**5**	**36**
		Ophiomyxidae			1	4	**1**	**4**
		Ophiuridae	4	369	9	126	**9**	**495**
Chordata	Ascidiacea	ascidians and sea tulips	1	35	3	44	**3**	**79**

Table 5b: List of the number of species/morphotypes within the major taxonomic groups of benthic invertebrates held at the South Australia Museum, which were taken during the voyage of the Aurora Australis in 1990.
Numbers in parentheses indicate the number of species identified in the group.

Phylum	Class / Subclass / Order	Group	No. of species/ morphotypes
Porifera		sponges	2
Cnidaria		Corals	10 (3)
		Anemones	1
		Hydroids	1
Annelida	Polychaeta	worms	3
Mollusca	Cephalopoda	squid and octopus	4
	Gastropoda	Snails, nudibranchs	2
	Polyplacophora	Chitons	1
	Bivalvia		1
Nemertea			1
Bryozoa			1
Sipunculida			1
Crustacea	Cirripedia		2
	Prawns/shrimps		4
Chelicerata	Pycnogonida	Sea spiders	5 (4)
Brachiopoda			1
Echinodermata	Asteroidea		21 (20)
	Crinoidea		1
	Echinoidea	sea/heart urchins, sand dollars	7 (4)
	Holothuroidea		2
	Ophiuroidea		1
Hemichordata	Pterobranchia		1
Chordata	Ascidiacea	ascidians and sea tulips	1

In light of the constraints of the data, the aims of the following analyses were (i) to determine whether species composition, based on presence/absence of the different taxa, differs between areas with different physical characteristics, and (ii) to identify taxa that are restricted in their range.

An analysis of the data to investigate the potential for assemblages to differ between areas with different physical characteristics was undertaken with typical multivariate analyses using Primer (Clarke & Warwick, 1994). Data were only of the presence-absence form. Bray-Curtis similarities were used in these tests. There was no evidence of stations aggregating into distinct assemblages based on either general physical characteristics or depth of the sampling stations. These results indicate that distinct localised assemblages may not be present as many species and morphotypes appear to be ubiquitous in the region. However, the result cannot be used to assume that there are no differences between areas, for all species. This is because the invertebrates were sampled opportunistically using fish survey trawls and may not provide fully representative samples from each station. The presence of habitat-forming species, such as corals and sponges, at some stations indicate the potential for some types of assemblages to be present in different areas but more detailed sampling would be required generally to confirm the specific characteristics of those assemblages.

A second approach was to examine whether any of the morphotypes or echinoderm species appeared to be confined to relatively localised areas. Summary results of this analysis are given in Table 6a and 6b. The distributions of each taxon are given in relation to a subdivision of the region into the physical local units described above but including a subdivision of the Southern Plateau into inner and outer sections.

Tables 6a and 6b show (i) the number of species and morphotypes within a taxonomic group found in each local unit and (ii) the number of stations within the local unit where representatives of that taxonomic group were present. They provide some guidance as to the diversity of fauna found in each local unit but primarily show the taxa found in each unit that are considered to be localised in their distribution. In this case, a taxon (morphotype or species) is considered potentially localised to a unit when it was found at more than one station in that unit and not found at more than one station in any other unit.

The analysis revealed differences in the number and types of taxa between the outer part of the Southern Plateau and the inner part of the plateau near to the territorial sea (Tables 6a,b, Fig. 10). The territorial sea and the inner Southern Plateau had the greatest diversity of taxa, with many taxa being restricted to this area, particularly the territorial sea. The benthic assemblage in the territorial sea had localised distributions of a number of taxa, including an asteroid, *Cycethra verrucosa*, and an ophiuroid, *Ophiacantha vivipara*. Conversely, some taxa were localised in the outer part of the Southern Plateau, notably the polychaete family Aphroditidae. In part, the increased diversity in the nearshore areas around the islands (the territorial sea) will be a reflection of the increased sampling effort and the use of sampling devices more able to sample the benthic invertebrates than the nets used in the fish surveys in the other areas.

Despite the overall similarities in composition of taxa between the territorial sea and the inner Southern Plateau, some taxa were not found in the territorial sea, such as the holothurian, *Psolidium incertum*. This is consistent with a north-south change in species composition along the central area, which includes the territorial sea, the Southern and Northern Plateau and Discovery Bank. Some taxa were restricted to this central area, including the asteroid families, Benthopectinidae and Labidiasteridae, and the holothurian family, Chiridotidae.

A more dominant pattern is an east-west division of some types of taxa present in the greater HIMI region, with the central area appearing to be an area of mixing of these groups. In the north-east, comprising Shell Bank, Northeast Plateau and Eastern Trough, these taxa include the glass sponges, prawns and shrimps (*Pasiphaea* sp. was only found in the Eastern Trough), an Idoteid isopod, the Ophiacanthid ophiuroids, *Ophiacanthus* sp. and *Ophiomitrella* sp. (two new species), and two ophiuroid families, Asteronychidae and Ophiomyxidae. The taxa restricted to the west, comprising Aurora, Coral and Pike Banks and the Western Trough, include gorgonian corals, the asteroid families, Asterinidae, Goniasteridae, Labidiasteridae, Odontasteridae and Poraniidae, the gorgonocephalid ophiuroid, *Astrotoma agassizii*, and barnacles.

The results also indicate that:

1. The western banks, Coral and Aurora, are likely to be similar to each other but different to other areas. They have a rich benthic fauna of corals, sponges and other sessile organisms, which are susceptible to physical disturbance by trawling (Koslow & Gowlett-Holmes, 1998). Of particular note is the presence of large gorgonian corals and stalked barnacles on Coral Bank.
2. Pike Bank has similarities to Discovery Bank and to Coral and Aurora Banks.
3. Discovery Bank has fauna similar to the Northern Plateau but is one location where tall erect glass sponges have been found. These sponges are considered to be important habitat features of the antarctic benthic environment and are susceptible to physical disturbance (Dayton, 1990).

4. Shell Bank is different to the other banks. Although richness of taxa on this bank is similar to Coral Bank, it has a different complement of taxa. Glass sponges are found on Shell Bank. As well, a number of echinoderm species were only found in this area, including the asteroids, *Astropecten* sp. (a new species) and *Rhopiella hirsuta,* and the holothurian, *Cucumaria godeffroyi*. Shell Bank is the only area with a distinctly different substratum – shell grit compared to basalt sand or rock.
5. The Northeastern Plateau has similarities to Shell Bank. In particular, they share the presence of a group of isopods of the Family Idoteidae, which were not found in the other areas.
6. The Eastern Trough can be considered as a separate area. This area is host to deep-water taxa such as prawns and shrimps. In particular, the shrimp *Pasiphaea* spp. is local to this area.

In general, the subdivisions of the area surrounding HIMI is supported by these results, except that the Southern Plateau needs to be divided into inner and outer subareas because of the affinities of these subareas to areas adjacent to the Southern Plateau.

In terms of the biogeography of echinoderms, O'Hara, O'Loughlin and Tutera (Museum of Victoria) identified 69 species of echinoderms sampled during the 1992 and 1993 surveys. They report that seven species cannot be assigned to known Southern Ocean species and may represent new species, possibly endemic to the Heard Island region. They compared these fauna with those at other antarctic and subantarctic locations (Branch *et al.*, 1993; O'Hara 1999, unpublished data) and found that 65% of species identified from HIMI have been reported from the wider Kerguelen Plateau, 57% were common with Marion Island, 32% were common with species reported from higher latitudes in eastern Antarctica and 10% were common with Macquarie Island. Eight (13%) of the known species are known only from the Kerguelen Plateau.

Table 6a: Benthic invertebrates (numbers of morphotypes) found in each physical local unit of the HIMI region during 5 research voyages.

The numbers in parentheses are the number of stations where the Class/Subclass/Group was found in the local unit. Footnotes are given when one or more of the morphotypes within a taxonomic group are localised in their distribution, i.e. found predominantly in the local unit. A morphotype is considered to be localised when it was found at more than one station in that local unit and not found at more than one station in any other local unit.

Local unit			Aurora Bank	Coral Bank	Pike Bank	Discovery Bank	Shell Bank	HIMI Nearshore	Southern Plateau Inner	Southern Plateau Outer	Northern Plateau	Northeastern Plateau	Eastern Trough	Western Trough	South of HIMI
Total number of stations in local unit			4	7	7	6	23	21	26	39	11	9	2	4	2
Phylum	Class / Subclass/ Group	Total morphs (species)													
Porifera	Glass sponge *	1			(1)	(2)	(3)						(1)		
	Other	1	(4)	(7)	(2)	(3)	(1)	(5)	(7)	(10)	(2)	(1)		(2)	(1)
Cnidaria	Coral [1]	13 (3)	2 (2)	2 (2)		1 (1)	3 (3)	1 (1)	4 (7)	4 (7)[2]	2 (2)	1 (1)	1 (1)	5 (3)	
	Anthozoa - anemone	1	(1)		(3)	(4)	(3)	(6)	(13)	(16)	(3)			(2)	(1)
	Hydroid *	1			(1)		(1)			(1)	(2)	(1)			
Annelida	Polychaeta	2[3]		1 (2)	1 (2)	1 (2)	1 (6)	1 (7)	1 (7)	2 (13)[4]	1 (3)	1 (2)			
Mollusca	Squid	1					(1)		(1)	(3)	(1)	(3)		(1)	
	Octopus	1	(1)		(1)	(1)	(1)	(1)	(3)	(5)	(1)		(1)	(1)	
	Gastropoda	2							2 (2)	1 (1)				1 (1)	
	Polyplacophora	1	(1)			(1)			(1)						
	Bivalvia	1				(1)			(1)						
Nemertea		1					(1)		(2)						
Bryozoa		1	(2)		(1)	(4)	(5)	(10)	(8)	(2)		(1)			
Sipunculida		1		(1)											
Crustacea	Cirripedia	2		2 (2)[5]					1 (1)						
	Amphipoda	4						4 (3)		1 (1)			1 (1)		
	Isopoda	6			1 (1)		1 (1)	2 (4)	2 (2)	4 (4)	1 (1)	1 (2)[6]	1 (1)		
	Prawns/shrimps	4								1 (2)	1 (1)	2 (2)	2 (3)[7]	1 (1)	
Chelicerata	Pycnogonida *	1	(1)		(1)		(2)	(3)	(3)	(9)[8]	(1)	(1)		(1)	
Brachiopoda		1	(2)	(2)	(2)		(4)		(1)			(1)	(1)	(1)	
Hemichordata	Pterobranchia	1						(1)							
Chordata	Ascidiacea	1	(3)	(4)	(5)	(3)	(5)	(7)	(8)	(5)				(1)	(1)

* individual morphs/species that have limited range

[1] gorgonian coral found in the Western Trough and on the western banks

[2] soft coral only found in the Southern Plateau Outer

[3] polychaetes were separated into Aphroditidae and other

[4] Aphroditidae local to this area

[5] stalked barnacles only found on Coral Bank

[6] a morphotype of Valvifera isopods, Family Idoteidae, was only found in this area and in adjacent areas on Shell Bank and the Eastern Trough

[7] the shrimp, *Pasiphaea* sp. is local to this area

[8] 5 species were identified

Table 6b: Echinoderms held at Museum of Victoria: the number of species found in each physical local unit of the HIMI region, shown in Fig. 10.

Numbers in parentheses are the number of stations where the Family was found in the local unit. Footnotes give species that are localised in their distribution, i.e. found predominantly in the local unit. A species is considered to be localised when it was found at more than one station in that local unit and not found at more than one station in any other local unit.

Local unit			Aurora Bank	Coral Bank	Pike Bank	Discovery Bank	Shell Bank	HIMI Nearshore	Southern Plateau Inner	Southern Plateau Outer	Northern Plateau	Northeastern Plateau	Eastern Trough	Western Trough	South of HIMI
Total number of stations in local unit			1	2	3	1	13	16	14	19	6	5	1	1	1
Class	Family	No. Species													
Asteroidea	Asteriidae	4	2 (1)	2 (2)			1 (1)	4 (13)	3 (5)	2 (4)[1]		1 (1)			2 (1)
	Asterinidae*	1	1 (1)	1 (1)	1 (1)										
	Astropectinidae	3	2 (1)		1 (1)		1 (1)[2]	2 (3)	2 (3)	1 (2)	2 (3)	1 (2)		1 (1)	
	Benthopectinidae*	1								1 (4)	1 (2)				
	Echinasteridae	3	1 (1)				1 (2)[3]		2 (2)			1 (1)			
	Ganeriidae	2					1 (1)	2 (4)[4]							
	Goniasteridae*	1	1 (1)			1 (1)									
	Labidiasteridae*	1		1 (1)				1 (6)	1 (5)	1 (1)					
	Odontasteridae*	3	1 (1)	2 (1)	1 (1)			2 (7)	1 (2)	1 (1)					
	Poraniidae*	1	1 (1)	1 (2)				1 (6)	1 (2)						
	Pterasteridae*	1		1 (2)			1 (5)	1 (2)	1 (1)						
	Solasteridae	2	2 (1)	2 (2)	1 (1)		1 (1)	2 (3)				1 (1)			
Crinoidea	Antedonidae*	2	1 (1)	2 (2)			2 (1)	2 (5)	1 (1)						
Echinoidea	Cidaridae	2		1 (1)			1 (1)	1 (3)[5]	2 (2)	1 (1)		2 (1)			
	Echinidae	3					1 (2)	2 (5)	3 (4)		1 (1)	1 (1)			1 (1)
	Schizasteridae*	2						2 (2)							
Holothuroidea	Chiridotidae*	1						1 (2)	1 (1)						
	Cucumariidae	7	1 (1)	1 (1)	2 (3)		6 (10)[6]	7 (9)[7]	5 (9)	2 (6)		3 (2)			
	Molpadiidae	1						1 (1)							
	Psolidae	4	1 (1)	2 (1)			1 (1)	1 (3)[8]	2 (2)[9]	1 (1)		3 (2)[10]			
Ophiuroidea	Amphiuridae	4		1 (1)				2 (2)	2 (5)	1 (1)		2 (1)[11]			
	Asteronychidae*	1										1 (2)[12]	1 (1)		
	Gorgonocephalidae	2		2 (2)[13]			1 (1)	1 (5)	1 (2)	2 (1)	2 (1)	2 (1)			
	Ophiacanthidae	5		3 (1)				2 (6)[14]		1 (1)		2 (1)[15]			
	Ophiomyxidae	1										1 (1)			
	Ophiuridae	9		1 (2)	2 (1)		3 (5)	4 (11)[16]	3 (8)	6 (9)	4 (5)[17]	5 (2)		1 (1)	

* individual morphs/species that have limited range

[1] *Smilasterias triremis* local to this area

[2] only record of a new species of seastar, *Astropectin* sp.

[3] *Rhopiella hirsuta* local to this area

[4] *Cycethra verrucosa* local to this area

[5] *Ctenocidaris nutrix* local to this area

[6] *Cucumaria godeffroyi* local to this area

[7] *Cucumaria kerguelensis*, *C. serrata* and *Trachythyone lechleri* local to this area; new species of sea cucumber, *Pseudocnus* sp. found around HIMI, the Southern Plateau Inner and the banks

[8] *Psolus ephippifer* local to this area

[9] *Psolidium incertum* local to this area

[10] only record of a new species of sea cucumber *Psolus* sp.

[11] only record of a new species of brittlestar, *Amphiura* sp.

[12] *Asteronyx loveni* local to this area

[13] *Astrotoma agassizii* local to this area

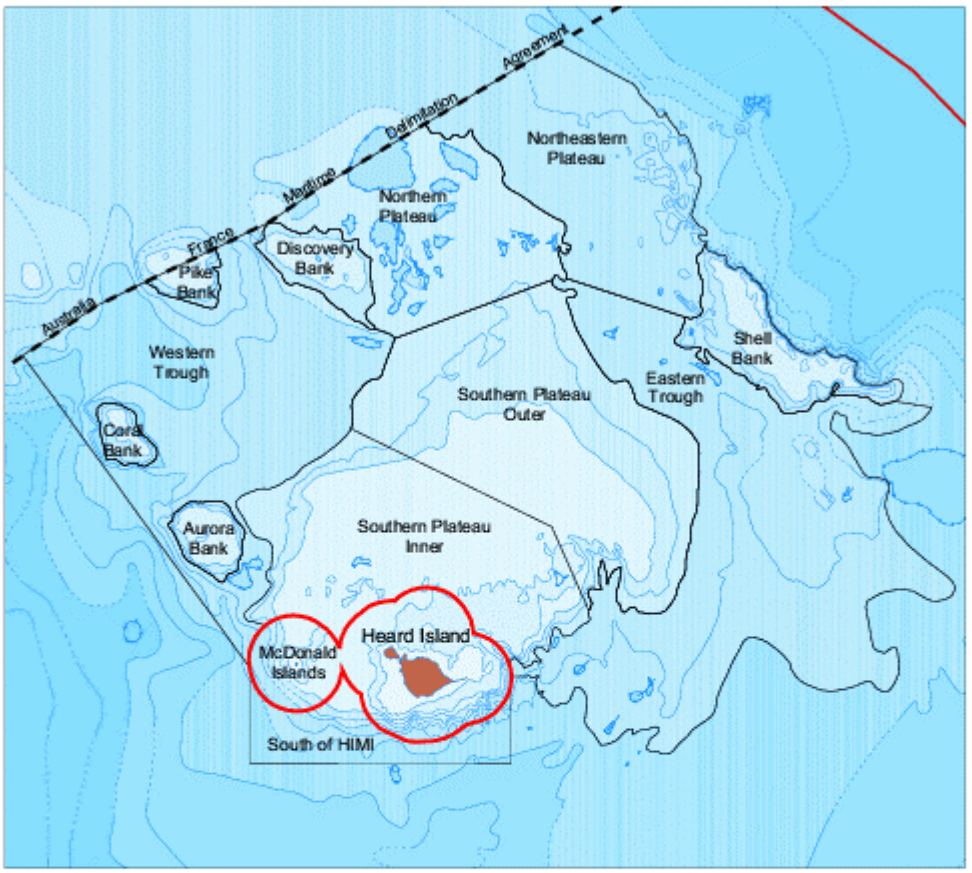
[14] *Ophiacantha imago* and *O. vivipara* local to this area

[15] only record of two new species of brittlestars, *Ophiacantha* sp. and *Ophiomitrella* sp.

[16] *Ophiura ambigua* local to this area

[17] *Ophiura* sp.2, only found in the Southern Plateau Outer and the Northern Plateau

Fig. 10 Biophysical local units within the HIMI AEEZ based on benthic assemblages, the substratum and the physical characteristics of the area.



Legend

Maritime Boundaries
- 12 n.m. territorial sea
- 200 n.m. AEEZ
- AFMDA

Bathymetric Contours
- Definite
- Approximate
- Depression Contour

Bathymetric Tints
- land
- 0 - 100 m
- 100 - 300 m
- 300 - 500 m
- 500 - 1000 m
- 1000 - 2500 m
- > 2500 m

Scale 1 : 2 750 000

0 50 100 150 200 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33'
Central Meridian 74°E
WGS84 Spheroid

Fish

The Kerguelen-Heard ichthyofauna is dominated by the subantarctic nototheniids (*Notothenia rossi, Lepidonotothen squamifrons, Dissostichus eleginoides*) and the channichthyids (icefish) (*Champsocephalus gunnari, Channichthys rhinoceratus*) (Williams & Duhamel, 1994). The inshore fish fauna of Heard Island is similar to that found at Îles Kerguelen and it is believed that the Kerguelen-Heard region is a single unit with regard to the fish (Williams, 1983). Four fish species (*Lepidonotothen mizops, Gobionotothen acuta, Notothenia cyanobrancha* and *C. rhinoceratus*) are endemic to the Kerguelen-Heard region (Williams, 1983, unpublished data).

Benthic beam trawls, undertaken by the French SIBEX II cruise on the banks south of Heard Island (BANZARE Bank), found most fish species were typically deep water groups such as Macrouridae, Liparididae and Zoarcidae, as the minimum depth of the bank is greater than 600 m (Williams & Duhamel, 1994). Abundances of all species were 44-455 kg km^{-2} at BANZARE Bank, 114-1129 kg km^{-2} at Heard Island, and 377-1889 kg km^{-2} at banks and slopes >600 m deep (Williams & Duhamel, 1994). Some of these figures are from a small number of trawls and should be treated with caution.

The AAD undertook three biomass surveys in the Australian sector of the Kerguelen Plateau to assess the distribution, abundance and biology of the most important species in this area for commercial fishing (Williams & de la Mare, 1995). Cruises were undertaken in Autumn 1990, Summer 1992, and Spring 1993. Each major fish species had its own characteristic distribution pattern and the fauna was typical of islands south of the Subantarctic Front and similar to that of Îles Kerguelen (Williams & Duhamel, 1994; Williams & de la Mare, 1995). Results on the biology of fish in the Heard Island region are in the process of being published (R. Williams, AAD, in preparation). Some information on the ecology of the major fish species has been published already (Williams & de la Mare, 1995; Constable *et al.*, 1998; de la Mare *et al.*, 1998).

Table 7 shows the benthic fish species caught during these surveys in the HIMI region. This table indicates the total abundance of each of these species caught during the three surveys in order to indicate the relative importance of the species in the area. The most abundant species were the two icefish, *C. gunnari* and *C. rhinoceratus*, two nototheniids, *L. squamifrons* and *D. eleginoides*, and the skates comprising *Bathyraja murrayi, B. eatoni and B. irrasa* (Williams & de la Mare, 1995). The Patagonian toothfish, *D. eleginoides*, were mostly juveniles in these surveys as the adults tend to be found in deeper water on the slopes of the Heard Island plateau (SC-CAMLR, 1996).

Two stocks of the mackerel icefish, *C. gunnari*, are recognised in the Heard Island region (de la Mare *et al.*, 1998), a potentially large stock on the Heard Island plateau and a smaller stock on Shell Bank (SC-CAMLR, 1997). These stocks were differentiated on the basis of the timings of the spawning season and recruitment. The Shell Bank stock spawns in April while the main stock on the plateau spawns in August-September.

The distribution of each fish taxon across the HIMI region is shown in Table 8. This table indicates the areas in which each taxon was found and the total number of stations indicates its prevalence in the area over the three surveys from which the species was recorded.

Table 7: Benthic fish species caught during three surveys in the HIMI region in the early 1990s.
The total mass (kg) of fish caught over the three surveys is shown (R. Williams, AAD, unpublished data).

Family	Species	Total mass (kg) caught in three surveys (1990-1993)
Channichthyidae	*Champsocephalus gunnari*	6090
Nototheniidae	*Lepidonotothen squamifrons*	2518
Nototheniidae	*Dissostichus eleginoides*	1145
Channichthyidae	*Channichthys rhinoceratus*	1093
Rajidae	*Bathyraja eatoni*	753
Nototheniidae	*Gobionotothen acuta*	384
Macrouridae	*Macrourus carinatus*	251
Rajidae	*Bathyraja murrayi*	103
Rajidae	*Bathyraja irrasa*	53
Nototheniidae	*Notothenia rossii*	28
Congiopodidae	*Zanclorhynchus spinifer*	16
Muraenolepididae	*Muraenolepis* sp.	7
Nototheniidae	*Lepidonotothen mizops*	3
Bothidae	*Mancopsetta maculata*	1
Zoarcidae	Zoarcidae	1
Zoarcidae	*Melanostigma gelatinosum*	<1
Moridae	*Antimora rostrata*	<1
Squalidae	*Etmopterus* sp.	<1
Rajidae	*Bathyraja* sp.	<1
Liparididae	Liparididae	<1
Bathydraconidae	*Bathydraco* sp.	<1
Astronesthidae	*Astronesthid* sp.	<1
Carapidae	*Echiodon* sp.	<1

Table 8: The number of stations within each biophysical local unit (shown in Fig. 10) of the HIMI region at which each fish species was observed.
The total number of stations in a local unit is derived from the surveys in 1990, 1992 and 1993.

Local Unit				Aurora Bank	Coral Bank	Pike Bank	Discovery Bank	Shell Bank	HIMI territorial sea	Southern Plateau Inner	Southern Plateau Outer	Northern Plateau	Northeastern Plateau	Eastern Trough	Western Trough	South of HIMI
Depth range of local unit (m)				300 - 500	300 – 500	300 – 500	300 – 400	180 – 350	0 – 300	200 – 500	300 – 500	~ 500	500 – 700	~750	500 - >1500	300 - >1000
Total number of stations in local unit				6	7	7	8	34	10	35	73	15	13	3	4	2
Family	Species															
Squalidae	*Etmopterus* sp.		BP										2			
Rajidae	*Bathyraja eatoni*		B	1		1	1	5	8	22	25	1				2
Rajidae	*Bathyraja irrasa*		B							2	4	2				
Rajidae	*Bathyraja murrayi*		B		1		1	2	5	9	19					
Rajidae	*Bathyraja* sp.		B					1								
Muraenolepididae	*Muraenolepis* sp.	**E**	B	1			3	1	2	6	8	1			2	
Moridae	*Antimora rostrata*		BP										2			
Macrouridae	*Macrourus carinatus*		BP		1					5	18	4	7	1	4	
Carapidae	*Echiodon* sp.		B										1			
Congiopodidae	*Zanclorhynchus spinifer*		B	4	6	5	2	13	5	13	2		1			
Liparididae	Liparididae		B				1			1	3	1	2	1	2	
Zoarcidae	*Melanostigma gelatinosum*		B							1	3	1	2		1	
Zoarcidae	Zoarcidae		B	1				1		2	4	4	6	1	4	
Nototheniidae	*Dissostichus eleginoides*		BP	4	6	7	8	30	6	33	51	14	13	3	2	1
Nototheniidae	*Gobionotothen acuta*	**E**	B						6	5	9					1
Nototheniidae	*Lepidonotothen mizops*		B	2	3	1	5	4	1	8	4					
Nototheniidae	*Lepidonotothen squamifrons*		BP	4	7	7	7	26	2	11	16	1	2			1
Nototheniidae	*Notothenia rossii*		BP		1				3	4	1					
Bathydraconidae	*Bathydraco* sp.		B							2	2	1			1	
Channichthyidae	*Champsocephalus gunnari*		BP	4			3	23	4	25	45					1
Channichthyidae	*Channichthys rhinoceratus*	**E**	B	6	6	7	8	31	9	32	60	10	1	1		1
Bothidae	*Mancopsetta maculata*		B					2			3					

E = endemic to Kerguelen-Heard region, B = benthic, BP = benthopelagic

The assemblages in the different areas can be broadly viewed in the following way:

- Shell Bank contains a distinct population of *C. gunnari* and provides habitat for juvenile *D. eleginoides* and a population of *L. squamifrons* on the southern edge.
- The Eastern Trough, Northeastern Plateau and the edge of the Southern Plateau have a fish fauna comprising mainly *D. eleginoides* and deeper water species such as the Macrouridae and Moridae. The Northeastern Plateau is the only known location within the HIMI region where Lucifer Sharks (*Etmopterus granulosus*) have been recorded.
- The Southern Plateau contains a separate stock of *C. gunnari*, concentrating in the shallow water in the eastern half of the region (principally Gunnari Ridge). The inner Southern Plateau is a nursery area for mackerel icefish. *D. eleginoides* is widespread, but there are mostly juveniles on the plateau surface, with larger fish generally on the slopes where some of the main fishing grounds occur. It is a principal habitat for skates, *C. rhinoceratus* and a variety of less common nototheniids.
- The Northern Plateau is deeper with fewer *D. eleginoides* and skates and a less abundant and less diverse fish fauna generally.
- The western banks, Discovery, Pike, Aurora and Coral have similar fish faunas. Pike Bank is an area reputed to harbour *C. gunnari,* but no more than a few individuals have been caught in recent years. Juvenile *D. eleginoides* and skates are also found at these banks. Strong midwater 'feed marks' (likely to be mesopelagic fish) have been recorded using acoustic gear over Coral and Aurora Banks; areas considered to be highly productive.
- The Western Trough has some areas with high productivity for *D. eleginoides.* This species is probably reasonably common throughout this area. Deep-water species such as *Macrourus carinatus* have been found here.

In general, the fish fauna is distributed widely across the plateau around HIMI. However, the fauna does vary from shallow to deep water and between the Shell Bank in the east and the remainder of the banks and plateau areas. These results suggest six main areas for the different fish faunas

1. the Plateau (including the Southern and Northern zones),
2. the deeper water of the Eastern Trough and Northeastern Plateau
3. the deeper water of the Western Trough
4. Shell Bank
5. Pike and Discovery Banks, and
6. Aurora and Coral Banks in the west.

Marine mammals

The indigenous marine mammals of HIMI comprise five species of true seals (Phocidae) and two species of eared seals (Otariidae) (crabeater, Weddell, Ross, subantarctic and antarctic fur, southern elephant and leopard seals) (Appendix 4). Heard Island is the only island in the world where all six species of antarctic seals have been recorded (DASETT, 1990). While leopard seals do not breed on Heard Island, they concentrate on the beaches there during winter in greater numbers than anywhere else in the world. Evidence suggests that these animals are site specific, returning annually to the island (DASETT, 1990). Three seal species breed at HIMI: the southern elephant seal, the antarctic fur seal and the subantarctic fur seal. Only these species are described in detail in this report.

Southern elephant seal *Mirounga leonina*

Southern elephant seals are the most abundant seal on Heard Island, and most of the population is found on the eastern side. These seals were taken in high numbers by sealers in the 19th century. While there has been a substantial recovery of the population since then, a 1985 survey at Heard Island found the birth rate in that year was 40% below that of 1948. The cause of this decrease, which has been mirrored in most other Southern Ocean populations, (the exception being at South Georgia), is still unknown and under investigation (DASETT, 1990).

Diet

Southern elephant seals are known to prey predominantly on squid and fish (Rodhouse *et al.*, 1992a; Green & Burton, 1993; Slip, 1995). The consumption estimates of Woehler and Green (1992) used a dietary composition of 75% squid and 25% fish (following Laws, 1984), but there are only limited data to support these dietary proportions at Heard Island (Slip, 1995). In 1988/89 (summer), 56 elephant seal stomach samples were collected from Heard Island (54 lavaged, 2 from postmortem) (Green & Burton, 1993). These samples were from 11 adult males, 26 adult females, 12 sub-adult seals (6 males, 6 females) and 7 juveniles (5 males, 2 females). Fifteen cephalopod taxa were found in 86% of stomachs, with *Moroteuthis ingens* the most abundant squid species numerically (32%) and estimated mass (50%) for adult female seals (Green & Burton, 1993). For adult males, *Alluroteuthis* sp., *M. ingens* and *M. knipovitchi* were the most abundant species numerically (20%) and *M. ingens* and *M. knipovitchi* were the most important species by estimated mass (30%). For both sub-adult and juvenile seals, *M. knipovitchi* was the most important species numerically (18% for each group) and estimated mass (38 and 44%, respectively) (Green & Burton, 1993).

In 1992/93, the diets of adult males (six moulting), adult females (6 breeding, 32 moulting) and juveniles (24 males, eight females; twenty-six of the juveniles were weaners and the other six were yearlings), were analysed at Heard Island (Slip, 1995). Seventeen species of cephalopods were found in 86% of stomachs (n = 76). *Psychroteuthis glacialis* was the most abundant species numerically (21%) and *Kondakovia longimana* was the most important species by mass (40%). Three other cephalopod species were common prey: *M. knipovitchi* (19% by estimated mass), *M. ingens* (13%) and *A. antarcticus* (10%). Sixty-six percent of stomachs contained fish remains and four species of fish were identified from otoliths (*E. carlsbergi, E. antarctica, D. eleginoides* and *G. nicholsi*) (Slip, 1995). Commercial fish species (*D. eleginoides* only) contributed 21% (by number) of fish consumed, although this estimate should be treated with caution as the sample size was very small. Adult and juvenile seals mostly ate similar prey, but smaller seals consumed smaller prey, with *Martialia hyadesi* the most common prey of juveniles, constituting 57.1% of the estimated biomass consumed (Slip, 1995). Crustaceans were reported in the diet of Southern elephant seals, but their importance is not known and their biomass was found to be insignificant in 1992/93 (Slip,

1995). However, Green and Burton (1993) found crustaceans were a common prey item, occurring in 17.5% of stomach samples analysed.

Foraging locations

Adult male and female southern elephant seals from around Heard Island were recorded foraging close to the antarctic continental shelf in winter, and adult females were recorded along the southeast edge of the Kerguelen Plateau in summer (Slip, 1997). The northern limit of foraging is approximately 46ºS, near the northernmost point of the plateau (Anon, 1997). Seals of both genders and different ages spent varying amounts of time foraging over the plateau (Table 9). Male and female seals = 3 years of age spent the most time around the plateau, with the time spent by older animals dependant on their breeding status (Green *et al.*, unpublished document).

Table 9: Time spent foraging by southern elephant seals over the Kerguelen Plateau.
(from **Green *et al.*, unpublished document**).

Sex	Age	% of population	Time spent foraging over plateau
Female	≤ 1	100	60 %
	2	100	50 %
	3	100	40 %
	≥ 4	80	3/9.5 months
	≥ 4	20	1.75/9.5 months
Male	≤ 1	100	60 %
	2	100	50 %
	3-6	100	40
	≥ 7 beachmasters*	31	2-4 weeks of post moult period
	≥ 7 non beachmasters	69	2-3 months of post moult period
	≥ 7	80	2-4 weeks of post breeding period
	≥ 7	20	1-2 weeks of post breeding period

*Beachmasters are bulls maintaining a territory on the beach.

Antarctic fur seal *Arctocephalus gazella*

HIMI is an important breeding location for antarctic fur seals, with well-established colonies on Heard Island and the McDonald Islands. The population increased five-fold from 435 to 2662 animals on Heard Island between 1963 and 1969, with an exponential increase in pup numbers between 1962 and 1988. A census in March 1992 indicated a continuing recovery in the population on the southeast of the island (Green, 1993).

Diet

At Heard Island, antarctic fur seals have been recorded feeding mainly on fish (Green *et al.*, 1989), unlike those in the South Atlantic Ocean, which feed predominantly on antarctic krill, *Euphausia superba* (North, 1996). Faecal samples were collected monthly from February 1992 to March 1993. The majority of samples were presumed to be from males as they outnumbered the females during the breeding season, and no females were seen ashore outside the breeding season. The prey species were found to change both seasonally and inter-annually (Green *et al.*, 1997). The majority of prey were pelagic myctophids (Genera: *Electrona*, *Gymnoscopelus*, *Protomyctophum* and *Krefftichthys*), which are characteristic of deep, off-shelf water and were generally taken in autumn and winter. The only other fish species taken in high numbers was the mackerel icefish (*Champsocephalus gunnari*), which was mostly taken from late winter to early autumn when it was co-dominant in the diet with the pelagic myctophid *K. anderssoni* (Green *et al.*, 1997). In 1990, 373 faecal samples were collected from a population composed of about 30% adult males, 40% subadult males and 30% juveniles (Green *et al.*, 1991). This study also found that pelagic myctophid fish were a

dominant part of the diet. Benthic fish (nototheniids and *Channichthys rhinoceratus*) and the bentho-pelagic fish *C. gunnari* were uncommon in diet samples that year.

Foraging locations
In 1992/93, male and female antarctic fur seals foraged in different localities and in different parts of the seas around HIMI. Females foraged to the northeast of Heard Island, feeding at night at shallow depths on schooling fish (*K. anderssoni*). Males foraged over the shelf around Heard Island in summer, feeding on benthic and bentho-pelagic fish (*C. gunnari*). Males also foraged to the south of Heard Island in deep water (>200 m) during winter, with some travelling to antarctic waters in winter to feed at shallow depths, presumably on krill (Green *et al.*, 1997; see also Ensor & Shaughnessy, 1990).

Subantarctic fur seal *Arctocephalus tropicalus*

Subantarctic fur seals were first recorded breeding on Heard Island in 1987/88. This was the first time the species was recorded breeding south of the Polar Front. It is not known if the species was present on the island before the sealing activities of the 19th century. It is currently considered an uncommon species at HIMI.

Seabirds

A total of 34 species of seabird have been recorded at HIMI (Appendices 5 and 6), of which 19 species are known to be breeding. There is one endemic species and one distinct subspecies.

Penguins are the most abundant seabirds at HIMI. They collonise the tussock and grassland of the coastal fringe of Heard Island, and the flats and gullies on McDonald Island. There are four breeding species of penguin (macaroni, gentoo, king and eastern rockhopper) and three non-breeding species (chinstrap, Adelie and emperor). Other species of seabird recorded breeding at HIMI include albatrosses, petrels, gulls, prions, terns, a fulmar, skua, greenshank, sheathbill and cormorant. Population estimates are shown in Appendices 5 and 6 and have been derived from Woehler (1991) and AAD (1995). Descriptions of the diets and feeding behaviours of the dominant seabirds that breed at HIMI are given below.

Macaroni penguin *Eudyptes chrysolophus*

The colonies of the macaroni penguins at HIMI are amoung the largest in the world, representing about 21% of the species' estimated world population of 9.3 million pairs. The macaroni is the most abundant penguin species at HIMI, with populations estimated at one million breeding pairs at each of Heard Island and McDonald Island (Apendix 5) (Woehler, 1991).

Diet
At Heard Island, macaroni penguins mainly feed on myctophids and euphausiids (Woehler & Green, 1992). During the chick rearing period, in 1992/93, adults fed on fish and euphausiids, but as the season progressed the proportion of euphausiids in the diet decreased by 93%, with the diet becoming almost entirely composed of the myctophid fish *K. anderssoni* (Green *et al.*, in press). Woehler and Green (1992) suggest macaroni penguins consume 77% by mass of crustaceans, of all crustaceans consumed by vertebrate predators, with *E. vallentini* and *T. macrura* being the most common prey species.

Foraging locations
Eighteen penguins were tracked during the chick rearing period, and foraged mainly within an eastern arc from north-northwest to east-southeast of Heard Island, extending to the shelf break about 300 km away (Green *et al.*, in press). Some penguins also travelled south of Heard Island to nearly 56ºS (Green *et al.*, in press).

Gentoo penguin *Pygoscelis papua*

Some gentoo penguins are present all year at HIMI. Colonies are present in the coastal tussock grasslands. The current breeding population at Heard Island has increased from approximately 10 000 pairs in the 1950s to 16 600 in 1987, which represents approximately six percent of the world population of 300 000 pairs (Woehler & Croxall, 1997).

Diet
The diet of gentoo penguins at Heard Island was studied in 1986/87. In that study, fish dominated the diet by estimated mass (91%), followed by crustaceans (8%), while an earlier study based on numbers showed the diet comprised of 22% fish and 75% crustaceans (Klages *et al.*, 1990). Small percentages of squid were also found in the samples (2% by mass, 3% by number). The most common fish prey species were *C. gunnari*, *E. carlsbergi*, *K. anderssoni*, *Harpagifer spinosus*, Notothenidae, *Paradiplospinus gracilis* and the crustacean *E. vallentini* (Klages *et al.*, 1990). It has been suggested that individual gentoo penguins, in the South Atlantic Ocean, tend to prey on either fish or krill, rather than a combination of both (Croxall *et al.*, 1988). Although this was not tested at Heard Island, prey composition in individual samples was skewed with 4 of 54 samples containing > 67% crustaceans (by mass) and 49 of 54 samples containing 67% fish (by mass) (Klages *et al.*, 1990). Fish (% mass) is believed to predominate in the diets of gentoo penguins at Heard and Macquarie Islands, whereas fish and crustaceans have been found to occur in much more equal shares at the Îles Crozet and on Marion Islands (Klages *et al.*, 1990).

Foraging locations
Gentoo penguins are regarded as inshore foragers, as most stomach contents sampled are found relatively intact. Also, they consume demersal species such as small Nototheniidae, *Harpagifer* and *Muraenolepis*, which are known to occur in the immediate vicinity of subantarctic islands (Williams, 1983; Fischer & Hureau, 1985). Although oceanic species dominated the diet samples from Heard Island in 1986/87 (Klages *et al.*, 1990), this is not inconsistent with inshore foraging because the depth of the plateau rapidly drops to depths greater than 500 m a few kilometers from the island.

King penguin *Aptenodytes patagonicus*

The king penguin population at HIMI is currently increasing at an exponential rate (B. Wienecke, AAD, pers. comm). Data collected between 1963 and 1993 suggests that the population (currently 15 000 breeding pairs), is doubling about every five years (Woehler & Croxall, 1997).

Diet
Dietary studies of king penguins from various breeding locations elsewhere have shown they feed almost exclusively on myctophid fish during summer and change to a squid-based diet during winter (Adams & Klages, 1987; Hindell, 1988a; Adams, 1990; Cherel *et al.*, 1996; Olsson & North, 1997; Moore *et al.*, 1998). Results of a 1992 study at Heard Island showed prey species diversity was low during the two chick growth phases (about seven prey species per month), as king penguins fed almost exclusively on the myctophid fish *K. anderssoni*. In winter, prey species diversity was higher (11-17 species per month), suggesting a more opportunistic feeding regime (Moore *et al.*, 1998). Heard Island is the only known breeding

location where *C. gunnari* forms a substantial part of their winter diet (17% by mass) (Moore *et al.*, 1998). The switch from fish to squid during winter is important because the energetic value of squid is less than that of fish (Cherel & Ridoux, 1992). Thus, during winter, penguins have to cope with a reduction in the energy component of their diet in addition to a reduction in prey availability (Moore *et al.*, 1998). Although king penguins only infrequently provision their chicks during winter (about every three months), the reduced quality and amount of food is considered to be an important factor contributing to their overall health (Moore *et al.*, 1998).

Foraging locations
The general foraging locations of King penguins were studied at Heard Island during 1992/93 (Moore *et al.*, 1999). An analysis of 29 time depth recorders that recorded 239 penguin days at sea found the penguins foraging locations changed inter-seasonally. In autumn and spring, adults foraged between 48ºS - 52ºS and 74ºE - 78ºE, about 370 km north-northeast of Heard Island (close to the Polar Front). Two penguins tracked during the 1992 winter travelled 2200 km northeast of Heard Island (to 95ºE latitude), along the northern ice limit, and 1220 km south of Heard Island to about 65ºS, respectively. In spring 1992, the penguins again foraged further north than in winter. The spring foraging areas in overlapped the autumn foraging areas (Moore *et al.*, 1999).

Eastern rockhopper penguin *Eudyptes chrysocome chrysocome*

The population of eastern rockhopper penguins at Heard Island has been estimated at 10 000 breeeding pairs, with approximately 100 pairs on the McDonald Islands.

Diet
The diets of eastern rockhopper penguins at Heard Island were studied for one month during the 1986/87 breeding season. The crustaceans, *E. vallentini* and *T. macrura*, were the dominant prey species found (both numerically and by estimated mass), followed by the myctophid *K. anderssoni* (Klages *et al.*, 1989).

Foraging locations
No research has investigated the foraging locations of eastern rockhopper penguins at HIMI. They are believed to be inshore foragers and it has been estimated from their diet that they forage about half as far as macaroni penguins during the non-breeding period (Klages *et al.*, 1989).

Heard Island cormorant *Phalacrocorax nivalis*

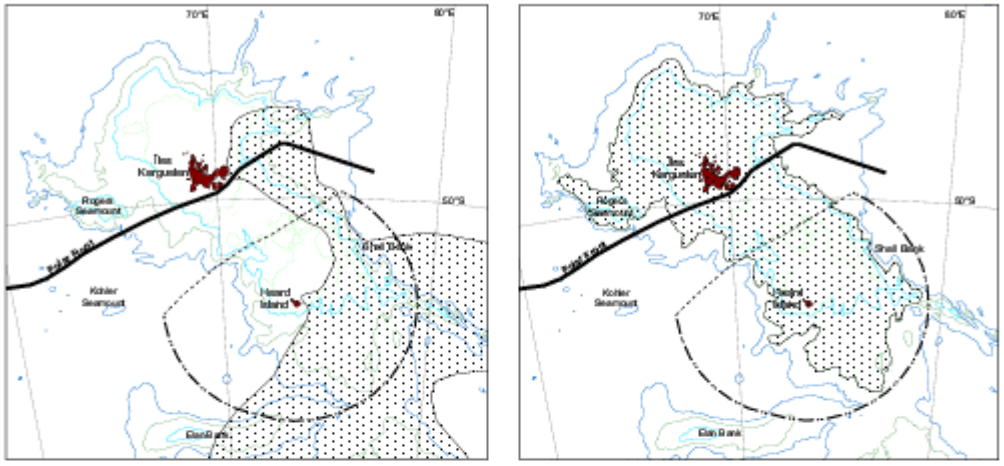
The Heard Island cormorant is endemic to Heard Island. It has not been recorded on McDonald Island and there are only three known breeding sites on Heard Island. The population has included marked fluctuations in numbers with a current population estimate of approximately 250 – 600 birds, including approximately 90 breeding pairs (Woehler, 1991). This endemic population meets IUCN criteria for classification as an endangered species (DASETT, 1990).

Diet
In 1992/93, the diets of the Heard Island cormorant consisted predominately of scale worms (Polychaeta: Polynoidea) and fish (Green *et al.*, 1990; Green & Williams, 1997). The high consumption of scale worms by all birds during the non-breeding season is regarded as unusual for shags, as nearby subantarctic species consume high proportions of crustaceans (del Hoyo *et al.*, 1992). During the breeding season, breeding birds switched to a diet of fish, consisting of mainly small nototheniids (Green & Williams, 1997). Eighteen fish were identifiable from casts of breeding birds: 13 were *Paranotothenia magellanica*, two were

Fig. 11 Foraging locations (stippled areas) of land-based marine predators on the Kerguelen Plateau.

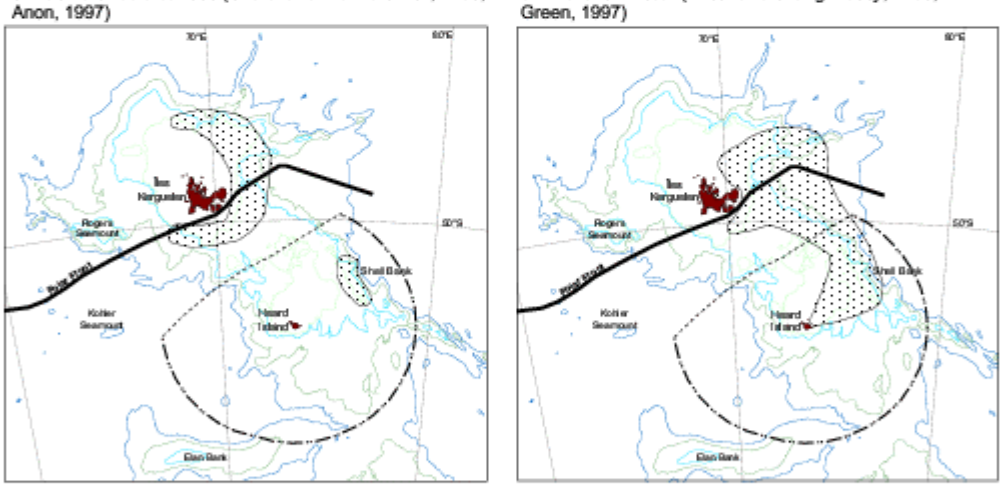
a. king penguin (Anon, 1997; Moore *et al.*, 1999)

b. macaroni penguin (Anon, 1997; Green *et al.*, 1998)



c. black-browed albatross (Cherel and Weimerskirch, 1995; Anon, 1997)

d. Antarctic fur seal (Ensor and Shaughnessy, 1990; Green, 1997)



Legend

Polar Front

Maritime Boundaries
- 200 n.m. AEEZ
- AFMDA

Bathymetry
- 500 m
- 1000 m
- 2000 m
- 3000 m

Scale 1:9 000 000

0 500 1000 1500 km

Projection: Lambert Conic Conformal
Standard Parallels: 51°33' and 53°33'
Central Meridian 74°E
WGS84 Spheroid

Notothenia cyanobrancha, one *N. rossii* and two *Harpagifer spinosus*. Other fish species identified from otoliths were *Gobionotothen acuta, Lepidonotothen mizops, L. squamifrons, Channichthys rhinoceratus, Zanclorhynchus spinifer* and *Paradiplospinus gracilis* (Green & Williams, 1997).

Foraging locations
In 1992/93, most Heard Island cormorants were recorded diving in depths of <2 m, but one breeding male was recorded diving to 60 m (Green & Williams, 1997). They are regarded as inshore foragers based on their diet, but the distances they travel from the island, and whether there are other regular foraging grounds are presently unknown.

Summary of feeding and foraging activities of land-based marine predators

Land-based marine predators from Heard Island feed predominantly on mesopelagic fish, most of which are myctophids, and squid. Commercial fish species appear in the diets of some of the predators. The mackerel icefish is known to occur in the diets of fur seals and king and gentoo penguins, and seems to be important for these species during winter. Juvenile Patagonian toothfish occurs in the diets of Southern elephant seals, but observations suggest that only low numbers of these fish are taken. Analyses for the CCAMLR Working Group on Ecosystem Monitoring and Management showed that the commercial fishery was unlikely to compete with elephant seals for toothfish (Constable *et al.*, 1997; SC-CAMLR, 1997).

The important foraging areas for land-based marine predators in the HIMI region appear to be to the northeast of the island on the shelf break to the north of Shell Bank, or further north towards the Polar Front. This is consistent with the foraging areas of many predators from Îles Kerguelen, which forage to the east and southeast of this island in the Polar Frontal zone (Fig. 11).

CURRENT COMMERCIAL AND OTHER ACTIVITIES

Fisheries Activities

Soviet, Polish, French and Ukranian vessels have fished for four species of fish (*Lepidonotothen (Notothenia) squamifrons*, *N. rossii*, *Dissostichus eleginoides* and *Champsocephalus gunnari*) in the Îles Kerguelen region since the early 1970's, but detailed records of the fishery only exist from 1980 (Duhamel & Hureau, 1990). Fishing occurred mostly outside of the Australian EEZ, except for some exploratory fishing in 1975 (Kock, 1992) and possibly some of the Soviet fishery in the early 1970's (Williams & de la Mare, 1995). The Îles Kerguelen fishery depleted stocks of *N. rossii*, which was fished during periods of spawning aggregation until it was protected in 1984 (Duhamel & Hureau, 1990). One of the four fish species of commercial interest has not been over-exploited – *D. eleginoides* (Duhamel & Hureau, 1990). Fishing has been regulated in the 200 n.m. zone since 1979, after the French EEZ was established in 1978. Currently, only *C. gunnari* and *D. eleginoides* are thought to have sufficient stocks to support a fishery (Williams & de la Mare, 1995). Table 10 summarises the total catch of these species, for each fishing season from 1986/87 to the present.

Table 10: Legal catches (tonnes) per split-year of Patagonian toothfish (*D. eleginoides*) and mackerel icefish (*C. gunnari*) within the Australian EEZ around Heard Island and within the French EEZ around Îles Kerguelen from 1986/87 to 1997/98.
Dashes mean no fishing was conducted. Adapted from the CCAMLR Statistical Bulletin, Volumes 2, 10 and 11. Surveys used for fisheries assessments are shown.

	Split Year											
	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98
Australian EEZ												
Tooth-fish			-	1[1]	-	0[1]	-	0[1]	-	-	860	2417
Ice-fish			-	1[1]	-	2[1]	-	3[1]	-	-	217[2]	67[2]
Finfish by-catch											4	3
Benthos by-catch											19	3
Seabird mortalities											0	0
Seal mortalities											1[3]	1[3]
French EEZ												
Tooth -fish	408	488	22	505	1561	1589	826	4197	4089	3652	3675	3832
Ice-fish	78	-	565	16	15	0	-	12	84	5	0	-

[1] General biomass surveys carried out on Aurora Australis
[2] Biomass surveys for *Champsocephalus gunnari* carried out on commercial fishing vessels
[3] Both seals were badly decayed and probably were dead well before being trawled up

Australian commercial fishing, within the AFZ around HIMI, began in April 1997 (R. Williams, AAD, pers. comm.) (Table 10), and continues to concentrate on *C. gunnari* and *D. eleginoides*. Catches reported from the 1989/90, 1991/92 and 1993/94 seasons are from the AAD exploratory fishing surveys. Commercial fisheries activities are subject to the *Fisheries Management Act 1991*, which is administered by the Australian Fisheries Management Authority. The fishing grounds within the AFZ have been circumscribed in this project's geographical information system (GIS) but commercial confidentiality prevents its release at this stage. The available catch per unit effort (CPUE) data for *D. eleginoides* has been analysed for the 1997 and 1998 fishing seasons, but due to the commercial nature of this information it must be treated as confidential and access is currently restricted. Fishing activities tend to be concentrated in two main areas rather than being dispersed over the whole plateau region.

Table 10 shows the interactions of these fisheries on other aspects of the marine environment as reported by observers to AFMA (AFMA, unpublished data). To date, there has been no assessment of the impact of these activities on the benthic environment.

The northern and central parts of the Kerguelen Plateau have been the target of illegal longline fishing for Patagonian toothfish in recent years. The northeastern area of the HIMI AFZ is the main area where illegal fishers have poached toothfish from the Australian EEZ.

Tourist Activities

Opportunities exist for recreation and tourist activities in the Territory. Few tourist visits have been made to the island due to geographical and climatic difficulties. Three Visitor Access Areas exist on Heard Island; Atlas Cove, Spit Bay and Long Beach. All activities within the Territorial waters require permits. Emergency entries into the area are permitted, but the Australian Antarctic Division (AAD) must be notified as soon as possible. Table 11 summarises the non-governmental visits to Heard Island as currently known by the AAD.

Table 11: Current records of non-governmental visits to Heard Island.

Location	Date	Vessel	Company	No. of people	Comments
Heard Island	1965	*Patenella*			Small mountaineering group.
Heard Island	1982	*Cheynnes II*			Amateur radio, mountaineering group.
Heard Island	1985	*Icebird*			Weather precluded visit.
Heard Island	1986	*Totorore*			
Spit Camp	05/12/92	*Kapitan Khlebnikov*	Quark	58	Weather precluded visit.
Capsize Beach	15/01/93	*Kapitan Khlebnikov*	Quark	72	Weather precluded visit.
Atlas Cove	1997	*Marion Dufresne*			Amateur radio expedition.
Atlas Cove	1997	*Marion Dufresne*			Amateur radio expedition.
Atlas Cove	01/12/97	*Kapitan Khlebnikov*	Zegraham		Tourist visit.
Atlas Cove	29/12/98	*Kapitan Khlebnikov*			Tourist visit.

ANARE at Heard Island

A permanently occupied station was maintained at Heard Island for seven years (1947-1955). Since then, ANARE visits to the island have been infrequent and generally for short periods, usually two or three days. There are only two recorded visits to McDonald Island in 1971 and 1980. Table 12 summarises the history of ANARE at Heard Island.

Table 12: ANARE visits to Heard Island.

Year	Date	Vessel	Voyage	Purpose of visit to HI	Comments
1997	18-20 March	*Aurora Australis*	V5		
1993	*Aug. – Sept.*	*Aurora Australis*		Heard Island Survey	
1993	*10-17 March*	MV *Icebird*	V8		
1992	Feb.	*Aurora Australis*		Wintering Field Party	5 ashore 28/01/92 – 17/03/93
1992	March	MV *Icebird*			Delivered cargo
1991	30 Jan. – 01 Feb	MV *Icebird*	V7		
1990	21 June	*Aurora Australis*	V7.2		
1990	16 May	*Aurora Australis*	V7.2		
1990	*19 – 20 Jan.*	*Polar Queen*	V5		
1988/89	*Summer*				

Year	Date	Vessel	Voyage	Purpose of visit to HI	Comments
1989	*30 Jan. – 01 Feb.*	*Lady Franklin*	V7 (88/89)		
1988	29 Feb.– 02 Mar. (02 - 05 Mar.)	*Lady Franklin*	V6 (87/88)	Summer party removed.	
1987	18 – 19 Oct.	MS *Nella Dan*	V2 (87/88)	Army LARC Detachment personnel ashore.	
1987	18 – 20 Sept.	MS *Nella Dan*	V1 (87/88)	Summer party ashore.	
1987	21 Jan.	MV *Icebird*	V6 (86/87)	Summer party removed.	
1986	15 – 20 Nov.	MS *Nella Dan*	V2 (86/87)	Summer party ashore.	Party ashore
1985	24 – 25 Nov.	MV *Icebird*	V3 (85/86)	Summer party removed.	
1985	Summer				4 personnel at Spit point and 6 personnel at Atlas Cove.
1985	29 Sept. – 04 Oct.	MS *Nella Dan*	V1 (85/86)	Summer party ashore.	
1983	12 March	MV *Nella Dan*	V7 (82/83)		
1980	March	MV *Cape Pillar*		Marine survey around McDonald Is. and HI.	11- 15 Mar. McDonald Islands 15 – 25 Mar. HI
1971	21 Feb.	MV *Nella Dan*	V4 (70/71)	Rescue one person.	
1971	25 Jan. – 09 Mar. Summer	MV *Gallieni* (French)		To study geophysical phenomena. 4 Australian members of the party.	1971 French-Australian Expedition at Atlas Cove.
1971	19 – 20 Jan.	MS *Nella Dan*	V2 (70/71)	Land stores for Australian Party to traverse the Island from Atlas Cove in Feb.	Visited McDonald Islands but no landing made.
1963	09 March	MS *Nella Dan*	V3 (62/63)		
1963	28 – 30 Jan.	MS *Nella Dan*	V3 (62/63)		Summer party (6 men) on HI 28 Jan. – 09 Mar.
1961	06 March	MV *Thalla Dan*	V3 (60/61)		
1960	05 March	MV *Thalla Dan*	V3 (59/60)		
1956	09 March	MV *Kista Dan*	V2 (55/56)		
1955	05 – 08) March	MV *Kista Dan*		Station evacuated after 7 years occupation.	
1955	23 – 25 Jan.	MV *Kista Dan*	V2 (54/55)	To load 15 dogs and kennels for Mawson.	
1954	Winter				Scientific program ceased on 31 Oct. and station dismantled.
1954	14 – 15 March	MV *Kista Dan*	V2 (53/54)		
1954	19 – 21 Jan.	MV *Kista Dan*	V2 (53/54)		
1953	Winter				Flora, fauna and geology written.
1953	21(26?) Feb. – 26 Feb. (6 Mar?)	MV *Tottan*	V1 (52/53)	Changeover.	12 sheep released at West Bay
1952	Winter			Magnetic instruments installed.	
1952	26 Feb. – 3 March	MV *Tottan*	V1 (51/52)	Changeover.	Big Ben active.
1951	7 Sept.	RRS *Discovery II*		To repatriate the ANARE cook/storeman.	
1951	Winter				1st circumnavigation on foot. Seismographs installed/operated.
1951	13 – 17 Feb.	HMAS *Labuan*	V1 (50/51)	Changeover of HI station.	
1951	5 – 8 Feb.	HMAS *Labuan*	V1 (50/51)	Changeover of HI station.	Forced to leave for Îles Kerguelen - Shortage of water.
1950	Winter				All out on V1 (1950/51); Huskies bred for future work in Antarctic.
1950	7 – 8 August	HMAS *Australia*	V3 (49/50)	Mercy mission: remove medical officer and leave replacements.	
1950	11 – 24 Feb.	HMAS *Labuan*	V1 (49/50)	Second resupply of HI, delivered 12 huskies and hut sites selected. Emergency provision hut erected at Spit Bay.	
1949	Winter			Topographical surveys of HI completed. Radiosonde observations added to the meteorological program.	
1949	5 – 11 Feb.	HMAS *Labuan* formerly LST 3501	V1 (48/49)	1st resupply of station and supported changeover of wintering party.	Ship made a running survey of the south coast of the Island.
1948	Winter			HI station commissioned 26/12/47. Topographical survey made and science program begun.	Ref: Fourteen men: story of the Australian Antarctic expedition to Heard Island by Arthur Scholes.
1947	11 – 28 Dec.	LST 3501	V1 (47/48)	Establish station at Heard Island- landed personnel and supplies.	

EXISTING MANAGEMENT REGIMES

Management Zones

Heard Island, McDonald Islands and the surrounding territorial sea (12 n.m. from shore) comprise a Wilderness Reserve (Fig. 3), managed as an IUCN Protected Area Management Category I according to the Heard Island Wilderness Reserve Management Plan (AAD, 1995). To reduce the possibility of interaction between the Wilderness Reserve and commercial fishing activities, there is a further 1 n.m. buffer zone surrounding the Wilderness Reserve, where fishing is prohibited (AFMA, 1998).

The Australian Fishing Zone (AFZ) and the Australian Exclusive Economic Zone (AEEZ) surround the Territory. The AFZ and AEEZ boundaries extend from 12 to 200 n.m. from the islands, except for an area to the northwest which is separated by the Australia France Maritime Delimitation Agreement boundary (Fig. 3) (AUSLIG, 1997).

Domestic and International Legal Regimes

Heard Island and McDonald Islands are managed as an external territory of Australia with a surrounding12 n.m. territorial sea. The *Heard Island and McDonald Islands Act 1953* provides for the legal regime (AAD, 1995). The two most significant Ordinances made under this Act are the *Territory of Heard Island and McDonald Islands Environment Protection and Management Ordinance 1987* and the *Criminal Procedure Ordinance 1993* (AAD, 1995).

The Territory is managed in accordance with the *Territory of Heard Island and McDonald Islands Environment Protection and Management Ordinance 1987* and the Heard Island Wilderness Reserve Management Plan (AAD, 1995) made under section 8 of the Ordinance. Commonwealth laws that extend to external territories are applicable to the Territory.

Australia claims the marine area to 200 n.m. from the shores of HIMI as its EEZ according to UNCLOS.

Internationally, the Territory is subject to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). The *Antarctic Marine Living Resources Conservation Act 1981* outlines Australia's obligations under the Convention. The Territory is not in the area subject to the Antarctic Treaty. Figure 1 shows the proximity of the CCAMLR statistical boundaries to the HIMI area. HIMI falls within the CCAMLR Statistical Division 58.5.2.

Commercial fishing activities are subject to the obligations under CCAMLR and the requirements of the *Fisheries Management Act 1991*, which is administered by the Australian Fisheries Management Authority.

No fishing is permitted within the 12 n.m. territorial sea according to the Heard Island Wilderness Reserve Management Plan. Fishing boats may enter the 1 n.m. buffer zone, extending from the 12 n.m. territorial sea, but are not permitted to engage in any fishing in that zone (AFMA, 1998). The Wilderness Reserve and the surrounding buffer zone comprises 6 488 km^2 in which fishing is prohibited (AFMA, 1998).

RECOMMENDATIONS FOR A MARINE PROTECTED AREA IN THE HIMI REGION

SUBDIVISION OF THE HIMI REGION INTO BIOPHYSICAL LOCAL UNITS

The analysis of the physical and biological environments at HIMI, coupled with consideration of the ecology of these areas identifies 13 potentially different biophysical local units (*sensu* IMCRA Technical Group, 1998; spatial scale of 10s – 100s of km). These are shown in Fig. 10 and described in Table 13.

Table 13: Physical and biological characteristics of local units (*sensu* IMCRA Technical Group, 1998) in the HIMI region.

Local Unit	Physical Characteristics	Biological Characteristics
Aurora Bank	• mesa-like bank rising steeply from deep water • flat but rugged top with pinnacles, boulders and sand • 300 – 500 m deep • locally highly productive in relatively warm, nutrient-rich waters as it is one of two banks that first intercepts the ACC	• rich benthic fauna, including giant barnacles and gorgonian corals • affinity with Coral Bank • the echinoid *Eurocidaris nutrix* only found here and on the other banks* • productive area for meso-pelagic fish • habitat for juvenile *D. eleginoides* and skates • similar fish fauna to Coral, Discovery and Pike Banks
Coral Bank	• mesa-like bank rising steeply from deep water • flat but rugged top with pinnacles, boulders and sand • 300 – 500 m deep • locally highly productive in relatively warm, nutrient-rich waters as it is influenced by relatively warm water of the ACC	• rich benthic fauna, including slow-growing gorgonian corals • affinity with Aurora Bank • stalked barnacles only found here • the echinoid *Eurocidaris nutrix* only found here and on the other banks* • localised distribution of the ophiuroid *Astrotoma agassizii* • productive area for meso-pelagic fish • habitat for juvenile *D. eleginoides* and skates • similar fish fauna to Aurora, Discovery and Pike Banks
Discovery Bank	• whale-backed bank rising from the Northern Plateau • reasonably flat with basaltic sand, but can be pebbly and craggy in places • about 300 – 400 m deep • influenced by relatively warm water of the ACC	• epibenthic fauna consists primarily of anemones, sponges and asteroids • tall erect glass sponges found here and at Shell Bank, NE Plateau and Eastern Trough • the echinoid *Eurocidaris nutrix* only found here and on the other banks* • localised distribution of the echinoid, *Ctenocidaris longispina** • habitat for juvenile *D. eleginoides* and skates • similar fish fauna to Aurora, Coral and Pike Banks
Pike Bank	• flat on top but pebbly and gnarly on slopes • eastern slopes steep • 300 – 500 m deep	• the echinoid *Eurocidaris nutrix* only found here and on the other banks* • habitat for juvenile *D. eleginoides* and skates • similar fish fauna to Aurora, Coral and Discovery Banks

Local Unit	Physical Characteristics	Biological Characteristics
Shell Bank	• isolated mesa-like bank with a flat, even top • steep craggy slopes with a craggy rim • only area with a distinctly different substratum - white sand and uniquely covered with a thick deposit of shell grit • 180 - 350 m deep • cool water • influenced by an eddy of productive water	• rich benthic fauna with high diversity of echinoderms • tall erect glass sponges here and Discovery Bank, NE Plateau and Eastern Trough • only record of a new species of asteroid, *Astropectin* sp. • localised distribution of the asteroid *Rhopiella hirsuta* • the echinoid *Eurocidaris nutrix* only found here and on the other banks* • localised distribution of the holothurian *Cucumaria godeffroyi* • a morphotype of Valvifera isopods of the Family Idoteidae is local to this area, the NE Plateau and the Eastern Trough • distinct population of *C. gunnari* • habitat for juvenile *D. eleginoides* • population of *L. squamifrons* on south edge • part of the main foraging area, including area to the north and east, for many land-based marine predators
Territorial Sea	• substratum is mostly smooth, medium-grain black basaltic sand, with basaltic cobbles and boulders common in the nearshore area • 0 - 300 m deep • substratum disturbed by wave action in water shallower than 200 m, particularly in the north, northeast and eastern areas • southern margins are steep slopes descending to 1000 m deep	• diverse benthic fauna near to the island with affinities to inner Southern Plateau • a new species of sea cucumber, *Pseudocnus* sp. found here, in the Southern Plateau Inner and the banks • localised distribution of the asteroid *Cycethra verrucosa* • localised distribution of the echinoid *Ctenodaris nutrix* • localised distribution of the holothurians *Cucumaria kerguelensis*, *Cucumaria serrata*, *Trachythyone lecheri*, *Psolus ephippifer* • localised distribution of the ophiuroids *Opiacantha imago*, *Opiacantha vivipara*, *Ophiura ambigua* • an asteroid morphotype and the ophiuroid, *Ophiacantha vivipara*, are local to this area • foraging area for nearshore flying birds, such as the endemic Heard Island cormorant
Southern Plateau Inner	• broad, flat, hard and even substratum • west, south and east margins are generally steep and undulating to craggy slopes • ground is mostly smooth, medium-grain black basaltic sand and grey silt • 200 – 500 m deep • influenced by relatively warm water of the ACC	• rich benthic fauna with affinities to nearshore areas in the Territorial Sea • asteroid *Briaster kerguelensis* only found in Southern Plateau (Inner and Outer) * • localised distribution of the holothurian *Psolidum incertum* • a new species of holothuroid, *Pseudocnus* sp. found here, in the Territorial sea and the banks • very young mackerel icefish have been found here • *D. eleginoides* is widespread with mostly juveniles on the plateau surface • a principal habitat for skates, *C. rhinoceratus* and a variety of less common notothenids

Local Unit	Physical Characteristics	Biological Characteristics
Southern Plateau Outer	• broad, flat and even substratum • east and west margins generally steep and undulating to craggy slopes • ground is mostly smooth, medium-grain black basaltic sand and grey silt • 300 – 500 m deep • influenced by cooler water from the Eastern Trough and the relatively warm water of the ACC in the west and north of this unit	• rich benthic fauna with affinities to the Eastern Trough, such as prawns, shrimps and isopods • variety of asteroids and the polychaetes from the Family Aphroditidae are local to this area • the asteroid *Briaster kerguelensis* only found in the Southern Plateau (Inner and Outer)* • localised distribution of the asteroid *Smilasterias triremis* • the asteroid *Bathydiaster loripes obesus* only found here and in the Northern Plateau* • the ophiuroid *Ophiura* sp.2 only found here and in the Northern Plateau • soft coral only found here • contains a separate stock of *C. gunnari*, concentrating in the shallow water in the eastern half of the unit • *D. eleginoides* is widespread, but there are mostly juveniles on the plateau surface, with larger fish generally on the slopes • principal habitat for skates, *C. rhinoceratus* and a variety of less common nototheniids
Northern Plateau	• relatively narrow region of the main plateau • very uneven topography • hard substratum of basaltic cobbles, small pinnacles, shell grit, black sand and grey silt • deeper than the Southern Plateau, averaging about 500 m depth • influenced by cooler water from the Eastern Trough and the relatively warm water of the ACC in the west and central areas of this unit	• similar benthic fauna to Discovery Bank and the Northeast Plateau • the asteroid *Bathydiaster loripes obesus* only found here and in the Southern Plateau Outer* • *Ophiura* sp.2 only found here and in the Southern Plateau Outer • fewer *D. eleginoides* and skates and a less abundant and diverse fish fauna generally
Northeastern Plateau	• hard substratum with cobbles, yellow sand and grey silt • 500 – 700 m deep which slopes into deeper water in the east	• similar benthic fauna to Shell Bank • tall erect glass sponges found here and at Discovery Bank, Shell Bank, and Eastern Trough • a morphotype of Valvifera isopods of the Family Idoteidae is unique to this area, Shell Bank and the Eastern Trough • only record of a new species of holothurian, *Psolus* sp. • only records of three new species of ophiuroid, *Amphiura* sp., *Ophiacantha* sp. and *Ophiomitrella* sp. • localised distribution of the ophiuroid *Asteronyx loveni* • only known location within the HIMI region where Lucifer Sharks (*Etmopterus granulosus*) have been recorded • fish fauna comprising mainly *D. eleginoides* and deeper water species such as the Macrouridae and Moridae • part of the main foraging area, including area to the north and east, for many land-based marine predators

Local Unit	Physical Characteristics	Biological Characteristics
Eastern Trough	• wide in southern part • substratum of fine grey sand and silt • about 750 m deep • contains cooler water from either the eddy in the lee of the plateau and/or of antarctic origin	• similar benthic fauna to Shell bank in the northeast • tall erect glass sponges found here and at Discovery Bank, Shell Bank, and NE Plateau • a morphotype of Valvifera isopods of the Family Idoteidae is unique to this area, Shell Bank and the Northeastern Plateau • habitat for deep-water taxa such as prawns and shrimps: the shrimp *Pasiphaea* sp. is local to this area and edges of NE plateau and Shell Bank • fish fauna comprising mainly *D. eleginoides* and deeper water species such as the Macrouridae and Moridae
Western Trough	• topographically similar to the Eastern Trough but it is a bit deeper and more open-to the influence of the ACC • 500 – >1500 m deep • experiences the warmest waters as this is the first location where the ACC encounters the plateau around HIMI	• high productivity • gorgonian corals found here and on the western banks • *D. eleginoides* is probably reasonably common throughout area • deep-water species such as *Macrourus carinatus* have been found here
South of HIMI (local unit is only a small portion of AEEZ to south of HIMI)	• relatively warmer water of the ACC moving over the southern parts of the plateau	• no information is available to describe this area except that a number of land-based marine predators forage to the south of the island

* South Australia Museum identification needs to be confirmed

OTHER FACTORS TO CONSIDER FOR CONSERVATION OF BENTHIC HABITATS IN THE HIMI REGION

Ecology of the benthic environment

Biogeography

Studies of benthic fauna in Antarctica have been concentrated around the Antarctic Peninsula and the Weddell Sea and, to a lesser extent, the Ross Sea (Arntz *et al.*, 1994). These assemblages have been shown to be very diverse with some species having great abundances and many with life histories typically involving slow growth, delayed maturity, long life and an absent pelagic phase (White, 1984; Arntz *et al.*, 1994; Brey *et al.*, 1994). As a result, the general view concerning biogeography of benthic invertebrate species in the antarctic is that all species belong to a single circumcontinental province. Those species with a pelagic larval phase having interconnected local populations around the continent, while those that brood their young have localised populations (White, 1984; Arntz *et al.*, 1994). However, these assessments are based on few quantitative data. Consequently, theories concerning the factors that may influence the distribution and abundance of benthic macro-invertebrates in shelf areas of the antarctic have been poorly tested and may not be applicable to the wider antarctic context.

Recent work on fauna in Prydz Bay, eastern Antarctica, revealed differences in the types and composition of fauna between Prydz Bay in eastern Antarctica and the Weddell Sea in the South Atlantic (A.J. Constable, AAD, unpublished data). Preliminary results show that the holothurian fauna in the Prydz Bay region has only 28% of species in common with the Weddell Sea fauna (O'Loughlin *et al.*, 1994).

A similar paucity of information is available on the biogeography of subantarctic benthos. Many species are considered to have a circumpolar distribution, although White (1984) (and later Knox, 1994) identified differences between the Indian Ocean islands and Macquarie Island and the South Atlantic islands. Interestingly, White (1984) and Knox (1994) place Heard Island into the antarctic region rather than the subantarctic region, separating this island from the other islands probably because Heard Island is south of the Polar Front. More recently, O'Hara (1998) compared the echinoderm fauna from Macquarie Island, Îles Kerguelen, the western subantarctic and eastern antarctic high latitudes. He found distinct assemblages in each of these locations and argues that limited dispersal in many echinoderm species in the subantarctic has led to separation of the assemblages. Results in this report for echinoderms and fish corroborate the view that the Heard Island region has a distinct local fauna, as well as the more widely distributed fauna.

Combined, these results for the antarctic and subantarctic raise doubts over hypotheses concerning general circumpolar distributions of many species. Consequently, the major regions of the subantarctic, such as the Kerguelen Plateau, are likely to have faunas distinct from other Southern Ocean regions and distinct differences are likely between the faunas around Îles Kerguelen and Heard Island.

Factors influencing the distribution of benthic invertebrates

The benthic environment in the Heard Island region ranges from shallow inshore waters to depths of 1000 to 2000 m. The Southern Plateau and the banks are mostly less than 300 m deep, typical depths considered for continental shelves elsewhere in the world. The remainder of the region falls within the depth range considered in studies of abyssal or deep-sea fauna.

Gage (1996) and others have reviewed extensively the literature on factors influencing deep-sea fauna. Typically, deep-sea fauna are considered to be much more diverse than continental shelf fauna (but see Gray, 1994). In the northern hemisphere there appears to be a trend of decreasing diversity from low to high latitudes while, in the southern hemisphere, high latitude fauna appears to be as equally diverse as in the tropics (Poore & Wilson, 1993).

Diversity of fauna is correlated with depth. Levin & Gage (1998) show that the highest diversity of macrobenthos and polychaete worms in the eastern Pacific and in the Atlantic occurs between 1000 m and 1500 m depth. This supports the widely held view that species diversity is low on the continental shelf areas, high on the mid-slope region and low again at abyssal depths. This has been examined theoretically by Pineda & Caswell (1998) who showed that this phenomenon cannot be explained by geometric constraints in these analyses and that other factors need to be explored.

Important factors considered to enhance species diversity generally in these environments includes relatively greater concentrations and occurrences of phytodetritus reaching the sea floor, and reduced disturbance from wave action and currents. Deep-sea storms or other actions that might disrupt assemblages or resuspend sediments and a mosaic of available types of habitat can also enhance species diversity (see Barry & Dayton, 1991; Gage, 1996 for review).

Other features that can result in higher diversity are areas that create localised upwellings, such as barriers to major currents (including seamounts and the upstream sides of banks and plateaus - Koslow & Gowlett-Holmes, 1998). High diversity is also found in areas where

productive waters can be concentrated, such as eddies in the lee of islands (Barry & Dayton, 1991). Also, bottom topography that accumulates organic material, such as valleys, can serve to enhance diversity and abundance of epifaunal and infaunal benthic invertebrates (Vetter, 1995; Vetter & Dayton, 1998).

Factors influencing antarctic and subantarctic benthic invertebrates

Few studies have looked closely at the factors influencing the ecology of antarctic or subantarctic invertebrates, except at the biogeographic level discussed above. A number of reviews provide useful background information on polar benthic communities (Dayton, 1990; Grebmeier & Barry, 1991; Dayton *et al.*, 1994). Many studies provide evidence of increased benthic productivity in shallower waters (< 100 m) but the range of sampling is often very restricted. In large-scale studies, depth appears less important than other factors such as substratum type, surface productivity and hydrology (e.g. Piependburg *et al.*, 1997).

Suspension feeders (sponges, byrozoans, corals and ascidians) are often found in abundance in shallower waters, particularly areas where phytodetritus from surface production is high (Gutt & Starmans, 1998). The abundance of deposit feeders appears largely dependent on the availability of sediments rather than water depth (Gutt & Starmans, 1998; Gambi & Bussotti, 1999). In the Ross Sea, Gambi & Bussotti (1999) found areas with shelly substrata or coarse materials were dominated by crustaceans, polychaetes and echinoderms, while finer sediments were dominated by infaunal polychaetes and bivalves.

Echinoderms are a common fauna in Antarctica and are likely to play an important role in the ecology of these systems. Many of these species appear to be adapted to a physically stable, low energy environment (McClintock & Univ Alabama, 1994). Grebmeier & Barry (Grebmeier & Barry, 1991) and Dayton *et al.* (Dayton *et al.*, 1994) also conclude in their general reviews that the production in the benthic environment is much lower than elsewhere in the world but maintains comparatively high biomasses because of this stable environment.

Sponges and other filter feeders are known to provide important habitat for other invertebrates (Dayton, 1990; Gutt & Ekau, 1996; Gutt & Starmans, 1998). Glass sponges (greater than 10 cm in height) support a variety of faunas, including echinoderms, molluscs, polychaetes and pycnogonids). These assemblages are known to be vulnerable to and recover slowly from physical disturbance, such as iceberg scouring (Dayton, 1990; Gutt *et al.*, 1996). As such, they would be vulnerable to trawling as well (Dayton *et al.*, 1994).

Summary of factors considered important in the HIMI region

Table 14 summarises the factors that may be important in generating different types of assemblages in the HIMI region and shows the biophysical units in which the effects of those factors may be most evident. In general, the overall subdivisions of the HIMI region, arising from the analyses of physical and biological characteristics, is appopriate at this stage. In addition, the steep sloping margins to the south of HIMI are likely to be a productive area with a diverse assemblage in depths between 500 and 1000 m.

Table 14: Summary of factors that may be important in generating different types of assemblages in the HIMI region.
The biophysical units in which the effect may be most evident is shown.

Factor	Biophysical area where this may be particularly important
Wave action	Territorial Sea
Physical disturbance (such as by trawls)	Aurora, Coral and Shell Banks, Northeast Plateau (corals, gorgonians, sponges)
Localised upwellings, productivity	Aurora, Coral Banks and Western Trough, Shell Bank, Northeast Plateau
Accumulation of organic material through bottom topography and eddies	Eastern Trough, eastern margins of the plateau and territorial sea, Shell Bank
Mid-slope regions (500 – 1500 m depth)	Western margins, south of territorial sea, east of Shell Bank and Northeast Plateau
Type of substratum	This varies between most biophysical units. Shell Bank has the most distinct type of substratum (shell grit and sand)

Threats to the HIMI environment

Currently, bottom trawling for Patagonian toothfish and mackeral icefish is the primary threat to the benthic environment. To date, no study has been undertaken to examine the effects of trawling on the HIMI environment. Studies elsewhere have described in detail the long-lasting effects of bottom trawling on the structure of epibenthic habitats, such as sponge, coral and bryozoan assemblages (Dayton *et al.*, 1995; Jennings & Kaiser, 1998; Koslow & Gowlett-Holmes, 1998; Thrush *et al.*, 1998). Until recently, disturbances of infauna in soft substrata were thought to not last as long as for epibenthic species (Jennings & Kaiser, 1998). However, a recent study showed that assessments of effects at the scale of the commercial fisheries rather than in small scale studies may be necessary to demonstrate the long-lasting ecosystem-level changes in soft-bottom systems that may have occurred (Thrush *et al.*, 1998).

Currently, the toothfish fishery concentrates on a number of localised grounds. However, the Patagonian toothfish is widespread in the HIMI region. Thus, all benthic zones identified in this report are potentially vulnerable to disturbance by trawling. It is unlikely this fishery will compete with predators of toothfish because the level of predation of toothfish is low. Also the escapement of juvenile fish from this fishery is sufficient to sustain predators, according to the current rules for setting catch limits on major prey species in CCAMLR (Constable *et al.*, 1997).

The fishery for mackerel icefish is not as large as for Patagonian toothfish. There is potential for some overlap between the icefish fishery at Shell Bank and the foraging activities of icefish predators. Shell Bank has a separate stock of icefish (de la Mare *et al.*, 1998), which is much smaller than that on the Southern Plateau. The Shell Bank stock is likely to have only a low long-term annual yield and this stock is currently protected from fishing under CCAMLR Conservation Measure 159/XVII (CCAMLR, 1998). Records from AFMA observers to date

indicate that these trawl fisheries have few direct interactions with land-based marine predators.

Future threats may include the development of a longline fishery for Patagonian toothfish in the region and the development of a pelagic trawl fishery for mesopelagic fish (myctophids). Illegal longline fishers have targeted the Northeast Plateau and Shell Bank areas and these are known foraging areas of local predators. Other than effects on benthos, the threats posed by legal or illegal longline fisheries mostly concern the incidental mortality of marine mammals and seabirds in these fisheries. Illegal longline fishing also threatens the long-term viability of the legal toothfish fishery.

A pelagic trawl fishery for mesopelagic fish (myctophids) has similar ramifications around HIMI as a trawl fishery for antarctic krill has in higher latitudes. There is potential for overlap in the foraging range of land-based marine predators reliant on these fish and the activities of the trawl fishery because of the concentrations of these fish to the northeast of the island and, potentially, to the west in the Western Trough.

RECOMMENDATIONS FOR A MARINE PROTECTED AREA (MPA)

This report has identified that the HIMI marine region has environmental values of global significance and is a unique area within the AEEZ. Consequently, it is important to include parts of this region in the National Representative System of Marine Protected Areas.

Currently, no classifications of mesoscale (100s – 1000s of km) or microscale (10s – 100s of km) areas have been undertaken for the Kerguelen Province around HIMI (IMCRA Technical Group, 1998). The AEEZ around HIMI is almost equivalent in area to that around Tasmania, excluding Bass Strait, in which there are four IMCRA inshore mesoscale regions identified. It is recommended that an MPA be established to protect unique features of the HIMI benthic environment, representative portions of the different types of habitat in the region and the pelagic area in which land-based marine predators concentrate their local foraging activities.

Description of Area Recommended for Protection

A number of areas are recommended for declaration as IUCN Protected Area Management Category I (Appendix 1), in addition to the existing protection given to the territorial sea. Additional areas are considered necessary because this report has identified that not all attributes of the HIMI environment are represented in the territorial sea. The recommended areas and their purposes are as follows:

- Territorial Sea. The existing 12 n.m. zone around HIMI provides for the protection of nearshore marine species as well as foraging areas for many flying birds, including the endemic Heard Island shag.
- South of HIMI. The inclusion of this area would provide a more complete representative section of the steep sloping margins of the Southern Plateau. Few data are available concerning this and other deep-water areas. However, as it is likely to be highly productive with a diverse assemblage in the depths between 500 and 1000 m, the inclusion of this area would be a precautionary approach to protecting some deep-water habitats.

- Discovery Bank and portions of Southern Plateau Inner, Southern Plateau Outer and the Northern Plateau. The inclusion of a strip encompassing Discovery Bank and portions of the inner and outer Southern Plateau and the Northern Plateau would provide representative habitats from these zones. These areas contain long-lived glass and other erect sponge habitats vulnerable to disturbance from bottom trawling, areas where juvenile Patagonian toothfish are abundant and an area where very small mackerel icefish have been found (in the Inner Southern Plateau, but outside the territorial sea). Thus, such a strip would provide important refuges for young fish that migrate to adjacent commercial fishing grounds.
- Coral and Aurora Banks and portions of the Western Trough. Coral and Aurora Banks are areas with diverse assemblages of benthic invertebrates, in particular, gorgonian corals, barnacles and other species that are vulnerable to disturbance from bottom trawling. The adjacent deeper water habitats are representative of the Western Trough and are thought to be highly productive.
- Shell Bank, deep waters to the north, and portions of the Eastern Trough and Northeastern Plateau. Shell Bank maintains a separate stock of mackerel icefish, which is considered by the CCAMLR Working Group on Fish Stock Assessment to be insufficient to support a commercial fishery (SC-CAMLR, 1997; SC-CAMLR, 1998). Australia has elected to close this area to the icefish fishery in the last two years. In addition, this bank maintains small aggregations of a variety of other fish species, including species that can be caught as by-catch to commercial trawling. Protection of Shell Bank will provide refuge for these small stocks as well as protecting the diverse echinoderm assemblage and other locally distributed species present on the bank. This area will also protect the unique shell grit habitat, which differs from the basaltic sand and cobbles of the greater HIMI area. The inclusion of the deep water habitats north of Shell Bank would protect the main foraging area around HIMI for land-based marine predators. These areas and the inclusion of portions of the Eastern Trough and Northeastern Plateau would provide a cross-section of habitats identified to be locally important as well as providing a representative area encompassing the eastern HIMI fauna.

Assessment against criteria for MPAs

The criteria to be used as a basis for the identification and selection of MPAs as part of the National Representative System of Marine Protected Areas (ANZECC Task Force on Marine Protected Areas, 1998) is given in detail in Appendix 7. The following is a discussion aimed at answering the specific questions in the appendix.

Identification

The following discussion centres on the areas recommended for IUCN Category 1 protection within the HIMI AEEZ.

Comprehensiveness

The HIMI region is designated as the Kerguelen Province in Australia's Interim Marine and Coastal Regionalisation (IMCRA Technical Group, 1998). It has been separated from Macquarie Island and from the higher latitudes surrounding the Australian Antarctic Territory. As a result, an MPA in the HIMI region will provide an important addition to the National Representative System of Marine Protected Areas (NRSMPA). An MPA has been declared to protect habitat for land-based marine predators and a representative sample of benthic habitats around Macquarie Island. The assemblage of land-based marine predators at HIMI is different to that at Macquarie Island, notably because of the presence of the endemic Heard Island Shag and the Macaroni penguins, large numbers of fur seals (*cf*. low numbers at Macquarie) and the absence of the royal penguins at HIMI . In addition, HIMI is south of the Polar Front compared with Macquarie, which is north of this front and closer to the Subantarctic Front. This results in HIMI being in a more productive and colder location (i.e. an environment more similar to the antarctic environment).

HIMI is different to the continental shelf areas around the Australian Antarctic Territory in the higher latitudes because it is free of sea ice and is subjected to the west-wind drift, creating an extreme seasonality and much more turbulent marine environment. Also, productivity around the island supports a fish-based marine ecosystem rather than a krill-based ecosystem.

As a consequence of its overall uniqueness, the inclusion of the different habitats surrounding HIMI in marine protected areas will be a significant addition to the NRSMPA.

Representativeness

The areas recommended for Category 1 protection in the MPA at HIMI include the suite of benthic and pelagic environments (habitats) identified in this report. These areas provide protection to environments that are different to those within the 12-nautical mile territorial sea, which has different benthic assemblages and a different hydrological regime. The recommended areas include representative portions of the important components of these different environments, including :

- the coral habitats on the western banks,
- the sponge habitats in the north and northeast,
- representative parts of the central Heard Island plateau (nursery areas for the main commercial fish species),
- the area including Shell Bank that is a primary foraging location for HIMI land-based marine predators as well as a small local population of the icefish, *Champsocephalus gunnari*, local concentrations of *Notothenia squamifrons*, a nursery area for toothfish and areas where some benthic invertebrates and habitats are concentrated. This area is

unique in its shell-grit habitat compared to the predominance of basaltic sand and cobbles found elsewhere, and

- deep-water assemblages recognised to be present as a result of deep-sea research in Antarctica and elsewhere in the world..

The Kerguelen Plateau stands in the way of the west wind drift and causes the confluence of a number of oceanographic fronts as well as creating small-scale upwellings, eddies and gyres. These features have been observed around the HIMI region and appear to create a mosaic of benthic and pelagic habitats, each with their own unique features based on the type of substratum, water masses influencing them and the productivity nearby. The scale of the MPA should be such that it provides the minimum area required to protect the recognised vulnerable areas (Aurora, Coral, Discovery and Shell Banks) plus additional areas to provide representative samples of the remaining mosaic. In the case of the latter, a precautionary approach is required. This is because there is some evidence for smaller-scale heterogeneity of habitats within the local units. Given this, 50 km sections of the other local units would encompass representative portions of that smaller-scale heterogeneity.

Biogeographic Importance

The Kerguelen Plateau is the largest oceanic plateau in the world. The HIMI area is dominated by an active volcano, which can affect the benthic habitats adjacent to the islands through landslides and deposits. The marine ecology of this area and other island areas in the Indian Ocean are known to be very different from the ecology of similar areas in the South Atlantic. The Kerguelen Plateau is also a much larger plateau than other subantarctic plateaus/islands and has a much greater influence on the local oceanography, which, together with a greater topographic variability, results in a high diversity of habitats within the region.

The HIMI region has a number of endemic fish and echinoderm species, demonstrating its uniqueness in the Southern Ocean. Tables 17a and 17b provide a general comparison of Heard Island with other subantarctic islands. In the Indian sector, HIMI is the only island area that lies to the south of the Polar Front. While the island is closest to Kerguelen Island on the plateau, that island is often to the north of the Polar Front. The nearest area beyond the Kerguelen Plateau that is linked oceanographically to HIMI is the Ob and Lena Banks, which do not have islands rising from them. From there, the nearest subantarctic island south of the Polar Front is Bouvet Island in the South Atlantic. The HIMI area is different to Macquarie Island because of the different water masses each experiences; Macquarie Island is north of the Polar Front.

Table 15a: Comparison of subantarctic islands in the region of the Polar Front – Location and terrestrial characteristics.

Island or group	Latitude	Longitude	Location relative to Polar Front	Terrestrial					
				Area (ha)	Protected area (ha)	Introduced flora	Introduced fauna	Degree of modification	Habitation
Sth. Orkney Is.	60º30' – 60º50'S	44º15' – 46º15'W	800 km South	~62 000	735	Yes	No	1-2	1
Sth. Sandwich I.	56º18' –59º28'S	26º14' – 28º11'W	South	31 000	-	No	No	1-2	1
South Georgia I.	53º30' – 55º00'S	35º30' – 38º30'W	South	375 600		Yes	Yes	1-3	1
Bouvet I.	54º25'S	3º24'E	South	5 000	5 000	No	No	1	0
Prince Edward I.	46º38'S	37º57'E	On	4 400	-	Yes	No	1	0
Marion I.	46º54'S	37º45'E	On	30 000	-	Yes	Yes	3	1
Îles Crozet	46º00' – 46º30'S	50º00' – 52º30'E	On	50 000	22 500	Yes	Yes	1-3	1
Îles Kerguelen	48º27'S – 50º00'S	60º27' – 70º35'E	On	700 000	8 000	Yes	Yes	1-3	1
Heard I.	53º06'S	73º30'E	South	~38 000	-	No	No	1	-
McDonald Is.	53º03'S	72º36'E	South	~260	-	No	No	1	-
Macquarie I.	54º37'S	158º54'E	North	12 785	12 785	Yes	Yes	3	1

Adapted from Clark and Dingwall (1985).

Degree of modification:
0 = Unaffected by man.
1 = Little modification: some exploitation of marine mammals and seabirds in the past, but populations are recovering; current alien species or human impact is minor; no permanent human presence.
2 = Localised modification: significant modification may occur in small, localised area; permanent meteorological/research stations may exist; alien species may be established, but their impact and that of man is limited overall.
3 = Significant modification: introduced species are well-established; native biota is modified to an irrevocable extent; human activities occur, with effects on biota and environment; permanent human settlements may be present.

Habitation:
0 = Uninhabited.
1 = Meteorological/scientific station manned year round.

Table 15b: Comparison of subantarctic islands in the region of the Polar Front – Marine characteristics and uniqeness.

Island or group	Major prey species in area	Marine dependant species	Uniqueness
South Orkney Islands	Krill	Antarctic fur, southern elephant, Weddell, leopard and crabeater seals; king, macaroni and rockhopper penguins.	
South Sandwich Islands	Krill	Antarctic fur, southern elephant, leopard and Weddell seals; Adelie, chinstrap, gentoo and macaroni penguins.	Several islands recently or currently volcanically active.
South Georgia	Krill	Antarctic fur, southern elephant and wedded seals; gentoo, king and macaroni penguins.	The islands host more than half the world populations of macaroni penguin, grey-headed albatross, northern giant petrel and Antarctic prion; hosts two endemic land birds.
Bouvet Island	Krill	Antarctic fur and southern elephant seals; chinstrap and macaroni penguins.	
Prince Edward Islands	Mesopelagic fish	Antarctic fur, subantarctic fur and southern elephant seals; gentoo, king, macaroni and rockhopper penguins.	
Marion Island	Mesopelagic fish	Antarctic fur, subantarctic and southern elephant seals; king, macaroni and rockhopper penguins.	World's second largest breeding population of king penguins; lesser sheathbill is endemic.
Îles Crozet	Mesopelagic fish	Antarctic fur, subantarctic fur and southern elephant seals; king, macaroni and rockhopper penguins.	The islands host more breeding seabirds than any other island group; numerous endemic insect species.
Îles Kerguelen	Mesopelagic fish	Antarctic fur and southern elephant seals; king, macaroni and rockhopper penguins.	Situated on one of the largest oceanic plateaus; numerous endemic insects associated with the Kerguelen cabbage.
Heard Island and McDonald Islands	Mesopelagic fish	Antarctic fur, subantarctic fur, southern elephant, leopard seals; gentoo, king, macaroni and rockhopper penguins.	Situated on one of the largest oceanic plateaus; Australia's only active volcanic site and heavily glaciated subantarctic island; Heard Island cormorant and some fish and echinoderms are endemic to Heard Island and the Black-faced sheathbill is a distinct subspecies.
Macquarie Island	Mesopelagic fish	Southern elephant seal, subantarctic fur and New Zealand fur seals; gentoo, king and Royal penguins.	Only breeding ground of Royal penguins.

Adapted from Clark and Dingwall (1985).

Naturalness

Heard Island and the McDonald Islands are the only subantarctic islands in the Indian Ocean that have no introduced fauna or flora. The marine environment has been the subject of some marine research (three main voyages) as well as commercial fishing. Fishing has mostly been regulated, except for some illegal longline activities. Legal fishing has been undertaken by benthic trawling mostly in localised areas. Widespread effects are unlikely to have occurred. Of the areas recommended to be protected, only Shell Bank has had some levels of fishing activity, but this has only been at low levels over a two-year period. The stock of mackerel icefish in this area is not considered to be able to sustain commercial harvesting.

Ecological Importance

The knowledge available for describing ecological importance is limited at this stage. However, the HIMI region has been identified as a unique area within a biogeographic and regional framework (IMCRA Technical Group, 1998). To this end, protection of the range of marine habitats and environments in this area will provide for the protection of rare and endemic species and the maintenance of genetic diversity in the region. The protection of the foraging areas around Shell Bank may provide protection for endangered predator species, such as albatross, as well as protecting some foraging areas for species that are still recovering from over-exploitation in the past, including fur seals and king penguins.

International or National Importance

HIMI was inscribed on the World Heritage List in December 1997 under criteria (i)[1] and (ii)[2]. HIMI represents an unparalleled example of an island group of outstanding natural beauty that has suffered little human intervention, and where significant ongoing geological, ecological and biological processes continue to occur in the absence of human disturbance (DASETT, 1990). The marine areas surrounding HIMI that have been recommended for Category 1 protection have international significance because of their biogeographic values. Such importance is consistent with and enhances the declaration of the World Heritage area at HIMI, which includes the territorial sea, without encompassing the entire AEEZ.

Uniqueness

The HIMI region has been identified as a unique area within a biogeographic and regional framework (IMCRA Technical Group, 1998). Protection of the range of marine habitats and environments in this area will provide protection for unique species (including some fish and echinoderms), populations, communities and small-scale systems in the region. This is a precautionary approach to the conservation of these values, which is consistent with the approach adopted by CCAMLR.

Productivity

No information is available on the productivity of the HIMI region specifically. The areas recommended for Category 1 protection would provide some refuge to the recruitment and productivity of commercial fish species, particularly the western banks , the eastern margin of the plateau and Shell Bank, where an oceanographic eddy has been observed and is thought to influence productivity.

[1] Criterion 1: Be outstanding examples representing major stages of the earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.

[2] Criterion 2: Be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.

Vulnerability Assessment

Antarctic and Southern Ocean benthic environments are known to maintain stable, long-lived assemblages, except in areas where icebergs can scour the substratum, anchor-ice freezes the substratum or where the substratum can be disturbed by wave action or, in the case of continental shelves, deep-sea storms. For the HIMI region, ice is not a problem. However, storms and the consequent waves can disturb some areas of the shelf. Most of these areas have been identified to occur within the 12 n.m. territorial sea. The other areas likely to be affected are directly to the east of HIMI. Consequently, it is expected that the remainder of the HIMI region would support stable, long-lived benthic assemblages.

Heard Island and McDonald Islands are active volcanoes and eruptions could disrupt benthic assemblages near to the island. In the past, the major submarine effects of eruptions of Big Ben have occurred to the south of HIMI.

Selection

Economic Interests

The major economic interest in the region is commercial fisheries. The Ocean Drilling project has found that the HIMI region is unlikely to provide opportunities for commercial mining activities. Tourism is likely to increase to the region but this will mostly be concentrated in the territorial sea.

Currently, fishing operations are undertaken primarily using bottom trawls targetting Patagonian toothfish and mackerel icefish. The areas recommended for Category 1 protection will provide significant refuge to the recruitment and productivity of these commercial fish species.

Indigenous Interests

None

Social Interests

The HIMI area has heritage value generally as indicated by the national and world heritage listings. The main values to the Australian community are its natural heritage and aesthetic values, including wilderness value, as well as the economic value provided to the Australian economy by the fisheries and tourism.

The areas that are suggested for Category I protection would provide protection for the natural and wilderness values of the region, while not impinging on the commercial values. It may well enhance sustainability of fisheries by providing refugia and protecting recruitment areas for exploited populations.

Scientific Interests

The areas that are recommended for Category 1 protection provide opportunities to study the basic ecology of the region, without interference by human activities. These areas also provide a spatial configuration of open and closed areas that would enable monitoring for the effects of fishing on different types of habitats and for monitoring whether the protected areas are achieving their objectives. It will also improve the long-term potential for undertaking scientific research into the natural values and function of the HIMI marine ecosystem without interference from commercial activities.

Practicality/Feasibility

The establishment of an MPA at HIMI will receive widespread community support because of the natural extension to the already accepted World Heritage listing of HIMI.

The area is naturally protected from over-use because of its remote location, except for commercial fisheries activities. Legal fishing is regulated by AFMA and the fishing activities are observed by official AFMA observers and monitored using remote vessel monitoring systems. Illegal fishing has been known to occur in the region but Australia is currently active to protect the area from such operations.

The areas recommended for Category 1 protection do not conflict with and will compliment the current management obligations.

Vulnerability Assessment

The areas recommended for Category 1 protection are representative of the different habitats in the region. Some of these areas are vulnerable to the effects of the primary human activity in the region, which is commercial bottom trawling. In particular, sponge and coral habitats are generally known to be vulnerable to these activities and, according to current data available, these habitats would be protected within the suggested Category 1 areas.

Replication

The areas suggested for Category 1 protection are representative of the different habitats in the HIMI region. They cannot be replicated elsewhere in the Australian EEZ and do not represent replicate areas within the HIMI region.

STEPS TO THE IMPLEMENTATION OF AN MPA IN THE HIMI REGION

Domestic

The primary interest groups in the conservation and management of the HIMI region will be environment groups and commercial fishing interests. In the case of the latter, two permits are currently provided for fishing in the HIMI region. A fisheries management plan is currently being developed by AFMA for implementation by the end of 2000. The existing companies as well as the fishing industry generally are likely to wish to comment on any conservation initiative in the region.

International

The HIMI AEEZ is part of the CCAMLR area. Australia has obligations to abide by the principles of the convention and CCAMLR Conservation Measures set down each year by the Commission of CAMLR. Australia maintains that it will abide by these obligations and, if necessary, will take more stringent steps to ensure the conservation of antarctic marine living resources and their associated ecosystems. This has occurred in one instance when Australia has demonstrated this commitment to CCAMLR by unilaterally closing commercial harvesting of mackerel icefish on Shell Bank (CCAMLR, 1997, paragraph 9.47-9.49). A representative MPA at HIMI will not jeopardise our obligations under CCAMLR and is unlikely to cause conflict between Australia and other members of CCAMLR.

FUTURE WORK TOWARDS A SUCCESSFUL LONG-TERM MPA IN THE HIMI REGION

The further development of an MPA will require some research to address the following questions:

1. What are the small- and large-scale effects of the current and expected future activities in the area?
2. Does the current MPA provide sufficient representation of the different kinds of marine habitats in the HIMI region, including deep-water habitats?
3. Is the protection of land-based marine predator foraging locations sufficient for the conservation of those species?
4. How well does the MPA configuration protect the features it is designed to protect?

The primary threats to the conservation of natural processes in the marine areas of the HIMI region are from fishing activities, including bottom trawling and longlining. These activities can directly interact with the environment through the by-catch of fish species in both types of fishing, through the by-catch or incidental mortality of invertebrate species and habitat degradation through trawling and through the incidental mortality of seabirds and marine mammals in longline fisheries.

Some work is currently being undertaken within Australia on the mitigation of the incidental mortality of seabirds in subantarctic longline activities. However, no field research has been undertaken to assess the effects of trawling on the benthic environment. Such work is important in order to evaluate the threats to the specific habitats identified in this report. It will involve comparing benthic assemblages in areas where fishing occurs with adjacent areas where fishing does not occur with sampling at a scale commensurate with the spatial scale of the fisheries (see Thrush *et al.*, 1998 for details). In addition, some experimental trawling will need to be undertaken to determine the vulnerability of some habitats not fully protected by Stage 1 to the effects of trawling. This information can then be used as a basis for determining actions that need to be taken in Stage 2 of the development of an MPA at HIMI.

Studies to examine more closely the representativeness of the MPA will require mapping of the different habitats, such as acoustic mapping of the substratum, combined with sampling of the benthos, particularly the habitat-forming benthos such as sponges and corals. This sampling does not need to be synoptic over the whole region but could be undertaken using a stratified random sampling design. Such a design would aim to determine the extent of differences in assemblages and habitats between the different biophysical units as they are presented in this report. The design could also be established to provide the baseline data required for comparing areas inside and outside the marine protected area. This would then form part of a long-term monitoring program to monitor for the MPA for its effectiveness at achieving its objectives.

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LIST OF ACRONYMS

AAD – Australian Antarctic Division

AADC – Australian Antarctic Data Centre

AEEZ – Australian Exclusive Economic Zone

AFMA – Australian Fisheries Management Authority

AFMDA – Australia France Maritime Delimitation Agreement

AGSO – Australian Geological Survey Organisation

AMBIS - Australian Maritime Boundaries Information System

ANARE – Australian National Antarctic Research Expeditions

ASAC – Antarctic Science Advisory Committee

AUSLIG – Australian Surveying and Land Information Group

BMR – Bureau of Mineral Resources, Geology and Geophysics

CCAMLR – Commission for the Conservation of Antarctic Marine Living Resources

CRC – Cooperative Research Centre in Antarctic and Southern Ocean Studies

CSIRO – Commonwealth Scientific and Industrial Research Organisation

EEZ – Exclusive Economic Zone

GEBCO – General Bathymetric Chart of the Oceans

GIS – Geographic Information System

HIMI – Heard Island and the McDonald Islands

IHO – International Hydrographic Organisation

IMCRA – Interim Marine and Coastal Regionalisation for Australia

IOC – Intergovernmental Oceanographic Commission

IUCN – International Union for Conservation of Nature

NGDC – National Geophysical Data Centre

NOAA – National Oceanic and Atmospheric Administration

NRSMPA - National Representative System of Marine Protected Areas

ODP – Ocean Drilling Program

UNCLOS – United Nations Convention for the Law of the Sea

APPENDIX 1: IUCN CLASSIFICATION OF MARINE PROTECTED AREAS

Category	Title	Description
1a	**Strict Nature Reserve**: Protected Area managed mainly for science	Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physical features and/or species, available primarily for scientific research and/or environmental monitoring.
1b	**Wilderness Area**: Protected Area managed mainly for wilderness protection	Large area of unmodified or slightly modified land and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.
II	**National Park**: Protected Area managed mainly for ecosystem conservation and recreation	Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for this and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.
III	**Natural Monument**: Protected Area managed for conservation of specific natural features	Area containing one or more specific natural or natural/cultural feature which is of outstanding value because of its inherent rarity, representative or aesthetic qualities or cultural significance.
IV	**Habitat/Species Management Area**: Protected Area managed mainly for conservation through management intervention	Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or meet the requirements of specific species.
V	**Protected Landscape/Seascape**: Protected Area managed mainly for landscape/seascape conservation and recreation	Area of land, with coast and seas as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, cultural and/or ecological value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection , maintenance and evolution of such an area.
VI	**Managed Resource Protected Areas**: Protected Area managed mainly for the sustainable use of natural ecosystems	Area containing primarily unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

Derived from IUCN (1994)

APPENDIX 2: MARINE INVERTEBRATES (EXCLUDING PROTOZOA AND NEMERTEA) RECORDED IN THE TERRITORIAL SEA AROUND HEARD ISLAND AND THE McDONALD ISLANDS

Phylum	Family	Species
PORIFERA		
CALCAREA (CALCISPONGIAE)	Grantiidae	*Leuconia joubini* (Topsent)
HEXACTINELLIDA (HYALOSTONGIAE)	Rossellidae	*Rossella antarctica* (Carter)
DEMOSPONGIAE	Tetractinellida	
	Desmacidonidae	*Iophon proximum* (Ridley)
	Tetillidae	*Tetilla leptoderma* (Sollas)
	Suberitidae	*Suberites caminatus* (Kirkpatrick)
	Keratosa	*Dendrilla membranosa* (Pallas)
CNIDARIA (COELENTERATA)		
HYDROZOA	Hydroida/Leptomedusae	*Schizotricha multifurcata* (Allman)
	Hydrocorallina/Stylasterina	*Errina antarctica* (Gray)
MOLLUSCA		
POLYPLACOPHORA	Paleoloricata/Lepidopleurina	
	Hanleyidae	*Hemiarthrum setulosum* (Dall)
GASTROPODA	Prosobranchia	
	Archaeogastropoda	
	Patellidae	*Nacella kerguelensis* (Smith)
		Patinigera macquariensis (Finlay)?
	Trochidae	*Solariella charopus caerulus* (Watson)
	Mesogastropoda	
	Littorinidae	*Laevilitorina heardensis* (Dell)
		Laevilitorina caliginosa (Gould)?
		Pellitorina setosa (Smith)
		Pellitorina pellita (Martens) (= *P. setosa*?)
		Macquariella hamiltoni (Smith)
	Omalogyridae	*Omalogyra atomus atomus* (Philippi)
	Struthiolariidae	*Perissodonta mirabilis* (Smith)
	Naticidae	*Amauropsis prasina* (Watson)
	Neogastropoda	
	Muricidae	*Trophon albolabratus* (Smith)
	Buccinulidae	*Neobuccinum eatoni* (Smith)
		Chlanidota vestita (Martens)
	Cancellariidae	*Admete specularis* (Watson)
	Turridae	*Typhlomangelia fluctosa* (Watson)
BIVALVIA (PELECYPODA)	Pteromorpha/Arcoida	
	Limopsidae	*Lissarca rubrofusca* (Smith)
		Limopsis marionensis (Smith)
	Philobryidae	*Philobrya laevis* (Thiele)
	Heterodonta/Veneroida	
	Cyamiidae (Turtoniidae)	*Kidderia bicolor* (Martens)
	Gaimardiidae	*Gaimardia trapesina trapesina* (Lamarck)?
CEPHALOPODA	Coleoidea/Octopoda	
	Octopodidae	*Benthoctopus levis* (Hoyle)

Phylum	Family	Species
ARTHROPODA		
CRUSTACEA	Ostracoda	*Bairdia simplex* (Stewardson Brady)
		Cythere kerguelenensis (Stewardson Brady)
		Cythere wyville-thomsoni (Stewardson Brady)
		Cythere foveolata (Stewardson Brady)
		Xestoleberis setigera (Stewardson Brady)
		Cytheropteron assimile (Stewardson Brady)
		Cytherideis laevata (Stewardson Brady)
		Sclerochilus contortus (Norman)
	Amphipoda/Gammaridea	
	Gammarellidae	*Pontogeneia chrosroides* (Nicholls)
	Hyalidae	*Hyale hirtipalma* (Dana)
	Iphimediidae	*Labriphimeda pulchridentata* (Stebbing)
	Liljeborgiidae	*Liljeborgia consanguinea* (Stebbing)
	Oedicerotidae	*Oediceroides rostratus* (Stebbing)
	Eusiridae	*Eusiroides pompeii* (Stebbing)
	Isopoda	*Exosphaeroma gigas* (Leech)
		Cassidinopsis cf. *emarginata*
BRYOZOA		
GYMNOLAEMATA/ CHEILOSTOMATA	Scrupocellariidae	*Menipea quadrata* (Busk)
	Bicellariellidae	*Cornucopina pectogemma* (Goldstein)
		Beania challengeri (Hastings)
		Beania magellanica (Busk)
		Bugula longissima (Busk)
	Scruparíidae	*Brettia inornata* (Goldstein)
	?Family	*Hippothoa flagellum* (Manzoni)
		Nellia oculata (Busk)
		Membranipora crassimarginata var. *erecta* (Hincks)
		Vincularia gothica var. *granulata* (d'Orbigny)
		Salicornaria clavata (Busk)
		Onchopora sinclairi (Busk)
		Reteporella flabellata (Busk)
		Cribrilina philomela var. *adnata* (Busk)
		Escharoides verruculata (Smitt)
		Schizoporella triangulata (Hincks)
		Myriozoum marionense (Busk)
		Cellepora albirostris (Smitt)
BRACHIOPODA		
ARTICULATA		*Terebratula uva* (Broderip)
		Notosaria nigricans (Watson)
		Aerothyris kerguelensis (Davidson)

Phylum	Family	Species
ECHINODERMATA		
ASTEROIDEA	Asteriidae	*Anasterias mawsoni* (Koehler, 1922)*
		Diplasterias meridionalis (Perrier, 1875)*
		Smilasterias scalprifera (Sladen, 1889)*
		Smilasterias triremus (Sladen, 1889)*
	Asterinidae	*Tremaster mirabilis* (Verrill, 1880)*
	Astropectinidae	*Astropectin* sp.*
		Bathybiaster loripes (Sladen, 1889)*
		Bathybiaster loripes var. *obesa* (Sladen)
		Leptychaster kerguelensis kerguelensis (Smith, 1876)*
	Benthopectinidae	*Cheiraster (Luidiaster) hirsutus* (Studer, 1884)*
	Echinasteridae	*Henricia simplex* (Sladen, 1889)*
		Henricia spinulifera (Smith, 1876)*
		Rhopiella hirsuta (Koehler, 1920)*
	Ganeriidae	*Cycethra verrucosa* (Philippi, 1857)*
		Perknaster fuscus (Sladen, 1889)*
	Goniasteridae	*Hippasteria falklandica* (Fisher, 1940)*
	Labidiasteridae	*Labidiaster annulatus* (Sladen, 1889)*
	Odontasteridae	*Acodontaster elongatus* (Sladen)
		Acodontaster elongatus elongatus (Sladen, 1889)*
		Odontaster meridionalis (Smith, 1876)*
		Odontaster validus (Koehler, 1906)*
	Poraniidae	*Porania antarctica* (Sladen, 1876)*
		Porania antarctica glabra (Sladen)
	Pterasteridae	*Pteraster affinis* (Smith, 1876)*
		Pteraster rugatus (Sladen, 1889)*
	Solasteridae	*Cuenotaster involutus* (Koehler, 1912)*
		Solaster regularis (Sladen)
		Solaster regularis subarcuatus (Sladen, 1889)*
CRINOIDEA	Antedonidae	*Antedon australis* (Carpenter, 1888)*
		Promachocrinus kerguelensis (Carpenter, 1888)*
		Solanometra antarctica (Carpenter, 1888)*
ECHINOIDEA	Cidaridae	*Ctenocidaris nutix* (W.Thomson, 1876)*
		Ctenocidaris speciosa (Mortensen, 1910)*
		Goniocadaris canaliculata (A. Agassiz)
	Echinidae	*Dermechinus horridus* (A.Agassiz, 1879)*
		Strechinus agassiz (Mortensen, 1936)*
		Strechinus diadema (Studer, 1876)*
	Euechinoidea	
	Echinacea/Echinoida	*Echinus margaritaceus* (Lamarck)
	Atelostomata/Holasteroida	*Pourtalesia carinata* (A. Agassiz)
		Pourtalesia ceratopyga (A. Agassiz)
		Hemiaster cavernosus (A. Agassiz)
	Schizasteridae	*Abatus cordatus* (Verrill, 1876)*
		Tripylus excavatus (Koehler, 1912)*

Phylum	Family	Species
HOLUTHUROIDEA	Chiridotidae	*Trochodota purpurea* (Lesson, 1830)*
	Cucumariidae	*Cucumaria godeffroyi* (Semper, 1868)*
		Cucumaria kerguelensis (Theel, 1886)*
		Cucumaria laevigata (Verrill)
		Cucumaria serrata (Theel, 1886)*
		Cucumaria serrata var. *intermedia* (Theel)
		Pseudocnus laevigatus (Verrill, 1876)*
		Pseudocnus sp.*
		Trachythyone lechleri (Lampert, 1885)*
		Trachythyone mira (Ludwig and Hedding, 1935)*
	Dendrochirotida	*Thyone muricata* (Studer)
		Pseudocnus laevigatus
	Molpadiidae	*Molpadia musculus* (Risso, 1826)*
	Psolidae	*Psolidium incertum* (Theel, 1886)*
		Psolus sp.*
		Psolus ephippifer (Thomson, 1876)*
		Psolus paradubiosus (Carriol and Feral, 1985)*
OPHIUROIDEA	Amphiuridae	*Amphiura angularis angularis* (Lyman, 1879)*
		Amphiura eugeniae antarctica (Studer)*
		Amphiura sp.*
		Amphiura studeri (Lyman)
		Amphiura tomentosa (Lyman)*
		Pandelia angularis
	Asteronychidae	*Asteronyx loveni* (Muller and Troschel, 1842)*
	Gorgonocephalidae	*Astrotoma agassizii* (Lyman, 1875)*
		Gorgonocephalus chilensis (Philippi, 1858)*
		Gorgonocephalus pourtalesii (Lyman)
	Ophiacanthidae	*Ophiacantha imago* (Lyman, 1878)*
		Ophiacantha sp.*
		Ophiacantha vivipara (Ljungman, 1870)*
		Ophiomitrella sp.*
		Toporkovia antarctica (Lyman, 1879)*
	Ophiolepidae	*Ophiolepis carinata* (Studer)
		Ophioglypha deshayesi (Lyman)
	Ophiomyxidae	*Ophioscolex nutrix* *
	Ophiuridae	*Ophiocten amitinum* (Lyman)*
		Ophiomisidium speciosum (Koehler)*
		Ophionotus hexactis (Smith, 1876)*
		Ophiura (Opiuroglypha) carinifera (Koehler, 1901)*
		Ophiura ambigua (Lyman, 1878)*
		Ophiura brevispina (Smith, 1876)*
		Ophiura sp.1*
		Ophiura sp.2*
		Ophiurolepis carinata (Studer, 1876)*
CHORDATA		
	Hemichordata/Pterobranchia	*Cephalodiscus* sp.
	Urochordata/Ascidiacea	
	Styelidae	*Polyzoa opuntia* (Lesson)
	Distomidae	*Colella pedunculata* (Quoy & Gaimard)
	?Family	*Aplidium irregulare*
		Ascidia challengeri
		Didemnum studeri
		Hypsistozoa fasmeriana
		Sycozoa sigillinoides

Adapted from AAD (1995).

* Echinoderm species identified in 1999 by the Museum of Victoria.

APPENDIX 3: FISH SPECIES IDENTIFIED IN THE TERRITORY OF HEARD ISLAND AND THE McDONALD ISLANDS

Family	Species
Squalidae	*Etmopterus sp.*
Rajidae	*Bathyraja eatoni* (Günther)
	Bathyraja irrasa (Hureau and Ozouf-Costas)
	Bathyraja murrayi (Günther)
	Bathyraja sp.
Muraenolepididae	*Muraenolepis marmoratus* (Günther)
Moridae	*Antimora rostrata* (Günther)
	Muraenolepis orangiensis (Vaillant)
Macrouridae	*Macrourus carinatus (*Günther*)*
Carapidae	*Echiodon* sp.
Congiopodidae	*Zanclorhynchus spinifer* (Günther)
Liparididae	*Paraliparis* sp.
Zoarcidae	*Lycodapus antarcticus* (Tomo)
	Melanostigma gelatinosum (Günther)
Nototheniidae	*Dissostichus eleginoides* (Smitt)
	Gobionotothen acuta (Günther)
	Lepidonotothen mizops (Günther)
	Lepidonotothen squamifrons (Günther)
	Notothenia rossii (Richardson)
	Notothenia cyanobrancha (Richardson)
	Notothenia coriiceps (Richardson)
	Paranotothenia magellanica (Forster)
Bathydraconidae	*Bathydraco antarcticus (*Günther*)*
	Bathydraco sp.
Channichthyidae	*Champsocephalus gunnari* (Lönnberg)
	*Channichthys rhinoceratus (*Richardson*)*
Bothidae	*Mancopsetta maculata* (Kotlyar)
Bathylagidae	*Bathylagus antarcticus* (Günther)
Centrolophidae	*Icichthys australis* (Haedrich)
Gempylidae	*Paradiplospinus gracilis* (Brauer)
Gonostomatidae	*Cyclothone* spp.
Harpagiferidae	*Harpagifer kerguelensis* (Nybelin)
Myctophidae	*Electrona antarctica* (Günther)
	Electrona carlsbergi (Tåning)
	Electrona subaspera (Günther)
	Metelectrona ventralis (Bekker)
	Gymnoscopelus nicholsi (Gilbert)
	Gymnoscopelus braueri (Lönnberg)
	Krefftichthys anderssoni (Lönnberg)
	*Protomyctophum bolini (*Fraser-Brunner*)*
	*Protomyctophum subparallelum (*Tåning*)*
	Lampanyctus achirus (Andriashev)
Paralepididae	*Notolepis coatsi* (Dollo)
Stomiatidae	*Stomias boa* (Risso)
	*Stomias gracilis (*Garman*)*

Adapted from AAD (1995).

APPENDIX 4: MAMMALS RECORDED IN THE TERITORY OF HEARD ISLAND AND THE McDONALD ISLANDS

Pinnipedia	**Status**
Otariidae	
Subantarctic fur seal	Breeding
Arctocephalus tropicalis (Gray)	Rare
Antarctic fur seal	Breeding
Arctocephalus gazella (Peters)	Common
Phocidae	
Southern elephant seal	Breeding
Mirounga leonina (Linnaeus)	Abundant
Weddell seal	Vagrant
Leptonychotes weddelli (Lesson)	Very rare
Crabeater seal	Vagrant
Lobodon carcinophagus (Hombron and Jacquinot)	Very rare
Leopard seal	Non-breeding visitor
Hydrurga leptonyx (Blainville)	Common
Ross seal	Vagrant
Ommatophoca rossii (Gray)	Very rare
Cetacea	**Status**
Hourglass dolphin *Lagenorhynchus cruciger* (Quoy & Gaimard)	Information inadequate
Killer whale *Orcinas orca* (Linnaeus)	Information inadequate
Minke whale *Balaenoptera acutorostrata* (Lacepède)	Information inadequate
Pilot whale *Globicephala melaena* (Traill)	Information inadequate
Southern bottlenose whale *Hyperoodon planifrons* (Flower)	Information inadequate
Spectacled porpoise *Phocaena dioptrica* (Lahille)	Information inadequate

Adapted from AAD (1995).

APPENDIX 5: BREEDING BIRDS RECORDED IN THE TERRITORY OF HEARD ISLAND AND THE McDONALD ISLANDS

Breeding birds reported	Approximate number of breeding pairs	
	Heard Island	McDonald Islands
Gentoo penguin *Pygoscelis papua* (Forster)	16 600	
King penguin *Aptenodytes patagonicus* (Miller)	15 000	
Macaroni penguin *Eudyptes chrysolophus* (Brandt)	1 000 000	1 000 000
Eastern rockhopper penguin *Eudyptes chrysocome chrysocome* (Forster)	10 000	100
Black-browed albatross *Thalassarche melanophrys* (Temminck)	600-700	82-89
Light-mantled albatross *Phoebetria palpebrata* (Forster)	200-500	Individuals observed
Wandering albatross *Diomedea exulans* (Linnaeus)	1	
Southern giant-petrel *Macronectes giganteus* (Gmelin)	3000	c. 1500
Subantarctic skua *Catharacta lonnbergi* (Mathews)	100 – 1 000	+
Cape petrel *Daption capense* (Linnaeus)	1 000 – 10 000	+
Common diving-petrel *Pelecanoides urinatrix* (Gmelin)	1 000 – 10 000	+
South Georgia diving-petrel *Pelecanoides georgica* (Murphey & Harper)	10 000 – 100 000	1 000 – 10 000
Wilson's storm-petrel *Oceanites oceanicus* (Kuhl)	+	
Antarctic prion *Pachyptila desolata* (Gmelin)	1 000 – 10 000	10 – 100
Fulmar prion *Pachyptila crassirostris* (Mathews)	1 000 – 10 000	Individuals observed
Antarctic tern *Sterna vittata* (Gmelin)	10 - 100	
Kelp gull *Larus dominicanus* (Lichtenstein)	100 – 1 000	
Black-faced sheathbill *Chionis minor nasicornis* (Reichenow)	100 – 1 000	10 - 100
Heard Island cormorant *Phalacrocorax nivalis* (Falla)	250 - 600 (endemic)	

KEY: + = Breeding reported but no estimate of population size available.
Adapted from Woehler (1991).

APPENDIX 6: NON-BREEDING BIRDS RECORDED IN THE TERRRITORY OF HEARD ISLAND AND THE MCDONALD ISLANDS

Non-breeding birds reported	Abundance
Chinstrap penguin	
Pygoscelis antarctica (Forster)	Visitor
Adélie penguin	
Pygoscelis adeliae (Hombron and Jacquinot)	Very rare
Emperor penguin	
Aptenodytes forsteri (Gray)	Very rare
Northern giant-petrel	
Macronectes halli (Mathews)	Few
Southern fulmar	
Fulmarus glacialoides (Smith)	Few
Antarctic petrel	
Thalassoica antarctica (Gmelin)	Few
Arctic tern	
Sterna paradisaea (Pontoppidan)	Common (in summer)
Snow petrel	
Pagodroma nivea (Forster)	Very rare
Blue petrel	
Halobaena caerulea (Gmelin)	Rare
White chinned petrel	
Procellaria aequinoctialis (Linnaeus)	Few
Black-bellied storm petrel	
Fregetta tropica (Gould)	Very rare
Greenshank	
Tringa nebularia (Gunnerus)	Very rare

Adapted from AAD (1995) and Woehler (1991).

APPENDIX 7: CRITERIA TO BE USED AS A BASIS FOR THE IDENTIFICATION AND SELECTION OF MARINE PROTECTED AREAS

IDENTIFICATION

Representativeness

Will the area:

- represent one or more ecosystems within an IMCRA bioregion, and to what degree;
- add to the representativeness of the NRSMPA, and to what degree.

Comprehensiveness

Does the area:

- add to the coverage of the full range of ecosystems recognised at an appropriate scale within and across each bioregion;
- add to the comprehensiveness of the NRSMPA.

Biogeographic importance

- Does the area capture important biogeographic qualities.

Naturalness

- How much has the area been protected from, or not been subjected to, human induced change.

Ecological importance

Does the area:

- contribute to the maintenance of essential ecological processes or life-support systems;
- contain habitat for rare or endangered species;
- preserve genetic diversity ie is diverse or abundant in species;
- contain areas on which species or other systems are dependent, eg contain nursery or juvenile areas or feeding, breeding or resting areas for migratory species;
- contain one or more areas which are a biologically functional, self-sustaining ecological unit.

International or national importance

- Is the area rated, or have the potential to be listed, on the world or a national heritage list or declared as a Biosphere Reserve or subject to an international or national conservation agreement.

Uniqueness

Does the area:

- contain unique species, populations, communities or ecosystems;
- contain unique or unusual geographic features.

Productivity

- Do the species, populations, or communities of the area have a high natural biological productivity.

Vulnerability assessment

- Are the ecosystems and/or communities vulnerable to natural processes.

SELECTION

Economic interests

Does the site:

- make an existing or potential contribution to economic value by virtue of its protection, eg for recreation or tourism, or as a refuge or nursery area, or source of supply for economically important species;
- have current or potential use for the extraction of or exploration for resources;
- have importance for shipping and/or trade;
- have usage by traditional users including commercial fishers;
- have value due to its contribution to local or regional employment and economic development.

Indigenous interests

Does the site:

- have traditional usage and/or current economic value;
- contain indigenous cultural values;
- have native title considerations.

Social interests

- Does the site have existing or potential value to the local, national or international communities because of its heritage, cultural, traditional aesthetic, educational, recreational, or economic values.

Scientific interests

- Does the site have existing or potential value for research or monitoring.

Practicality/feasibility

Does the site:

- have a degree of insulation from external destructive influences;
- have social and political acceptability, and a degree of community support;
- have access for recreation, tourism, education;
- have compatibility between an MPA declaration generally and existing uses;
- have relative ease of management, and compatibility with existing management regimes.

Vulnerability assessment

- Is the site vulnerable and susceptible to human induced changes and threatening processes.

Replication

- Will the site provide replication of ecosystems within the bioregion.

Taken from ANZECC Task Force on Marine Protected Areas, 1998.