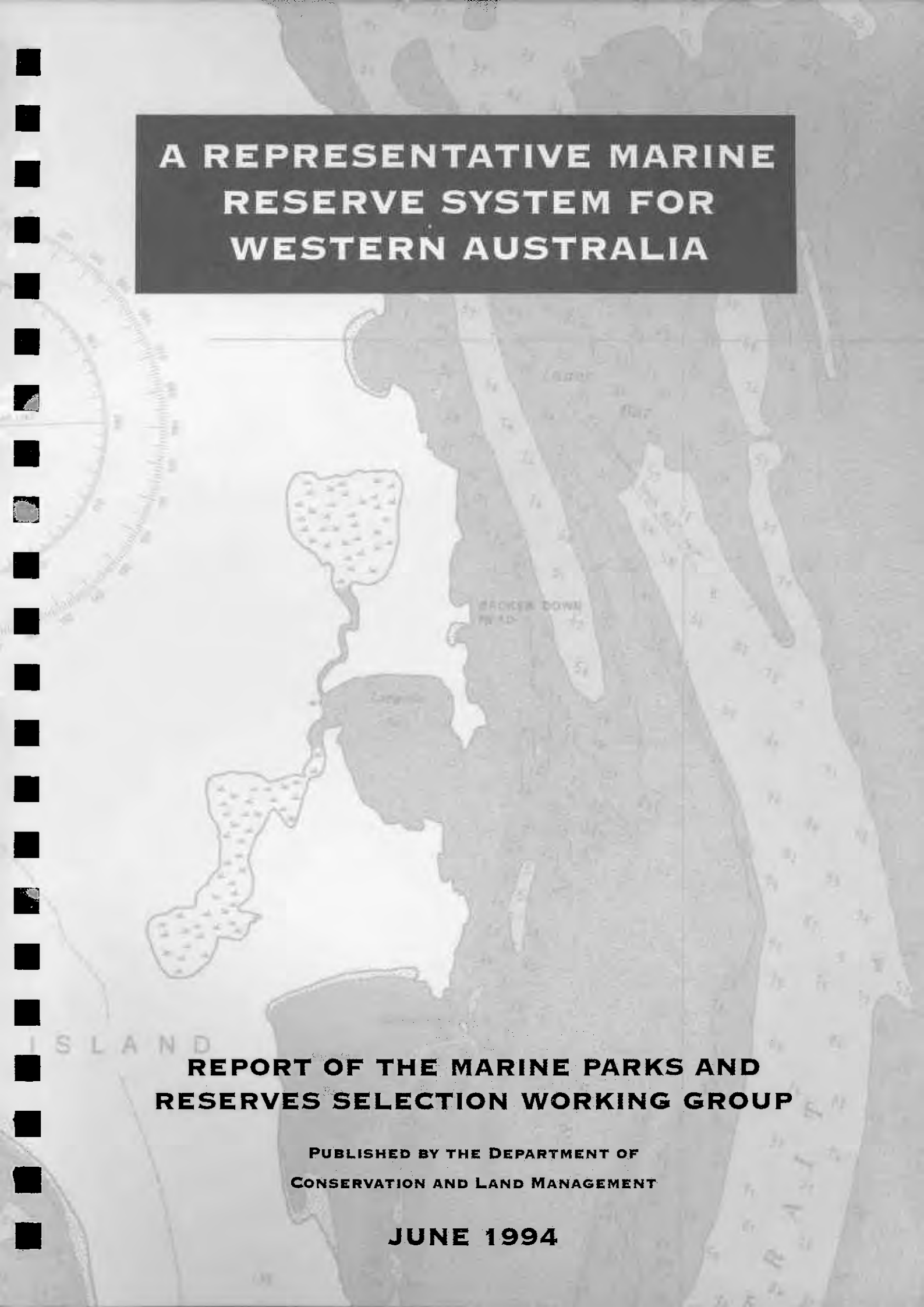
A REPRESENTATIVE MARINE RESERVE SYSTEM FOR WESTERN AUSTRALIA



REPORT OF THE MARINE PARKS AND RESERVES SELECTION WORKING GROUP

PUBLISHED BY THE DEPARTMENT OF
CONSERVATION AND LAND MANAGEMENT

JUNE 1994

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This report prepared by the Marine Parks and Reserves Selection Working Group for the Hon Kevin Minson MLA, Western Australian Minister for the Environment, is published on behalf of the Working Group by the Department of Conservation and Land Management.

The valuable contribution made by the Chairman and members of the Working Group, over a number of years, is gratefully acknowledged, as is the financial assistance towards the work of the Working Group, in recent years, from the Commonwealth Government through the Ocean Rescue 2000 Program.

The views expressed in this report are those of the Working Group, and are not necessarily the views of the Western Australian Department of Conservation and Land Management, the Western Australian Minister for the Environment, or the Commonwealth Government.

Syd Shea
EXECUTIVE DIRECTOR
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

MAKING A SUBMISSION

We want to know what you think of the proposals in this report; have you thought of writing a submission?

WHY WRITE A SUBMISSION?

It is an opportunity to provide information, express your opinion, suggest alternatives and have a say on how we are proposing to develop the marine reserve system in Western Australia.

If you prefer not to write your own submission you could make a joint submission with others.

WHAT HAPPENS TO YOUR SUBMISSION?

All submissions will be summarised according to the topics discussed. The report will then be reviewed in the light of the submissions, according to established criteria (see overleaf). A summary of the submissions will be published, including an indication of how the report was or was not amended in response to the submissions, along with the final report. If a submission is marked CONFIDENTIAL it will not be quoted in the summary or published.

WHAT MAKES AN EFFECTIVE SUBMISSION?

To ensure your submission is as effective as possible:

- make it concise and clear;
- list your points according to the parts (and page numbers) in the report;
- describe briefly each subject or issue you wish to discuss;
- say whether you agree or disagree with any or all of the report's contents, particularly the recommendations within each subject or just those of specific interest to you; clearly state your reasons (particularly if you disagree); and
- give sources of information where possible; and suggest alternatives to deal with any issue with which you may disagree.

Note: It is as important to indicate those recommendations you agree with as it is those with which you disagree.

Each submission is important in its own right but those that give reasons for concerns, give support where appropriate and offer useful information and suggestions are most useful.

DEADLINE

Submissions are welcome for three months until 11 November, 1994.

WHERE TO SEND YOUR SUBMISSION

Written submissions should be sent to:

Executive Director
Department of Conservation and Land Management
PO Box 104
COMO WA 6152
Attention: Manager Marine Unit

CRITERIA FOR ANALYSING PUBLIC SUBMISSIONS

The report will be amended if a submission:

- provides additional information on physical, biological or geographical features of relevance to the recommendations;
- provides additional information on affected groups of direct relevance to the recommendations;
- indicates a change in Government legislation, management commitment or management policy; proposes strategies that would better achieve objectives; or
- indicates omissions, or a lack of clarity.

The report *will not* be amended if a submission:

- clearly supports the draft proposals;
- offers a neutral statement or no change is sought;
- addresses issues beyond the scope of the report;
- makes points which are already in the report or were considered during its preparation;
- is strongly opposed to other submissions with the existing recommendations providing a preferred option; or
- contributes options which are not feasible (generally due to conflict with legislation, or Government policy).

GUIDE TO THIS REPORT

The report is divided into five parts:

- Part I: Introduction
- Part II: Marine Reserves of the Kimberley and the Sahul Shelf
- Part III: Marine Reserves on the Canning and Pilbara Coasts and the Rowley Shelf
- Part IV: Marine Reserves on the West Coast
- Part V: Marine Reserves on the South Coast

The Working Group's recommendations occur throughout the text, but are also gathered into a Summary of Recommendations section after Part V.

Part I is a general introduction to the Western Australian marine environment, with a statement of the principles applied in the process of selection of areas for consideration for reservation.

Each of Parts II to V contains a general statement about the physical and biological features of a section of the coast, current resource utilisation, existing marine reserves, descriptions of the major ecosystem units which the Working Group considers have particular significance, and recommendations on which specific areas warrant consideration as reserves.

It is important to note that the recommendations in this report do not constitute the Notices of Intent required under the *Conservation and Land Management Act* 1984 which must be published for public comment before marine parks and marine nature reserves may be declared.

Hon. Kevin Minson MLA
Minister for the Environment

23 May 1994

Dear Mr Minson

Marine Parks and Reserves Working Group Report

At its meeting on February 1, the Working Group approved the final draft of the report subject to some minor amendments. The amendments have now been made. I am pleased, on behalf of the Working Group, to forward the report for your consideration.

It has been our experience that the function of marine reserves is not widely understood in the community. Although strong community support quickly develops, for example the local support now evident for the Ningaloo Marine Park, initial response is often negative from some sectors. The Working Group believes that a public participation program is needed to gain general public support for the recommendations contained in the report. It is our hope that you will decide to release the report for public comment and establish a process for its review, in the light of public input, before the report is adopted by the Government.

With the submission of this final report to you, the task of the Working Group is completed. However, should you decide to release the report, the members would welcome an opportunity to be involved in the review of public comment.

Yours sincerely

Barry Wilson

B.R. Wilson
Chair
Marine Parks & Reserves Working Group

MARINE PARKS & RESERVES WORKING GROUP

The Working Group was initially appointed by the Minister for the Environment in 1986. The Group held a series of workshop sessions to consider information gathered on stretches of the Western Australian coast from the Kimberley to Eucla. Drafts were prepared after each session for further discussion at successive meetings until the Group was satisfied with the results. The drafts and the final report were prepared, with contributions from Working Group members, by Murex Consultants Pty. Ltd. Maps were prepared by the Department of Conservation and Land Management Land Information Branch.

Since the initial appointments, some members have moved to other positions and have been replaced by other specialists in their fields. The following is a list of people who have served on the Working Group at some stage. Those noted with an asterisk were involved in the early work of the Working Group but not in the preparation of the report.

MEMBERS OF THE WORKING GROUP

Dr P.F. Berry *BSc. (Hons), MSc., PhD.* Western Australian Museum
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Dr H.E. Jones *BSc., PhD.* Western Australian Fisheries Department
Dr H. Kirkman *BAg. Sci., MAg. Sci., PhD.* CSIRO Division of Fisheries & Oceanography
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Dr B.R. Wilson FTS (Chair) *BSc. (Hons), PhD.* Murex Consultants Pty. Ltd.

Note: Although not a member of the Working Group, Dr E.P. Hodgkin contributed material on estuaries.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT SUPPORT

Mr H. Chevis *BSc., MSc.*
Mr R.F. May *BSc., Dip. Ag. Sci.*
Mrs S. King (secretarial support)
Land Information Branch (preparation of maps)

MUREX CONSULTANTS STAFF

Dr B.R. Wilson FTS *BSc. (Hons), PhD*
Mr D.B. Johnston *M.App. Sc.(Surv. & Map,), Dip. Cartography*

AIMS AND SCOPE

The aims of this report are to review what is known of the flora and fauna, habitats and geomorphology of Western Australian coastal waters, and to identify areas that have particular value for conservation, scientific and public recreation, making them worthy of reservation for these public purposes.

Each set of recommendations in the body of the text is preceded by background information about the natural attributes of the area in question and the reasons the Working Group selected it as a worthy candidate for reservation. The locations of the areas are shown on the maps.

For quick reference, the recommendations are also listed independently in the section 'Summary of Recommendations' following Part V.

The Working Group consisted chiefly of marine scientists familiar with the coast and its flora and fauna and recreational uses. The group did not consider mining or commercial fishing, although these activities were noted where they were known to occur. Consideration of such values and uses of the selected areas would be more appropriate at a future phase of the marine reserves program, before implementation begins.

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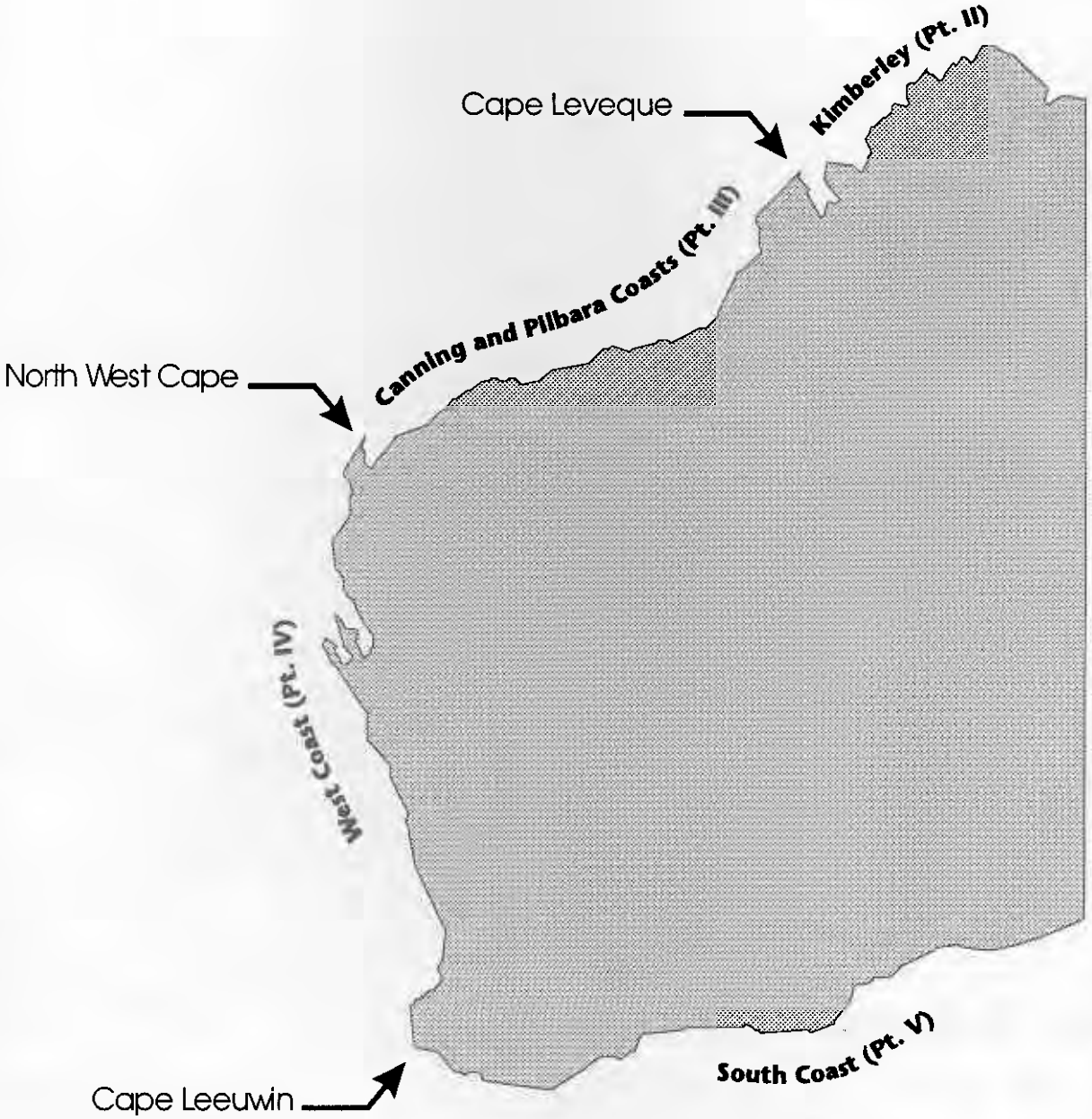

Map showing the four sections of the Western Australian coastline dealt with in this report

A REPRESENTATIVE MARINE RESERVE SYSTEM FOR WESTERN AUSTRALIA

Report of the Marine Parks and Reserves Selection Working Group

PART I

INTRODUCTION

CONTENTS

PART I: INTRODUCTION

1. GENERAL INTRODUCTION

1.1. Background

The State Conservation Strategy (1987) sets as one of its principal goals the establishment of a conservation reserves system representative of the flora and fauna and habitats of Western Australia. Protection of natural values outside the reserve system, to an extent that is consistent with other land-uses, is another primary conservation goal.

The need to apply these conservation strategies to the marine environment as well as to the terrestrial environment has only recently gained credence. There is growing community awareness and concern about degradation of some of Western Australia's estuarine and marine environments through alienation, pollution and overuse. The situations of concern range from obvious pollution (eg. Peel-Harvey Estuary) to generalised awareness that "the fishing is not like it used to be". On the other hand, there is also growing awareness that Western Australia possesses estuarine and marine resources of great potential for fisheries, other useable resources, recreation and tourism. In order to protect and wisely use these resources for long-term community benefit, effort must be focused on management of the marine environment. A representative reserve system is an essential part of any environmental management program, and estuarine and marine environments are no exception (Rooney *et al.*, 1978; Salm & Clark, 1984; CONCOM, 1985; Australian Committee for IUCN, 1986; Kelleher & Kenchington, 1990).

Marine reserves serve several important functions. They are intended as places where plants and animals and their habitats may be protected or managed to ensure long-term survival in natural conditions. Like their terrestrial equivalents, marine conservation reserves help protect species and preserve the diversity of life. They may also be a resource for education, recreation and tourism programs. Many national parks play a fundamental role in the tourism industry. Marine parks may have the same function. The Great Barrier Reef Marine Park, for example, is the basic resource upon which a major proportion of the Queensland tourism industry is based. Reservation allows management programs to be put in place to ensure that the resource is both accessible and sustainable.

Western Australia is blessed with a long and varied coastline and an abundance of marine life. Maritime recreation and tourism are very important in this State. Recreational fishing is an important element in the lifestyle of many Western Australians. Recreational fishing and the dive tour industry both play important roles in regional and local economies. Sites like the Ningaloo Reef and the Perth metropolitan reefs are already extensively used by local people and national and international visitors. There is potential for further development of these activities to improve both local quality of life and the potential for commercial tourism, but increased use of the natural resource will need increased protection and management.

The degree to which marine ecosystems are "inter-connected" is much greater than in their terrestrial equivalents. In the sea the water medium itself is the whole or part habitat of a very large proportion of marine living things. Planktonic and nektonic plants and animals that live their entire lives drifting or swimming in the water comprise the bulk of the marine biomass. Even most marine benthic (bottom living) organisms have larval stages that are planktonic and may be widely dispersed by water currents. The water mass is also the site of most of the ocean's primary production. The resulting energy may be carried by water currents from its place of origin over long distances to support other ecosystems. Water currents may also quickly spread pollutants from the site of origin to nearby habitats.

The openness of marine ecosystems has several consequences for environmental management. They may be influenced by events beyond their own boundaries yet they may be quickly recolonised from other areas by means of planktonic larvae if they become degraded. Marine reserve management must take these factors into account.

In addition to their nature conservation and public recreation functions, marine protected areas play an important role in the long-term sustainable use of the living resources of the coastal zone. It is

now well established that marine areas where habitats have become degraded or where living resource stocks have become depleted through overuse, may be much more quickly repaired and replenished if there are protected, unexploited areas nearby. This is true where tourism has degraded the habitat or where fishing has depleted the target stocks. The following quotation from a recent IUCN Newsletter makes this point:

> "In recent years there have been a number of theoretical studies that indicate marine reserves may be useful as fishery management tools in multi-species tropical fisheries. Mathematical models suggest that reserves closed to fishing, can improve fishing outside the reserves by providing both a source of juveniles and adults which move out of the reserve and by maintaining a large spawning population which produces larvae which settle outside the reserve. Empirical studies are scarce but a recent paper in the *Journal du Conseil* 'A direct test of the effects of protective management on abundance and yield of a tropical marine reserve,' (1990, volume 47, no. 1, p. 40-47, by Alcala and Russ), provides empirical evidence that reserves can improve yields. The authors compared yields from fishing on the coral reefs at Sumilon Island in the Philippines when 25% of the reef habitat was closed to fishing with yields from fishing during a period when the entire reef habitat was fished. *They estimated that closing 25% of the reef habitat to fishing resulted in 54% higher catches for the entire island than catches obtained when the entire reef area was fished.*"
> [Emphasis added. Source: IUCN-CNPPA Newsletter No. 54, April-June 1991.]

At present Western Australia has eight marine reserves, seven established under the Conservation and Land Management Act 1984 (CALM Act) and one under the Rottnest Island Authority Act 1987. Recognising the need for a Statewide marine parks and reserves system, the State Government established a Working Group in 1986 comprising marine scientists and planning officers representing a range of Government agencies and academic and research bodies. The brief of the Working Group is to review the coast as a whole, and to identify areas that have particular values for conservation, scientific, and public recreation purposes making them worthy of reservation, so improving the representativeness of the State marine reserve system.

Given the multiple purposes of a marine reserve system, it is necessary to select and reserve areas with either high nature conservation value or recreational use, or both. Nowadays, when nature tours and appreciation of the natural environment are becoming so important in outdoor recreation, nature conservation values, such as high species diversity and animal breeding colonies, may be significant elements of the recreational resource. Sometimes the particular conservation value may be incompatible with access for recreational use but often the two purposes may be fulfilled simultaneously, with appropriate management.

There are sometimes circumstances where coastal areas should be reserved because they are already subject to heavy recreational use and need to be managed. At the other extreme, an area may have extreme conservation or scientific value for a specific reason - the reservation of the Hamelin Pool Marine Nature Reserve for protection of stromatolites and other sedimentary deposits is an example. More generally, however, the principle of representative habitat types and biota is the basis of reserve selection.

It must be emphasised that the available information on the habitats, flora and fauna and recreational potential of many parts of the Western Australian coast is very limited. Although the Working Group has done its best to gather what information exists, it is inevitable that further studies will bring to light areas of high conservation and recreational value that have been overlooked in this survey. The recommendations in this report should not preclude the addition of other areas of high value that may be discovered in future.

The areas proposed in this report as worthy of consideration for reservation have been identified on the grounds of conservation, scientific and public recreation values. It is acknowledged that further consideration of management issues, especially those relating to boundaries and impacts on existing users, will be necessary before any reserve is declared. The boundaries shown in the maps of this report, where they occur, are provisional only, and may be modified during the necessary further public consultation phases.

The recommendations in this report reflect the professional judgements of the Working Group. They do not constitute the public notices required by the statutory processes for marine reserve

declaration described in Section 1.2. If the Government adopts the report in principle, it will be necessary for each area recommended for reservation to be considered individually and in detail. Before any area can be reserved, a *notice of intent* must be published, specifying its proposed boundaries and purposes and inviting public comment. Endorsement of the Minister for Fisheries will be necessary. Only when these steps have been taken, may the Minister for the Environment publish the declarations in the Government Gazette. Final approval of each reserve proposal then depends on acceptance by Parliament.

Part I of this report contains basic descriptive information about the biological and physical environment of WA coastal waters, which the Working Group prepared as a basis for its work. The later parts deal with particular details of each of the major biogeographical zones along the coast, from north to south, using the modified criteria recommended in the Council of Narure Conservation Ministers' report (CONCOM, 1985), and identify areas that the Working Group considers to be worthy of reservation for conservation or recreational purposes.

1.2. Statutory basis for marine parks and marine nature reserves in Western Australia

In Australia, land is "owned" by the Crown or by private individuals under freehold tenure. Crown land may be leased, reserved for particular public purposes, or held as Vacant Crown Land. In many traditional societies in maritime countries, areas of the sea may also be held in some form of "ownership", at least concerning the rights to its produce, but these concepts are not well developed in contemporary western societies. The Commonwealth and State territorial seas are owned solely by government, there is no private freehold, and the major part of the territory is regarded as a "common" with its resources accessible to everyone. Statutory provisions for leases and limited access to fishery and mineral resources cover a minor part of these waters.

Coastal lagoons, estuaries and rivers in the south-west of Western Australia are subject to particularly heavy use and their management is often complicated by the fact that many different authorities are involved. The Waterways Commission has been established to ensure that waterways are conserved and effectively managed to maintain or enhance environmental quality and public amenity. The Commission is established under its own legislation and has powers for the declaration of waterways in need of coordinated management as Management Areas. The Swan River is a special case and co-ordination of management is the responsibility of the Swan River Trust. Powers to control pollution in the estuary of the Swan are delegated to the Trust under the Environmental Protection Act.

Reservation of areas of the territorial sea for particular public purposes is a relatively new concept.

Aquatic reserves may be declared under Section 30 of the Fisheries Act 1905 for the purposes of protecting fish stocks or their habitats, or for other purposes relating to the fishing industry. A Fisheries Act aquatic reserve cannot be established over the same waters and land that comprise a marine nature reserve or marine park under the CALM Act. Similarly, aquatic reserves cannot be established for the same purposes as those assigned to CALM Act marine reserves. Aquatic reserves declared under the Fisheries Act would be vested in the Minister for Fisheries and managed by the Department of Fisheries. However, no marine or estuarine area has been reserved in Western Australia under Fisheries legislation. Retention of the aquatic reserves provisions in the Fisheries Act is currently under review.

Legislative provisions for the declaration of marine reserves for nature conservation and public recreation, equivalent to terrestrial national parks and nature reserves, were introduced in Western Australia in 1984 with passage of the Conservation and Land Management Act (CALM Act). Most marine areas below High Water Mark that are reserved for the purposes of conservation and public recreation are declared under Section 13 of the CALM Act and are vested in the National Parks and Nature Conservation Authority. Land above High Water Mark that is adjacent to or integrally related to reserved marine areas may be declared under Part 111 of the Land Act 1933, as either marine park or marine nature reserve. Provisions of the CALM Act relating to the declaration and management of marine reserves were amended in 1988 and 1991.

There is one marine reserve established under special legislation in Western Australia - the Rottnest Island Authority Act 1987 established the Rottnest Island Reserve including the waters surrounding the island for a distance of 800 m. The marine part of the Rottnest Island Reserve does not have the status of a marine park but is reserved for the same purposes.

Marine reserves established under the Conservation and Land Management Act are of two types:

1. ***Marine Nature Reserve***: Marine nature reserves are reserved for:

> "(a) the conservation and restoration of the natural environment;
> (b) the protection, care, and study of indigenous flora and fauna; and
> (c) the preservation of any feature of archaeological, historic or scientific interest."

Marine flora and fauna may not be "taken" (ie. killed or interfered with) in marine nature reserves except for scientific purposes under licence. Recreational and commercial fishing are not permitted.

2. ***Marine Park***: Marine parks are reserved for:

> "... the purposes of fulfilling so much of the demand for recreation by members of the public as is consistent with the proper conservation and restoration of the natural environment, the protection of indigenous flora and fauna and the preservation of any feature of archaeological, historic or scientific interest; ... "

This defined purpose is qualified by the following:

> "... but in the event of any conflict or inconsistency between any of the foregoing purposes and any provision of the Fisheries Act 1905 relating to commercial or recreational fishing, the latter shall prevail."

Thus, commercial and recreational fishing are permissible in marine parks in accordance with the Fisheries Act and administered by the Fisheries Department.

The Declaration Process

The CALM Act specifies the procedures for declaration of marine parks and marine nature reserves, which include:

- publication of a notice of intent specifying the boundaries of the proposed reserve and its proposed purposes;
- a period of not less than 2 months for public comment;
- referral to Local Authorities and the Minister for Fisheries;
- submission of the proposal by the Minister, modified as he thinks fit, to the Governor for consideration of the publication of an order in the Gazette effecting the reservation;
- tabling of the order in each of the Houses of Parliament within 6 sitting days of its gazettal; during the following 14 sitting days either House may pass a resolution disallowing the order which would thereupon cease to have effect.

The Act provides that the Minister

> "shall not make a submission to the Governor ... unless the Minister to whom the Fisheries Act 1905 is for the time being committed concurs with the submission".

Management

Once declared, marine parks and marine nature reserves are vested in the National Parks and Nature Conservation Authority and managed by the Department of Conservation and Land Management. In the case of marine parks, commercial and recreational fisheries are managed by the Fisheries Department.

The CALM Act specifies procedures for the development of management plans by the National Parks and Nature Conservation Authority, including publication of drafts and periods for public comment, and the eventual referral of the plans to the Minister for his approval.

Under the provisions of the Act, if the Minister for Fisheries has made submissions on a proposed management plan for a marine park, the Minister:

> "... shall not approve the proposed plan -
> (a) unless he is satisfied that it gives effect to those submissions; or
> (b) unless he has referred the proposed plan to the Governor and is satisfied that it gives effect to the decision of the Governor, so far as the submissions or the decision relate to the taking of fish (within the meaning in the Fisheries Act 1905) in the park."

The CALM Act contains provisions allowing for the zoning of marine parks and marine nature reserves, so that spatial separation of incompatible activities may be achieved. Preparation and approval of management plans follow a statutory process, which obliges the management authority to manage a marine reserve and its specified zones in accordance with the approved management plan.

Marine parks and marine nature reserves declared under the CALM Act may be classified as Class A, in which case the purpose and boundaries of the reserve may not be amended or cancelled except by an Act or a resolution of one of the Houses of Parliament.

The Rottnest Island Authority Act gives the Authority the power to protect, maintain and restore the flora and fauna and natural environment of the Rottnest marine reserve. Regulations have been passed by the Authority declaring two small marine areas as "conservation zones" where flora and fauna are totally protected. Control of fishing activities within the remainder of the reserve is effected under the Fisheries Act.

There are no statutory requirements for management plans or public participation in planning in the case of Fisheries Act aquatic reserves.

1.3. Designing a marine reserve system for conservation and public recreation in Western Australia

Conservation reserves are intended to contribute to the maintenance of biological diversity and a sustainable and enjoyable environment. Broadly, the main aims are to provide secure natural habitats for indigenous flora and fauna where species and communities of species may persist indefinitely, and where people may experience and enjoy the environment in a natural state. Secondary, but also important aims are to secure natural areas and their biota for study and reference purposes, and to ensure continuance of natural processes that have positive effects on environmental health and human economic activities.

Given the multiple aims of a conservation reserve system, the design and selection criteria must involve both socio-economic and biological factors.

Natural areas with high scenic quality are highly valued as recreational reserves. Accessibility and infra-structure for management are important socio-economic factors that must be taken into account in selecting natural areas for designation as recreation reserves. High biological diversity and biological and geological features of special interest are also important factors in selecting natural areas for recreational use. However, in some circumstances, recreational activities may need to be constrained to avoid damage to these natural values. Areas with high natural values that are subject to intensive recreational use may need intensive management to protect those values and reservation is a means by which management can be effectively implemented.

There has been a number of attempts to develop a methodology for designing reserve systems for conservation of flora and fauna (eg. Bolton & Specht, 1983). A strictly biological reserve selection method would be based on the criteria of **diversity, representativeness, naturalness** and **effectiveness**.

Most methodologies begin with a biogeographical classification of the region and select ecosystem types within the biogeographical units in order to achieve the best possible representativeness. The

assumption is usually made that a reserve system that is representative of the region's ecosystems will maximise species diversity contained within them, even though details of the actual floral and faunal composition may be unknown.

The "naturalness" criterion gives preference to areas that have been little affected by human activity. (Paradoxically, this is a criterion for selecting recreation reserves as well as nature conservation reserves, even though increased public access may reduce the naturalness of the areas.)

The "effectiveness" criterion refers to the manageability of the area and includes size and boundary factors. Larger areas are usually more naturally sustainable than smaller ones.

Following a series of seminars, the Council of Nature Conservation Ministers produced a working paper on the development of a marine reserves system in Australia (CONCOM, 1985). The CONCOM paper recommends a two-level classification of the Australian coastline, firstly on geographical regions and secondly on habitat type, as a basis for the selection of a representative system of marine conservation reserves (referred to as "Marine and Estuarine Protected Areas" or MEPAs).

This report is based on a modified version of the CONCOM classification of coastal biogeographical regions. The Western Australian coast has been divided into four sections, ie. Kimberley, Canning-Pilbara, West Coast and South Coast. The divisions between them (in the areas around Cape Leveque, North West Cape and Cape Leeuwin) represent parts of the coast where significant changes in biota occur. The biological differences between the four sections are believed to have developed as a result of the geological events that shaped the Australian continent as well as modern climatic and other environmental conditions.

In terrestrial systems, the next level of classification after the biogeographical one is usually based on vegetation. This is not so relevant in the sea. The Working Group has found it helpful to apply a classification of coastal geomorphology as the second level in the process. Coastal marine habitats are very much dominated by landform and sediment type. The concept of "**major distinctive coastal types**" has been adopted as the second level of classification, based mainly on geomorphological criteria. Within those coastal types a number of ecosystem types occur (eg. coral reefs, mangals, rocky shores, seagrass beds, tidal flats) whose local expression is greatly influenced by the gross geomorphology of the area.

This structured classificatory approach to reserve selection has led to a concept of a four-tiered system for environmental management of Western Australian coastal waters.

1. The broadest tier of the system regards the entire area of the State's territorial waters as equivalent to a "common". Its resources, living and inanimate, may be utilised by appropriately authorised people and agencies subject to regulations established under such State legislation as the Fisheries, Environmental Protection and Petroleum Acts. In some respects the marine common is akin to Vacant Crown Land in the terrestrial environment. Although management of non-reserved areas is beyond the scope of this Working Group's brief for marine reserves, members hold the view that there is a need for more consideration to be given to environmental management of the whole coast.

2. The second tier in the system is that of *major distinctive coastal type* described above. An example is the Ningaloo Reef with its lagoons, reefs and off-shore zones. Another is the section of coast between the southern end of Exmouth Gulf and Onslow with its wide mangals, the intertidal and shallow sublittoral flats seaward of them and the wide supra-tidal flats behind them. The South West estuaries also fall into this category. In each of these examples the ecosystem as a whole is definable in geomorphological terms and is likely to have a high degree of internal ecological integrity.

Each of these examples has special merit in conservation and resource management terms, within the wider coastal context, and is worthy of special care and management attention. Such marine areas could be treated as environmentally significant areas subject to more stringent protection with respect to resource utilisation than the surrounding "common". Management and protection could be exercised through fishery, environmental protection, waterways and mining legislation, as has been

done in the case of the coastal lagoons and estuaries in the south-west of the State (see Section 1.2). An alternative would be to reserve the whole of these areas for management as multiple-use marine protected areas.

3. The third tier of the system is that marine areas of special recreation, resource or conservation value should be reserved for specified uses, giving a greater level of protection and management. These might include areas representative of the habitats found within a distinctive coastal type or areas of unique recreational or environmental value. Areas selected for reservation specifically for the purposes of conservation and public recreation would usually be within a major distinctive coastal type subject to special management and would thus be afforded the necessary buffer against adverse external influences. In some cases marine recreational and conservation reserves could be large and comprise an entire distinctive coastal type or ecosystem unit, such as Nornalup-Walpole Inlet, Shark Bay or the Ningaloo Reef.

4. Finally, the fourth level of the concept is for marine areas of extreme conservation value or sensitivity that should be reserved to afford total protection against any form of use which might produce or risk change in their ecosystems or affect any of their species or features. Such reserves or zones could be designated to protect features of special importance (eg. turtle nesting sites, stromatolites) or to protect communities in pristine condition for scientific reference or public education and enjoyment purposes. Marine nature reserves and marine park sanctuary zones will usually be relatively small.

In this four-tiered marine management system reserves are areas set aside for specific public purposes within a "whole of coast" management context. The scheme overcomes the difficulty that ecosystems of isolated marine reserves may be hard to maintain if they are surrounded by and inter-connected with unmanaged areas of "common". The marine reserve system proposed in the following parts of this document assumes that means will be found to provide adequate management of the marine environment surrounding them.

2. EXISTING MARINE RESERVES

The Western Australian Conservation Through Reserves Committee (CTRC) recommendations of the 1970s and 80s included proposals for several marine reserves. At that time there was no Western Australian legislation for the declaration of marine reserves other than "aquatic reserves" under the Fisheries Act. With passage of the CALM Act (1984) statutory provision was made for declaration of marine reserves for nature conservation and public recreation purposes.

Some of the CTRC recommendations for declaration of marine reserves have now been implemented, often with modification of the originally suggested boundaries resulting from negotiation with the fishing industry and other interested parties, and from additional knowledge of conservation and recreational values. Western Australian marine reserves existing as at 30 June, 1993 are as follows:

CALM Act marine reserves

- Ningaloo Marine Park (224 000 ha., declared 3/4/87)
- Marmion Marine Park (9 350 ha., declared 1/5/87)
- Shoalwater Islands Marine Park (6 545 ha., declared 25/5/90)
- Rowley Shoals Marine Park (23 388 ha., declared 25/5/90)
- Swan Estuary Marine Park (340 ha., declared 25/5/90)
- Shark Bay Marine Park (748 735 ha., declared 30/11/90)
- Hamelin Pool Marine Nature Reserve (132 000 ha., declared 25/5/90)

Special legislation marine reserve

- Rottnest Island Reserve (declared 1987)

3. NATURAL MARINE SYSTEMS IN WESTERN AUSTRALIA

3.1. General

In broad terms two different factors determine the characteristics of coastal biota and habitats. Geological and climatological history determine the broad geographic distribution patterns of species, while physical environmental factors determine the particular combinations of species forming local communities and ecosystems. A "representative" system of reserves must take into account both broad biogeographic and local ecosystem factors.

Marine environmental management is a new and developing field. As on land the basic objective is to ensure that natural features are sustained indefinitely. This may require measures to protect them from inappropriate or excessive use. A key to success will be understanding the interactive biological and physical components of marine natural systems.

A broad overview of the Western Australian coastal and estuarine environment has been given by Wilson, Hancock & Chittleborough (1979). Hodgkin & Major (1978) published an index to ecological information on estuaries and embayments of Western Australia. Other more specific references are given in appropriate Sections of this report.

3.2. Distribution patterns of the WA marine flora and fauna

Distribution patterns of the Australian marine fauna have been reviewed by Wilson and Allen (1987). Distribution patterns of marine flora are generally similar and their review may serve as a source of information on both marine flora and fauna distributions in Western Australian waters.

Basically, there are two fundamental marine floral and faunal provinces in WA, a tropical province in the north, and a temperate province in the south.

The tropical northern flora and fauna belong to the vast **Indo-West Pacific Region** which stretches from the east coast of Africa to French Polynesia in the central Pacific, and from the Ryukyu Islands of Japan to the northern coasts of Australia. A majority of species found in northern WA are widespread throughout that region, although there is significant local endemism, especially in those groups which lack a long-lived planktonic dispersal stage.

The temperate flora and fauna belong to the **Southern Australian Region** which extends across the entire south coast of the continent. The majority of southern Australian species are endemic to this Region. There is also a significant degree of local endemism along the south-western and south-eastern coasts of southern Australia.

The modern Indo-West Pacific floral and faunal elements are descendants of the flora and fauna of the once even greater Tethyan Province which, during the early Tertiary, occupied the world's entire tropical zone. The modern Southern Australian marine floral and faunal elements have a much more varied and complex history. The region is dominated by species which originated from an ancient high-latitude southern hemisphere biota. These species account for much of the very high level of endemicity in the southern marine flora and fauna. They have a different evolutionary history to the species of the northern Indo-West Pacific elements. However, in the south-west, there are many endemic species derived in more recent times from Tethyan and Indo-West Pacific ancestors.

The central west coast of WA, ie. from about Carnarvon to Cape Leeuwin, is a zone of overlap between these two major floral and faunal provinces.

It follows from this brief summary that the marine floras and faunas of the northern and southern coasts respectively are quite different in species composition, due to quite different geological histories. There are also modern processes, however, which influence the present geographic ranges of species, ie. local climate, ocean currents and the geomorphological character of coastal habitats.

3.3. Ecosystems

The two highest levels of biotic (biological) organisation in natural systems are **populations** of particular plant and animal species and **communities** comprised of interactive sets of populations of different species. Communities of marine organisms in turn interact with physical or abiotic systems (eg. weather, water circulation, sediments) of the environments in which they occur to form recognisable combinations of habitat and biota called **ecosystems**. Ecosystems may be defined by either their physical or biological characteristics but they always encompass both types of processes.

Ecosystems represent important functional units which must be considered in their entirety when developing strategies for marine reserve management.

Ecosystems may extend over hundreds of metres (eg. coral islands), or over hundreds of kilometres (eg. the Ningaloo Reef). Regardless of their size, or the level of organisation at which they are defined, it is the interaction of biological and physical processes which determine the pattern and productivity of the diverse marine ecosystems which characterise the Western Australian coast. It is of great significance to management that these processes are already being modified by human activities in many marine environments of Western Australia.

All ecosystems interact with others, due to such factors as water flow or animal migration. This interaction ranges from subtle exchanges to direct influence on the structure or even the existence of geographically-associated ecosystems. Migratory animals range across ecosystem boundaries during their seasonal cycles of activity. Some marine animals (eg. the Shark Bay dugong population) are confined within one ecosystem. Others depend on different ecosystems for different activities, eg. marine turtles and sea birds which feed in the ocean and breed and rest on the land.

A particular feature of marine ecosystems is the extent to which species depend on very different and geographically separated ecosystems for different stages of their life cycle. Most important are the many cases of marine animals which have a pelagic larval stage floating in the upper layers of the ocean, alternating with a more sedentary, or even attached, sexually mature, adult stage living on the sea bed.

This is one of the features of marine ecology responsible for a much higher degree of ***inter-connectedness*** than is the case with terrestrial ecosystems. A forest may be greatly influenced by recruits brought in by wind or migratory animals, but for the most part it is self-contained. A coral reef may depend to a much larger extent on immigrants brought to it by water currents from "upstream" for continuance of its generations and, for daily sustenance, its members may depend on water-borne planktonic food and nutrients from outside the system.

Water currents and tidal flows also play a much greater role in the distribution of energy (as organic food and inorganic nutrients) from one ecosystem to another, than wind and water achieve in terrestrial environments. For example, mangals (mangrove assemblages) are extremely high producers of organic detritus, constantly feeding energy into adjacent coastal ecosystems by means of the pumping action of tidal flows. Some coastal ecosystems are enriched by nutrients derived from adjacent deep-water ecosystems, or from the land *via* river flow or groundwater seepage.

This very high degree of inter-connectedness between marine ecosystems means that there is also a high degree of interdependence which must be taken into account when planning a marine reserve system and managing coastal marine environments. Healthy mangals and estuaries, for example, are essential as nursery areas and sources of food for coastal marine ecosystems; any effective reserve system must give special attention to the protection of these most important areas. Well developed tropical mangals in the Indo-West Pacific Region may have a rate of primary production of as high as 5 kg carbon per m^2 per year, equal to the primary production of tropical rainforests, and much of this material is released into the adjacent coastal waters.

3.4. Physical basis to ecosystem definition

While it is important to stress the biological components of ecosystems and hence devise a system of classification that reflects this emphasis, it is also helpful to view ecosystems from a physical perspective. The physical framework can be often more easily defined and described than the biotic components. Classification of ecosystems is most conveniently based on physical descriptors, as follows.

At the largest scale the recognised marine ecosystems based on physical structure are:

(i) continental shelf systems;
(ii) shore systems;
(iii) estuarine systems.

This represents a gradient from wholly open marine systems to partly marine-partly land influenced systems. These main ecosystem types with their internal subdivisions, and some of their conspicuous biotic assemblages are briefly described below.

Continental Shelf systems

Continental shelves fringe the shores of Western Australia. In some instances the shelves are relatively narrow and simple. In other areas the shelves are bathymetrically complex, broad and internally very heterogeneous. Major publications that deal with continental shelves are Fairbridge (1953) and Collins (1988). Continental shelves may have substrates of sand, gravel, rock or mud, and these constitute major habitat settings on the sea-bed for different biota. There is also the habitat provided by the oceanic water column which supports a host of free-swimming and free-floating life forms.

Shore systems

The shore systems are located in the broad zone between the open oceanic system and the hinterland. Within the shore system there are:

- beaches;
- rocky shores;
- tidal flats;
- sounds and embayments;
- deltas.

Beaches are composed of sand or gravel and are relatively simple systems. The other types of shore systems, however, can be quite complex in terms of internal geomorphology, substrates, energy gradients and water depths. Accordingly the range of biotic assemblages which inhabit shore systems can be similarly complex.

Rocky shores can be of limestone, or granite, gneiss, or other indurated metamorphic and sedimentary rock, and the extent of their development is dependent on the coastal setting and the hinterland geology.

Tidal flats can be dominated by mud, sand, rock, or rock pavement, with concomitant changes in the benthic biota.

Sounds and embayments tend to be dominated by mud in their deepwater parts and may be fringed by more complex shorelines.

Deltas tend to produce tidal flat and beach systems within their structure.

Estuarine systems

The estuarine systems are inland of the shore systems and consist of lagoons, inlets and embayments where fresh water influx has a major effect, either daily with tide or seasonally with the climate, or both. Estuaries contain a complex of physical and chemical variations and support a variety of benthic, nektonic and planktonic plants and animals. Estuaries are transitional ecosystems between fully marine and fully freshwater systems.

3.5. Currents

The current systems around the Western Australian coasts have been extensively studied. Summaries may be found in Pearce & Cresswell (1985) and in a special volume of the Journal of the Royal Society of Western Australia dealing with the influence of the Leeuwin Current on coastal climate and marine life, edited by Pearce & Walker (1991).

The dominant currents influencing the WA coast are:

i) The West Wind Drift, a circumpolar current which flows across the southern face of the continent from west to east. It carries larval dispersal stages in that direction and is responsible for the presence of some Australian species in the New Zealand biota, and the presence on the southern Australian coast of certain species which have southern hemisphere circumpolar distributions.

ii) The Pacific-Indian Current (derived from the South Equatorial Current of the Pacific) which flows across the northern face of the continent from east to west (interrupted to a large extent by New Guinea) bringing Pacific water (and larvae) onto the North West Shelf.

iii) The Leeuwin Current which flows offshore from north to south down the central west coast, carrying the propagules of tropical species into the Southern Australian Region (Pearce & Walker, eds., 1991). This current varies seasonally and annually in its rate of flow and extent of southward penetration.

3.6. Geomorphology

Apart from the influence of climate and currents, many of the important differences in marine habitats from north to south, result from geological and other physical features. According to Jutson (1950) six to twelve major geomorphologic zones can be recognised around the Western Australian coast. The recognition of these zones is based primarily on the combinations of natural features of climate, coastal geology, rivers, tides, coastal water movement and exposure to oceanic forces. Other authors have provided a more simple subdivision of the Western Australian coast, recognising major sectors related to subcontinental scale geology (eg. Woods, 1980; Woods et. al., 1985; Gill, 1982). On the other hand some authors, with more detailed work, have subdivided what appear superficially to be single units into complexes of units, eg. Galloway (1980) and Semeniuk (1993a) for the tropical Western Australian coast, and Searle & Semeniuk (1985) for the inner Rottnest Shelf coast. It is at the local scale that organisms respond and the species composition of communities is determined.

For the purposes of this study 10 primary geomorphic coastal zones are recognised along the Western Australian coast. They are briefly described below in order from north to south.

1. ***Cambridge Gulf.*** This is a large seasonal estuary and gulf characterised by broad tidal flats backed by a hinterland of high relief. The region is macrotidal and with relatively low wave energy although the terrain toward the outer reaches of the system is subject to wave action. The area is set in a semiarid tropical climate. Mud flats and some sand and gravel flats dominate the shore zone. Sediment is brought in annually by the Pentecost, King and Ord Rivers. The dominance of mud, and the macrotidal and wind and wave conditions result in water being turbid throughout the year. Mangrove formations are conspicuous features of the shore vegetation.

2. ***The Kimberley Coast.*** This coast is characterised by low-energy (ie. low wave action) conditions, except for occasional severe cyclonic storms. It is a ria coast with deep embayments and many islands. It also has a high but seasonal rainfall, and there are many large rivers which flood annually. Consequently, the shelf areas off the Kimberley coast are characterised by terrigenous sediments and the coastal waters are turbid. There is also an extremely high tidal range. Mangals, tidal mud and sand flats, and some rocky shores are the dominant habitats. Coral reefs occur but are not usually well developed except around offshore islands. Semeniuk (1985) recently subdivided this coastal zone into medium and small scale habitat units that are characteristic of the whole ria-type shore in this region.

3. *King Sound*. This large sound, encompassing the Fitzroy River estuary and Stokes Bay, is similar in many aspects to Cambridge Gulf. It is a large gulf with some features of a seasonal estuary. Its shores are characterised by broad tidal flats. The region is macrotidal with relatively low wave energy. The area is set in a semi-arid tropical climate and the estuary/gulf is the receiving basin for the Fitzroy, May and Meda rivers. Mud flats, sand flats and gravel flats dominate the shore types, but to the north there is local development of rocky shores as the system grades into the ria shore complex of the Kimberley coast. As with Cambridge Gulf the dominance of mud and the extreme tidal range result in turbid waters in the area throughout the year. The southern part of King Sound has been subdivided by Semeniuk (1981a, b) into 5 shore types.

4. *Canning Coast*. This coastal zone, extending from Cape Leveque to Cape Keraudren, is characterised by shores of Mesozoic rock, oolitic limestone, or dune sand, against which have accumulated dunes, barrier dunes and associated inlets, and tidal embayments. The coast is characterised by little or no fluvial run-off, a carbonate mud-dominated sedimentary system and a shore with alternating small embayments and headlands (Semeniuk 1985). The northern part of the area is set in a semiarid climate and the southern part in an arid climate. The shore has a very large tidal range but wave energy varies from moderate along some parts of the Dampier Peninsula coast and Eighty Mile Beach, to low within the broad shelving embayments such as Roebuck Bay.

5. *The Pilbara Coast*. This coast is also a low-energy coast and the climate is arid. The coastal geomorphology has been described by Semeniuk (1993a). Although there are large rivers, they are seasonal and flooding is infrequent. Nevertheless, the shelf sediments consist primarily of terrigenous muds, and long beaches and muddy tidal flats dominate the shoreline. Coral reefs are better developed than on the Kimberley coast but are not a major feature except on the more distant islands and along the shelf-break.

Along the Pilbara coast systems of barrier islands and associated protected lagoons, embayments, deltas, and archipelago-ria shores predominate and the coast is either open or partly protected by chains and clusters of small islands. The hinterland has moderately high topographic relief with Pre-Cambrian rocks, and is drained by numerous rivers and streams. These fluvial features have built a coastal plain and deltas along the coast. The boundary of the Pilbara coast section is well defined in the north by the DeGrey River and its delta, and in the south by the Yannyare and Ashburton Rivers and their deltas.

There are 3 main factors contributing to the gross development of regional coastal types in the Pilbara coast:

- deltaic construction to develop delta lands, and post depositional destruction of deltas to develop barrier islands;
- accumulation of aeolianites along former shorelines forming Pleistocene ooid limestone ridges, often also developing barrier islands; and
- extension of the Pilbara hinterland geology as bedrock outcrops in the coastal zone.

The Pilbara zone can be viewed as a system of nearly continuous stretches of barrier islands composed of shelly limestone or ooid limestone behind which are the protected embayments, lagoons and tidal flats. This prevalent pattern is disrupted locally by active deltas, or by bedrock outcrops, to develop a contrast in coastal form at the regional scale.

6. *North West Shelf Oceanic Province*. The outer part of the North West Shelf, from the North Kimberley to North West Cape, comprises an oceanic province. It is sometimes divided into a northern part known as the Sahul Shelf, and a southern part known as the Rowley Shelf. Except where there are tidal scour channels, the bottom sediments of the shelf tend to be fine silty sands or muds.

There is a series of coral atolls along the shelf-edge, and a number of outer-shelf and mid-shelf islands. Together these comprise an oceanic geomorphic zone. The islands can be naturally grouped into categories based on materials that comprise their cores; these categories also tend to form geographic groupings. The categories are:

- Tertiary-Pleistocene coralline limestone atolls;

- Tertiary limestone islands;
- Pleistocene ooid limestone islands;
- Pleistocene shelly limestone islands;
- Holocene sand islands.

The shelf-edge atolls (Seringapatam, Scott and the three atolls in the Rowley Shoals) are formed on the tops of faulted blocks of coralline Tertiary limestone and are ancient structures. The largest of the coastal islands is Barrow in which the Tertiary limestone is an extension of a structural trend from Cape Range. The Lowendal Group and Montebello Islands are formed of Pleistocene ooid limestone. The remainder are relatively small islands composed either of Pleistocene shelly limestone, or Holocene sand, or Pleistocene limestone core with a Holocene sand mantle.

7. *The Cape Range-Gascoyne Coast.* Overall this is a moderately high-energy zone, encompassing the coast from Cape Range to Kalbarri. It comprises uplifted Tertiary sedimentary rocks and Quaternary limestone and basin deposits forming a regional-scale barrier in the Cape Range area. Ridges of limestone and sandstone form rocky shores which are subject to high-energy wave action.

This zone abuts arid lands with few rivers which flood infrequently. The shelf is relatively narrow, dominated by bioclastic carbonate sediments, and has relatively clear waters. Coral reefs are well developed and there are some species-poor mangals in protected areas. The Ningaloo Reef, the Gascoyne Delta, the Shark Bay embayments, and the rocky Zuytdorp Cliffs in exposed areas are significant features of the region, each forming a very different kind of marine habitat, making this sector one of the most varied and complex on the WA coast.

Although moderate to high wave energy is a major feature of this coast, there are embayments where wave energy is less and fine sediments accumulate. The limestone ridges cradle small embayments in which mangrove environments may develop, as along the southern and south-western shores of Exmouth Gulf. There are also two major embayments, Exmouth Gulf and Shark Bay, which are protected from the strong prevailing southerly wind of the region by the peninsulas forming their western boundaries, although the embayments are subject to storm impact from the north. As a result, mud accumulates in their relatively low-energy environments. This sediment is derived from eroding shores, the aeolian hinterland and fluviatile sources.

8. *The Central West Coast* (ie. Kalbarri to Cape Naturaliste). This coast is a microtidal, relatively high-energy area, with a moderately narrow shelf, clear water and few rivers, and is dominated by bioclastic carbonate and quartz sediments. The coastline is commonly of long sandy beaches with occasional limestone cliffs and headlands, and with offshore limestone island and reef complexes. Limestone rock platforms are a feature of this coast. There are many estuaries, of which three, the Swan, Peel-Harvey and Leschenault, are large and permanently open to the sea. Cockburn Sound is a major enclosed marine embayment. Jurien Bay, Warnbro Sound and Geographe Bay are major but more open embayments. Sheltered lagoonal habitats are developed behind off-shore limestone reefs in many localities. Although south of the usual latitude for coral reef development, there are significant shelf-break coral reefs at the Houtman Abrolhos which have developed as a consequence of the southerly-flowing Leeuwin Current.

Searle & Semeniuk (1985) subdivided the coastal environment of the central west coast south of Dongara into five distinct natural sectors. Each sector has its own distinctive ancestral geomorphology, processes of sedimentation-erosion-transport, stratigraphic evolution and modern coastal geomorphology. These coastal sectors are:

- Wedge Island-Dongara sector, characterised by a complex nearshore bathymetry of ridges and depressions, limestone rocky shores erosionally scalloped at a large scale, extensive shoreward migrating dune fields and asymmetric accretionary cusps of Holocene sediments;
- Whitfords-Lancelin sector, characterised by marine ridges and depressions, limestone rocky shores and isolated accretionary cusps of Holocene sediment;
- Cape Bouvard-Trigg Island sector, characterised by a complex bathymetryic morphology of marine ridges and depressions developed on limestone, and extensive but discrete sites of Holocene sediment accumulation resulting in prograded beach ridge and aeolian sand plains;

- Leschenault-Preston sector, characterised by a barrier dune-estuarine lagoons system and a simple submarine bathymetry;
- Geographe Bay sector, characterised by a low hinterland, a broad, open, north-facing embayment and by simple bathymetry.

9. *The South West Coast* (ie. Cape Naturaliste to Israelite Bay). This is a high-energy coast exposed to heavy wave action driven by the West Wind Belt. Off-shore the sediments are primarily bioclastic carbonates and the water is clear. The geology of the coast is predominantly granitic and the shoreline is characterised by high granite headlands with curving sandy beaches between. Three shore types of lesser extent also occur. In many places there are cliffs and rock platforms developed in superficial Quaternary limestone deposits between or below the granite headlands. Between Cape Leeuwin and Black Head, along the southern face of the sedimentary Perth Basin, the shore is beach. At one location in Cheyne Bay where the sedimentary Bremer Basin meets the coast, a boulder shore is formed along an outcrop of the Eocene Pallinup Siltstone.

Rainfall is relatively high in the west but lower in the east. There are many small rivers and many estuaries of different types.

10. *The Great Australian Bight*. Here also there is a heavy swell. The wide shelf is dominated by bioclastic carbonates and the water is clear. The adjacent land is arid and there are no rivers or estuaries. The shore-line is dominated by long sandy beaches and high limestone cliffs.

From this account of coastal geomorphology it is evident that physical features of the coastal zones, together with climatic characteristics, create a range of very different habitat types along the WA coast, superimposed upon the historical biogeographic zones. For the most part, these geomorphic coastal zones conform with or combine to form the biogeographic zones recognised in this report. There are two exceptions. The western portion of the South West Coast (9), between Cape Naturaliste and Cape Leeuwin, lies within the West Coast sector while the coast east of Cape Leeuwin lies within the South Coast sector. The North West Shelf Oceanic Province (6) is also split, in this case between the Kimberley coast and the Canning-Pilbara coast.

3.7. Marine and Coastal Ecosystems in Western Australia

In this section the major marine **ecosystems** which are represented in Western Australia are briefly described. (The term ecosystem is discussed in Section 3.3.)

The level of ecosystem classification we have chosen usually corresponds to that of the dominant biological **community** within the ecosystem (eg. seaweed-kelp beds, mangroves). In some cases ecosystems are classified in terms of their physical boundaries (eg. the rocky intertidal, southern estuaries) because it is these which constrain their main ecological processes. While this multiple-level approach to the classification of marine ecosystems may not be consistent, it is ecologically defensible, and it serves the purpose of this report well because it defines practical units of management.

The ecosystems discussed are as follows:

3.7.1. Saltmarsh;
3.7.2. Rocky shore;
3.7.3. Seaweed-kelp bed;
3.7.4. Seagrass meadow;
3.7.5. Coral reef;
3.7.6. Southern estuary;
3.7.7. Mangal;
3.7.8. Tidal flat;
3.7.9. The oceanic environment.

3.7.1. Saltmarshes

Saltmarshes are a coastal wetland type characteristic of temperate regions (latitudes higher than about 30 degrees). Mangroves dominate the equivalent shore types of tropical regions (latitudes lower than about 30 degrees). However, mangroves and saltmarshes overlap and coexist in the subtropical/warm-temperate zone between latitudes 30^{o} and 35^{o}. The occurrence of saltmarshes, mangroves and other coastal wetlands (saltpans, or salt flats, and freshwater-dependent vegetation) is strongly influenced by the relative salt and freshwater regimes, viz.:

- Reed swamps depend on the dominance of a freshwater source.
- Saltmarsh halophytes (plants able to tolerate elevated salinity) are associated with the inundation of both seawater (sometimes as spray) and freshwater (especially from nocturnal dew formation).
- Saltpans, or salt flats, with sparse halophytes and algal/microbial surface crusts, are characterised by intermittent tidal inundation and limited freshwater intrusion.
- Mangroves, like saltmarshes, are also able to withstand elevated salinities but extend lower down the shore and are even better adapted to marine inundation than are saltmarsh halophytes.

In Western Australia, saltmarshes are poorly developed because of limited areas of freshwater inflow. However, saltmarsh halophytic vegetation has relatively high regional significance as it is often the only herbaceous vegetation in the coastal zone. Halophyte persistence depends on dew formation, occasional rainfall, seasonal floods, and ground water. Saltpans, or salt flats, are often a dominant feature in low-profile coastal areas of Western Australia where soilwater/groundwater becomes very hypersaline and mangroves cannot grow.

Large amounts of detritus may form in saltmarsh habitats and the export of these organic materials (and nutrients derived from them) is important to more seaward communities. Depending on the degree of their development, saltmarshes may serve as important habitat for birds, fishes and invertebrates. By binding coastal sediments, saltmarshes help to control erosion.

3.7.2. Rocky shores

Rocky substrates of the littoral zone are of particular interest because the phenomenon of vertical zonation is pronounced, the habitats of many of the animals and plants which live there being restricted to a narrow horizonal band around the shore. Different zonation patterns occur, depending on the kind of rock, range of tide, degree of wave action, and biogeographic province. Frequency and duration of exposure of the rock surface to the air and sun during periods of low tide are the primary physical factors determining the zonation patterns.

Intertidal zonation has been well studied on the limestone rock platforms of the Western Australian central west coast (Hodgkin, 1960; Marsh & Hodgkin, 1962) but hardly at all in the north or on the granitic shores of the south coast.

Southern Western Australia

Usually zonation of marine plants between tide marks on rocky coasts is obvious but in southern Western Australia the lunar tide is very slight and tides are complicated by the water levels rising and falling with changing barometric pressure. This irregularity and relatively small change in level does not yield such obvious zonation of communities as may occur in regions with greater tidal range.

In the southern part of the State rocky shores are of two quite different types (see Section 3.6, coastal zone types 8 & 9). From Cape Naturaliste southwards granitic rock is the most common type. This tends to weather into relatively smooth slopes descending into the sublittoral zone in areas exposed to heavy wave action, or to form boulder zones where wave action is less severe. Zonation patterns are most distinct on the open ocean rock slopes. The animals and plants which live there are necessarily adapted to cling tightly to the substrate by some means - sessile animals like limpets, abalone, chitons and barnacles, and algae with strong basal holdfasts tend to dominate. Intertidal boulder shores with rock pools provide a much greater variety of micro-habitats, and hence a richer flora and fauna, and vertical zonation patterns are not as clear.

On the west coast, offshore limestone reefs run in broken chains parallel to the coast. They are the remains of consolidated aeolian sand dunes submerged by various changes in sea level. In many places along the west coast these Quaternary limestones form rocky shores. On sections of the south coast there are superficial limestone deposits of the same period on or between the granitic headlands.

On these limestone shores, profiles have developed which are very different to those of granitic shores. The limestone erodes by physical, chemical and biological means quite differently to granitic rocks. Horizontal (shorewards) erosion is often much faster than vertical erosion and horizontal rock platforms commonly develop between tide levels. At the shoreward limit of the platform, the combined action of physical and biological factors undercuts the rock face and creates a "notch" in the upper intertidal zone. The height at which the platform develops is largely dependant on the force of wave action. An ecological effect of the horizonal platform is to split the vertical zonation, separating the upper slope of the intertidal zone from the lower slope.

Rock platforms of such shores are covered by water for most of the time but when the tide falls they may quickly become bare and exposed to the air and sun. The shoreward parts are exposed for the longest periods. Shallow pools like rice-paddies with slightly elevated rims commonly occur where sedentary animals and plants can find shelter from desiccation at low tide, provided that the duration of isolation from the sea is not too prolonged and that the weather is not so hot that temperatures become lethal and the pool water becomes de-oxygenated. Mass mortality of the intertidal biota of limestone rock platforms occasionally occurs during periods of extreme low tide and extreme hot weather.

At the highest levels on the shore (ie. the upper part of the notch) the only plants are thin-layered, prostrate lichens and filamentous green algae which penetrate into the rock pores. The action of the grazers which feed on them is a major factor in the erosion of this part of the shore. This high zone may be wet only by wave splash at high tide and few animals and plants can exist there. Those which can include grazers like the littorinid and siphonarian gastropods, the latter being air-breathers.

Lower in the intertidal zone, grazers also predominate, especially limpets and chitons. However, where there is a sufficient period of immersion, sessile filter-feeders like barnacles, mussels and tubiculous polychaete worms may also establish distinctive zones. Leafy green, brown and red algae and carnivores like crabs and thaid whelks also appear in the mid-tidal zone. Calcareous red algae are characteristic of this part of the shore. Like the animals the algae are often very distinctly zoned. The permanent molluscan and echinoderm grazers, and the transient fish and crustacean grazers which invade the intertidal zone at high tide, generally keep the algae grazed down to a "turf" but if the grazers are killed by a catastrophic weather event, such as extreme hot weather during periods of low tide, or by pollution, or are removed by predation, the algae may develop into a thick cover on the rocky shore.

Australian temperate rocky coasts have the most diverse algal speciation in the world. In southern Western Australia rock platforms and offshore reefs support at least 900 species of algae.

Northern Western Australia
In the north of the State tidal range is generally much greater than in the south, wave action is less severe, and there is a much greater variety of animal species. These three factors produce rocky shores which have very different profiles and different biological zonation patterns.

The highest zone, ie. the supra-littoral, is characterised by littorinid and siphonarian grazers much as it is in the south, although the species are generally different. In the upper and middle littoral zone animals which have a particularly important impact are *Saccostrea* (a genus of oysters) which build substantial ramparts in the intertidal zone, *Brachidontes* (a genus of mussels) which form mats on the rock surfaces, and the borers *Lithophaga* (another genus of mussels) and *Lithothyra* (stalked barnacles) which make burrows in limestone rocks several centimetres deep, opening them up to the destructive effects of wave action and chemical corrosion.

Because of the preferred vertical zones of these species, limestone shores in the north often have a double notch. In the highest part of the intertidal zone a notch is formed by the abrasive action of

grazing animals and wave action, together with chemical effects. In the lower part the burrowing action of the borers, together with grazing and physical and chemical action may also eat into the rock face. But in the middle zone occupied by the oysters there is a horizontal ridge or shelf between the upper and lower notches, partly due to the growth of the oysters. This forms the double notch characteristic of Western Australia's northern limestone rock platforms.

On northern shores where there are granitic or other "hard" rocks, smooth intertidal slopes rarely develop as they do on the south coast. This is because there is far less wave action. Instead, hard rock shores in the north tend to form rock piles or cliffs. Zonation in the upper and middle littoral of such shores is again dominated by the accretionary effects of oysters and mussels but the borers have little impact.

3.7.3. Seaweed-kelp beds

Shoreline and offshore reefs in temperate regions support a diversity of algal species which form an important component of rocky shore and sublittoral ecosystems. In temperate zones algae may be so dense as to form a distinct ecosystem known as a seaweed-kelp bed. Although such beds are usually developed on rocky substrates, it is useful to treat them as a distinct ecosystem type for they have characteristics different from those of other rock substrates. They develop particularly in temperate regions because higher latitudes do not have the multitude of herbivores that reduce algal communities to turfs as they do in the tropics.

The diverse assemblages of algae in seaweed-kelp beds are habitat for a large number of animals adapted to living on and amongst algae. The high biomass of plants and sessile animals, and the high productivity of the plants, produce a large biomass of detrital material. This is found on the sea floor between the reefs and the shore and on the shore in large drifts, particularly during winter, and after storms. The decomposition and mechanical breakdown of drift material produces dissolved organic matter, and results in the release of plant nutrients and suspended particulate material into the water column.

In the warm temperate waters of southern Western Australia the most abundant and visually dominant alga is the kelp *Ecklonia radiata* which, in many places, forms a complete cover from 2m to about 14m depth, becoming less well represented as the reefs become deeper. Underneath the kelp cover is a diverse assemblage of calcareous encrusting red algae. In other areas and in depths greater than 10m, *Caulerpa* species and fleshy red algae are more conspicuous. At shallow depths, the annual reproductive fronds of the brown alga, *Sargassum lacerifolium*, grow rapidly from September until April but decline in winter. There are relatively few large herbivores in this plant-dominated system.

In the shallow sublittoral zone of the west coast *Ecklonia, Sargassum* and other leafy brown algae frequently form extensive seaweed-kelp beds which play a major role in the energy cycles of coastal waters. For example, at the Abrolhos they are a major contributor to the high biotic productivity which supports the rock-lobster fishery. Competitive interaction of the algae and corals at that locality is one of the most interesting features of west coast biogeography and ecology (Johannes *et al.*,1983).

3.7.4. Seagrass meadows

Seagrasses are flowering plants able to live permanently in marine environments. They form the basis of a characteristic ecosystem. Aspects of seagrass biology and their ecological importance in the Australian region are discussed in Larkum, McComb & Sheperd (1989).

Seagrass meadows cover vast areas of the sea bed along the WA coast. The seagrass communities of southern WA (ie. Shark Bay to the SA border) are probably the most extensive in the world. Seagrass extends from the mid-intertidal zone to greater than 50m depth, usually occurring in shallow, sand-silt, soft-bottom habitats. A depth zonation pattern of different genera and species is evident, reflecting the interaction of a number of parameters including intertidal exposure, substratum stability and light availability. In addition, temperature and salinity tolerance of individual seagrass species will affect their local and latitudinal distribution.

Trophic interactions within seagrass communities and between associated ecosystems (eg. mangroves, coral reefs) are not only complex but are essential in maintaining the integrity and

productivity of seagrass assemblages. The total community represents a rich and highly dynamic food chain which sustains resident and migratory marine animals and birds. Seagrass communities are a major source of organic detritus in the coastal zone. Utilisation of the detrital and living plant resources involves most classes of invertebrates, some of which are eaten by carnivores higher in the food chain. In the north, turtles and dugong are direct consumers of seagrass. Food availability and shelter make seagrass communities an important nursery for juvenile fishes, rock lobsters and prawns, and many other animals. Commercially important fishes and lobsters often shelter in associated habitats by day and travel large distances to feed in seagrass beds at night.

The coastal waters of Western Australia contain 11 of the 12 genera of seagrasses found throughout the world. Twenty-four species are represented. *Posidonia* is the richest genus with eight species found from Shark Bay to the South Australian border.

Unlike most other coasts in Australia, the strongly seasonal estuaries of southern Western Australia do not represent a major habitat for seagrass beds, although seagrasses are ecologically important in most of them. The open coast has the largest seagrass beds. They are located in positions protected by offshore reefs or, in the case of the southern coast, by the physical aspects of the bays. Generally, a single species of seagrass dominates in most areas but natural, localised erosion and disturbance may create sites of dynamic change with greater diversity and varying abundance of species.

The tropical seagrasses are well represented around the northern islands but do not form extensive beds along the open coast where the effects of strong currents and large tidal flows dominate. The distribution of seagrasses in northern Western Australia is outlined by Walker & Prince (1987).

The ecological importance of seagrass ecosystems in trophic transfers, maintenance of fishery resources and coastal stabilisation makes the need for sound conservation and management practices particularly vital.

Although seagrasses may be relatively resilient to some natural and human impacts, such as storms or anchor and propeller damage, other activities such as coastal engineering projects, landfilling, dredging and sand-mining can cause complete destruction. Thermal pollution, sedimentation, nutrient enrichment, sewage discharge, oil and chemicals have also been shown to deplete seagrass communities. Toxic elements from agricultural run-off can have marked effects on seagrass systems in estuaries and landlocked bays.

Recent studies in Cockburn Sound and elsewhere have shown that seagrass communities do not readily recover after suffering severe damage from pollution (personal observation Kirkman).

3.7.5. Coral Reefs

Coral reefs are found throughout the tropics and subtropics, usually between 30°N and 30°S, and are confined to regions where the annual mean water temperature is greater than about 18°C. Various physical factors interact to determine geographical and depth distribution of coral reefs.

Australian corals and coral reefs, including those of Western Australia, are described in Veron (1986a). Veron & Marsh (1988) published an annotated list of the hermatypic corals of Western Australia and major coral reefs systems of the State. Coral reef handbooks have been published by Kenchington & Hudson (1984) and Mather & Bennett (1984).

With the exception of a few deep-water genera and species, reef-building corals occur in water less than about 50m in depth with maximum growth taking place in less than 20m, reflecting the depth to which light may penetrate in sufficient quantity to maintain metabolism by zooxanthellae. Optimum coral growth occurs at 25-29°C and at normal ocean water salinity .

Coral reef systems are found characteristically in waters having low nutrient concentrations. Excessive nutrient loads can be detrimental to coral survival.

Reef-building coral species are found along the entire coast of Western Australia from the north Kimberley to the Great Australian Bight, although there is a marked progressive diminution of species from north to south. At southern localities the few coral species may be abundant but do not

form reefs. Coral reefs, with their typical communities are developed only as far south as the Houtman Abrolhos (lat. about 30°S). At higher latitudes than this corals occur as isolated colonies on rocky substrates.

A wide variety of coral reef types is found along the tropical and subtropical coasts of the State. Tertiary tectonic activity and Pleistocene transgressions and regressions around the continental margins of Western Australia have left a legacy of geological structures providing the foundations for modern coral reef development. The variety of reef types results in part from the different structural foundations on which they are built, and in part from the regional climate and hydrological conditions.

Five coral reef provinces may be recognised in Western Australian coastal waters:

i) *Platform reefs of the Sahul Shelf*
The waters of this area, off the coast of the North Kimberley, are generally turbid and the substrates muddy (see Section 3.6). There is a high tidal range and strong tidal current flow. Nevertheless corals grow prolifically and extensive modern coral banks and large platform reefs are formed. Adele, Browse, Long and Ashmore Reefs, the Holothuria Bank and Hibernia Reef are major examples. The inner parts of the Sahul Shelf have been successively flooded and laid bare by Pleistocene sea-level changes so that coral growth has been intermittent. The modern reefs have been very little studied but appear to be very diverse in species of corals and other coral reef plants and animals.

ii) *North West Shelf shelf-edge atolls*
Seringapatam Reef, Scott Reef and the Rowley Shoals form a series of large shelf-edge atolls growing on block-faulted Pleistocene and Tertiary coralline limestones. They have deep central lagoons, wide reef flats and steep reef-front slopes. Several of them have small unvegetated sand cays. These atolls are extremely rich in coral species and support a diverse marine flora and fauna typical of clearwater oceanic atolls. Many of the atoll species are not found in the coastal reef communities closer to the mainland.

iii) *West Kimberley and Pilbara fringing reefs*
There is extensive coral reef development, growing mainly on Pleistocene coastal limestone foundations, on the seaward sides of many islands along the coast from the Lacepedes to the Muirons. The best developed reefs are around the more distant offshore islands, eg. the Montebellos. The diversity of species is moderately high on these reefs where the tidal range is great and the water moderately turbid.

iv) *Ningaloo Reef*
There is a fringing-barrier reef system, some 260 km long, developed on Tertiary limestone foundations along the western side of the Cape Range Peninsula anticline. The continental shelf is very narrow in this region and the waters are clear. There is a shallow lagoon between the reef and the shore. Species diversity is moderately high with many oceanic coral reef species occurring there but which are not found on the inshore reefs of the Pilbara coast to the north.

v) *Houtman Abrolhos*
This remarkable reef and island complex is located in relatively high latitudes (about 30°S.) and appears to be established and sustained by the warm, southerly-flowing Leeuwin Current. The reefs are platform reefs or pseudo-atolls, with a foundation of Pleistocene coralline and coastal limestones. Diversity of coral species is surprisingly high for such latitudes. Brown algae play a prominent role in the reef energy cycles, and appear to compete with the reef-building corals, so that the ecosystem is atypical of coral reefs in some respects (Johannes et. al., 1983).

Because of their complexity, coral reef systems can show a variety of responses to stresses, such as storm damage, or pollution from such sources as sediments, thermal effluents, or nutrient enrichment. A common response following such events is a progressive transformation from predominantly living coral to a dead substrate covered by macroalgae. There are also occasional catastrophic upsets to coral reef communities when coral predators become excessively abundant. Episodic outbreaks of the Crown-of-thorns starfish (*Acanthaster planci*) have caused localised destruction on the Dampier Archipelago coral reefs. The coral-eating gastropod *Drupella cornus* has

caused very extensive damage to back-reef communities of the Ningaloo Reef. Whether such predator outbreaks are due to natural causes or some form of human interference in natural ecological processes is unknown. Whatever the cause, coral reef communities are usually slow to recover, even when the cause of the stress is removed.

Tropical coral reefs rarely sustain major single-species fisheries like those found in nutrient-rich temperate waters and in areas of upwelling. The rock-lobster fishery at the Abrolhos is an interesting exception, probably related to the atypical ecosystem features resulting from the dominance of brown algae (Johannes *et al.*, 1983). Over-fishing of resident, migratory and pelagic fishes from reefal waters can lead to major changes in coral reef ecosystems. Selective fishing (ie. of particularly popular species) can result in subtle changes to fish communities detrimental to the reef ecosystem as a whole.

3.7.6. Southern estuaries

The term 'estuary' as used here includes all partially enclosed coastal waters into which rivers flow and which are, at one time or another, open to the sea, and does not include coastal lakes that are never open to the sea. Saltmarshes may be considered extensions of estuarine ecosystems into the supra-littoral zone. While acknowledging this they are dealt with separately in Section 3.7.1 of this report.

In southern Western Australia (ie. south of Shark Bay) the estuaries are quite well studied (Hodgkin & Major, 1978; Hodgkin & Clark, 1987-1990) and, although they are extremely variable in structure, hydrology and biology, they fit the usual notion of "estuary" reasonably well. Estuaries of the northern part of the State, however, are relatively poorly studied and they are dominated by mangal habitats. For this reason the estuaries of northern Western Australia are not dealt with in this section but are treated as mangals in Section 3.7.7.

Physiographically, most southern estuaries have lagoons (locally called 'inlets'), the tidal reaches of tributary rivers, and narrow entrance channels through Pleistocene or Recent dune systems to the sea. However, there are also a number of riverine estuaries which do not have lagoons. All, except Oyster Harbour and the Swan estuary, have entrance bars which obstruct tidal exchange with the sea. (The Swan bar was removed by dredging to develop Fremantle Harbour in 1897.) Many estuaries also have fluvial bars which partially isolate riverine reaches from the lagoons.

Southern estuaries vary greatly in size from Peel-Harvey with an area of 130 km^2 to several that have lagoons 1 km^2 or less. There are also great differences between the estuaries in their geology and morphology. For example, the Swan estuary is an inundated meandering coastal river complex with a channel through Pleistocene limestone dunes; Leschenault Inlet is a barred lagoon behind Holocene barrier dunes; Nornalup Inlet and Wilson Inlet are in basins enclosed by Pleistocene dunes and with Pre-Cambrian headlands; several very shallow south coast estuaries are in river valleys excavated in the soft Pallinup Siltstone.

Hydrologically the estuaries of the South West are 'seasonal estuaries'; estuary water alternates between nearly fresh in winter and brackish, marine, or hypersaline in summer-autumn. This is caused by the extreme seasonality of rainfall and river flow, the small tidal range, and the obstructing entrance bars. It is a very different situation from that in a conventional estuary where the tides cause the position of the salinity gradient to shift up and down the estuary daily.

The definition of estuary used here excludes coastal lakes that are not open to the sea, however it should be noted that several of the southern coastal lakes have rivers and lagoons that were estuarine until recently. Their bars are now high and never break, but in other respects they are similar to semi-permanently closed estuaries. Culham Inlet, the largest, was certainly estuarine until at least 4000 Before Present (BP) (and probably within the last few hundred years). The Jerdacuttup Lakes were probably estuarine during the mid-Holocene. Lake Nameless (in the Fitzgerald River National Park) may also have been estuarine during the mid-Holocene. The Vasse-Wonnerup lagoons were once estuaries, probably in the seasonally open, lagoonal category, but are now artificially closed by locks and maintained as freshwater wetlands.

The hydrological and ecological status of the estuaries depends to a large extent on how often the bars are breached. Three categories are recognised:

1. *Permanently open estuaries.*

The following estuaries belong to this permanently open category:

- Murchison;
- Swan-Canning;
- Peel-Harvey (Serpentine, Murray and Harvey rivers);
- Leschenault (Collie River);
- Hardy (Blackwood and Scott rivers);
- Nornalup-Walpole (Deep and Frankland rivers);
- Oyster Harbour (King and Kalgan rivers).

Although the bars of these estuaries never close they do restrict tidal exchange to a greater or lesser extent. River water floods them in the rainy season. During periods of low river flow, sea water enters and a salinity gradient progresses upstream. Extreme stratification of the water may develop in the riverine parts.

2. *Seasonally open/closed estuaries*
There are two types of estuary in this category: those where there is a coastal lagoon into which the rivers flow, and those where the rivers flow directly into the sea and there is no lagoon.

a) *Lagoonal estuaries*: Larger estuaries including the Broke (Shannon River); Irwin (Bow and Kent rivers); Wilson (Denmark and Hay rivers); and estuaries with an area less than 2 km^2: Greenough, Moore, Parry, Torbay, Taylor, Normans, Cordinup, Cheyne.

b) *Riverine estuaries:* Chapman, Margaret, Donnelly, Warren, Gardner, Torradup, Munglinup, Alexander, Blackboy, Thomas, Jorndee, Poison. On the west coast, the Hutt, Buller and Irwin Rivers have short stretches of estuarine water.

In estuaries of this category the bars close when effective river flow ceases, isolating them from the sea. They usually open annually when river flow breaches the bars, or when they are breached artificially. The large estuaries of this category are seldom fully marine, but some smaller estuaries become marine or even hypersaline in summer.

3. *Semi-permanently closed estuaries*
Beaufort, Wellstead, Gordon, St Mary, Fitzgerald, Dempster, Hamersley, Oldfield, Stokes, Barker.

These are estuaries where the bars remain closed for several years at a time and only open when there is above-average seasonal river flow or when there is flood flow (either winter or summer). They are all in the low rainfall area east of Albany, with less than 600 mm annual rainfall near the coast and 400 mm inland. The heavy winter rains of September-October 1971 broke the bars of all these estuaries, as did the summer floods of January 1990. Most bars only stay open for a few weeks, but the Gordon and Wellstead bars sometimes remain open for several years. Estuary water may be brackish following river flow but becomes increasingly saline while there is little or no river flow; it may then become hypersaline through evaporation. Many of these estuaries dry up altogether following long periods with no river flow.

Ecology
Substrate type, bar behaviour, water depths and changes in water level, and the hydrology all influence the ecology of the estuaries. There are usually extensive areas of shallow sand and mud flats and deeper water mud basins, but most estuaries have limited areas of natural solid substrates (rocks and logs) except in riverine parts. Macrophytes are important substrates for epiphytes and fauna. In those estuaries which are permanently open to the sea and receive regular tidal water, there may be development of extensive seagrass beds.

The time, season, duration and frequency of bar opening determine the recruitment of marine/estuarine fauna. Changing water levels determine when and where both emergent and aquatic plants and benthic fauna can settle and survive. However, it is the hydrology, the great range of salinity experienced and the duration of exposure to the salinity extremes, that largely determines the diversity of species and their distribution.

In the Swan the number of species of benthic macrofauna decreases progressively from the entrance channel where stenohaline marine species may be present seasonally, through the lagoon with euryhaline estuarine-marine species, to the riverine part dominated by a dozen true estuarine species (Chalmer *et al.*, 1976).

Other southern estuaries (except Oyster Harbour) have a more limited diversity of species, dominated by true estuarine species and a few estuarine-marine species (Hodgkin and Clark, 1987-1990). Studies of the faunas of southern estuaries include those on : Blackwood (Wallace, 1976), Peel-Harvey (Chalmer and Scott, 1984) and Wilson Inlet (Platell, 1990).

Most fish and other nektonic estuarine fauna, such as crabs and prawns, spawn in the ocean and enter and leave estuaries in response to changing salinity. There are a few exclusively estuarine species. The diversity of species within an estuary is principally related to the salinity regime. For example, 137 species of fish are recorded from the Swan (Loneragan *et al*, 1987), probably about half that number in Peel-Harvey and decreasing numbers in other estuaries where salinity range becomes more extreme. There is often massive mortality of fish and benthic fauna when the water becomes hypersaline in closed estuaries. Recruitment is from the saline rivers, the from the sea when floods break the bars. Initially the fauna may be diverse but as the water becomes hypersaline species die out progressively (Lenanton and Hodgkin, 1985).

Conservation value

The harshness of the extreme seasonal variation in water salinity and associated physical conditions, and the inconsistency of those conditions in many of the southern estuaries from one year to the next, determine that species diversity in their aquatic faunas and floras is relatively low and that community structures are unstable. Nevertheless, the estuaries of southern Western Australia are highly productive in the biomass and nutrient sense and provide rich feeding grounds for fish and nursery areas for a number of coastal species. They are also important feeding grounds for waterbirds, especially for the many migratory species of waders. The Peel-Harvey Estuary is a designated Wetland of International Importance under the *Convention on Wetlands of International Importance Especially as Waterfowl Habitat* (known as the RAMSAR Convention) in recognition of its significance as habitat for waterbirds.

The southern estuaries are valuable scenically and for recreational fishing, boating and other aquatic activities. Several of them support long-established net fisheries. Some are currently the sites of oyster culturing establishments and there may be further opportunities for development of aquaculture industries without damaging the estuarine environments.

Human activities have had a variety of impacts on estuaries of the South West. Sometimes these have benefited the estuaries in the sense that a more equable environment is created permitting a higher diversity of aquatic species to persist there, eg. dredging the entrance of the Swan at Fremantle. More often they have been detrimental as the result of the discharge of industrial wastes and sewage. Recently, nutrients from fertilisers have made a number of estuaries eutrophic. Probably the most serious long term threat is from clearing in catchments and the consequent eutrophication and sedimentation in estuaries that are already shallow. In Stokes Inlet the sedimentation rate has increased tenfold following clearing, from <1 mm a year to 20-25 cm of dry sediment in the last 30 years.

Given the high aesthetic and commercial values of the southern estuaries there can be no doubt that they deserve special management to ensure that their water quality and biological systems are maintained. However, this is a very difficult thing to achieve and requires management of the catchments beyond the limits of the estuaries as well as management of the estuaries themselves.

3.7.7. Mangals (Mangroves)*

Mangrove communities occur in the intertidal zone, growing along the edges of brackish and seawater shores, and comprise plants (trees and shrubs) able to colonise waterlogged and saline soils. Mangroves control coastal erosion and contribute to shoreline accretion.

The ecology of mangals has been studied extensively. Useful references in the Australian context are Lugo & Snedaker (1976); Galloway (1980); Hamilton & Snedaker (1984); Hutchings & Saenger (1987).

Globally, mangals are characteristic of tropical and subtropical regions and are limited by low air temperature (< about 20°C) although the grey mangrove (*Avicennia*) will tolerate temperature minima around 10°C. The presence and health of each mangrove stand are determined by the interaction of tides, salinity and water table parameters in the presence of other physical factors, for example, low energy and low profile coastlines. Saltwater input minimises competition by other plants, and the availability of silt and terrestrial sediments provides nutrients and substrates.

Diverse flora and fauna are associated with mangroves, and adult and juvenile fishes frequently migrate from offshore ecosystems to feed and seek shelter during growth. The biotic density of these communities reflects their complex food chains and the integrated trophic exchange of terrigenous materials, marine materials, and mangrove primary production between the mangal system and the adjacent terrestrial and marine ecosystems.

As primary producers, mangroves make significant contributions to estuarine and inshore productivity via an energy flow pathway based on detritus. Leaves and branches fall into the water, or onto the sediment substrate, where they are microbially decomposed and made soluble. Particulate organic matter sustains elaborate food chains within mangrove stands and also is flushed out of the mangals to benefit nearshore marine ecosystems. The high productivity sustained through detrital food chains originating in mangals contributes to the high biomass and dense populations of resident and migratory animals of the mangals themselves and adjacent habitats.

Important publications on the floristics, distribution of mangroves species and the community structure of mangal systems in Western Australia are those of Semeniuk & Wurm (1987), Semeniuk, Kenneally & Wilson (1978), Wells (1981) and Johnstone (1990).

Mangal Floristics and Regional Distribution of mangrove species in WA

Eighteen species of mangrove have been recorded from Western Australia (Semeniuk, 1983).

The most diverse mangals occur in the humid tropics, with few species extending into the temperate regions. As with many other groups of animals and plants, there is a trend for a decrease in species diversity of mangroves with increasing latitude.

In arid regions, salt flats and salt marshes develop at landward edges of mangals and replace mangroves. On a regional basis, there is a progressive decrease in species diversity as aridity increases. In Western Australia this means a decrease from the high diversity centre in the North West Kimberley, west and south down the WA coast, compounding or at least paralleling the trend for a decrease in species diversity with increasing latitude.

Mangals of Western Australia occur in 4 climatic zones which are (in order of species diversity):

- tropical subhumid (16 species);
- tropical semiarid (8 species);
- tropical arid (5 species);
- subtropical arid (>5 species).

Although there are few data, it can be assumed that diversity of associated fauna will show the same trend, ie. decrease from tropical subhumid to subtropical arid.

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* Following contemporary practice the term '**mangal**' is used to refer to the vegetation assemblages of trees known as mangroves associated with tidal flats. 'Mangrove' is commonly used in lay terminology as a synonym of 'mangal'.

Rhizophora stylosa and *Avicennia marina* are probably the most common mangrove species along the Western Australian coast. The southernmost outlier of *R. stylosa* occurs at Yardie Creek in the Ningaloo Marine Park. South of that point, *A. marina* is the only mangrove species present. There are small mangals comprised solely of this species in the mouth of the Gascoyne River, at several locations in Shark Bay, and at the Abrolhos. The most southerly occurrence of *A. marina* is at Bunbury.

The associated fauna in the well-developed mangal ecosystems along the northern coast is very rich (Wells, F.E., 1983, 1984, 1986a and b; Wells, F.E. & Slack-Smith, 1981) and includes a number of important fishes, such as barramundi, bream, prawns, and mud (mangrove) crabs. Further south, the relatively less developed mangrove ecosystems have an important role as centres of high primary productivity.

Mangal habitats

The physical settings

While the geographical distribution of mangrove species determines the potential size and composition of the mangal communities at any point on the coast, the realised floristics and structure of particular mangals are set by the habitat conditions prevailing there. Habitat is determined by a combination of regional geomorphological/stratigraphic features and local physical features (Wells, 1981; Semeniuk, 1985).

Four major types of coastlines relevant to the development of mangrove habitats were recognised by Semeniuk (1985). These coastline types are:

- ria shore - archipelago settings;
- delta - barrier island settings;
- sheltered bay-embayment settings;
- gulf settings.

Ria shores are deeply indented coastlines formed by subsidence of the land and the inundation of coastal river valleys. Coastal islands are formed by the same process so that ria and archipelago settings are inter-gradational at the regional scale. Similarly, deltas and barrier islands are inter-gradational.

Within these four primary regional coastal types there are recognisable coastal types at a smaller scale. For example, along the Canning-Pilbara coast 12 coastal types are recognised for the purposes of this report (see Part III, Section 1.1.2).

Within each of these coastal types there are particular habitats which support characteristic assemblages of mangrove species and formations. Individual mangals vary in floristic (and faunistic) composition, species richness, community structure, and zonation, according to local geomorphological features, tidal range, substrate, aquifers, physiochemical processes and salinity. Freshwater seepage, in particular, has a large influence.

Mangrove formations in Western Australia are difficult to classify because much compositional and structural variation exists at the regional scale. Even at the local scale one formation type commonly grades into another because of small scale responses to physiochemical gradients. Mangrove systems in other countries, comprising fewer floristic components, have lent themselves to classification into structural types, eg. the riverine, basin, fringing and dwarf categories of McNae (1966), Lugo and Snedaker (1976) and Wells (1981) and the structural schemes of Specht (1981). The floristics of the mangals are not incorporated into the nomenclature of these classifications. This approach is not successful in Western Australia

The approach of Semeniuk (1985) and Semeniuk and Wurm (1987) is adopted here, wherein, in the first instance, mangrove formations are classified according to their habitat setting. This approach encompasses the implication of physiochemical variation present in the habitat, and consequently also encompasses (and implies) the variation in structure and floristic gradation and zonation present in the mangroves within that habitat. The major mangrove habitats (and assemblages) are:

- muddy tidal flat assemblages;
- sandy tidal flat assemblages;
- tidal creek assemblages;
- spit/chenier assemblages;
- alluvial fan assemblages;
- hinterland fringe assemblages;
- rocky shore assemblages;
- beach assemblages;
- shoal assemblages;
- lagoon assemblages.

Some of these types are specific to certain geomorphic settings, whereas others occur throughout tropical north-western Australia. In addition to variations in habitats locally and regionally, there is compositional (floristic) variation regionally, in response to climate (Semeniuk 1983). Thus, floristically, assemblages colonising similar habitats will vary from region to region.

From these considerations it follows that establishment of a reserve system representative of the mangal habitats and the mangrove flora of Western Australia will need to take account of variation produced by geographic distribution of species, regional climatic type, regional and local coastal types, and site-specific habitat types. Within each of the primary climatic types, reservation of areas representative of the coastal types will usually encompass most of the habitat types and, thereby provide a representation of the variety of mangal formations and mangrove species.

Susceptibility of Mangals

Mangroves may be disturbed or destroyed by natural events such as cyclones, tidal waves, or coastal erosion. Human activities also may have far-reaching effects. For example, landfilling and dredging can cause changes in drainage patterns, deforestation in the hinterland can increase sediment runoff and deposition in the mangals, and changes in agricultural practices and coastal development can change the environment and deplete mangroves. Discharges from power and desalination installations can modify temperatures and salinity. (A 3-5°C increase in ambient seawater temperature in the tropics can cause mangrove mortality, as well as up to 90% reduction in the density and mass of associated fauna.) Water pollution by refuse dumps, sewage, oil and chemicals can be detrimental to mangroves and associated food chains important to people.

Mangals, especially the high diversity mangals of the far north, are worthy of conservation in their own right and attention should be paid to preserving an example of each of the varied mangrove habitat systems in each of the major geomorphic provinces and subprovinces in tropical Western Australia. However, they have particular importance to conservation of coastal waters, irrespective of their own species richness, because of the great contribution they make to coastal nutrient flows and as nursery areas for many marine species.

3.7.8. Tidal flats

Tidal flats occur predominantly in the coastal zones of northern Western Australia where tidal range is moderate to high. As described in an earlier Section (3.4), they comprise mud flats, sand flats, rock pavements and boulder or pebble flats and pavements.

In addition to substrate variations from locality to locality due to shore energy gradients and variations in source materials, there is variation in inundation due to rising shore level. As a result, there is a large variation in smaller scale habitats on the tidal flat (see Semeniuk, 1985). There is a correspondingly large variation in biotic assemblages which inhabit the tidal flats. Habitat heterogeneity within a tidal flat system such as at Dampier Archipelago (Semeniuk, Chalmer & Le Provost, 1982) is reflected by an equally varied distribution of biotic assemblages. Conversely, a monotonous tidal flat system may be inhabited by relatively simple aggregations of biotic assemblages.

For the purposes of this study, because of the varied biota on the tidal flats, it is preferable to treat the total various assemblages as "tidal flat assemblages".

Tidal flats commonly are temporary sinks for detritus that is transported into the system from adjoining productive areas such as mangals, samphire flats, or offshore seagrass/algae meadows. Tidal flats also function as important nursery grounds for a variety of fish and invertebrates such as swimming crabs and molluscs. Their importance lies in providing short term shelter in residual pools at low tide and in providing food for the juvenile fauna. Shallow water and tropical conditions promote the growth of seagrass, algae and diatoms and these, with material imported from other primary producing areas, form the basis of the trophic web.

The most common types of assemblages inhabiting the tidal flats of northern Western Australia are described below. The assemblages are informally named after a conspicuous, or dominant, or identifying biotic element, and the assemblages are described in terms of composition, general substrate conditions and general tidal setting.

1. *Uca* (fiddler crab) - *Macrophthalmus* (crab) assemblages. These encompass a range of *Uca* species and *Macrophthalmus* species, together with mud skippers (fish), polychaete worms and, less commonly, potamidid whelks (gastropods). They are variable regionally, but the assemblages invariably inhabit mid to low-tidal mud flats.
2. *Mictyris* assemblage. This is a soldier crab assemblage that inhabits low to mid-tidal sand flats.
3. *Scopimera* assemblage. This is a sand bubbler crab assemblage that inhabits low to mid-tidal sand flats.
4. *Callista -Anomalocardia* assemblage. This assemblage inhabits sandy and muddy sandy low to mid-tidal flats, and is composed of various molluscs, crustaceans, polychaetes and echinoderms. Conspicuous molluscan genera are the bivalves *Callista, Tellina, Mactra, Anomalocardia, Placamen* and *Dosinia,* and the gastropods *Natica, Polinices, Cerithium, Clypeomorus* and *Nassarius.*
5. *Anadara* assemblage. This assemblage is composed of small molluscs, polychaetes, mudskippers and crustaceans, with the conspicuous bivalved mollusc *Anadara*. It inhabits mid-tidal to low-tidal mud flats.
6. *Halophila* assemblage. This is a seagrass assemblage with components of molluscs and echinoderms that inhabit low-tidal sand flats.
7. Xanthid assemblage. This assemblage is composed of various xanthid crab species together with encrusting sponges, benthic algae and sessile molluscs that inhabit low-tidal to mid-tidal rock pavements, especially those formed of flat limestone.

Other assemblages are comprised of mixed molluscs, polychaetes and other invertebrates and seem to be aggregations of species that are specific to particular regions or tidal flat settings (eg. the low-tidal flats of Broome differ from those of the Kimberley and Exmouth Gulf).

Tidal flats are susceptible to natural and human-induced disturbance of the environment. Natural disturbances may include cyclone-induced erosion or sediment transport, or flood-induced blanketing of substrates by different sediment types. Human-induced disturbances may include the effects of dredging and spoil dumping, so creating turbid water, and the discharge of toxic materials into the water column which then may seep into the substrate.

3.7.9. The oceanic environment

The term 'oceanic' usually refers to the far offshore marine environment but in this context it is used for the habitats within the water mass above the continental shelf as well as beyond it. Although no marine reserves are proposed specifically to represent the oceanic habitat, it is obvious that an element of this habitat will be present in every marine reserve and reference must be made to its principal features.

The ocean water mass is itself the habitat of a vast number of marine plants and animals. Its upper part, where light penetrates, is known as the photic zone. In those oceanic waters where there are high concentrations of dissolved nutrients, this zone may support very large densities of photosynthetic plants and other organisms that feed on them. The principal environmental factors that influence oceanic habitats and their plant and animal communities include water currents, water turbidity (to which is related the depth of the photic zone), temperature, salinity and other physical properties of the water, especially dissolved nutrients.

Three terms used for oceanic organisms are nekton, plankton and micronekton.

The *nekton* are the larger swimming animals, such as fishes and squids, that live permanently in the water mass.

Plankton is the term used for organisms, plants or animals, which float in the sea drifting at the mercy of water currents. Although their abundance varies dramatically from one area to another, their total biomass probably accounts for the largest proportion of marine life. Photosynthetic planktonic plants and bacteria are the basis of most of the ocean's primary productivity. Planktonic plants (phytoplankton) and animals (zooplankton) range from single-celled to complex, multi-celled organisms. They include creatures that spend their entire lives drifting in the water column and the egg and larval stages of others whose adult lives are spent on the sea floor or as nekton.

Micronekton is a term used by biological oceanographers to describe marine swimming animals in the size range 10-100mm. The size is intermediate between plankton and nekton. Included in the micronekton are many hundreds of species of fin-fishes, crustaceans and cephalopods. Micronekton surveys are extensively used in biological oceanography when determining water mass affinities, sites of ocean upwelling and pollutant inputs. A few species support commercial fisheries harvesting micronektonic adults. There are also commercial fisheries based on nektonic or benthic adults of species which have micronektonic larvae. In Western Australian coastal waters, micronekton is commercially significant on the North West Slope, where deep-water prawn fisheries have developed since 1985. Two species of carid and four species of penaeid prawns are the mainstays of those fisheries.

Many inshore fishes, molluscs and crustaceans have planktonic or micronektonic larvae and juveniles as part of their life-cycle. The phyllosoma larvae of the commercially important Western Rock Lobster, *Panulirus cygnus,* are members of the micronekton. They live far offshore, migrating inshore prior to metamorphosis and recruitment into the adult population. Collection of phyllosoma larvae during this inshore phase provides the basis for the prediction of the fishery yield in future years. Settlement of phyllosoma from the micronekton to the benthos is dependent on coastal habitats such as seagrass and reefs of limestone and coral.

With the notable exception of the larvae of the Western Rock Lobster, there is little information on Western Australian plankton and micronekton. Some offshore sampling has been done by Australian and international oceanographic research ships. Most inshore sampling has been in the vicinity of urban areas, eg. in Cockburn Sound.

These studies indicate that the plankton and micronekton densities do not reach the high concentrations known from some other coasts. The FAO (1972) *Atlas of the Living Resources of the Sea* gives figures of 100-150 mgC/m^3/d for phytoplankton production and 51-200 mgC/m^3/d for zooplankton off the central west coast and slightly higher levels for the North West Shelf. These relatively low concentrations probably relate to the relatively low nutrient levels of the ocean waters off the Western Australian coast.

The scant knowledge of the plankton and micronekton of Western Australian waters remains an obstacle to developing knowledge of coastal marine ecosystems. The environmental factors that influence the planktonic larval development and recruitment into adult populations of most inshore benthic animals remain unknown.

A REPRESENTATIVE MARINE RESERVE SYSTEM FOR WESTERN AUSTRALIA

Report of the Marine Parks and Reserves Selection Working Group

PART II

MARINE RESERVES IN THE KIMBERLEY REGION

CONTENTS

PART II: MARINE RESERVES IN THE KIMBERLEY AND THE SAHUL SHELF

1. INTRODUCTION

The section of the Western Australian coast considered in Part II extends from the Northern Territory border to Cape Leveque. It includes the northern part of the North West Shelf Oceanic Province sometimes known as the Sahul Shelf, from the mainland shore to the limit of the State territorial waters. This does not exactly accord with the region commonly known as the Kimberley. However, there is an abrupt change of coastal geomorphology at Cape Leveque, with a corresponding change in marine habitats, so that it is a convenient point for a boundary between the Kimberley and Canning-Pilbara sectors for the purposes of this report. This boundary conforms with the biogeographical zones described in the Council of Nature Conservation Ministers working paper on marine protected areas (CONCOM, 1985).

The Kimberley is one of the most remote and inaccessible stretches of the Australian coast, extending for a distance of about 1 000 km. Much of it is now uninhabited. Until the years immediately following World War II, Aboriginal groups lived in traditional circumstances along these shores and there were several mission stations. The mission at Kalumburu remains. In recent times Aboriginal communities have been re-established at One Arm Point, Cone Bay and Oombulgurri. The ports of Derby in the west and Wyndham in the east are the only major coastal settlements. Between Derby and Wyndham there is no road access to the coast (except for several four-wheel-drive tracks) and the only settlements are the above-mentioned Aboriginal communities and small communities on Koolan and Cockatoo Islands and at Kuri Bay.

The Kimberley coast is of extraordinary beauty. The high, colourful cliffs and densely vegetated hinterland, craggy headlands and sheltered inlets create a varied landscape which is like no other. For this reason commercial tourism has already established operations in the region in spite of (or perhaps because of) its remoteness.

Almost all the rugged hinterland is reserved, for either Aboriginal or conservation and public recreation purposes. There is pastoral land in the vicinity of King Sound and between Cambridge Gulf and the Northern Territory border. Mining leases (for bauxite) are held over land at Mitchell Plateau.

In 1980 the Western Australian Environmental Protection Authority published a report on conservation reserves in the Kimberley (System 7) based on an earlier, comprehensive report by the Conservation Through Reserves Committee. Although the emphasis of these reports was on the terrestrial environment, both contained recommendations for 'aquatic reserves'. The Department of Conservation and Land Management published an update of that report in 1991 (Burbidge *et al.*), including additional proposals for marine reserves on the Kimberley coast. Those recommendations are incorporated into this account.

The Working Group acknowledges that Aboriginal people have traditional interests in this area and that any proposal for reservation of coastal waters will need to be discussed with them. Administrative arrangements for the establishment and management of marine reserves in the Kimberley will necessarily involve Aborigines. These matters will be addressed during the implementation phases of the marine reserves program.

An extensive bibliography on the geomorphology and biology of the Kimberley region was compiled but not published by Goudie & Sands in 1986 at the Kew Botanic Garden in connection with the *Kimberley, Australia, 2000* expedition.

1.1. Coastal geomorphology

An important factor in coastal ecology of the Kimberley, both marine and terrestrial, is the pattern of rainfall. The North Kimberley coast between Cape Londonderry and Walcott Inlet is an area of high rainfall, with an annual average in excess of 1 000 mm. East of Cape Londonderry and south of Walcott Inlet the rainfall decreases.

Four major distinctive coastal types may be recognised in the Kimberley.

1.1.1. Cambridge Gulf

In the east, Cambridge Gulf is a broadly open seasonal estuary located at the head of the wide Joseph Bonaparte Gulf. Its shores are muddy and there is extensive development of mangals and supra-tidal mud flats. The geomorphology of the Gulf has been described by Wright *et al.* (1972), Wright *et al.* (1973) and Thom *et al.* (1975).

1.1.2. King Sound

In the west, King Sound is also a wide, open gulf with a shore of relatively low relief and some features of a seasonal estuary (Semeniuk, 1985). It too has extensive mangal and supra-tidal mud flat habitats. The stratigraphy, sedimentology and Holocene history of tidal flats in King Sound have been described by Semeniuk (1980, 1981a, 1981b, 1982).

1.1.3. North Kimberley

Between Cambridge Gulf and King Sound the north Kimberley coast is of the heavily dissected, ria type with relatively high relief. The resulting coastal valleys have been inundated by the sea forming a complex shore with many islands, landlocked gulfs, inlets and headlands. Tidal range is up to 11 m and in some areas vast areas of mud flats are exposed at low tide.

The ria nature of the North Kimberley coast provides a very wide range of local micro-habitats determined, in part, by the degree of protection from wind and wave action. The landlocked gulfs and inlets of the region contrast as habitats with the seaward, exposed shores of the headlands and islands. The whole of the mainland Kimberley coast is characterised by muddy shores due to the high seasonal rainfall and strong tidal currents. Terrigenous mud substrates also dominate across the inner part of the continental shelf. These are the conditions which produce mangal and tidal mud flat habitats rather than sandy beaches and coral reefs.

1.1.4. Oceanic islands

The continental shelf is rather wide off the Kimberley coast. The shelf edge is depressed, presumably by subsidence, and the continental slope begins at a depth of about 600 m. The deep Timor Trench separates the Australian shelf from the island chain of eastern Indonesia. Browse and Adele Islands are two mid-shelf islands built on platform coral reefs. There is also a series of mid-shelf reefs and banks, including Holothuria Bank. Near the shelf edge there is a series of reefs and banks, namely Sahul, Fantome, Ashmore and Cartier, the two last-named with medium sized islands. Further south are two large shelf-edge atolls, Seringapatam Reef and Scott Reef. Although the inner shelf waters are muddy, conditions become increasingly oceanic towards the shelf edge. Fringing reefs of high species richness grow on rocky substrates along the mainland shores. The mid-shelf and outer shelf banks and the shelf-edge atolls are true coral reefs. Accounts of the coral reefs and islands of the Sahul Shelf have been given by Teichert & Fairbridge (1948), Fairbridge (1950), Veevers (1973), Powell (1976), Hinz, *et al.*. (1978), Wilson (1985), Berry & Marsh (1986) and Berry (1993).

1.2. Marine flora and fauna

Biological exploration of the Kimberley coast and coastal waters has not been extensive and information about the marine flora and fauna there is sparse.

The earliest collections of marine fauna were taken during Phillip Parker King's hydrographic surveys of the region in 1819-21 aboard the vessel HMS "Mermaid". Molluscs from those collections were described by Gray (1827). Some collections were made during hydrographic surveys by the "Penguin" in 1890-91. A brief note on the corals of Holothuria Bank collected during that voyage was published by Bassett-Smith (1899). In recent years studies of a mangal fauna in Admiralty Gulf have been published (Wells, F.E., 1981; Wells & Slack-Smith, 1981). In 1991 the Western Australian Museum surveyed marine fauna along the North Kimberley coast and produced a summary report (Morgan (ed.), 1992). There have been descriptions of the coral reef faunas at Seringapatam Reef (Wilson, 1985), Seringapatam and Scott Reef (various authors in Berry (ed.), 1986) and Ashmore and Cartier Reefs (various authors in Berry (ed.), 1993).

Although knowledge of the Kimberley marine fauna remains far from comprehensive, some general features are evident. The nearshore fauna is only moderately diverse, probably mainly due to the prevalence of muddy and macrotidal conditions. Many species endemic to northern Western Australia are present in the nearshore habitats. In contrast, the offshore islands and reefs have a more typical Indo-West Pacific fauna and a very high diversity (Wilson, 1985; Wells, 1986b). A suite of coral species known only from turbid lagoons and inshore waters is well represented on the inner shelf Kimberley reefs (Marsh, 1992). This pattern appears to be true of all the major taxonomic groups.

The mangals of the Kimberley have been moderately well studied (Thom *et al.*, 1975; Semeniuk *et al.*, 1978; Semeniuk, 1980, 1983, 1985; Wells, A.G., 1981; Johnstone, 1990). The greatest species diversity and structural complexity occurs in the high rainfall zone between Cape Londonderry and Walcott Inlet. Large and structurally complex mangals provide habitat for a suite of mangrove birds (Johnstone, 1990) and bats (McKenzie & Rolfe, 1986; McKenzie & Start, 1989).

Saltwater crocodiles (*Crocodilus porosus*) are natural inhabitants of the coastal waters and estuaries of the Kimberley. Although their numbers became depleted as a result of hunting for their skins in post-war years, they have partially recovered since hunting was prohibited. These animals breed on sandy banks behind the mangals in some of the estuaries.

Many of the nearshore islands and some mainland beaches are nesting sites for turtles.

1.3. Tourist potential

Because the Kimberley coast is largely uninhabited and there is so little access, its tourist potential is limited. Boats from Derby also sometimes venture beyond King Sound. Similarly, small boats from Wyndham sometimes venture as far as the False Mouths of the Ord for fishing expeditions. Tourists with four-wheel-drive vehicles occasionally visit Port Warrender in Admiralty Gulf, via Mitchell Plateau. There are small resorts at Cockatoo and Koolan Islands in the Buccaneer Archipelago and at nearby Cape Leveque providing access to the marine environment at the western end of the sector. A remote fishing base-camp was established near the mouth of the Drysdale River, visitors being flown in by float plane and helicopter, but the venture proved to be uneconomical and has been discontinued. A similar proposal for a site at Cape Londonderry has not yet been put into effect.

At present the main tourist operations are tours along the coast by charter vessel. There are several boats which take live-aboard passengers for trips lasting several days. The tours visit a selection of the scenic locations, especially the estuaries of the Prince Regent River and King George River and some of the coastal islands.

The offshore islands are so remote and bleak that they offer little potential for tourist developments.

1.4. Fisheries

In spite of their remoteness, the waters of the Kimberley coast support an increasingly diverse range of commercial and recreational fishing activities.

The coastal waters between Cape Leveque and the Northern Territory border are trawled for prawns. (Collier Bay and Admiralty Gulf are closed to the prawn trawling fishery.) The main species targeted is the banana prawn.

Pearl oysters are cultivated on a large scale at several locations including the mouth of King Sound, Talbot Bay, Doubtful Bay and Kuri Bay. Live silver-lip pearl shell (*Pinctada maxima*) is collected by divers in nearshore waters and taken to the grow-out areas in the oyster leases. The pearl industry is one of the State's most valuable fisheries.

Trochus shell (*Trochus niloticus)* is fished commercially by the Aboriginal community at One Arm Point. The shell is collected on rock platforms around the islands of the Buccaneer Archipelago during periods of low tide. Most of it is exported for button and shell jewellery manufacture.

Demersal finfish are commercially harvested using trap, line and trawling methods. At present the main fishing grounds are north-west of Broome but fishing occurs right around the coast and as far out as Ashmore Reef. Target species include scarlet and saddle-tailed sea perch, snapper, emperors, sweetlips, cod and coral trout. Increasing attention is being focused on the shark fishery resource off the Kimberley coast. This fishery is mostly offshore, beyond the limit of the State territorial waters, and is under Commonwealth control.

A shore-based, limited-entry, gillnet fishery targeting barramundi and threadfin salmon operates in nearshore waters. Trolling for mackerel is also an important fishery in the area.

The charter boat industry operates fishing trips along the Kimberley coast, offering attractive recreational fishing opportunities for a variety of sport and game species.

2. EXISTING MARINE RESERVES

There are no Western Australian marine reserves in the Kimberley region but Ashmore Reef is a marine National Nature Reserve designated under the Commonwealth National Parks and Wildlife Conservation Act. Cartier Reef and Commonwealth waters near Scott Reef are included on an Australian Nature Conservation Agency indicative list of marine areas being considered for proclamation as marine reserves under Commonwealth legislation.

3. RECOMMENDATIONS FOR MARINE PROTECTED AREAS ON THE KIMBERLEY COAST

In the later Parts of this report, for the purposes of selecting a representative reserve system, division of the principal biogeographic sectors is based first on recognition of major distinctive coastal types (see Part 1, Section 1.3). Consideration is then given to each of the most prominent ecosystems which occur within those coastal types. This structured approach is not so readily applied to the Kimberley. While the eastern section (Cambridge Gulf), the western section (King Sound), and the oceanic islands comprise major distinctive coastal types and have different climates, the majority of the Kimberley coast is of a single geomorphological type, though locally very complex and diverse in respect of marine habitats. Within that zone, areas have been selected which provide the greatest range of the habitats.

The Working Group has relied heavily on interpretation of aerial photographs and remote sensing imagery to identify marine habitats, supplemented by limited first hand knowledge of the coast, as a basis for reserve selection. Consequently, recommendations that particular marine areas be considered for reservation are often tentative and further work will be needed in many cases before firm proposals may be put forward.

The outstanding scenic values of some sections of the Kimberley coast, and special nature conservation features such as dugong feeding areas and turtle nesting sites, were also taken into consideration.

3.1. Cambridge Gulf (Map II-1)

The area under consideration includes the East Arm of Cambridge Gulf and the mangal system known as the False Mouths of the Ord.

Tenure

The land on the west side of Cambridge Gulf is Aboriginal Reserve and there is a major Aboriginal community at Oombulgurri. Land to the south and east is nature reserve and pastoral lease.

The land forming the Cape Domett headland at the eastern side of the Gulf's entrance is Vacant Crown Land. So too are Adolphus Island and several smaller islands in the Gulf and the land forming the tongues of the False Mouths of the Ord.

Bordering a portion of the East Arm and the False Mouths of the Ord there is a Class C Nature Reserve (No. 31967).

Geomorphology

Cambridge Gulf marks the boundary between the East Kimberley and North Kimberley biophysical districts described by McKenzie (1981). Rainfall is seasonal (summer) with an annual average of about 800 mm at the mouth of the estuary, decreasing to 680 mm upstream at the port of Wyndham. Tidal range is about 8 m and the waters of the Gulf and the adjacent shallows of Joseph Bonaparte Gulf are turbid.

Cambridge Gulf also marks a point of abrupt change in coastal type. The eastern side of the Gulf is of low relief, dominated by the wide delta of the Ord where an extensive mangal is developed. The western side is relatively high and has narrow fringing mangals in small bays between rocky headlands. From Cape Dussejour, the headland at the western entrance of the Gulf, north-westwards to Cape Londonderry, the coast has high relief with rocky shores exposed to the prevailing easterly winds and there are only a few small mangals in the bays.

The Gulf is the open estuary of the Ord, King, Pentecost, Durack and Forrest Rivers. About 60 km to the east on the other side of the WA/NT border is the similar estuary system of the Fitzmaurice, Victoria and Keep Rivers. At the head of Joseph Bonaparte Gulf, the coast is of low relief, with a mangal fringe backed by very wide, bare, supra-tidal flats. These two estuarine systems, the swampy coast between and the shallow nearshore waters of the Gulf, comprise a major distinctive coastal type

which is peculiar to the "Top End" of Australia. The Western Australian portion of this system contains a section of the mangal fringe/supra-tidal flats habitat east of Cape Domett and the Cambridge Gulf estuary itself.

Perhaps the most striking feature of the estuary is an extensive mangal in the north east corner. It has an area of more than 500 km² and comprises a complex, dendritic system of drainage channels leading to a series of wide tidal rivers known as the False Mouths of the Ord, protected from the open sea by the Cape Domett peninsula.

The headwaters of the estuary are split into two tidal rivers known as the West and East Arms of the Ord. The Ord River itself flows into the East Arm while the King, Pentecost , Forrest and Durack Rivers flow into the West Arm. Both East and West Arms have extensive mangal development along much of their margins and wide supra-tidal flats behind.

Flora and fauna
The estuarine flora and fauna of Cambridge Gulf is virtually unstudied and unknown. Given the geomorphological complexity of the estuary and the structural and floristic diversity of the mangals, the aquatic biota is certain to be species-rich and abundant.

The floristics, community structure and associated vertebrate fauna of the extensive Cambridge Gulf mangals have received some attention (Thom *et al.*, 1975; Semeniuk *et al.*, 1978; McKenzie & Rolfe, 1986; Johnstone, 1990). They consist of closed forest up to 15 m high and contain at least 15 mangrove species, with distinct zonation and high structural complexity. The mangal at the False Mouths of the Ord is one of the largest and biologically richest in the State. It is of the bay type. The mangals of the East Arm are representative of the riverine type with different structure. Johnstone (1990) briefly described the mangal on the eastern side of the East Arm mouth opposite Adolphus Island.

Nature Reserve 31967 bordering the East Arm was created following a study of potential breeding habitat for the saltwater crocodile (*Crocodilus porosus)*. This and other parts of the Cambridge Gulf estuary are considered to be important breeding habitat for this animal.

Both mangals are rich in terrestrial birds which utilise mangal habitat. Johnstone (1990) listed from the Cambridge Gulf mangals 21 of the 22 birds regarded as specialist "mangrove species" which occur in the Kimberley. The closed canopies of the mangals are an ecological equivalent of rainforest and they contain relict populations of several terrestrial bird species. Burbidge *et al.* (1991) reported that the Cambridge Gulf mangals support the only known Western Australian population of the Black Butcherbird and a population of flycatchers that is morphologically intermediate between the Lemon-breasted Flycatcher and the Brown Flycatcher. The rare Mangrove Kingfisher, Chestnut Rail and other mangrove specialists are also present. In addition, the wide mud flats bordering the tidal creeks and rivers provide feeding habitat for a large variety of waders. These mangals and the supra-tidal flats behind them form part of an area listed as a Wetland of International Importance for conservation of waterbirds under the RAMSAR Convention.

As well as terrestrial birds, several arboreal mammals inhabit these mangals. These include the only known East Kimberley population of the Mosaic-tailed Rat (*Melomys burtoni*) and 17 species of bat.

On the north side of Cape Domett, facing the open sea, there is a significant nesting site of the Flatback turtle. Pelican Island offshore near the WA/NT border is an important nesting site for the Australian Pelican.

In summary, the eastern side of Cambridge Gulf, particularly the False Mouths of the Ord and the East Arm provide outstanding examples of mangal habitat of two different types, together with a rich bird and mammal fauna and important habitat for the saltwater crocodile. Together with the similar estuary of the Victoria, Fitzmaurice and Keep Rivers in the Northern Territory, the estuary is certainly responsible for much of the primary production which feeds the ecosystem and maintains the trawl fisheries of Joseph Bonaparte Gulf.

Recreation
Cambridge Gulf is inaccessible except at the port of Wyndham located on the West Arm of the Ord. The muddy waters and extensive mangals do not lend themselves to recreational use although there is some recreational fishing from Wyndham. There is some potential for scenic boat tours around the Gulf.

Previous recommendations
Burbidge *et al.* (1991) recommended that Reserve 31967 be upgraded to Class A and that the area from low water mark to 40 m above high water mark adjacent to the reserve and at the False Mouths of the Ord be added to the reserve. This recommendation has since been implemented.

That report also recommended that the lower reaches of the Ord, the waters adjacent to the existing reserve, and the waters adjacent to the False Mouths be declared a marine nature reserve.

Working Group recommendations
Noting the high biological diversity of the Cambridge Gulf estuary, especially in the eastern mangals and nearby areas, the unique character of the estuary in terms of its geomorphic and biological community structure, and the importance of the system as a contributor to the biological productivity of Bonaparte Gulf, the Working Group believes that there is a good case for reserving this area for nature conservation.

After some consideration the Working Group decided not to recommend extending the reservation to the NT border because, although the fringing mangals and supra-tidal flats of that shore are a significantly different coastal type to those of Cambridge Gulf, they are not likely to support a diverse flora and fauna and not likely to need management for public recreation purposes.

The Working Group recommends that:

> "the eastern side of Cambridge Gulf, east of a line between White Stone Point on Lacrosse Island and Nicholls Point on Adolphus Island, and encompassing the False Mouths of the Ord, together with the waters of the tidal portion of the East Arm of the Ord, be considered for reservation for the conservation of marine flora and fauna and protection of mangal habitat. At the mouth of the Gulf the reserve should extend seaward to the limit of State territorial waters and eastwards from Cape Domett for a distance of approximately 15 km."

3.2. Londonderry (Map II-2)

Cape Londonderry is the most northerly point of the Western Australian mainland. Little is known of the marine environment in the region. The following brief description of the area is based largely on interpretation of aerial photographs and some notes made by the Western Australian Museum Kimberley survey of 1991.

Tenure
The Cape Londonderry Peninsula is Vacant Crown Land. The mainland areas south and east of it are Aboriginal Reserve.

Geomorphology
Cape Londonderry is located at the top of a wide peninsula forming the eastern side of Napier Broome Bay. The northern and eastern shores of the peninsula are rugged with colourful lateritic and sandstone cliffs up to 50 m high and many small, irregular bays with small sandy beaches between rocky headlands.

A major feature evident on the aerial photographs is a wide area of shallows on the northern side of the peninsula between Cape Londonderry and Cape Talbot. These appear to be fringed with reef and to support extensive seagrass beds. There is a similar reef area surrounding Lesueur Island.

There are two major estuaries, one at the mouth of the King George River and the other at the mouth of the Drysdale River. Both have significant development of mangal. The narrow gorge of the

upper King George Estuary is navigable for some distance upstream. At two positions there are waterfalls flowing over the sides of perched valleys into the estuary.

Flora and fauna

The marine environment of the area has been little studied and information about its habitats and flora and fauna is sparse. It is evident from aerial photography that marine and estuarine habitats are very diverse and a rich biota is certain to be present. The Western Australian Museum survey of August 1991 visited the King George Estuary and Lesueur Island and collections of marine animals and plants were made at those locations. Morgan (1992) described the marine habitats surrounding Lesueur Island as a "reef with live coral and limestone; small drop-off to rubble and bommies of live coral". Coral was the dominant biota on the reef.

Recreation

The extent to which this section of the coast is used by Aboriginal people is not known to the Working Group. People from Kalumburu fish and hunt dugong in Napier Broome Bay and it is likely that they sometimes travel as far north as the shallows between Cape Talbot and Cape Londonderry. A remote fishing base-camp was established at the mouth of the Drysdale River, accessed by float plane and helicopter, but the venture no longer operates.

Commercial charter vessels travel along this coast with tourists. The falls in the King George Estuary are a particularly important scenic location.

Previous recommendations

The EPA System 7 report recommended that the Vacant Crown Land of the wide peninsula be declared a Class A Reserve for national park, including the islands of mangroves in the estuary of the Drysdale River, with the boundary extending to the low watermark.

Burbidge *et al.* (1991) endorsed the EPA recommendation and added that the waters contiguous with the national park, including the seagrass banks, be declared a Class A marine national park. [NB. There is no marine national park category in present Western Australian legislation although such was under consideration when that report was being prepared.]

Working Group recommendations

It is acknowledged that the following recommendations are based almost solely on photo-interpretation and accounts of the scenic quality of the coast. Field studies will be needed to confirm the high values of the seagrass, reef and mangal habitats before these recommendations proceed and boundaries are decided.

The Working Group endorses the earlier recommendations, though noting that there is no category for marine national park in the current legislation. Given the high recreational and tourism potential of the area the most appropriate reserve category would be marine park.

The eastern and western extent of the proposed marine reserve is problematical. In the west, because of the configuration of the Drysdale Estuary, it is not possible to limit the marine reserve to the waters contiguous with the proposed national park. It will be necessary to extend the reserve westwards along the southern shores of the estuary which are Aboriginal reserve land. The western boundary of the marine reserve could be located along a line running northward from Red Bluff and through West Governor Island so including the north eastern part of Napier Broome Bay.

Limiting the marine park to the waters contiguous with the national park in the east would exclude Lesueur Island, the estuary of the King George River and the spectacular King George Falls. As the falls are an important feature in potential recreational use of the park and Lesueur Island and its surrounding reefs have high conservation values, the Working Group believes that consideration should be given to including these areas within the marine reserve.

The eastern and western sides of the proposed marine reserve abut Aboriginal Reserve land and it will be necessary for the boundaries to be discussed with the relevant Aboriginal communities.

The Working Group recommends that:

> "Western Australian coastal waters west and north of the Cape Londonderry Peninsula, including the estuaries of the Drysdale and King George Rivers and extending eastwards as far as Cape Rulhieres, should be reserved for the purposes of public recreation and the conservation of flora and fauna."

3.3. Vansittart Bay - Admiralty Gulf (Map II-3)

The stretch of coast between the Sir Graham Moore Islands and Cape Voltaire is extremely complex, with wide bays, narrow inlets and many islands and off-shore banks. Information on marine habitats, flora and fauna is very limited. The Western Australian Museum Kimberley survey of August 1991 collected specimens at several locations within the area. The Working group's attention was drawn to four natural features worthy of consideration for reservation.

Tenure
Most of the coast adjacent to the area under consideration here is Aboriginal Reserve. The area between the Lawley and Mitchell Rivers is leased for mining. The coast is uninhabited except for an Aboriginal community at Kalumburu near the head of Napier Broome Bay, and a mining camp at Mitchell River, inland from Port Warrender at the head of Admiralty Gulf.

Geomorphology
Rainfall in this area is heavy and there are many small patches of rainforest below cliffs along the shore. The landscape is extremely rough. Along the shore rocky headlands alternate with sandy bays, some of which have fringing mangals. There are extensive tidal and subtidal sand and mud banks in the bays, some of which are believed to carry seagrass beds. There are many rocky islands.

The long, finger-like arms of the Bougainville Peninsula, with long, narrow, shallow bays between them, are a special feature of the Kimberley coast. Another significant feature is Long Reef, a very large, offshore, rock platform reef.

Three major rivers enter the sea in this sector, the King Edward, Lawley and Mitchell, each with a small estuary and mangal systems. The Lawley and Mitchell Estuaries are strikingly different. The former is an open estuary with wide, complex mangals at its upper reaches. The Mitchell is a narrow estuary that follows a fault line entering Admiralty Gulf. Deeply dissected sandstones occur along both its banks.

Flora and fauna
In spite of the muddy conditions, corals are common and form small fringing reefs in many localities. Marsh (1992) observed that the highest diversity of corals found on the Kimberley coast by the Western Australian Museum survey was in the Institut Islands. Seventy one species were found in that area. The survey found relatively poor coral growth on Long Reef.

The molluscan fauna associated with mangals at Walsh Point, Port Warrender was described by Wells & Slack-Smith (1981). They found that the community was similar in composition and structure to those in comparable environments in the Central Indo-West Pacific Region. Wells, F.E. (1981) also described the molluscan communities around the rocky islands of Admiralty Gulf.

The floristics and structure of mangals in the Lawley and Mitchell estuaries have been described in detail by Wells, A.G. (1981) and Johnstone (1990).

The mangal of the Lawley Estuary is floristically rich (Johnstone, 1990). The dominant creek vegetation is mixed, low, closed forest (5-10 m) consisting of *Avicennia, Sonneratia, Camptostemon, Xylocarpus, Rhizophora, Bruguiera, Aegiceras* and *Aegialitis*. The landward areas are vegetated with stands of *Ceriops* and *Excoecaria*. Tall, pure stands of *Bruguiera parviflora* occur on the upper reaches of Rail Creek, and whipstick thickets of *Aegiceras* often grow in the seaward zone among the *Rhizophora*. Scattered shrubs of *Osbornia* and *Lumnitzera* occur along the landward edge.

Johnstone (1990) also briefly described the mangal at Point Walsh, just beyond the mouth of the Lawley Estuary. It is less floristically rich than the Lawley mangal and is distinctly zoned with a seaward zone of *Avicennia* and *Sonneratia*, a middle zone of low, closed forest of *Rhizophora* and *Camptostemon*, and a landward zone of *Bruguiera exaristata* , *Ceriops* and *Avicennia*. There is a wide supratidal mudflat behind the mangal.

The Mitchell Estuary has only a scattered, narrow, fringing mangal, except in the smaller tributaries (Wells, 1981). The front mangroves are an association of *Sonneratia alba* and *Avicennia marina*, followed immediately by a low closed forest of *Rhizophora stylosa.* On the landward side the forests include associations of *Camptostemon, Avicennia, Rhizophora* and *Xylocarpus*. The landward extension of the mangal is limited by rocky terrain along the banks.

Thus the three mangals in the Lawley Estuary, Mitchell Estuary and at Walsh Point are quite different in their floristic composition and structure.

Recreation

There is very little access to this region from the land. The only road access is a four-wheel-drive track to Walsh Point in Port Warrender. Commercial charter boat tours along the Kimberley coast call in at many of the bays in the area. The sheltered bays of Vansittart Bay are popular localities in view of their scenic qualities.

Previous recommendations

The EPA System 7 report recommended that land in the Mitchell and Lawley River areas be set aside as Class B National Park. Burbidge *et al.* (1991) recommended that the reserve be Class A and that its boundaries be extended, and also that the waters adjacent to the eastern portion (ie. at the head of Port Warrender) be declared a marine national park.

Burbidge *et al.* (1991) recommended that the Sir Graham Moore Islands, the Osborne Islands and Cassini Island be declared Class A reserves for the conservation of flora and fauna. They also recommended surveys of other islands in Admiralty Gulf to determine their conservation value, and that future management plans for the Cape Bougainville Peninsula consider reservation and management of rainforests.

Working Group Recommendations

Although information on the flora and fauna of this remote part of the Kimberley coast is sparse, the Working Group believes that four marine areas within the area warrant consideration as candidates for reservation and recommends as follows:

"1. Vansittart Bay
Noting the accounts of the high recreational potential, marine habitat variety and abundant marine fauna, that there be a biological survey of waters of Vansittart Bay with a view to selecting an area or areas for reservation for conservation of marine flora and fauna and public recreation. The area surveyed should include the waters south of the Eclipse Islands and Mary Island.

"2. Port Warrender
The Working Group endorses the earlier recommendation of Burbidge et. al. (1991) that a marine reserve be declared in the waters adjoining the proposed national park at the mouth of the Lawley River. However, as there is no category for marine national park, the reserve should be marine park or marine nature reserve. In view of the high nature conservation value of the area and the limited potential for public recreation, the appropriate category would be marine nature reserve.

"The area considered for reservation should be south of a line eastward from Walsh Point upstream in the tidal rivers of the Lawley Estuary as far as the limit of tidal waters, thus including both the Walsh Point and Lawley mangals.

"3. Mitchell River
Consideration should be given to reservation of the Mitchell River Estuary for the purpose of conservation of marine flora and fauna. The area considered should include the waters of Walmesly Bay south of Pickering Point and extend upstream to the limit of tidal waters.

"4. Long Reef
The Working Group recommends that there be geological and biological surveys of Long Reef and that reservation be considered at a later date."

3.4. Prince Frederick Harbour / Saint George Basin (Map II-4)

Like the previous area this section of the coast is uninhabited and with very limited access. There are no roads to the coast except for a four-wheel-drive track to the Prince Regent River from Mount Elizabeth Station.

Tenure
The central part of this coastal area is the Prince Regent River Nature Reserve, a Class A reserve which is designated as a Biosphere Reserve under the UNESCO Man and the Biosphere Program. North and south of the nature reserve the land is Aboriginal Reserve.

Geomorphology
The geology and physical environment of this area have been briefly described by Miles *et al.* (1975) and Burbidge & McKenzie (1978). This is a ria coastline of extreme complexity and with a high, rugged hinterland. There are very many inshore and offshore islands. The shores are mostly rocky but there are sandy beaches in many of the bays and some fringing mangals. Prince Frederick Harbour and Saint George Basin are two very large marine gulfs, the former with a wide mouth and the latter with a narrow entrance. The Hunter and Roe Rivers enter Prince Frederick Harbour and the Prince Regent River enters Saint George Basin. Two very large mangals occur in Saint George Basin.

Flora and fauna
A biological survey in the Prince Regent River Nature Reserve (Miles & Burbidge, 1975) provided rather extensive information on the terrestrial flora and fauna of the reserve but there is little information on the marine fauna of the area. The Western Australian Museum Kimberley survey of August 1991 (Morgan, 1992) made collecting stations at several of the offshore islands within this sector and in the estuary of the Prince Regent River.

Rocky habitats dominate these shores but there are extensive intertidal mud and sand banks, especially in Prince Frederick Harbour and Saint George Basin. Both estuaries contain significant breeding populations of the saltwater crocodile.

There are fringing mangals in many of the bays and two large, complex mangals in Saint George Basin. The floristics and structure of the mangals at the mouths of the Roe, Hunter and Prince Regent Rivers have been described by Wells (1981). The two large mangals on the north and south sides of Saint George Basin were described by Johnstone (1990). The latter are two of the largest blocks of mangal in Australia, each comprising over 70 km^2 of mangrove forest. They include tall stands up to 10 m of pure *Bruguiera parviflora* forest. In some locations the mangals are backed by vine forest.

Recreation
Because of its remoteness and lack of land access, this uninhabited section of the coast is very seldom visited. It also has extremely high scenic values, being surrounded by high rugged country and it is already a major destination for commercial tourist charter boat operations. King Cascade in the Prince Regent Estuary is a popular destination with the tour industry.

Previous recommendations
The EPA System 7 report recommended extensive additions to the terrestrial reserves in this area, including a number of the coastal islands. Burbidge *et al.* (1991) endorsed and extended these recommendations. When all the present Vacant Crown Land is reserved as recommended, the entire coast and all the coastal islands in this sector will be either Aboriginal reserve or conservation reserve.

The EPA System 7 report also recommended:

"8. Aquatic Reserves be declared to include :

(a) Prince Frederick Harbour seaward to Cape Torrens and the unnamed cape south of the Anderdon Islands, and

(b) St George Basin seaward to Uwins Island and Cape Wellington, including Rothsay and Munster Waters;

"9. the aquatic reserves extend from high water mark ;

"10. the aquatic reserves be classified as Class A reserves and vested in the WA Wildlife Authority."

Burbidge et. al. (1991) endorsed the EPA recommendations but said they should be Class A marine national parks.

Working Group recommendations

The Working Group has not considered the marine habitats surrounding the many nearshore and offshore islands of this sector because there is such little information about them. Further study may show that the waters around the outer islands, eg. Montalivet and Maret Islands, may warrant reservation. However, the Working Group believes that there are sufficient grounds for reservation of the two marine gulfs in the sector and recommends as follows:

"The recommendations of the EPA and Burbidge *et al.* (1991) that the waters of Prince Frederick Harbour and Saint George Basin should be reserved should be implemented, except that there is no category of marine national park. The appropriate designation to meet the intent of those recommendations would be marine park.

"The Working Group suggests that the seaward boundaries of the two marine reserves should be varied from those of the earlier recommendations. In the case of Prince Frederick Harbour the boundary should be across York Sound between Cape Torrens and Augereau Island. In the case of Saint George Basin the boundary should be across Brunswick Bay between High Bluff and Cape Wellington, incorporating the waters of Hanover Bay. These boundaries include portions of the more open ocean marine habitats and can be precisely located for management purposes."

3.5. Montgomery Islands (Map II-5)

Tenure

The Montgomery islands and the adjacent High Cliffy Islands are part of Reserve 23079 for the Use and Benefit of Aborigines. It is used by Aborigines primarily as a dugong (*Dugong dugon*) hunting area.

Geomorphology

This low island complex is built upon an extensive intertidal and shallow subtidal rock platform, probably consisting of sandstone. The High Cliffy Islands are constructed of sandstone while the Montgomery Islands comprise Quaternary sediments. There are vast areas of mud and sand bank deposits on the rock platform.

Flora and fauna

Little is known of the flora and invertebrate and fish faunas of the Montgomery reefs. There are some fringing reefs but this is not a coral reef in any sense. From inspection of aerial photographs of the reefs it appears that a wide range of habitats are represented and a diverse fauna and flora is likely. It is known that well developed seagrass beds are present in the subtidal shallows. These provide the food resource of the dugong population.

Recreation

This is a remote area and the shoal waters surrounding the islands and reefs do not encourage boating. Recreational fishing is very limited. Subsistence hunting and fishing by Aboriginal people will continue on a small scale.

Previous recommendations

The EPA made no recommendations in respect of the Montgomery Islands but Burbidge *et al.* (1991) recommended that the waters surrounding the islands be declared a Class A marine park.

Working Group recommendations
With very little information available the Working Group is not in a position to do more than endorse the earlier recommendations of Burbidge *et al.*, primarily on the grounds that a known habitat of the dugong is worthy of protection. However, the extensive intertidal and subtidal rock and sand flats constitute an unusual feature on the Kimberley coast and it is probable that they support a diverse flora and fauna. The hunting of dugong in the area by Aborigines is not necessarily incompatible with marine reserve status, provided that the dugong population is monitored and the numbers of animals taken are at sustainable levels.

Accordingly the Working Group recommends that:

> "The waters surrounding the Montgomery and High Cliffy Islands should be considered for reservation for the conservation of flora and fauna, with provisions made for a sustainable level of dugong hunting by Aborigines.
>
> "The Working Group suggests that the outer boundary of the marine reserve should be located at a suitable bathymetric contour around the banks and reefs."

3.6. Walcott Inlet and Secure Bay (Map II-5)

Walcott Inlet and Secure Bay are two estuarine gulfs of very different character near the southern margin of the Kimberley ria coast.

Tenure
Most of the northern shore and the south western shore of Walcott Inlet are Vacant Crown Land. A portion of the north-eastern shore is Aboriginal Reserve. Much of the southern shore is pastoral lease. The land west and south of Secure Bay is Defence land.

Geomorphology
Walcott Inlet is a broad, shallow, drowned river valley. The Calder, Charnley and Isdell Rivers enter its upstream reaches. Secure Bay is an inundated ria valley. The surrounding land of both inlets is rugged and extremely scenic. Both inlets have a very narrow entrance and a tidal range of up to 11 m so that tidal rips through the entrances are pronounced. The entrance to Secure Bay, known as "The Funnel", has been proposed as a site for a tidal power station.

Walcott has wide mud flats, especially at the eastern end, and some fringing mangals. Secure Inlet has two remarkable, wide, dendritic mangals.

Judging from aerial photographs, there are many similarities between these two inlets and Doubtful Bay and George Water a few kilometres further north.

Flora and fauna
The estuarine flora and fauna of Walcott Inlet and Secure Bay have not been investigated. Given their different physical characters it is probable that the animal and plant communities present also differ. Walcott is a known habitat of the saltwater crocodile. Its wide intertidal flats are feeding areas for large numbers of water birds.

Recreation
Access to both inlets is only by sea and that is difficult because of the strong tidal rips at the entrances. At present there is virtually no recreational use of this area, although the scenic quality is exceptional and, when the Walcott Inlet National Park is established and better access is provided, recreational use will increase.

Previous recommendations
The EPA System 7 report recommended that all Vacant Crown Land surrounding Walcott Inlet be declared National Park. The park would extend to the southern and eastern shores of Doubtful Bay. This recommendation was endorsed by Burbidge *et al.* (1991) who also recommended that the waters of Walcott Inlet be declared Class A marine national park.

Working Group recommendations
The Working Group endorses the recommendation of Burbidge *et al.* (1991) for the reservation of the waters of Walcott Inlet. As there is no category of marine national park the appropriate category of reserve in keeping with the recreational use of the surrounding national park would be marine park.

The Working Group noted the extensive and unusual mangal system and scenic values of Secure Bay and believes that it should be added to the proposed marine park. Marine park status would not necessarily be incompatible with future use of this feature for the generation of tidal power.

The Working Group was also impressed by George Water and Doubtful Bay as likely crocodile and bird habitat and by the extensive mangal there, although there is little information about those areas. Further studies should be undertaken to identify the most important areas of these inlets for nature conservation purposes and reservation of them should be considered at a later date. Preference given here to Walcott Inlet and Secure Bay as a marine park representing the enclosed inlet environment of this section of the coast is based on the fact that Walcott is surrounded by proposed national park.

Accordingly the Working Group recommends that:

> "1. The tidal parts of Walcott Inlet and Secure Bay should be considered for reservation for the purposes of public recreation and the conservation of flora and fauna, with the seaward boundaries being across the entrances at Yule Entrance and The Funnel respectively.
>
> "2. There be a survey of the habitats, flora and fauna of George Water and Doubtful Bay and assessment made of the natural values of these areas and consideration given to reservation of them or parts of them, for the conservation of flora and fauna."

3.7. Buccaneer Archipelago (Map II-6)

The Buccaneer Archipelago is a scatter of small to medium sized islands and banks at the mouth of King Sound.

Tenure
Several of the islands in the Archipelago are nature reserves. The others are Vacant Crown Land.

Geomorphology
The area is extremely diverse with rocky islands, coral reefs, algal reef flats and shallow sandy banks with extensive seagrass beds. Tidal range is in the order of 11 m and tidal rips and currents are strong. Cygnet Bay is a broad, sheltered bay. The eastern shore is extremely complex with narrow peninsulas, almost land-locked bays and numerous islands. Consequently marine habitats are very diverse. The waters at the mouth of King Sound are turbid but among the outer islands the water is semi-oceanic and relatively clear.

Flora and fauna
There are no detailed published accounts of the marine flora and fauna of the Buccaneer Archipelago but the notes of the Western Australian Museum Kimberley survey (Morgan, 1992) and verbal accounts from marine scientists who have visited there indicate that the biota is both abundant and diverse.

The area is extensively used by turtles and dugong.

Recreation
The Archipelago has tourist development potential. The One Arm Point Aboriginal community has cultural interests there.

Fisheries
The One Arm Point Aboriginal community maintains a commercial trochus shell fishery on the reefs and banks among the Archipelago. In the sheltered bays on the western and eastern sides of King Sound, within the area under consideration here, there are several pearl oyster leases.

Previous recommendations
The EPA System 7 report recommended that biological surveys of the islands of this Archipelago be undertaken with a view to recommending the creation of specific reserves. The surveys were subsequently completed. On that basis the then Department of Fisheries and Wildlife proposed that a number of the islands be declared reserves for conservation of flora and fauna. Since then negotiations with the relevant Aboriginal communities have produced a proposal for joint management of the islands for Aboriginal and conservation purposes. This included reservation of the waters of the Archipelago as marine park. Burbidge et. al. (1991) endorsed these proposals.

Working Group recommendations
The Working Group endorses the proposals that the waters of the Buccaneer Archipelago be declared marine park and zoned for multiple use according to a management plan developed in collaboration with the Aboriginal community.

After considering the proposed boundaries, the Working Group believes that the values of the marine park would be greatly enhanced by extending the boundaries to include Cygnet Bay in the west and Talbot Bay in the east. The Working Group's preferred boundaries are indicated in Map II-6.

The presence of pearl culture leases and operations within the area of the proposed marine park is noted. Providing that this industry is managed with due care for the many sensitive natural values of the marine environment, the Working Group considers that this activity would be compatible with multiple-use marine park status.

The Working Group recommends that:

> "The waters of the Buccaneer Archipelago, including Cygnet Bay in the South West and Talbot Bay in the east, should be considered for reservation as a multiple-use marine park."

3.8. Oceanic Coral Banks and Islands (Map II-7)

On the mid and outer portions of the Sahul Shelf there are several islands and banks of great scientific interest and conservation importance. These include the shelf-edge atolls known as Seringapatam and Scott Reef, the shelf-edge islands and platform reefs of the Ashmore-Cartier complex, and the mid-shelf islands and platform reefs known as Browse and Adele.

[Note: the Rowley Shoals are shelf-edge atolls further south and are dealt with in Part III.]

Browse Island is Western Australian State territory, together with the waters surrounding it for a distance of 3 nautical miles. The waters within 3 nautical miles of the emergent sand cay at Scott Reef are State territory. Adele Island is freehold land owned by the Commonwealth but the waters around it belong to the State (see also Map II- 6).

Ashmore, Cartier, Seringapatam and a portion of Scott Reef are Commonwealth territory and although they are significant elements in the shelf marine environment they are not within State jurisdiction. However, it should be noted that the Commonwealth has already declared a marine nature reserve around Ashmore and has reservation of the other areas under consideration. From the point of view of reserve system design the Commonwealth and State marine reserves of the oceanic region need to be considered together. The Working Group has taken this into account although it has no brief for recommending Commonwealth reserves.

Adele Island is built on a coralline platform reef held freehold by the Commonwealth Government. The EPA System 7 report recommended that negotiations be undertaken for return of it to the State and its subsequent declaration as a Nature Reserve. Extensive coral reefs surround the Island. The structure is an unusual near-shore platform reef of great scientific interest. It is considered to be rich in species and of exceptional conservation value.

Browse Island is presently unvested but was recommended for declaration as Nature Reserve by the EPA System 7 report. It is believed to be an important turtle and bird nesting site and is surrounded by extensive coral reefs. It is an off-shore platform reef of immense scientific interest.

Geomorphology
Descriptions of the geomorphology and geology of the oceanic reefs and atolls, and additional references, may be found in Teichert & Fairbridge (1948), Fairbridge (1950), Powell (1976), Hinz, *et al.* (1978), Wilson (1985), Berry & Marsh (1986) and Berry (1993).

Marine flora and fauna
Descriptions of the marine invertebrates and fishes of Scott Reef, Seringapatam Reef and Ashmore and Cartier Islands may be found, with additional references, in Wilson (1985), Berry & Marsh (1986) and Berry (1993).

Previous recommendations
The EPA System 7 report recommended that Adele Island be returned to the State by the Commonwealth and declared a Class B reserve for the conservation of flora and fauna. Burbidge *et al.* (1991) endorsed that proposal, though recommending Class A status, and proposed that the waters surrounding the island should be declared Class A marine nature reserve.

The EPA System 7 report recommended that Browse Island be declared a Class B reserve for the conservation of flora and fauna. Burbidge *et al.* (1991) endorsed that proposal but suggested Class A status and proposed that the waters around the island be declared a Class A marine nature reserve.

Working Group recommendations
The Working Group endorses the earlier recommendations for declaration of marine reserves around both Adele and Browse Islands. It is noted that, in the case of Adele, the surrounding reef extends beyond the limit of State jurisdiction. As it is an integral part of the coral platform reef and ecosystem it is important that the whole reef be reserved. The Working Group suggests that the State authorities liaise with the Commonwealth with a view to securing reservation under Commonwealth legislation of those parts of the reef under Commonwealth jurisdiction and subsequent joint management of the whole marine reserve.

The Working Group also believes that consideration should be given to the reservation of Scott Reef. Although part of the reef is under State jurisdiction and part under Commonwealth jurisdiction, the Working Group believes that the reef complex should be managed as one unit, with appropriate collaboration between the State and Commonwealth management agencies.

The Working Group recommends that:

> "1. Consideration should be given to reservation of the State waters surrounding Browse and Adele Islands and Scott Reef.
>
> "2. The relevant Commonwealth authorities should be approached with a suggestion that those areas of Scott Reef and the reef around Adele Island which are under its jurisdiction, should be reserved under Commonwealth legislation so that the State and Commonwealth areas can be managed as ecologically integral units."

A REPRESENTATIVE MARINE RESERVE SYSTEM FOR WESTERN AUSTRALIA

Report of the Marine Parks and Reserves Selection Working Group

PART III

MARINE RESERVES ON THE CANNING AND PILBARA COASTS AND THE ROWLEY SHELF

CONTENTS

PART III: MARINE RESERVES ON THE CANNING AND PILBARA COASTS AND THE ROWLEY SHELF

1. INTRODUCTION

The section of the WA coast considered in Part III includes the Canning coast of the West Kimberley, the Pilbara coast, and the southern part of the North West Shelf Oceanic Province sometimes known as the Rowley Shelf. The northern boundary of this section is at Cape Leveque and the southern boundary at North West Cape. Between these limits the study area extends from the high tide mark of the mainland and coastal islands to the limit of State territorial waters (see Index to Maps III). It includes those sections of the Rowley Shoals which are under State jurisdiction. These boundaries conform with those of the biogeographic zones described in the Council of Nature Conservation Ministers' working paper (CONCOM, 1985).

The amount of information available about the marine habitats, flora and fauna of the Canning and Pilbara coasts varies greatly along this coast. Some areas, such as the Dampier Archipelago, are fairly well studied but other areas have received scant attention. The Working Group has used its collective experience and knowledge of the area to interpret aerial photographs and satellite imagery, and a classification of coastal geomorphology (see Part 1 and Section 1.2 of this Part) to identify major distinctive coastal types. The objective has been to select areas representative of each of these types and the habitats, biotic communities, and recreational resources they contain for consideration for reservation. In addition the Working Group has sought to identify areas of special conservation (eg. turtle and seabird nesting sites) or recreational value for consideration as specific purpose reserves.

The Working Group is aware that petroleum exploration permits and some petroleum production licences apply to much of the coastal and offshore waters of this section of the WA coast, including some of the areas identified here as being worthy of reservation for conservation and recreation purposes. It is also recognised that commercial fishing occurs throughout the area and that, under the powers of the Fisheries Act, certain zones have been declared for particular fishery operations. These existing and potential economic uses have been noted where they were known but they have not influenced the reserve selection process. Legal or management problems likely to result from conflict between the activities of the petroleum or fishing industries and constraints which could be imposed by reserve declaration must be addressed before any reserve proposal is developed further.

Similarly, several Aboriginal communities are established at coastal sites along the Canning-Pilbara coast and Aboriginal people maintain traditional interests in many of the marine areas considered in this report to be worthy of reservation for nature conservation and recreational purposes. It will be necessary to consult the appropriate Aboriginal people prior to the declaration of these reserves and to seek their participation in management.

1.1 Coastal geomorphology

General characteristics of the Canning and Pilbara coasts are described in Section 3.6 of Part 1 of this report. Both are located in arid or semi-arid areas. The former has little or no fluvial run-off while the latter has many rivers and streams which are subject to seasonal flow and flooding. Wave energy is moderate to low and there is a large tidal range.

For the purposes of reserve selection it is convenient to consider first the geomorphology of the coastal environment of the sector. Three primary divisions may be recognised: the continental shelf with its seabed and waters, the mainland coastline, and the coastal islands. These may be further divided into distinctive coastal types. In addition, several major habitat types (eg. coral reefs) occur in the region. The detailed community structure and species composition of habitats are greatly influenced by the nature of the local geomorphology.

A reserve system including representatives of each of the mainland coastal types, and the nearshore and offshore islands, banks and reefs, would be likely to represent the habitats, communities and species characteristic of the region.

1.1.1 The Rowley Shelf

The North West Shelf extends from the vicinity of Melville I. in the NT to North West Cape. It is sometimes divided into a northern section know as the Sahul Shelf and a southern section known as the Rowley Shelf, with the dividing line being off Cape Leveque. The Sahul Shelf was considered in Part II of this report. This section deals with the southern Rowley Shelf portion.

There are many islands on the Rowley Shelf, particularly in the western sector. These are discussed separately in Section 1.1.3 (including the reefs and cays of the Rowley Shoals).

The Rowley Shelf is the widest section of the WA continental shelf extending to about 354 km off Cape Jaubert (shown on Map III-2). As a result of tectonic subsidence, the outer shelf-edge break is also deeper than usual, being at an average depth of about 560 m. The shelf may be regarded as an extension of the deep sedimentary basins of the north west part of the State. It is the site of extensive oil and gas fields.

The Rowley Shelf, and indeed the whole North West Shelf of which it is a part, is a feature of very long standing in geological terms. As a sedimentary basin it has been receiving marine sediments since the early Palaeozoic.

The inner waters of the Rowley Shelf, subject to run-off from the adjacent rivers and to disturbance by the strong tidal flow, are relatively turbid. The outer waters are generally clear. Thus, the marine environments of the shelf are broadly divisible into nearshore and offshore components. The outer zone has been termed the North West Shelf Oceanic Province.

The nearshore zone is characterised by muddy substrates and the intertidal zone is dominated by mud and sand flats or muddy rocky shores. The sediments are mostly of terrigenous origin. In the offshore zone the substrates of the shallows are more often sandy. The bottom sediments of the deeper parts of the outer Rowley Shelf are fine sands, muds and oozes, mostly of biogenic origin.

There can be no definite boundary between the nearshore and offshore environmental types although it approximates to the 10 m bathymetric contour. Because this contour has particular environmental relevance in the island-rich West Pilbara, it is shown as defining the boundary between offshore and nearshore distinctive coastal types on Maps III- 7, 8 & 9.

1.1.2 Mainland coastal types

For the most part the mainland coast has low relief and consists of long sandy beaches or mangals backed by sand dunes, but there are many lagoons, bays and inlets and some rocky headlands and low limestone cliffs. The relatively high relief and rocky shores of the inundated Dampier Archipelago are an exception within the region.

The western part of the mainland Pilbara coast is characterised by deltas, barrier islands and associated lagoons with extensive development of mangals, backed by wide supra-tidal flats. The deltas may be active or inactive. The barrier islands are remnants of eroded shorelines. Thus, this sector of the coast is undergoing considerable change, with both depositional and erosional processes presently operating. The resulting geomorphological variability creates a variety of coastal habitat types, each characterised by distinctive community structure and species composition.

The Canning coast and the eastern part of the Pilbara coast are characterised by long stretches of sandy beach alternating with large, deeply indented bays. The bays form complex geomorphological and ecological units in their own right, usually with barrier islands at their entrances, lagoons with mangals backed by inundated flats around their shores, and extensive development of tidal sand and mud flats.

For the purposes of selecting areas of the coast containing representative habitats, using geomorphological criteria, it is possible to recognise 11 distinctive coastal types along the mainland coast of the Canning-Pilbara Region:

1. bay;
2. dune/ridge barred bay;

3. active delta;
4. inactive delta;
5. inactive delta with barrier;
6. barrier limestone coast;
7. eroded barrier with bays;
8. beach/dune coast;
9. ria/archipelago coast;
10. chenier coast;
11. sand dune hinterland coast.

Within each of these broad-scale coastal types there is a recurring set of medium to small-scale marine habitats that support diverse mangrove formations and intertidal flat, beach and rocky shore communities.

The bays of the Canning and eastern Pilbara coasts are worthy of special consideration. The coast between Cape Leveque and Cape Bossut exhibits a recurring geomorphic pattern of bays and dune/ridge barred bays. The primary features are:

- large-scale V-shaped bays, with smaller V-shaped headwaters; carbonate mud systems characterising the upper tidal parts and sandy substrates characterising the lower tidal parts;
- a system or series of Quaternary barriers and spits, usually along the southern or south-western portion of the bays, resulting in the formation of a southern shore complex consisting of a series of smaller barred embayments;
- scalloped V-shaped interfaces between the high tidal zone and the hinterland.

Bays and barred bays that show these geomorphological features are Pender Bay, Beagle Bay, Carnot Bay, Cape Boileau, Willie Creek, Crab Creek, and the Lagrange complex.

Within and associated with these bays there are two types of tidal flats - sand dominated flats that occur on the open shores, and mud dominated flats that occur typically in the more sheltered areas within the bays. Rocky shore habitats may occur along the barrier headlands. A variety of mangal types are developed in the embayment settings within the larger V-shaped bays, according to the local habitat conditions.

From the point of view of nature conservation and ecosystem management, it would be desirable to reserve one (or more) of these V-shaped bays in its entirety, containing a typical suite of habitat types, as a self-contained ecological unit.

Four distinctive habitats which are characteristic of the Canning-Pilbara coast are of particular interest.

(i) *Mangals*

For the purposes of this report a classification of mangal habitats is given in Section 3.7.7 of Part I. Mangroves and mangal habitats are extensive in the Canning-Pilbara sector, especially in the bays of the Dampier Peninsula and in the west Pilbara. There are few places in the world where mangals occur in arid conditions. In this respect the Pilbara mangals, though not rich in species, are of great scientific importance (Semeniuk, 1993b).

The floristics and community structure of mangals in the region have been studied by Semeniuk *et al.* (1978), Semeniuk & Wurm (1987) and Semeniuk (1993a, 1993b). Johnstone (1990) has also described a series of mangals along the coast and the birds which inhabit them.

Ten types of mangal assemblage are recognised. They form wide forests in some parts of the mainland shore, although species diversity is less than that found in the mangals of the North Kimberley due, in part, to the arid and semi-arid climate. Small but complex mangals are a feature of the bays which characterise the Canning and eastern Pilbara coast. Minor mangals are also found on sheltered shores of many of the coastal islands. As previously stated, within each of the 11 distinctive coastal types of the Canning and Pilbara coasts there is a recurring set of medium to small scale habitat types that support different mangal assemblages. Preservation of samples of each of the broad

scale coastal types within a reserve system would maximise the probability that the range of mangrove species and mangal types, associated physio-chemical processes, and associated flora and fauna, are represented. There is no doubt that these mangal systems contribute very significantly to the nutrient resources of the Pilbara coastal waters. It is very important that they be carefully managed and protected.

The Working Group noted that in order to maintain the nutrient cycles and productivity of the coastal zone and preserve the nursery areas of many coastal species including scale fish and crustaceans which are the target of both commercial and recreational fisheries, it is necessary to properly manage and protect the whole mangrove system of the region.

(ii) *Intertidal flats*

Intertidal mudflats are a feature of the mainland shores of this sector, usually associated with fringing mangals in bays and lagoons. Intertidal sandflats are also a significant feature of this coast. With such a large tidal range, especially on the Canning coast, the mudflats and sandflats of mainland shores are often very wide (sometimes a kilometre or more) crossed by deep drainage channels. They support rich and diverse faunas of burrowing invertebrates. Some of them are extremely important feeding areas for migratory birds.

There are extensive intertidal sand flats also around some of the nearshore and offshore islands. These habitats and their infaunal communities are somewhat different to the coastal flats but they too support a high diversity of invertebrates.

Many of the regionally endemic species occur in these habitats. Mudflat and sandflat communities of these types are found no further south than Exmouth Gulf but they extend across northern Australia into the Gulf of Carpentaria. Comparable habitats on the mainland shores of eastern Queensland (the Solanderian Province) have many species in common but there are also many differences.

(iii) *Rocky shores*

Rocky shores are of two types on the Canning and Pilbara coasts. In the central Pilbara, particularly in the Dampier Archipelago, many shores are dominated by Pre-Cambrian igneous rocks with rock walls or boulder fields sloping into the sea. Elsewhere on the mainland coast and more frequently on the coastal islands, there may be limestone aeolianite, oolitic, or beach-rock shores.

The limestone shores of the region are frequently eroded into horizontal intertidal rock platforms with a double intertidal notch at the inner edge formed by wave action, chemical erosion and the activity of boring and burrowing organisms. The double notch of limestone shores is a particular feature of the outer Pilbara islands. The zone separating the upper and lower notches is dominated by the growth of rock-oysters (*Saccostrea*) and associated fauna. The horizontal platforms form rock pavement habitats, usually covered with algal growth, and support very diverse invertebrate faunas. Typically the algae are heavily grazed by herbivorous fishes at high tide to form a low "algal turf". The front edges of the rock platforms may bear coral growth. In many cases there is extensive coral reef development in the sublittoral zone of the reef front and reef-front slope.

Rock platforms are particularly well developed on the seaward shores of some of the offshore, oceanic islands, most notably Barrow, the Monte Bellos, the Muirons and the outer islands of the Dampier Archipelago. Because of their clear water and moderate wave action, the floral and faunal composition and community structure of rock platforms of these outer islands differ significantly to those of the inner islands and mainland shores.

(iv) *Coral reefs*

Coral reefs are well developed in this sector, as discussed in Section 3.7.5 of Part I. They include the shelf-edge atolls of the Rowley Shoals, offshore coral banks and platform reefs of the West Pilbara, and extensive fringing reefs such as those of the Lacepedes, the Dampier Archipelago, the Monte Bellos, the Muirons and other coastal islands. In most cases the coral reefs are developed as a thin veneer on non-coralline limestones around the reef fronts and slopes. The long-standing coral reefs of the Rowley Shoals are an exception to this generality. Species diversity of these coral reef systems is quite high (Veron & Marsh, 1988) although there is little species endemicity.

1.1.3 Islands

The islands of the Rowley Shelf are of several types:

1. Metasedimentary and igneous islands of the Dampier Archipelago (Semeniuk *et al.*, 1982; Trendall, 1990). The core of most of these islands consists of Archaean metasedimentary and igneous rocks of the Fortescue Group. They are relics of the higher parts of the mainland flooded by the last Pleistocene transgression. For the most part they lie within the nearshore zone.

   (Some outer islands of the Archipelago are of different origin and composition, representing relics of the Pleistocene shelly, ooid and aeolianite limestone shores. The shore habitats they provide are more akin to the limestone islands of other areas - see 3.)

2. Offshore islands of the Barrow complex comprise Tertiary limestones, which are relics of the structural trend from the Cape Range anticline. They include Barrow Island itself and North and South Muiron Islands.

3. Offshore and nearshore islands composed of shelly or ooid Pleistocene limestones. Many of these are formed along Pleistocene shore-lines since transgressed by higher sea-levels. The outer islands of the Dampier Archipelago, eg. Delambre, Legendre and Kendrew, are included in this category (Semeniuk *et al.*, 1982).

4. Holocene sand islands formed on shallow banks.

5. Shelf-edge atolls of the Rowley Shoals. These are built of coralline limestone upon fault blocks of Tertiary and Mesozoic limestones and emerge from great depths at the shelf break (see Berry & Marsh (1986) for description and references). They are actively growing coral reef systems. Of the three atolls in the group two, Clarke and Imperieuse Reefs, have emergent sand cays and are therefore under WA State jurisdiction. They are very like Scott Reef and Seringapatam Reef on the shelf break of the Sahul Shelf further north.

Each of these island types has its characteristic types of shore habitats, determined, in part, by substrate and degree of exposure to wave action. For example the igneous rocky shore habitats of the Dampier Archipelago islands are very different to the limestone shores of Barrow Island, the sand cays of the Serrurier Island complex, and the coral reefs of the Rowley Shoal atolls.

Also, the marine habitats surrounding the nearshore and offshore islands naturally exhibit the conditions of the turbid nearshore and clearer water offshore zones of the Rowley Shelf (see Section 1.1.1). The habitats surrounding the offshore islands tend to approximate oceanic conditions.

1.2 Marine flora and fauna

Scientific study of the marine flora and fauna of the Canning-Pilbara coast did not begin in earnest until quite recently. None of the scientific expeditions of the last century made any collections of marine specimens on this coast although some specimens collected by the pearl fishing industry during the latter half of that period, especially from the vicinity of the pearling ports of Broome and Cossack, found their way into the hands of European scientists. British marine naturalist W. Saville Kent collected a few corals from the Lacepede Islands and the in vicinity of Broome which were referred to in monographs published by Brook (1893), Bernard (1896, 1897, 1903, 1905, 1906) and Matthai (1928). The first major sampling of the marine fauna was by the Mjoberg Expedition of 1910-13, which also operated mainly in the vicinity of Broome. The results of this productive expedition were published by a series of authors over a period of years under the title Results of Dr E. Mjoberg's Swedish Scientific Expeditions to Australia 1901-13 (*K. Svenska Vetenskapsakademiens Handl.)*. Montague made a small collection of marine fauna at the Monte Bello Islands in 1912 (Montague 1914). H.L.Clark collected echinoderms along the Canning coast as far south as Wallal in 1929, and again in 1932 when he also did some dredging offshore. This material was included in his monographs on the echinoderm fauna of Australia (Clark 1938, 1946).

Since 1960, staff of the Western Australian Museum have made extensive collections of marine fishes and invertebrates at a number of Pilbara localities including Barrow Island, Muiron Islands, Exmouth Gulf, the Dampier Archipelago and the Monte Bello Islands. A joint expedition of the Western Australian Museum and the Bernice P. Bishop Museum of Honolulu, sponsored by Mrs Mariel King, carried out a three-month dredging and diving survey along the western Pilbara coast in 1960, resulting in large collections of marine invertebrates, especially molluscs. Detailed surveys of the marine fauna have been carried out by the Western Australian Museum and the Department of Conservation and Environment in the Dampier Archipelago, Rowley Shoals and the Monte Bello Islands (references given in the appropriate Sections). An illustrated guide to the fishes of North-Western Australia was one outcome of those surveys (Allen & Swainston 1988). Another illustrated monograph of the fishes of the region (Sainsbury *et al.*, 1985) resulted from a survey of the deep trawling grounds on the outer part of the North West Shelf conducted by CSIRO Division of Fisheries Research.

Although, as noted in Part I Section 3.2, the marine flora and fauna of the North West Shelf has predominantly Indo-West Pacific affinities and the majority of species are widespread in that vast biogeographic region, there is a significant degree of local endemicity. Most of the endemic species are common to the northern Australian coast between North West Cape and the Torres Strait, leading marine biogeographers to designate it as a biogeographical province named the Damperian Province. The Canning-Pilbara sector under discussion here represents the western portion of that province. The endemicity is most marked in the nearshore zone.

The fish, invertebrate and marine plant communities of the nearshore reefs, banks and tidal flats have a rather different composition from those of the shelf-edge atolls and offshore islands (Wilson, 1985; Wells 1986b). These differences between the inner and outer shelf biota are largely due to the very different habitats provided by the turbid and more highly nutrified waters of the former and the clear oceanic conditions in the latter. The outer part of the shelf is apparently much influenced by the southerly flowing currents originating with the Timor Current which draws Pacific water through the Timor and Java Seas (Wyrtki 1957, 1973). The coral reefs around the islands and atolls of the North West Shelf edge contain many widespread tropical species with Indonesian and Pacific affinities that are not represented in the nearshore communities (Wilson, 1985; authors in Berry, 1986). Many of those species spill around North West Cape and populate the clear-water reefs of the Ningaloo Marine Park and areas further south by means of the Leeuwin Current which originates on the North West Shelf.

For these ecological and physical reasons, North West Cape is a point of major biogeographic change on the WA coast, separating the marine flora and fauna of the North West Shelf from those of the Dirk Hartog and Rottnest Shelves to the south. It is therefore an appropriate biogeographical boundary and useful in classification of the coast for marine reserve selection purposes.

Relatively little is known of the marine flora of the Pilbara and Canning coasts or the islands of the North West Shelf. There has been no systematic study of either the algal or seagrass communities in the region.

Seagrass meadows occur in the shallows in many parts of the Pilbara-Canning coast but they do not appear to be as extensive as those on the west and south coasts of the State. Intertidal rock flats carry a fair growth of algae and some of the shallow offshore banks seem to be algal-dominated rather than coral-dominated, but there are no dense seaweed-kelp beds like those of the southern temperate coast. Nevertheless, seagrass and algal beds are obviously an important element of the region's ecosystems and they support a diverse fauna of herbivorous fishes, turtles and dugong.

The Lacepedes and many of the Pilbara islands are important nesting sites for turtles and seabirds. These have been identified and assessed in an unpublished report by officers of the Department of Conservation and Land Management (pers. comm., Dr Keith Morris, 1988).

1.3 Tourist potential

The coast and islands of the Pilbara and Canning sectors presently have moderate use by local people seeking aquatic recreation, ie. boating, fishing and diving. Naturally these activities are concentrated in the vicinity of population centres, notably Broome, Port Hedland, Karratha-Wickham-Dampier, Onslow and Exmouth. Local recreational use of these coastal resources is an important aspect of life in the area and undoubtedly it will increase. Heavy fishing pressure is alleged at some localities where recreational fishing is concentrated (see 1.4).

The coast and islands of the sector have only moderate potential for the development of marine-oriented commercial tourism. Most visitors will be interested primarily in the magnificent fishing or fascinating natural history of this remote coast. The beaches of the Canning coast are rightly a big attraction for tourists, mainly based in Broome. There are two island-based fishing camps off Onslow. Charter boats operating from all of the main ports offer fishing and diving trips to the offshore waters and islands.

A recent Tourism Development Plan for the Pilbara Region (Barrington & Partners, 1986) and subsequent Implementation Strategy 1991-95 (Pilbara Regional Development Advisory Committee & WA Tourism Commission) noted the modest potential for day visits to coastal areas and islands, proposed the development of additional boat ramp facilities at several locations, and recommended that a study be undertaken to investigate the possibility of developing additional island holiday accommodation off the Onslow coast.

Scenically the islands of the Dampier Archipelago have many attractions and there is some potential there for developing additional accommodation in the proposed national park. The colourful rock piles sloping into the sea, fringed by mangroves or sandy beaches, are scenically unique. However, other islands in the region are generally low in profile, sparsely vegetated, and rather bleak in prospect. The severe, arid to semi-arid climate of the region, and the lack of potable water makes these islands attractive only to those willing to cope with hard environmental conditions. There seems to be little scope for resort development.

Nevertheless, there is potential for development of the charter boat industry, especially for fishing and dive tours to the outer islands (see Section 1.4). Perhaps there is also potential for development of natural history tours to the islands to observe such features as the turtle nesting and seabird rookeries which, in season, provide such an impressive spectacle.

1.4 Fisheries

Presently there is an economically important and diverse range of both commercial (including aquaculture) and recreational fishing practised in waters off the Pilbara coast. These fishing operations are centred at the ports of Broome, Port Hedland, Port Samson, Onslow, Dampier and Exmouth.

Commercial fishing operations comprise seven established fisheries and a number of developing fisheries. Pearling is the key industry of the region. Live pearl shell for subsequent use in the pearl culture phase is harvested by divers from several areas off the Pilbara coast between Exmouth Gulf and King Sound. The principal harvest area is off Eighty Mile Beach. Pearl culture leases where "seeded" pearl oysters are held at low density on long lines or in baskets are located at the Monte Bello Islands, Dampier Archipelago, off Eighty Mile Beach, and in the Buccaneer Archipelago.

Prawn trawling activities are managed by three separate limited-entry fisheries, the Exmouth Gulf, Onslow and Nickol Bay fisheries, which are located between Exmouth Gulf and 120°E longitude. The major target species are the tiger, western king, and banana prawns, with substantial catches of endeavour prawns also taken.

The majority of the finfish catch is taken by two separate limited entry fisheries, the Pilbara trap (and line) fishery, and the Pilbara Fish Trawl industry. Both these fisheries extend from North West Cape

to 120°E longitude. There is a shore-line closure to the 30 m isobath for the trap fishery. The prime target species are the nor-west snappers, emperors and cods.

Access to shore-line beach netting for fin-fish in Exmouth Gulf is restricted under the management arrangements for the Exmouth Gulf Beach Seine Fishery. The main target species include several species of mullet, whiting, bream and garfish. Bony (or Perth) herring are also sought seasonally for the bait market. Netting activities between the northern boundary of this fishery and 19°S latitude, targeted mainly at threadfin salmon and barramundi, are presently operated by licensed Western Australian "wet" fishermen.

Specific management programs are presently being developed for the tropical rock lobster and mud crab fisheries. The lobster fishery is centred primarily in the Dampier Archipelago where the animals are taken by diving. A small local-market fishery for mud crabs operates in tidal creeks and mangrove areas along much of the Pilbara coastline. Some licensed commercial aquarium fish and specimen shell collectors also operate throughout the region.

There has been a recent escalation of the level of effort expended on the capture of a range of shark species in the region. At present shark fishing activities between North West Cape and 120°E longitude are managed by the State, whilst those to the east of this are mostly managed by the Commonwealth. Longlining activities target mostly large sharks for the international fin markets. Gill netters generally seek smaller animals to supply both local and international markets with shark meat.

The Commonwealth-managed North West Deepwater Trawl Fishery, which primarily takes deepwater crustaceans, operates on the continental slope between 114 and 125°E longitude. The Rowley Shoals lie just inside the eastern boundary of this fishery. The Commonwealth also manages a small designated trawl area for western king prawns immediately west of 122°E longitude (north west of Broome).

For some years the inshore waters adjacent to the Pilbara's developing population centres have experienced substantial and increasing levels of recreational fishing pressure. Although boat anglers targeting a range of tropical food and game fish have exerted most of this pressure, shore-based angling, netting in tidal creeks and estuaries, and diving primarily for rock lobster have all contributed.

The charter industry, operating from the major ports of the Pilbara, caters for an increasing number of recreational line fishermen. Management arrangements for this developing industry are presently being finalised.

Management plans for all the commercial fisheries, together with recent development of a long-term strategy for recreational fishing throughout the State, are aimed at providing the basis for sustainable management of the fish and crustacean resources of the Pilbara coast.

1.5 The hydrocarbon industry

The North West Shelf is a productive area for hydrocarbons, both petroleum and gas. The Barrow Island field has been producing since 1966. In the 1980s production began from several other fields off the Pilbara coast, most using islands as a base for offshore production facilities. Exploration is continuing in an area from North West Cape to north of Karratha with the expectation of further discoveries.

2 EXISTING MARINE RESERVES

2.1 Rowley Shoals Marine Park (see Part II, Map II-7)

Clerke and Imperieuse Reefs, the two atolls under State jurisdiction in the Rowley Shoals, have been declared Class A marine park under the Conservation and Land Management Act. The park was gazetted on 25 April, 1990, the two sections totalling 23 250 ha. in area. The Commonwealth Government has declared the third of the shelf-edge atolls in the group, Mermaid Reef, a marine park under the Commonwealth National Parks and Wildlife Conservation Act.

The geomorphology and marine fauna of the Rowley Shoals have been described by Fairbridge (1950), authors in Berry (1986) and Veron & Marsh (1988). Fairbridge considered them to be geomorphologically the most perfect examples of shelf atolls in Australian waters. Recent biological studies have shown that the marine fauna of these reefs is exceptionally rich and diverse, representing the oceanic coral reef community types characteristic of the central Indo-West Pacific Region and very different to the communities of the nearer shore coastal reefs. So far 52 genera and 184 species of scleractinian corals have been recorded from these reefs (Veron in Berry, 1986), slightly less than the figures for the more intensively studied Scott and Seringapatam atolls further north. The fish fauna is equally rich with, at last count (Allen & Russell in Berry, 1986), 688 species of 258 genera.

In addition, the underwater scenery is quite spectacular. The Rowley Shoals are now well known internationally as one of the world's great dive sites. The anchorages within the Clerke Reef and Mermaid Reef lagoons are already popular destinations for charter vessels operating dive and recreational fishing tours in that vicinity. Development of such operations will certainly continue.

At the time of preparing this report there is no management plan for the State marine park. It is expected that the main management objectives will be protection of the very significant flora and fauna of the reefs and lagoons, and such recreation as may be consistent with that first objective.

3. RECOMMENDATIONS FOR MARINE RESERVES ON THE PILBARA AND CANNING COASTS AND ROWLEY SHELF.

Previous recommendations of the Conservation Through Reserves Committee (Systems 7, 12, 8, and 9) and Department of Conservation and Land Management report entitled Nature Conservation Reserves in the Kimberley, Western Australia (Burbidge *et al.* 1991) are incorporated within the following recommendations of the Working Group.

3.1 West Coast of Dampierland (Map III-1)

The Dampierland Peninsula is generally of low relief and sandy. Its northern tip, Cape Leveque, marks the southern limit of the Kimberley's ria coast and the beginning of the very different coastal types typical of what is here termed the Canning coast. The eastern shore of the Peninsula forms the western side of King Sound and was considered in Part II.

The western shore of the Dampier Peninsula is characterised by sand dunes, long sandy beaches, a few low rocky headlands, and a series of the deep, V-shaped bays discussed in Section 1.1.2. The climate is sub-humid and there are no rivers or major creeks flowing to the sea. Nevertheless, because of the fine-grained nature of the coastal rocks and the extreme tidal range, the near-shore water is turbid.

The V-shaped bays are a feature of the Canning coast. They comprise a repeated set of secondary geomorphological types and marine habitats. They tend to have low rocky headlands with limestone or sandstone reefs and extensive sand flats on the seaward corners, well developed mud flats and mangals at their heads, and moderate supra-tidal flats between the high tide level and the terrestrial vegetation of the hinterland. In many respects each of the V-shaped bays can be regarded as a separate ecosystem with a high degree of internal integrity, although there must also be significant connectedness with the adjacent coastal waters.

Rocky shores at the headlands tend to form rock platforms or boulder fields, often at several distinct levels within the intertidal zone and with extensive tidal pools. Although many scleractinian and soft corals grow in the lower pools, coral reef development is minor. There is usually moderate development of algal turfs and a rich invertebrate fauna.

Extraordinarily wide intertidal sand flats are perhaps the most notable feature along the open ocean shores of this sector. Some of these are more than a kilometre wide at low spring tide. They exhibit a range of sediment types from fine silty sand in nearshore situations to coarse, shelly rubble where there is a strong tidal flow. They are often very strongly sculptured with ripple marks and drained by complex, dendritic systems of tidal channels. There is very little plant growth on these flats, although sparse seagrasses grow in some shallow pools. Faunistically, on the other hand, these flats are remarkably rich. They carry very dense and diverse populations of bivalved molluscs and other burrowing infauna which are preyed upon by large numbers of fishes at high tide, and by wading birds at low tide. At the extreme outer edge (at low spring tide level) they bear dense growths of soft coral and sponges. The large biomass of these flats is no doubt supported by the high production of organic material in the bays behind them.

The mangals in the bays are typically complex in their zonation and floristic composition although they are less species-rich than the mangals of the north Kimberley coast where rainfall is higher, and several of the mangal structural types are missing. Johnstone (1990) recorded 12 species of mangrove from the region and noted the scarcity of tall *Rhizophora* and *Sonneratia* forest. He recorded 16 of the 22 species of birds which typically inhabit the mangals of the Kimberley. Structurally, several different mangal types can be recognised, each characteristic of particular geomorphic settings. The patterns of mangal types are repeated in each of the V-shaped bays from Pender Bay in the north to Lagrange Bay south of Broome.

The only offshore islands on this section of the coast are the Lacepedes. With that exception there are no coral banks or off-shore reefs and the continental shelf slopes more or less regularly, though with

some deep tidal scour channels. The nearshore bottom sediments consist mainly of terrigenous muds.

Previous recommendations
There are no previous recommendations for marine protected areas on the western coast of the Dampier Peninsula. However, the CTRC report and subsequent EPA recommendations included a proposal for the reservation of a section of vacant Crown Land along the coast between Cape Borda and Lombadina Point as a nature reserve. This proposal was endorsed by Burbidge *et al.* (1991).

In this report two marine areas of the Dampierland coast are identified as worthy of reservation.

3.1.1. Pender Bay

Tenure
The peninsula of Cape Borda and the coastal land to the north of it is vacant Crown Land. The southern shore of Pender Bay, including Perpendicular Head, is Aboriginal Reserve. The land at the head of the bay is pastoral lease.

Petroleum Exploration Permit EP 104R3 covers the adjacent hinterland in the Pender Bay/Beagle Bay area and extends into the inshore waters of Pender Bay.

Geomorphology
Pender Bay is a typical example of the Canning coast V-shaped bays. It has a broad mouth with rocky headlands at either side of Cape Borda in the north and Perpendicular Head in the south and moderately deep waters between. The southern shore between Perpendicular Head and Bell Point is northward-facing and exposed, with sandy beaches and extensive intertidal sand flats. The northern shore is shorter, with a rocky headland at Cape Borda, fronted by very wide sand flats, abruptly changing to mangal habitat to the east. The head of the bay has a major mangal backed by supra-tidal flats.

Conservation values
Although there are no data on seagrass beds in this bay, the area is a major site of dugong hunting by Aborigines and the presence of seagrass habitat may be inferred.

There have been no systematic surveys of the marine fauna and flora of Pender Bay although staff of the Department of Conservation and Land Management have carried out cursory studies on the sand flat and mangal faunas at Cape Borda. In that area at least, the intertidal fauna is extremely rich and is typical of that of the Canning coast.

Recreation
Scenically both Cape Borda and Perpendicular Head are attractive. Their sandstone rocks are colourful and their landforms varied. However, most visitors go there for the fishing or shell-collecting.

Access to the southern shore of Pender Bay is difficult and the land is reserved for Aboriginal use. There is little prospect of extensive recreational development there, except for the use of local people.

Cape Borda is part of an area proposed to be reserved as a nature reserve and extensive recreational developments there are not likely. The headland and adjacent beaches and the mangal are commonly visited by Aborigines and, to a lesser extent by non-Aboriginal people from Broome. Road access is difficult. There is a boat launching site in the bay on the northern shore just east of Cape Borda.

The best prospects for recreational developments in this area are for day visits to Cape Borda but supervision would be necessary. Recreational fishing and shell-collecting would be consistent with marine park status, subject to management.

3.1.2. Lacepede Islands

Tenure

The Lacepede Islands are located about 18 km west of the mainland coast of the Dampier Peninsula north of Broome. The group consists of West Island (106.6 ha) and Middle Island (53.6 ha) which together comprise Class C Nature Reserve No. 7279 for the conservation of flora and fauna, East Island (32 ha) which is a Commonwealth lighthouse site, and Sandy Island (8.2 ha) which is Vacant Crown Land.

Geomorphology

The four islands are sparsely vegetated Holocene sand islands built on a limestone rock platform. No details are available on the structure of the reefs surrounding the islands. However, from aerial inspection and verbal reports of visitors to the islands it has been determined that they are surrounded by a complex of shallow lagoons and intertidal and subtidal rock pavements and sand and muddy sand cays. The complex is about 16 km long, separated from the mainland by the Lacepede Channel. The surrounding sea is generally less than 20 m deep and is usually turbid.

Recreational use

People from Broome and the adjacent mainland occasionally visit the reefs around the Lacepedes for recreational fishing. Some tourist charter operators take their customers ashore on the islands to observe the seabirds, under permit from the Department of CALM. There is no potential for development of holiday accommodation on these islands because of their desolate nature and lack of fresh water.

Marine flora and fauna

A brief account of the flora and fauna of the islands is given by Burbidge *et al.* (1991). The main biological importance of the islands is as nesting sites for marine turtles and seabirds. The islands are major nesting sites for the Brown Booby (*Sula leucogaster)* and the Lesser Frigate-bird (*Fregata ariel)*. Other birds nesting there include the Australian Pelican (*Pelecanus conspicillatus*), the Common Noddy (*Anous stolidus)* and the Fairy Tern (*Sterna nereis)*. The Lacepede colonies of the Brown Booby are the largest in the world and the Lesser Frigate-bird colonies are the largest in the Indian Ocean.

The islands are also the site of a major rookery of the Green Turtle (*Chelonia mydas)*. A current turtle tagging project operated there by the Department of CALM in collaboration with the local Aboriginal community, seeks to determine migration patterns of this species. Preliminary results indicate that female green turtles which feed as far away as the Gulf of Carpentaria and Indonesia travel to this site for their egg-laying in the early summer months.

The Flatback Turtle (*Nator depressus)*, an endemic northern Australian species which is declared threatened under the Western Australian Wildlife Conservation Act, is also recorded nesting on these islands.

There is limited information available on the marine flora and fauna of the reef platforms and sand flats surrounding the Lacepedes. The English marine naturalist Saville Kent visited the islands in the early 1890s and collected and photographed corals (Saville-Kent 1897: pp 219-222). His small collection of corals is now in the British Museum of Natural History. From that source came the original specimens of the coral *Montigyra kenti* Matthai, 1928, but the species has not been collected there (or elsewhere) since.

Marine biologists from the WA Museum and the Australian Institute of Marine Science briefly visited the Lacepedes in July 1982 and collected some invertebrates from the intertidal and sublittoral zones. Mud flats and wide sand flats with algae but few corals were noted on the southern side of West Island. On a second visit, in May 1987, a landing was made on Middle Island. On that occasion the group noted barren, muddy flats on the south side and a barren, stepped, intertidal rock platform on the north side covered with a sparse algal turf. The intertidal flats are subjected to severe tidal scouring and the apparent sparseness of their biota is perhaps not surprising.

The limited collecting and study of the marine communities at the Lacepedes, together with aerial inspection, reveal that the outer edges of the reef platforms and some of the shallow lagoons and

channels support extensive coral reefs and the presence of some seagrass beds in the lagoons. Given the close proximity of the reefs to the mainland and the relatively turbid water, it is likely that the sublittoral reef communities are rich in species. The limited invertebrate collections that have been made at the Lacepedes indicate that there are few species in common with the shelf-edge and mid-shelf platform reefs further offshore and further north.

Declaration of a marine conservation reserve around the islands would assist protection of the very important turtle and seabird nesting sites and the habitats of these animals before and after breeding. The marine habitats, flora and fauna may also be worthy of special protection measures in their own right. The habitats represent the Holocene sand island type on a limestone platform, with a variety of fringing coral reef, intertidal sand flat, algal and seagrass bed, rock platform, and channel habitats.

Previous recommendations

Following the CTRC recommendations, the EPA recommended that the reserve should be extended to the low water mark to protect turtles and up-graded to Class B. These recommendations were endorsed by Burbidge *et al.* (1991) who further recommended that Sandy Island should be added to the reserve (Rec. 2.4).

Working Group Recommendations

1. Pender Bay - Cape Borda:

"(i) that a survey be carried out of the supratidal, intertidal and shallow sublittoral marine habitats and flora and fauna of the Cape Borda-Pender Bay system and the Sandy Point-Beagle Bay system;

"(ii) that, as an outcome of the survey, an area of the coast be selected for declaration as a marine reserve for public recreation and protection of flora and fauna, to represent the V-shaped bay systems characteristic of the Canning coast."

2. Lacepede Islands:

"that there be a survey of the intertidal and shallow sublittoral marine habitats and reef platforms surrounding the Lacepede Islands, and an assessment made of their suitability as a marine reserve for the conservation of flora and fauna."

3.2. Roebuck Bay - Lagrange Bay (Map III-2)

The coastline from Broome (Gantheaume Point) to the northern end of the Eighty Mile Beach (Cape Missiessy) represents a unit of considerable geological and geomorphological variety with a wide range of marine habitats. It encompasses the port of Broome and the Roebuck Bay RAMSAR "Wetland of International Importance" (see below).

Tenure

A small area of the shore and near-shore waters south of Gantheaume Point, Broome is declared "closed waters" under the Fisheries Act for the protection of invertebrate fauna. Shell-collecting is prohibited there.

A portion of the northern part of Roebuck Bay is gazetted as the Port of Broome.

The hinterland includes the town-site of Broome, Aboriginal Reserve and pastoral land. There is a small Nature Reserve south of Broome occupied under lease by the Royal Australasian Ornithologists Union for use as the Broome Bird Observatory. At the northern end of Roebuck Bay a portion of the adjacent Roebuck Plains Station was recently purchased by the Government for addition to the proposed marine park. Elsewhere there is a 40 m strip of vacant Crown Land between High Water Mark and the adjacent pastoral lease boundary.

In recognition of its importance as habitat for migratory shorebirds the shores and hinterland of Roebuck Bay are designated as a Wetland of International Importance. On that account the State has obligations to provide adequate protection for the conservation values of that area.

Petroleum Exploration Permit EP 114R2 covers the adjacent hinterland in Roebuck Bay and extends into the adjacent State waters.

Geomorphology

This section of the coast lies at the southern end of the subhumid region extending northward to King Sound. It is a relict of a major palaeodrainage system originating in the present Great Sandy Desert region, but today it is characterised by the absence of any river transporting sediments. It includes two major bays of distinct coastal types (see Section 1.1.2). Roebuck Bay represents the coastal bay type (type 1) and Lagrange Bay represents the dune-ridge barred bay type (type 2), each having its characteristic mangal and other habitats.

Offshore the sea floor slopes gently to the west-north west. A narrow north-west-trending tidal channel of depths to 100 m (the Roebuck Deep) extends to 2 km offshore. Tidal range is up to 10 m.

The coastline contains a variety of landforms including rocky headlands, shores and intertidal platforms, extensive gravel, sand and mud-flats, sandplain cliffs, a variety of mangal types and broad open beaches. This variety is matched by a high diversity of flora and fauna, particularly in the intertidal and mangal habitats. The coast also contains a representation of the coastal types which evolved in the Pleistocene and Holocene in the southern Kimberley and Canning regions.

The sequence of coastal landforms and habitats is characterised by rocky capes and headlands of Quaternary age overlain by complexes of Pleistocene and Holocene dune ridges. Extensive suites of relict Pleistocene beach ridges are the principal characteristic of what constitutes an exceptionally complex geomorphological history of sediment deposition, weathering and erosion.

For the purposes of this report, three coastal sectors are recognised within this unit.

(i) *Roebuck Bay Sector*

This northernmost sector includes Gantheaume Point and the shores of Roebuck Bay. It is of Pleistocene origin and includes three components with distinctive landforms representing coastal type 1.

The first of these components is the peninsula at Broome where sandstones, overlain by Pindan sands, form extensive cliffs and narrow beaches.

The second landform type on the northern side of Roebuck Bay is of Pleistocene and Holocene origin. Relict Pleistocene dune landforms and more recent Holocene coastal dunes are a major feature. The coastal plain of this sector is characterised by aeolian dunes parallel to the shoreline, beach ridges, and extensive supra-tidal mudflats. The shore is comprised of low, red, semi-consolidated, sandstone cliffs, vegetated above with a low, open eucalypt woodland. Much of the shore is actively prograding. Below the cliffs in the upper intertidal zone there is a zone of gritty beach sand or brown beach rock and beyond that a very wide mudflat sloping gently out to the shallows of the bay. There are a few fringing mangroves in some places. Substantial mangals are developed only where there are tidal creeks such as Crab Creek.

In the southern part of Roebuck Bay from Crab Creek to Bush Point there is a third landform consisting of a remarkable linear mangal which is structurally unique on the Western Australian coast. This mangal is wide, strongly zoned, and drained by a series of transverse tidal creeks, each dendritic and originating in wide supratidal samphire flats fronting the grassy Roebuck Plain of the low hinterland. It contains a variety of mangal habitats and assemblages. The seaward zone consists of low, open to closed forest of *Avicennia, Aegiceras, Camptostemon* and *Rhizophora* with some *Aegialitis* forming an understorey. *Avicennia* is the most common species forming dense stands in the landward zone. Scattered trees and shrubs of *Excoecaria* occur on the landward fringe.

In addition to the mangal itself there is an equally remarkable, very wide, intertidal mudflat seaward of the mangroves. The mudflat is several kilometres wide at the southern end of the bay where it forms a broad spit projecting northwards from Bush Point.

Mangal and mudflat development also occurs south of Bush Point as far as Cape Villaret but there is not the linear form which typifies the coast further north and there are several small bays.

(ii) *Cape Villaret to Cape Latouche Treville Sector*
This stretch of coast is dramatically different to the shores of Roebuck Bay. Low Pindan cliffs are fronted by narrow beaches, interrupted only by a complex of early Cretaceous sandstones and mudstones at Cape Gourdon.

(iii) *Cape Latouche Treville to Cape Missiessy Sector*
From Cape Latouche Treville southward to Cape Missiessy where the northern end of the 80 Mile Beach terminates, there is a complex sequence of the bay systems referred to in Section 1.1.2 as dune/ridge barred bay (coastal type 2). The bays include Port Smith, Lagrange Bay, Admiral Bay, Geoffroy Bay and Desault Bay. They comprise rocky headlands, structurally complex mangals of a type different from those of Roebuck Bay, and extensive intertidal, subtidal and supratidal mud, sand and gravel flats fronting deep tidal creeks draining the mangals. The extensive mangals bordered by supratidal, halophytic mudflats and adjacent grasslands and woodlands are a dominant feature of this coast.

Rocky headlands are the major controlling feature of the coastline together with extensive intertidal rock platforms which are incised and weathered to form a highly complex and unusual landscape visible at low tide. At False Cape Bossut there is a wide intertidal rock platform with extensive boulder fields and flat areas with tide pools standing at various heights above low water level. The principal rock type is referred to as the Bossut Formation, which is a poorly cemented, partly cross-bedded, fine to coarse grained calcareous and quartzitic sandstone of Quaternary origin.

The largest of the dune-ridge bay systems in this area is at Lagrange Bay between Cape Bossut and False Cape Bossut. It contains a full suite of the sub-units characteristic of this coastal type, including several discrete mangal systems, very extensive and well developed intertidal sand and mud flats and rocky platforms.

Marine flora and fauna
Roebuck Bay and Lagrange Bay represent excellent examples of the coastal bay (type 1) and dune/ridge bay (type 2) respectively, and contain exceptional examples of intertidal mud-flat and mangal ecosystems.

The mudflats of Roebuck Bay have particular conservation value as they are a primary feeding site for a variety of migratory birds which make their first landfall and their last point of departure there on their annual migration from and to their breeding areas in Siberia and other parts of the northern hemisphere. The birds arrive exhausted and they spend several days or weeks feeding on the invertebrates of these flats, building up their body weight before continuing their journey to feeding areas in southern Australia. Conversely, on their return journey the birds build up their body weight and reserves on these flats before beginning their extraordinarily long flight to their northern breeding grounds. The Roebuck Bay mudflats are one of the most important arrival and departure sites for migratory birds in northern Australia.

Close to the shore about 15 km south of Broome the Royal Australasian Ornithologists Union (RAOU) has established the Broome Bird Observatory on a small CALM reserve. The RAOU operates this facility as a centre for a major international bird-banding program. It is proposed that public interpretive facilities be established there as a means to further public interest in the conservation of migratory birds and as a contribution to the tourist resources of the district.

The importance of the Roebuck Bay mudflats to migratory birds and the designation of the Bay as a "Wetland of International Importance" under the RAMSAR Convention was noted above under Tenure.

Little marine research has taken place along this stretch of coast. The Mjoberg Swedish Scientific Expeditions (1910-13) made extensive collections of invertebrates, mainly from the pearling grounds off Lagrange Bay, and H.L. Clark collected echinoderms in the area during his visit to Broome in 1929. Taxonomic accounts of these collections were published in the specialist journals of the period.

The WA Fisheries Department has also conducted fishery surveys of coastal waters in the area in more recent years. Nevertheless, there is no published information on marine habitats or communities.

Inspection of the mudflats and muddy sandflats of both Roebuck Bay and Lagrange Bay by representatives of the Working Group indicated that their invertebrate faunas are especially diverse, comprising species typical of the muddy coastal waters of the North West Shelf, including the suite of endemics referred to in Section 1.2. A very large fauna of burrowing bivalved molluscs is a feature of the area. The rocky headland and intertidal rock fields at False Cape Bossut also provide habitat for an extremely diverse rocky shore community. The intertidal fauna has a species-richness greater than that of coastal habitats further north or south, reflecting the obvious high organic productivity of these bays and the great habitat diversity.

The large mangals of this sector are also of outstanding structural diversity. They include muddy flat, sandy flat, tidal creek, chenier, hinterland and rocky shore assemblage types, as developed in sheltered bays (see Section 3.7.7 of Part 1). The linear mangal of the southern part of Roebuck Bay is unique. Species diversity of mangal flora is high and many species are at the southern limit of their tropical distribution in this vicinity.

The Working Group considers that the coast between Gantheaume Point and Cape Missiessy has geological and biological features of high value for both conservation and recreation. These values include a broad range of habitat types, some unique for the Western Australian coast, an extremely rich marine fauna, geomorphological features of great scientific interest, and probably the most important site in Australia for migratory wader bird habitat. These features require particularly careful management.

Integrated management of the coastal waters and hinterland will be a key factor in management of this area. It is important that supratidal flats together with adjacent land within the complex web of mangals and their catchments be incorporated into a single management unit. The lines of distinction between land units are intricate and complex and not always clearly definable.

Recreational and commercial uses

The Working Group noted that there is a modest degree of recreational fishing by local people in the creeks entering Roebuck Bay and the several bays in the southern part of this sector. In addition there is some commercial fishing, notably for mud crabs.

There is a large contemporary Aboriginal presence in the area and many culturally and historically important sites exist along the coast. The Aboriginal community of Broome makes fairly extensive use of the mudflat and mangal environments of Roebuck Bay for recreational and subsistence fishing and the gathering of molluscs and other invertebrates at low tide. Similarly, the Aboriginal people from Lagrange use the mudflats and creeks of the bays in that area.

Burbidge *et al.* (1991) noted the potential for developing facilities and interpretive activities for observing the migratory birds in the Roebuck Bay area as an important international tourist attraction. In collaboration with the Broome Shire, the RAOU's Broome Bird Observatory is already having some success in that direction as well as operating a bird-banding program.

Previous recommendations

The CTRC and EPA reports did not consider this area. Burbidge *et al.* (1991) recommended that a Class A Marine Park be declared in the Roebuck Bay area. That recommendation included only the intertidal mud flats and land along the shore between Fall Point and Sandy Point. Neither the EPA nor the CALM Kimberley report considered other parts of this sector.

Working Group Recommendations:

As a designated RAMSAR wetland, Roebuck Bay is an obvious candidate for reservation. As well as its status as bird habitat it includes a large mangal of very unusual structure and exceptionally well-developed mudflats. The Working Group endorses the earlier recommendation of Burbidge *et al.* (1991) that a marine park be declared in Roebuck Bay but believes that further work is needed to define the most appropriate boundaries. From an ecological and management point of view, limiting

the park to the intertidal flats is not appropriate. It would be preferable to reserve the whole waters of the bay and such parts of the adjacent hinterland which directly contribute to its ecosystem functions, ie. the tidal creeks and supra-tidal flats.

Also, the Working Group considers that boundaries should be set north and south of those recommended in the 1991 report. The rocky shore of Gantheaume Point has particular conservation values in terms of its invertebrate marine fauna and the presence of dinosaur footprints. Inclusion of that area within the marine reserve would help resolve the management problems that prevail there and increase the habitat diversity of the reserve. The southern boundary recommended by Burbidge *et al.* at Sandy Point would be undesirable as the Roebuck Bay coastal geomorphic continues southwards to Cape Villaret.

For these reasons the Working Group suggests that the Marine Park should include a larger area than that recommended by Burbidge *et al.* (1991), while noting that the Port of Broome would need to be excluded.

The proposed Roebuck Bay Marine Park should be managed specifically for the protection of habitat for migratory birds and the ecosystems upon which they depend. Nevertheless, the Working Group believes that the current level of commercial, recreational and subsistence fishing in Roebuck Bay is compatible with that management objective.

The Working Group was also impressed by the features of Lagrange Bay which is perhaps the best example on the coast of the dune-ridge bay coastal type. It has an exceptionally wide range of habitats and biotic assemblages and an extremely rich marine fauna including many of the North West Shelf endemic species.

Accordingly the Working Group recommends as follows:

1. Roebuck Bay Marine Park:

"(a) That the waters of Roebuck Bay be reserved as Marine Park for public recreation and protection of flora and fauna.

"The marine park should exclude an area (whose precise limits will need to be defined) encompassing Broome Harbour.

"The Working Group suggests that the boundaries could be from the north side of Gantheaume Point to Cape Villaret and from High Water Mark to the limit of the Territorial Sea but further study and discussion will be needed on this aspect.

"(b) That foreshore areas not already reserved behind High Water Level adjacent to the central and southern parts of the park, should be added to the marine park by reservation under the Land Act. This action is pivotal for successful integrated management. The shoreward boundaries of this proposed reserve have not been fully determined but they should encompass those coastal areas of pastoral leases which are an integral part of the drainage and geomorphological systems of the coast."

2. Lagrange Bay

"That there be further study of the flora, fauna and habitats of the coastal waters, tidal creeks and supra-tidal flats between Cape Latouche Treville and Cape Bossut including Lagrange Bay, and an assessment made of the present commercial and recreational uses of these areas, with a view to the selection of the most suitable sections for reservation for the purposes of public recreation and protection of flora and fauna."

3.3. Eighty Mile Beach (Map III-3)

Eighty Mile Beach is the 220 km stretch of coast between Cape Missiessy and Cape Keraudren.

Tenure
The beach, the intertidal flats between low and high tide levels, and a 40 metre strip of land above high tide level have the status of vacant Crown Land. For the most part, the hinterland is pastoral lease (Anna Plains, Mandora, Wallal Downs) but there is a small reserve for public recreation at Wallal.

In recognition of its importance as habitat for migratory shorebirds the beach from Cape Missiessy to Cape Keraudren, including the 40 metre strip above high tide level, is part of an area designated under the RAMSAR Convention as a Wetland of International Importance. On that account the State has obligations to provide adequate protection for its conservation values.

An area of coastal waters offshore in the southern portion is covered by Petroleum Exploration Permit WA-233-P.

Geomorphology
Eighty Mile Beach is an almost continuous, gently curving beach representing a current phase of marine transgression over the low-lying and flat plains of the Canning Basin.

The beach is, on average, about 100 m wide, with a moderate slope to muddy tidal sand flats. It consists of white siliceous sand. Although nearly continuous, there are a few small muddy bays with sparse mangroves (mainly *Avicennia).* The tidal flats are very wide, extending seaward up to several kilometres in places. They are largely unvegetated except at the outer edge exposed at extreme low tide where there is moderate growth of algae, sponges and soft corals.

Behind the beach there are low sand dunes vegetated with *Crotolaria* and *Spinifex.*

Marine flora and fauna
The beach itself is an unusual and spectacular geomorphic feature and worthy of protection for that reason.

There have been no systematic studies of the intertidal flora and fauna along the shores of the Eighty Mile Beach. Cursory examination of beach drift and information obtained from local people and shell collectors suggest that the tidal flats and shallows beyond support a rich community of invertebrates.

The most significant conservation value of this area is its importance as habitat for migratory shorebirds. Its status as a RAMSAR "Wetland of International Importance" has been noted above.

Studies over the past decade by the Royal Australasian Ornithologists Union (RAOU) have shown that Eighty Mile Beach is one of the three outstanding shorebird sites in Australia. (The others being Roebuck Bay and a section of the Gulf of Carpentaria in Queensland.) On arrival from their northern hemisphere breeding grounds, the migratory birds spread out to feed over the exposed sand and mud flats at low tide but concentrate in immense flocks on the narrow beach slopes and cays at high tide. Some species also use the mangals themselves and the supratidal samphire flats behind.

Under the RAMSAR Convention, sites are defined as having "national importance" for the conservation of a bird species if they hold more than 1% of the Australian population of that species. On this definition Eighty Mile Beach has national importance for 19 shorebird species. Aerial surveys of Eighty Mile Beach have recorded up to 337 500 birds present at one time. Distribution of birds along the Eighty Mile Beach is not uniform. Approximately 90% of the birds concentrate in the northern section between Cape Missiessy and Wallal. Ground counts have found concentrations of up to 140 000 birds in the 15 km section south of Anna Plains. There is a sharp decline in the number of birds south of a small area of mangal near Wallal.

Recreation
For the most part the shore along this section of the coast is inaccessible although there are station tracks to the beach in several places and a public road into a caravan park at Wallal. Public use of the beach is very limited. The wide tidal flats fronting it and the low sand dunes behind do not make it an attractive place for fishing, swimming, diving or other traditional beach activities. Shell collecting and beachcombing are perhaps the most common activities, apart from simply enjoying the spectacle of the long beach. Most visitors come for short day or overnight visits - usually as a stop-over during journeys north or south along the highway.

Previous recommendations
Most of the information on the significance of this area for shorebird conservation has become available only recently. Neither the EPA in its 1975 report on System 12, nor the report by Burbidge *et al.* (1991) made any recommendations in respect of Eighty Mile Beach.

Working Group recommendations

"1. While noting that the whole of Eighty Mile Beach receives environmental recognition as a RAMSAR Wetland of International Importance, the Working Group recommends that a section be reserved for the protection of marine flora and fauna and the habitat of migratory shorebirds. The area reserved should include the tidal flats and the 40 metre strip of land above high tide level, ie. it should extend at least from low tide level to the boundary of the adjacent pastoral leases.

"2. The Working Group recommends that consideration should also be given to the reservation of an area of coastal waters seaward of low tide level, preferably to the limit of State waters, as a buffer to the beach reserve.

"3. Noting that the RAOU study of Eighty Mile Beach is not yet complete, the Working Group recommends that a decision on which section should be reserved should be deferred until it is possible to accurately identify the areas of most importance to migratory shorebirds, although preliminary indications are that it should be a section in the vicinity of Anna Plains."

3.4. Keraudren (Map III-4)

The eastern Pilbara coast, from Cape Keraudren westwards to Port Hedland, sees an abrupt change of coastal geomorphology and marine habitats. There are two small offshore islands. North Turtle Island lies about 20 km off the coast north-west of Larrey Point. Bedout Island is a small mid-shelf island about 40 km north of Poissonnier Point.

Tenure
The hinterland of this section of coast is pastoral lease, with a 40 metre strip of vacant Crown Land between the boundary of the leases and the high tide level. North Turtle Island and Bedout Island ane Class A Nature Reserves.

Geomorphology
At the western end of the Eighty Mile Beach, a little east of Cape Keraudren, there is an abrupt change of coastal type. The shores become rocky with small beaches and several major bays.

Immediately west of the Cape there is a dune/ridge barred bay complex, classified as coastal type 2, characterised by a dune/ridge bar. This is the most westerly example of this coastal type. It contains a well developed mangal behind the dune ridge. To the west of the bay there is a stretch of low coast with rocky headlands and narrow sandy beaches, interrupted in several places by small tidal creeks (eg. Pardoo Creek) each with mangal development.

Near the western end of the sector is the mouth of the De Grey River with its delta. The De Grey enters the sea at Breaker Inlet between Poissonnier Point and Larrey Point. In this vicinity there are very extensive mud and sand banks associated with the river delta.

The waters adjacent to this sector are turbid and gently shelving. Bedout and North Turtle Islands are both small rocky islands surrounded by shallow reefs.

Marine flora and fauna

The mangal behind the dune ridge west of Cape Keraudren has a closed forest of *Rhizophora,* often with an understorey of *Aegialitis,* along the seaward zone. *Avicennia* and scattered *Bruguiera* and *Ceriops* grow along the sides of the drainage creeks. Thickets of *Ceriops* and *Rhizophora* border the inner margins of the mangals where wide supratidal mudflats and samphire flats begin. Within Breaker Inlet and along the banks of the mouth of the De Grey River there are mangroves, almost exclusively *Avicennia*, which are low and sparse, and frequently interrupted by bare mud flats. A few stunted *Rhizophora* occur at the river mouth.

There has been no survey of the marine flora or fauna of this shore. It is possible only to speculate that the biota is likely to be typical of the coastal flora and fauna of the region, differing only in community structure according to the somewhat different coastal geomorphology.

The Saltwater Crocodile appears to have been establishing itself in the estuaries of this coast in recent years.

North Turtle Island is an important nesting site for the Australian Pelican (*Pelecanus conspicillatus*), Pied Cormorant (*Phalacrocorax varius)* and White-bellied Sea-Eagle (*Haliaeetus leucogaster*). There is no available information on the marine flora and fauna and habitats of the waters surrounding the island.

Bedout Island is a very important sea bird nesting site for the Brown Booby (*Sula leucogaster*), Common Noddy (*Anous stolidus)*, Crested Tern (*Sterna bergii)*, Lesser Crested Tern (*Sterna bengalensis)*, Lesser Frigate-bird (*Fregata ariel)*, Masked Booby (*Sula dactylactra)*, Roseate Tern (*Sterna dougalii)*, Silver Gull (*Larus novaehollandiae*) and Sooty Tern (*Sterna fuscata)*. There is no available information on the marine flora and fauna and habitats of the surrounding waters.

Previous recommendations

There are no previous recommendations for marine reserves in this area.

The EPA 1975 System 8 report recommended that Bedout Island and North Turtle Island be declared Class A reserves for the conservation of flora and fauna.

The EPA report also recommended that biological and sedimentological surveys be carried out on tidal and supratidal flats in the coastal waters of the Pilbara coast as far east as Cape Keraudren, and that any further development which might cause destruction of mangroves be subject to approval by and under the supervision of the EPA. The latter recommendation would include the mangals and intertidal flats of this sector.

Working Group Recommendations

"1. That there be a survey of the marine habitats and flora and fauna of the mainland coast between Cape Keraudren and Spit Point, with special attention given to the mangals and sand/mud flats, and that an assessment be made of their regional significance with a view to selecting the most diverse and representative area for consideration as a marine reserve.

"2. The Working Group endorses the EPA recommendations for the declaration of North Turtle Island as a Class A reserve for the conservation of flora and fauna and recommends that the waters surrounding the island, from the Low Tide Mark to the limit of State waters, be also reserved for protection of seabirds, turtles and their habitats, and marine flora and fauna generally.

"3. The Working Group endorses the EPA recommendations for the declaration of Bedout Island as a Class A reserve for the conservation of flora and fauna and recommends that the waters surrounding the island, from Low Tide Mark to the limit of State waters, be also reserved for the protection of seabirds and marine flora and fauna generally."

3.5. Depuch (Map III-5)

The coast between Cape Thouin and Cape Lambert is complex, consisting mainly of mangal but with several low rocky headlands and beach sections. There are many small nearshore islands and, near the centre of the sector, the large rocky island known as Depuch.

Geomorphology and flora and fauna
This is a section of the Pilbara coast which needs to be surveyed before consideration is given to selection of representative areas as candidates for reservation.

It is clear from inspection of aerial photographs that the mangals of this coast are very extensive and diverse, and that they differ structurally in many respects from those to the east and west. Several of the rivers that enter the sea along this coast have active deltas, classified in Section 1.1.2. as coastal type 3. The extensive mangal system at the mouth of the Yule River is a good example. However, the Working Group was not able to obtain detailed information about the habitats or community composition of the mangals in this sector and was not able to make any comparison of them for the purpose of selecting representative areas for reservation. Nor was any information available on the nearshore benthic flora and fauna.

Nevertheless, one small beach area near the north-eastern end of the sector, known as Cowrie Beach, is an important turtle-nesting site and consideration was given to its potential as a reserve for conservation of flora and fauna.

3.5.1. Cowrie Beach
Cowrie Beach, south west of Cape Thouin and about 140 km east of Karratha, is a popular site for recreational use and one of the few WA nesting sites of the threatened Flatback Turtle (*Nator depressus)*. Through cooperation between the Port Hedland Shire and the Department of Conservation and Land Management, special management provisions have been made to protect the turtles and their nesting habitat during the nesting season. However, a more formal arrangement is needed to ensure that the site is adequately protected in perpetuity.

Tenure
The hinterland is part of Mundabullangana pastoral lease which has its seaward boundary at 40 m above High Water Mark. The 40 m strip between the boundary and High Water Mark is Vacant Crown Land. There is a small (20.25 ha.) Commonwealth lease on the flats adjacent to Cowrie Beach which is the site of a Transport DECCA station with two aerials and associated buildings. A much-used trig point (Thouin R 131) is situated behind West Cowrie Beach.

Geomorphology
Cowrie Beach extends from the mouth of the creek to a limestone shore ridge some 3.3 km to the west. Beyond the limestone ridge there is a separate 400 m stretch of beach known as West Cowrie Beach terminated by a mangrove-covered rocky point separating the Cowrie Beach complex from Munda Beach.

The beach deposits are of Holocene origin, fronted by an oolitic limestone pavement and backed by Holocene dunes, the oldest at a height of over 10 m. The primary dunes are vegetated by *Spinifex longifolius.*

Cowrie Creek is a discrete mangal unit with a deep tidal creek receiving flood waters from the Yule River. At the seaward edge of the creeks, on mudbanks and muddy islands, are mature closed forests of *Rhizophora* and *Avicennia* with an understorey of *Aegialitis.* The smaller creeks are vegetated with *Avicennia* forest of thick-trunked trees to a height of 5 m, backed by whipstick *Avicennia.* There are some *Ceriops* on the landward side.

Marine flora and fauna
The Flatback Turtle is a threatened species under the State Wildlife Conservation Act and is endemic to northern Australia. The species nests on beaches at a number of localities from Yeppoon, Queensland to the North West Shelf. In Western Australia known major nesting sites of the species are at Helpman Island, the Lacepede Islands and Cape Domett in the Kimberley, and Rosemary,

Hauy, Varanus and Barrow Islands and Cowrie Beach in the Pilbara. There is also low density nesting on mainland beaches of the Pilbara at Eighty Mile Beach, Cemetery Beach, Cape Thouin, Cleaverville and Wickham.

The Cowrie Beach rookery is one of the largest for this species in this State. Data collected by CALM officers during the 1988/89, 1989/90 and 1990/91 seasons indicate that several hundred females lay their eggs at this site annually.

The Working Group notes that Cowrie Creek itself has high conservation value in that it represents a type of mangal system characteristic of the Pilbara coast. There would be merit in including it within the proposed reserve for this reason.

Recreational use

Recreational use of Cowrie Beach is heavy, the site being only 1 hour's drive from Port Hedland and accessible by 2WD vehicles. Recreation includes camping, boating (there is a serviceable boat ramp at Cowrie Creek), fishing, off-road driving, and turtle-watching. As many as 80 people have been observed on Cowrie Beach at one time. Visitors camp on the limestone ridge, at Cowrie Creek and on the beach itself.

This is the only major turtle rookery on the mainland Pilbara coast and it offers opportunities for educational viewing including commercial tourism. Such use is already occurring. Special management will be needed to ensure that viewing does not adversely affect the breeding success of these animals.

Management issues

Clearly Cowrie Beach is an important area deserving protection and special management. There are several management issues. Off-road vehicles using the beach itself and the primary dunes have damaged vegetation and may be having a significant impact on egg clutch and hatchling survival. Noise and light from camps and poor public viewing procedures have been observed to have detrimental effects on adult turtle and hatchling behaviour. There is predation by foxes, varanid lizards, birds and crabs. The capacity of the turtle population to sustain predation is not known.

Previous Recommendations

There are no previous recommendations for marine reserves in this sector.

As mentioned in Section 3.4, the EPA 1975 System 8 report recommended that biological and sedimentological surveys be carried out on tidal and supratidal flats in the coastal waters of the Pilbara coast as far east as Cape Keraudren, and that any further development which might cause destruction of mangroves be subject to approval by and under the supervision of the EPA. These recommendations would include the mangals and intertidal flats of this sector.

Working Group Recommendations

In view of the lack of information about the marine flora and fauna of the mangals and nearshore waters of the coast in the Depuch sector, the Working Group has not been able to recommend any particular areas for reservation which would represent coastal type 3 and these habitat types within the region. Further photo-interpretation work and field surveys are needed before this is possible.

Cowrie Beach is a special case. The Working Group considers that reservation of the beach and hinterland is urgently needed to support protection of the very important Flatback Turtle rookery. Not much would be gained by including the waters in front of the beach within the reserve. However, there is good reason for including the tidal waters of Cowrie Creek which is a small but significant, self-contained mangal unit.

Declaration of the coastal lands as a CALM Act marine nature reserve or Land Act nature reserve would have the disadvantage that recreational fishing and camping could not be permitted. There would be procedural advantages, however, in declaring the intertidal zone and the 40 m strip as marine park under the CALM Act or the Land Act, thus allowing recreational fishing to continue, subject to careful management to avoid interference with the turtle breeding activities.

Accordingly the Working Group recommends that:

"1. That a survey should be carried out of the mangal and nearshore marine habitats of the coast between Cape Thouin and Cape Lambert so that one or more parts of it may selected for reservation to represent coastal type 3 and protect nearshore marine and mangal habitats and their flora and fauna.

"2. That the stretch of shore of Cowrie Beach and West Cowrie Beach, extending from the boundary of the adjacent pastoral lease to the Low Tide Mark, but including the tidal waters of Cowrie Creek, be reserved for the purpose of public recreation and protection of flora and fauna.

"3. That the breeding success of the Flatback Turtles at this site be monitored and any necessary steps be taken to ensure that predation of the adults and young and other forms of disturbance are kept to a minimum."

3.6. Dampier Archipelago (Map III-6)

The Dampier Archipelago is one of the major features of the Pilbara coast. It is close to several important ports and the regional centre of Karratha. Its environment, flora and fauna, both marine and terrestrial, have considerable regional significance and are subject to increasing human impact.

Tenure

Most of the islands of the Dampier Archipelago are reserves vested in the NPNCA, and are under the management of the Department of Conservation and Land Management. Exceptions are the Intercourse Islands and Legendre Island. At the time of preparation of this report, most of the island reserves are nature reserves while some are recreation reserves. A recent Management Plan (Dampier Archipelago Nature Reserves Management Plan 1990-2000, Department of Conservation and Land Management, approved 6 June, 1990) contains a recommendation that all the island reserves should be declared national park. A separate management plan is being prepared for the Burrup Peninsula.

Geomorphology

The Dampier Archipelago is an inundated landmass now comprising islands, rocky reefs, coral reefs and shoals rising from a sublittoral plain of 5-20 m depth (Semeniuk *et al.*, 1982). The Archipelago represents coastal type 9, that is ria/archipelago coast (Section 1.1.2). Prior to inundation about 6 000–8 000 years ago, the coastline ran around the periphery of the area that is now the archipelago. The position of the previous shore is represented today by a steep slope to the 30m contour around the archipelago close to the outer shores of the outer islands. These outer islands are the remnants of consolidated limestone ridges formed along the previous coastline.

The climate of this region is semi-arid with an average annual rainfall of 315 mm, and is subject to periodic cyclonic storms. There are no major rivers entering the sea in the immediate vicinity. Mean spring tidal range is 5.6 m and there are strong tidal currents among the islands. The near-shore waters are usually turbid while in the outer Archipelago the water may be moderately clear. There is often a very distinct boundary between the turbid inner and clear outer water.

The majority of the islands in the Archipelago consist of Archaean metasedimentary and igneous rocks of the Fortescue Group, often with Holocene shelly sand plains (Kreiwaldt, 1964). In landform they resemble the adjacent mainland with low, rounded hills formed by rock piles and rugged cliffs. Some of them have moderate elevation. Outer islands, including Delambre, Hauy, Legendre, Brigadier and Kendrew (Wilson & Marsh, 1974) are low limestone islands of Pleistocene or Holocene origin, usually with low, undercut sea cliffs and superficial sand dunes and beaches.

Marine flora and fauna

There has been a moderate amount of research on the marine fauna and habitats of the Dampier Archipelago. The WA Museum carried out a survey of Crown-of-thorns Starfish on the coral reefs off Kendrew Island during the years 1972 to 1974 (Wilson, 1972; Wilson & Marsh, 1974). This study included preparation of faunal lists of the fishes, corals and other marine animals of the Archipelago, was extended by additional survey work in 1978, and culminated in an unpublished report on the marine fauna and flora of the Dampier Archipelago. Further work on the Crown-of-thorns was done in subsequent years by the Department of Conservation & Environment (Simpson & Grey, 1989), the

Department of Conservation & Land Management (Wilson & Stoddart, 1988). and the Australian Institute of Marine Science (Johnson & Stoddart, 1988). This coral predator appears to be present in large numbers on coral reefs in the Archipelago, at least episodically, and at such times does considerable damage to the coral communities.

During the period 1981 to 1986, the Department of Conservation & Environment conducted and supported extensive surveys of the marine fauna and habitats in the Archipelago, especially with respect to industrial developments there and the potential for pollution. A number of publications resulted from this work which form a useful basis for marine environmental management and planning. Chittleborough (1983) published a progress report detailing the objectives of the study. Semeniuk *et al.* (1982) described the marine environments of the Archipelago including a detailed description of the main biotic assemblages. Paling (1986) classified a number of reef sites into broad groups using numerical techniques. Simpson (1988) published a comprehensive report on the ecology of scleractinian corals in the Archipelago. Blaber *et al.* (1985) described the community structure and zoogeographic affinities of coastal fishes of the Dampier region. Mills & Pitt (1985) and Mills *et al.* (1986) published data on tidal dynamics and currents.

Marine habitats in the Archipelago are extremely varied, as might be expected with such varied land and seascapes. The seabed within the Archipelago is mainly of mud and fine sand. This substrate supports an extremely rich and diverse benthos. Many shallow bays have wide muddy sand flats which also support rich burrowing faunas. Seagrass beds are not well developed.

All of the islands are sparsely vegetated but some of them support relict populations of plants and animals representative of the mainland biota, and accordingly have very high conservation values . There are also very important rock art sites on several of the rock pile islands and on the Burrup Peninsula. Several of the beaches are important turtle nesting sites and some of the small, outer islands and rocks support large seabird colonies.

On the eastern side of the Archipelago, Nickol Bay represents a very different type of habitat. The western shore of the Bay, that is the eastern side of the Burrup Peninsula, is rocky with small bays and beaches and a few fringing mangals, comparable to the shores of the western side of the Peninsula and some of the inner islands of the Archipelago. In contrast, the southern and south-eastern shores are characterised by wide mudflats and extensive growth of mangroves. The Bay itself is shallow and has a muddy bottom.

The mainland coast west of the Archipelago, that is west of West Intercourse Island, is classified as type 11 in Section 1.1.2. It is dominated by mangal habitat, mainly of the tidal creek, spit/chenier, and alluvial fan assemblages (see Part I, Section 3.7.7.). Particularly notable is the mangal on the delta of the Maitland River. The mangals are fronted by mud flats. and the shallow, muddy waters of Regnard Bay. A large portion of the mangal between Dampier and West Intercourse Island has been destroyed for the establishment of salt ponds.

There are also small mangals fringing sheltered bays of some of the inner islands, most notably in Flying Foam Passage and the southern bays of Enderby Island. These mangals are of the muddy tidal flat, sandy tidal flat, beach and rocky shore assemblages of the ria-archipelago coastal type (see Section 1.7.7 of Part 1). They contain the mangrove species *Avicennia marina, Rhizophora stylosa, Ceriops tagal, Aegialitis annulata, Bruguiera exaristata* and *Aegiceras corniculata.*

Corals and Coral Reefs

The Archipelago has a diverse coral fauna with 216 species of 57 hermatypic coral genera being recorded (Veron & Marsh, 1988). Many of these species range from inshore to offshore habitats within the Archipelago, but a small suite of species is confined to the turbid inshore waters and others are found only on the outer reefs (Marsh, 1978; Paling, 1986).

In the inshore waters of the Archipelago corals grow prolifically on the sublittoral rock slopes. Some of the highest coral species diversity has been recorded in this habitat type, for example on the slopes around Conzinc I. However, these corals do not form coral reefs in the strict sense. The best coral reef development occurs on the seaward slopes of the outer Archipelago, such as those west and east of Delambre I., at Hamersley Shoal south west of Legendre I., on Sailfish Reef north west of

Rosemary I., on the seaward side of Kendrew I., and on the north-west side of Enderby I. These coral reefs exhibit typical fringing reef form with a coral-rich, reef-front slope dissected by deep spurs and grooves, a reef edge zone with a reef flat behind and, in places, a shallow back-reef and lagoon.

These coral reefs of the Dampier Archipelago are a significant feature of the Pilbara coastal marine environment. They support communities of fishes and invertebrates that are comparable in diversity to those of other parts of the Indo-Pacific coral province and share many species in common with them. However, because of the peculiarities of the Archipelago's geomorphology and biogeographical history, community structure and faunal composition of these reefs is unique.

Soft Substrates
Another feature of the Archipelago's marine environment is the rich soft-substrate benthic invertebrate fauna. This is especially evident on the intertidal flats which occur throughout the Archipelago. These range from muddy flats associated with the mainland mangals to the clean, coarse-grained sand flats and cays more common in the outer areas. Although there has been no published account of this element of the marine fauna it is well known that it is exceptionally rich in species.

Of particular interest among the molluscs, for example, are 5 regionally endemic species of the volutid gastropod genus *Amoria.* These beautiful animals are greatly sought after by the specimen shell trade. They were once moderately common on the intertidal sand flats in the Archipelago but have been heavily over-collected throughout the region. They are vulnerable to local extinction because of their lack of a pelagic larval stage.

Recreation
There is extensive recreational use of the waters of the Archipelago by local people from the nearby towns of Dampier, Karratha, Wickham and Roebourne. Recreational fishing, diving and shell-collecting are popular activities. Most households in the district own a small boat capable of travelling among the islands. Of all the islands of the Pilbara coast these have the greatest potential for tourism.

Previous recommendations
The Dampier Archipelago Islands Management Plan approved in 1990 contains a recommendation that waters of the Archipelago should be declared marine park but boundaries were not suggested.

Working Group recommendations
The Working Group had no difficulty in agreeing that the waters of the Dampier Archipelago warrant reservation but the determination of boundaries for such a reserve was problematical. There is potential for pollution of the waters in the vicinity of the industrial and harbour facilities of Dampier and the western side of the Burrup Peninsula and in the shipping lane which bisects the Archipelago through Mermaid Sound, and potential for conflict between management objectives of the port-industrial developments and conservation.

For these reasons the Working Group concluded that a Dampier Archipelago marine reserve should exclude the inner portion of Mermaid Sound and the functional area of the Port of Dampier. The park would then comprise two primary sectors, connected on the northern side. The western part would encompass Rosemary, Malus, Enderby, Eaglehawk, West Lewis and the western and northern shores of East Lewis Islands. The eastern part would include the northern tip of the Burrup Peninsula, Conzinc, Dolphin, Angel and Gidley Islands, the island complex and waters north of Gidley I., Hamersley Shoal, and Legendre, Hauy and Delambre Islands. The Working Group considers that the waters of Nickol Bay are not an integral part of the Archipelago ecosystem and does not propose that they should be included in the reserve, except for the area across the top between Dolphin, Hauy and Delambre Islands.

The Working Group considers that the area proposed to be included in the reserve, while avoiding the principal shipping lanes and industrial areas, adequately represents the coral reef, mangal and sand and mudflat habitats of particular importance in the Archipelago, and that it provides good buffers for the turtle and seabird nesting sites on the islands. It also contains the most important recreational areas worthy of management and long term preservation.

The suggested boundaries are straight lines between easily identifiable points in the seascape wherever possible. In the case of the eastern sector, a suitable western boundary for management purposes could be the eastern limit of the prohibited anchorage area, between Conzinc Island and the western tip of Hamersley Shoal, where the gas pipeline is laid. This would include the important coral communities on the rock slopes of Conzinc and other small islands.

Accordingly the Working Group recommends that:

> "...the waters of the Dampier Archipelago, excluding the Port of Dampier, be reserved for the purposes of public recreation and protection of flora and fauna, and that the seaward boundary should be the limit of the State Territorial Sea."

3.7. Cape Preston (Map III-7)

This part of the report focuses on a short stretch of coast between Gnoorea Point and the delta of the Fortescue River and an area of adjacent nearshore waters.

Tenure

The hinterland of this sector comprises the Mardie, Balmoral and Karratha pastoral leases of which the seaward boundary is 40m from High Water Mark. The strip between High Water and the lease boundaries is currently Vacant Crown Land. A fishing shack lease of about 100 ha. (De Witt Location 184) is present on Preston Island. A Public Purpose Reserve (of 258.9 ha.) number 380, for a landing and rock well, is present at the mouth of the Fortescue River.

Offshore, North Regnard, South West Regnard and Carey Islands are part of a Class A Nature Reserve bearing the number 33831.

Geomorphology

Excellent examples of two of the distinctive coastal types listed in Section 1.1.2 of this Part are represented in the area, ie. a chenier coast (coastal type 10) east of Cape Preston and an inactive delta (coastal type 4) at the mouth of the Fortescue River, each with its characteristic complex of mangal types and assemblages. The Fortescue inactive delta is one of two deltas of this type on the Pilbara coast (the other being the delta of the Robe River). There are also supra-tidal salt flats, sand islands, rock pavements, bar systems, and extensive sandflat habitats.

Cape Preston is a low, rocky headland at the northern tip of Preston Island. The island is separated from the mainland only by tidal creeks. It is flanked on its western and eastern sides by extensive intertidal muddy sandflats. Preston Spit is a flat rock platform at just above extreme low tide level, extending more than a kilometre westward from Preston Island.

Offshore, Fortescue Road crosses the north-west corner of the area under consideration and ranges in depth from 8 to 15 m. In Regnard Bay and south-west of the Preston Spit the sea-bed is shallow, mainly less than 2 m, and there are many emergent rocks and banks constituting foul ground. Wind generated waves of short fetch prevail, from the SE/NE in winter and SW/NW in summer. Tidal range is from 3.8 m (MHWS) to 0.2 m (MLWS), the water is turbid and the substrate muddy.

Intertidal mudflats dominate the shore in most areas. There are sandy beaches on the eastern and western sides of Preston Island which also has a wind driven linear dune system on its west side. Rock, mud and sand flats connect Preston Island, Carey Island and others to the mainland at low tide. Point bars and shoals form part of the tidal creek system.

Intertidal and sublittoral rock pavements (of both igneous and sedimentary origin) flank Preston Island and Gnoorea Point and extend from Cape Preston to North East Regnard Island (the Regnard Pavement). In some areas the subtidal pavements support macroalgal and coral communities. Extensive sand sheets cover much of the Regnard Pavement, including that part west of Cape Preston where they cover much of the rock platform comprising the Preston Spit.

Marine flora and fauna
One of the low coastal islands, North East Regnard, is a significant rookery of the Wedge-tailed Shearwater.

The muddy rock pavements, sand and mud flats of the shore in this region support a range of community types and a very rich flora and fauna which is characteristic of the coastal waters of the Pilbara, including the suite of regionally endemic species referred to in Section 1.2. In spite of the muddiness of the water, there is an abundant and diverse fauna of corals in the sublittoral zone. The corals do not form coral reefs in the strict sense but grow, together with sponges, soft corals and green algae, wherever there are rocky substrates. The fringe of this diverse community is exposed along the flanks of the Preston Spit (and probably elsewhere in the region) at extreme low tide.

Extensive mangals are developed on the Fortescue delta, in an embayment east of James Point where Yagabiddy Creek enters, in an embayment immediately south of Cape Preston, and east of Cape Preston. These mangals represent a variety of the assemblages characteristic of the chenier and inactive delta coastal types. They occupy an area of approximately 5 800 ha. In addition, isolated and small groups of mangrove trees, mainly *Avicennia marina,* colonise the upper intertidal zone of the mudflats along most of the shore. Extensive supratidal cheniers are developed on the seaward side of the mangal east of Cape Preston. Behind all of the major mangals there are wide supratidal flats, much of them covered by algal mats. Over 50 sand islands, ranging in size from 10's of square metres to 10's of hectares, occur on the supratidal flats. With such geomorphological variety it is not surprising that many different types of mangal assemblage are present and both floral and faunal communities are species-rich.

In summary, the shores of the area under consideration contain a wide range of the habitats representative of the West Pilbara coast, including the best examples of the chenier and inactive delta coastal types, and there is a corresponding species-rich flora and fauna.

Recreational and commercial use
There is recreational use of some parts of the area but much of it remains pristine. There is a boat ramp at the mouth of the Fortescue River used by recreational fishers to gain access to many of the mangrove creeks in that vicinity. Camping occurs at Gnoorea Point. Access to the central area in the vicinity of Preston Island is by means of disused station tracks and that area is rarely visited.

A semi-permanent camp established on Preston Island is used for operation of a radio positioning station relating to offshore petroleum exploration. A fishing camp on Preston Island is no longer used.

The waters of the area are within Zone 1 of the Pilbara Fish Trawl Fishery, the Pilbara Trap Fishery, and Zone 3 of the Onslow Prawn Fishery. The Working Group considers that it would be appropriate to use the inner (shoreward) boundary of these designated fishery areas as the seaward boundary of any reserve so that the reserve would not include any commercial operations.

Previous recommendations
The EPA (1975, System 8, rec. 8.7) recommended a biological and sedimentological survey of this area in the context of its contribution to the supply of nutrients to the adjacent marine ecosystem. The survey has not been carried out although since 1975 some further information has become available.

Working Group recommendations
The mangals, muddy intertidal flats and extensive shallows east and west of Cape Preston are species-rich and undoubtedly contribute significantly to the energy budget of the coastal waters in the region. The varied marine habitats are diverse and represent the mainland coast of the central Pilbara, especially coastal type 10, so that the area is an excellent candidate for setting aside as a marine conservation reserve.

The area considered here is close to the eastern part of Regnard Bay which is suggested for inclusion within the proposed Dampier Archipelago marine park (Section 3.6 - see Map III-6). A case can be made for a single marine reserve extending from the Archipelago to Cape Preston and encompassing

all the waters of Regnard Bay, combining within the one reserve major examples of coastal types 9 and 10. For this reason the recommendations of this Section should be considered together with those for Section 3.6.

After some consideration the Working Group decided not to propose inclusion of the Fortescue inactive delta in the proposed marine reserve. This coastal type is repeated further south in the Robe River delta (Section 3.8). However, if the boundaries of the marine park proposed within that sector do not include the Robe delta, inclusion of the Fortescue delta within the proposed marine reserve at Cape Preston should be reconsidered.

Accordingly the Working Group recommends:

> "1. That the section of coastal waters between Gnoorea Point and James Point, encompassing South West Regnard Island, Preston Island, Preston Spit and Carey Island, be considered for reservation for the purposes of protection of mangal habitat, prawn and fish nursery areas, turtle nesting and feeding areas, and marine flora and fauna generally.
>
> "Alternatively, consideration could be given to extension of the proposed Dampier Archipelago Marine Park (Section 3.6) westwards to encompass all the waters of Regnard Bay and North Regnard, South West Regnard, Preston and Carey Islands.
>
> "Extension westwards to include the inactive delta of the Fortescue River should be considered if the inactive delta of the Robe River is not included in the reserve of the Robe-Cane sector.
>
> "2. That the 40m strip of vacant Crown Land between High Water Mark and the boundary of the adjacent pastoral leases be added to the Marine Park by reservation under the Land Act."

3.8. Robe (Map III-8)

This sector covers the coast between the mouths of the Fortescue and Ashburton Rivers and includes the coastal town of Onslow.

Tenure
The hinterland is pastoral lease with the boundary 40 m above High Tide Mark. The position of the boundary is difficult to determine.

The islands are incorporated into a single Class A Nature Reserve which bears the number 33831.

The northern inshore part of the sector is covered by Petroleum Exploration Permit EP137 R2 and the offshore part by Petroleum Exploration Permit EP341. The southern inshore part of the sector is covered by Petroleum Exploration Permit EP110 R3 and the offshore part by Permits EP367 and EP357.

Geomorphology
This section of the coast and coastal waters contain quite different nearshore and onshore units. The outer portion, ie. the nearshore sublittoral shelf, is shallow with muddy substrates and numerous small, low limestone islands. This nearshore shelf-island unit continues north and south beyond the limits of the sector. The onshore unit comprises the coastline.

The coastline contains representatives of 4 of the distinctive coastal types listed in Section 1.1.2, that is inactive delta (coastal type 4), inactive delta with barrier islands (coastal type 5), barrier limestone coasts (coastal type 6) and eroded barrier with bays (coastal type 7).

As noted in Section 3.7, there are two examples of inactive delta on the Pilbara coast, the deltas of the Robe and Fortescue Rivers, the former being within this sector.

A feature of the geomorphology of the mainland shore of this sector is the development of low barrier islands seaward of the mangals (coastal types 5, 6 and 7). These shore-line types are not well developed elsewhere in the Pilbara. The limestone pavements along the seaward side of the barrier

islands are of special interest geomorphologically and create the conditions for the development of the particular mangal types which characterise this section of the coast.

In addition to its varied coastal geomorphology, this sector contains perhaps the most diverse mangals on the Pilbara coast. One stretch of over 75 km of the shore, on either side of the delta of the Robe River, is dominated by mangal habitat. It is structurally diverse and isolated from the mangals of the Fortescue Delta to the north and the Exmouth Gulf complex to the south.

In addition, this sector includes an important segment of the nearshore shelf-island system typical of the inner Rowley Shelf west of Dampier. There are many small, low islands close to the mainland shore which frequently have fringing mangals of the muddy tidal flat type and intertidal mud flats around them. Intertidal mudflats and rock pavements are particularly well developed around the Mary Anne Group of islands.

Marine flora and fauna

There have been no systematic surveys of the marine habitats, flora or fauna of this sector although V. Semeniuk and D. Walker (pers. comm. July, 1992) have examined the mangal and coastal geomorphology and seagrass communities in some detail.

The main significance of the marine environment of this sector is the diversity of coastal geomorphology and type of mangal development, and the importance of the mangals as a source of nutrients for the adjacent marine ecosystem and as a nursery area for fisheries.

Johnstone (1990) recorded brief notes on the mangal at the mouth of the Cane River. Near the mouth of the river on its north side there is a *Rhizophora* forest to a height of 8 m, backed by tall, mature *Avicennia* forest and woodland. Further upstream on the northern bank the *Rhizophora* trees are not so tall and often mixed with *Avicennia*. Some *Ceriops* and low *Avicennia* grow on the landward side. Thickets of closed *Ceriops* and *Aegiceras* grow on the sandy islands between the river channels.

The extensive mudflats and sandflats fronting the limestone barrier islands are the habitat of very rich epibenthic and burrowing invertebrate faunas. The flats are also much used by migratory waders as feeding areas.

In the shallow sublittoral zone there are extensive seagrass and algal beds on rock pavements. Turtle and dugong feed on these areas and turtles nest on the beaches.

The waters are turbid but nonetheless there are many corals wherever there are firm substrates in the sublittoral zone.

Recreation

There is moderate recreational use of the coast in the south-western part of this sector, especially in the vicinity of Onslow. However, the north-eastern mangal is inhospitable and inaccessible from the land and so is little used. The adjacent islands and waters are also visited infrequently by recreational fishers. The islands have very little potential for tourism.

Previous recommendations

The EPA (1975, System 8, rec. 8.7) recognised the importance of these mangals as a source of nutrients for the adjacent marine ecosystem and a nursery area for fisheries and recommended that biological and sedimentological surveys be carried out to assess their significance in these respects. Detailed surveys have not been done but further information is available.

The EPA (1975, System 8, rec. 8.4) recommended that all the islands from the Mary Anne Group to South West Regnard Island be declared Class B nature reserves. The EPA (1975, System 9, rec. 9.7) also recommended that Weld Island should be declared a Class A nature reserve and other islands west of this be considered for declaration as Class B nature reserves.

Working Group recommendations
Although available information and inspection of aerial photographs clearly indicate that this sector contains many significant geomorphological and biological features, the Working Group was not able to recommend any particular section of it for reservation because of the lack of adequate information. Field survey work is needed to establish which areas most adequately represent the variety of geomorphology, habitats, flora and fauna that are present.

However, the Working Group noted that the nearshore islands of the northern part of the sector, that is between Sholl and Yammadery Islands, have recently been collectively designated as the Great Sandy Island Nature Reserve (see Map III-8). Should the results of field surveys indicate that the northern part of this sector contains geomorphology, habitats, flora and fauna suitably representative of the sector, there would be merit in selecting the waters surrounding those islands for designation as a marine reserve.

Therefore the Working Group recommends:

> "1. That there should be a survey of the marine habitats, flora and fauna of the Robe mangal and adjacent nearshore waters to identify areas of particular conservation value in terms of mangal habitat, prawn and fish nursery areas, dugong and turtle feeding areas, and marine flora and fauna generally.
>
> "2. That, unless the results of the survey indicate that the most desirable areas for marine conservation are elsewhere within the sector, consideration should be given to the declaration of the waters surrounding the islands designated as the Great Sandy Island Nature Reserve and encompassing the Robe mangal south to the Cane River, including the inactive delta of the Robe River.
>
> "3. That the strip of land between the High Water Mark of the area selected for designation as marine reserve and the boundary of the adjacent pastoral lease, should be added to the reserve."

3.9. Exmouth Gulf (Map III-9)

Exmouth Gulf is one of the largest embayments on the Western Australian coast. Its eastern and southern shores are dominated by mangal and mudflat habitats of great importance for nature conservation and for sustaining local fisheries.

Tenure
The hinterland of this section of the coast is occupied by pastoral leases. The strip of land between the High Water Mark and the seaward boundaries of the pastoral leases is vacant Crown Land. On the eastern side of the Gulf this boundary is difficult to locate because of the low nature of the terrain. Inshore islands along the sector are vacant Crown Land.

Almost the entire area is covered by petroleum exploration permits. Permit EP325 R1 covers most of the area while EP 342 intrudes into the northern part and EP166 R2 intrudes into the southern part. Small areas of the Gulf are also included within Permits EP41 R4 and EP359.

Geomorphology
Exmouth Gulf sits astride a significant boundary between the geomorphologically distinct Pilbara and Gascoyne coastal sectors (see Section 3.6 of Part I) with the dividing line being Sandalwood Peninsula. The eastern shore of the Gulf, which is mangal dominated, belongs to the former sector, while the western shore, including the mangal system of Gales Bay in the south-west, belongs with the Cape Range Peninsula to the Gascoyne.

The climate is arid and the streams which flow into it are small and flow only after cyclonic rains. However, at the north-eastern entrance to the gulf the Ashburton River discharges very large volumes of water when flooding and some of this probably temporarily affects the gulf.

The waters of the gulf are generally turbid. Although sheltered from strong prevailing winds the gulf is occasionally affected by cyclonic storms. Tidal range is about 3 m but storm surge, especially at the southern end of the gulf, may carry sea water well beyond the normal High Tide Mark.

The shelf-island system which characterises the West Pilbara near-shore marine environment (see Section 1.1.1) extends down the eastern shore to the head of the gulf. There are characteristic low limestone islands along the eastern side with muddy beaches and rock pavement shores. In some areas the intertidal rock pavements bear extensive macroalgal beds and coral and rocky shore communities.

Along the eastern shore from just south of Locker Point to Giralia Bay there is a mangal of distinctive character. Three of the major coastal types described in Section 1.1.2 are represented in this system. In the northern section the Ashburton delta is an excellent example of the active delta (coastal type 3). Further down the eastern side of Exmouth Gulf the shore represents the beach/dune coast (coastal type 8) and the sand dune hinterland coast (coastal type 11). Each of these contains its characteristic assemblages of mangal and other coastal habitats.

Landward of the mangals there are very wide supratidal flats which in many places are inter-fingered or merge imperceptibly with the low-lying, vegetated hinterland. The western boundaries of the adjacent pastoral leases are defined only by reference to the High Water mark, although its position is difficult to locate. Protection of these adjacent land areas is critical to the ultimate protection of the mangal ecosystem and consideration should be given to incorporation of a coastal strip above High Water mark into the proposed reserve, with clearly definable boundaries.

On the western shore of the gulf, ie. from North West Cape south to the Bay of Rest, the shore comprises narrow beaches backed by dunes and fronted by sand and rock flats. The Bay of Rest and Gales Bay contain small but complex mangal systems distinct from that of the gulf's eastern shore.

Marine flora and fauna

The eastern side of Exmouth Gulf south of Tubridgi Point is the site of one of the largest mangals in the State. It is crossed by transverse tidal creeks, backed by wide supratidal salt flats, and fronted by intertidal mudflats. There is no doubt that these mangals and flats are the source of much of the nutrient which supports the valuable prawn fishery in the gulf, and functions as a nursery area for juvenile prawns and other harvested species as well as unharvested species.

There has been fairly extensive survey of the prawn nursery areas and other fisheries of the gulf by the Fisheries Department but relatively little study on other aspects of the marine flora, fauna and habitats. WA Museum staff have gathered information on the invertebrate faunas of the mangals, especially molluscs (Wells, 1983) and decapod crustaceans.

Six species of mangrove are present in the mangals of Exmouth Gulf. The two bays at the head of the gulf have mangals of rather different structure (Johnstone, 1990). In Giralia Bay there is a seaward zone of *Avicennia*, mainly thick-trunked trees growing to 4 m. This gives way to a zone of low, closed forest (to 2 m) of immature *Avicennia* and scattered immature *Rhizophora*. The landward side of this mangal consists of open *Avicennia* woodland and stunted thickets. In contrast, the mangal at Gales Bay has a seaward zone of mature *Rhizophora* (to 4-5 m) succeeded by a central zone of mature *Avicennia* forest and woodland and, in some areas, mixed *Rhizophora* and *Avicennia*. The landward side grades into thickets of *Avicennia* with occasional *Ceriops*.

In addition to the range of mangal assemblages, this area contains significant mudflats and sand flats, with their associated epibenthic and burrowing faunas. These communities represent the most westerly of their type. Similar communities occur elsewhere on the Pilbara coast but do not extend beyond North West Cape. They contain a number of species endemic to the Kimberley-Pilbara region which are here close to the western limit of their geographic range.

In the shallow waters of the gulf fronting the mangals there are extensive seagrass beds (with at least 4 species) providing feeding habitat for turtles and one of the State's more important dugong populations. The dugong population in the eastern part of the gulf has been estimated to number about 1 000 animals (R. Prince pers. comm.).

Several low limestone islands fronting the mangals are nesting sites for seabirds including Osprey, Australian Pelican, Pied Oyster Catcher, Crested Tern and Fairy Tern. The mud and sand flats are significant feeding areas for a variety of migratory wading birds.

The shores and near-shore habitats of the western side of the gulf are quite different to those of the east. There are sand flats, often with rocky outcrops, sloping into the sublittoral zone. The invertebrate fauna along this stretch of coast is diverse and abundant. In the southern sector (just north of the Bay of Rest) the sea floor is stony with a shallow sand cover and supports extensive beds of soft corals and sponges.

Recreational and commercial uses

The beaches south of Exmouth are extensively used by local people for swimming and fishing. There is little swell and, except in easterly weather, this is a lee shore.

The eastern side of Exmouth Gulf is remote from the highway and major roads and has little access. It is little used for recreational fishing. There is more access to the southern end of the gulf and consequently a greater degree of recreational fishing there. The southern part of the gulf area is also popular with amateur net fishers.

The gulf itself is the site of the Exmouth Gulf Prawn Limited Entry Fishery (see Government Gazette No. 28, 17 March, 1989). In recognition of the importance of the mangal and adjacent shallows as a nursery area for prawns and other important species, the eastern side and southern end of Exmouth Gulf have been designated under Fisheries legislation as a prohibited area for the trawling industry. Commercial beach seine netting for mullet and whiting operates in the southern portion of the gulf.

The warm, sheltered and highly productive waters of the eastern shores of Exmouth Gulf lend themselves to mariculture and there are several existing and proposed sites for such developments.

Previous recommendations

The EPA (1975, System 9) noted that the mangals of this shore provide a supply of nutrients to the adjacent marine ecosystem as well as being a nursery area for fisheries and recommended :

> "that biological and sedimentological surveys be carried out in the coastal segment from Exmouth Gulf to Mary Anne Islands (rec. 9.8);
> that Simpson, Tent, Round and Whalebone Islands be declared Class A nature reserves (rec. 9.7.1);
> that consideration be given to declaration of other islands in the vicinity as Class B nature reserves (rec. 9.7.2)."

The recommended surveys have not been carried out but some further information is now available.

Working Group recommendations

The distinctive eastern mangal and adjacent coastal waters of the gulf already receive a measure of protection under the Fisheries Act. Marine reserve status would enhance that protection. Reservation of the supra-tidal flats between the mangal and the hinterland would be essential to ensure adequate management of the mangal and coastal habitats of the marine reserve. Although they represent a different mangal type, the mangals of Gales Bay and the Bay of Rest should be included in the reserve. By extending the reserve north along the south-western shore to a point in the vicinity of Learmonth a section of the very different habitats of the western shore would be included. Reservation of a small section of the coastline near Exmouth would then adequately represent the western shore habitats.

Accordingly the Working Group recommends:

> "1. That the nearshore waters on the eastern and south-western sides of Exmouth Gulf be considered for reservation for the protection of mangal habitat, prawn and fish nursery areas, turtle and dugong feeding areas, and coastal marine fauna and flora generally, and for recreational fishing and such commercial fishing and mariculture as may be consistent with the former purposes.
>
> "2. Boundaries:
> (a) that the north-eastern limit of the proposed marine reserve should be located at Locker Point and the south-western limit in the vicinity of Learmonth;
>
> "(b) that the marine area reserved should extend from the High Water Mark seaward to about the 10 m bathymetric contour, or some suitable straight lines approximating that contour;

"(c) that the 40 m strip of vacant Crown Land between the adjacent pastoral leases and High Water Mark should be added to the marine reserve by reservation under the Land Act, together with such portions of the adjacent pastoral leases as will produce simple, clearly definable boundaries.

"3. That the EPA 1975 recommendations for declaration of islands in the area as nature reserves should be implemented as soon as possible. The Working Group is of the view that all the island nature reserves should be designated as Class A."

3.10. West Pilbara Offshore Islands (Maps III-8, 9)

Offshore along the coast west of the Dampier Archipelago and within the outer or oceanic zone of the Rowley Shelf there is a series of islands, mostly comprising Holocene sand cays and Pleistocene or Tertiary limestones. The waters around the outermost of these islands are relatively clear, approximating oceanic conditions, and so are quite different from those surrounding the islands nearer the mainland coast where muddy conditions prevail. The largest of these offshore islands are Barrow and the Monte Bello Islands complex, the Serrurier Islands group, Thevenard Island, and the North and South Muiron Islands, all of which are reserved for conservation of flora and fauna.

Barrow and the Monte Bello Islands are emergent structures on a distinct sublittoral platform and are dealt with separately in Section 3.11.

Thevenard Island has marine habitats most like the turbid conditions around the inner islands which are represented in the proposed marine protected areas along the coast. The surrounding waters are also subject to disturbance by the operations of the petroleum industry. For these reasons this area was not considered to be a strong candidate for reservation.

The Serrurier and the Muiron groups, on the other hand, have rather distinctive marine habitats surrounding them and they are considered in this section.

3.10.1 Serrurier Islands

The Serrurier Island complex is a group of offshore islands and emergent rocks at the western end of the Rowley Shelf. There are three medium-sized islands in the group, Serrurier, Flat and Bessieres.

Tenure

The Serrurier Islands comprise a Class C Nature Reserve for the protection of seabirds and turtles and their nesting sites. They fall within Petroleum Exploration Permit TP/6 R1.

Geomorphology

This island group represents the coastal type described in Section 1.1.3 as island type 3, composed of shelly or ooid Pleistocene limestones and Holocene sands. They are similar to some of the Pilbara coastal islands but lie within the offshore zone described in Section 1.1.1 which is characterised by clearer water (see Map III-8). As well as the three medium-sized islands, there are several small Pleistocene limestone and Holocene sand islands and emergent rocks, namely Round and Table Islands, Hood Reef, Black Ledge and Bowers Ledge. These emergent structures stand on a shallow bank of 5-8 m depth. Because of the distance from the muddy mainland, the littoral and shallow sublittoral soft substrates on the seabed surrounding the islands are fine to coarse-grained calcareous sand rather than muddy sand.

Marine flora and fauna

Wedge-tailed Shearwaters, Silver Gulls, Ospreys, White-breasted Sea Eagles, Caspian Terns and Crested Terns nest on these islands. The Serrurier Island Wedge-tailed Shearwater rookery is the largest for the species in the Pilbara region.

Serrurier Island is also an important nesting site for Green Turtles and possibly other turtle species.

There has been no systematic survey or collecting of the marine flora or fauna of this area. Inspection of aerial photographs indicates that there is a variety of habitat types present including sublittoral and intertidal rock pavements, sand flats, algal beds and well developed seagrass beds in the shallows.

There are extensive coral reefs around the front edges and reef-front slopes of the rock platforms. These have been inspected in the field by CALM staff. Coral growth is luxuriant - possibly the best in the Pilbara from a scenic point of view. Coral reef fishes and other associated fauna appear to be correspondingly diverse.

From the photo-interpretation of habitats, field inspections by CALM staff, anecdotal reports by shell-collectors and recreational fishermen, and the clear water conditions, the Working Group concludes that fish and invertebrate species diversity is likely to be high. Although the marine communities around the Serrurier group undoubtedly share many species with the sand, mud and rock flats of the mainland and inner island shores, there is likely to be a larger proportion of coral reef species and somewhat different community structure.

The other offshore island and reef complex of this nature in the vicinity is Thevenard. Although there are no detailed data on the faunas and floras of these two groups to allow a proper comparison, the Working Group believes that the more remote location and clearer water conditions of the Serrurier complex make it a much better candidate for designation as a marine protected area.

In some respects the Serrurier coral reef complex is a match for the Lacepede reefs much further north. Both are mid-shelf fringing reef systems growing on Pleistocene rock platforms. When survey data are available, the coral reef faunas of these two areas will make an interesting comparison. Together with the coral reefs of the Rowley Shoals Marine Park, the proposed Dampier and Monte Bello Marine Parks, and the proposed Biggada (Barrow Island) Marine Nature Reserve, they would adequately represent the varied coral reef systems of the Rowley Shelf.

Serrurier Island and its surrounds have many attractions for recreational fishers and divers. There are few such attractive islands in the western Pilbara. There are several safe anchorages and landing sites for small boats on Serrurier and the distance from the mainland is only moderate so that it is accessible to recreational fishers and campers. Camping is allowed on the island only by permit but that rule is difficult to enforce.

3.10.2. Muiron Islands

The two elongate, medium sized, sparsely vegetated Muiron Islands, North and South, lie at the western end of the Rowley Shelf, not very distant from the shelf edge. Sunday Island is a small limestone and sand island south-east of the two main islands in the group, near the mouth of Exmouth Gulf.

Tenure

North and South Muiron Islands comprise Class C Nature Reserve (No. C31775), for the conservation of flora and fauna, jointly vested in the National Parks and Nature Conservation Authority and the Shire of Exmouth. They lie within an area covered by Petroleum Exploration Permits EP 342 and TP/9.

Geomorphology

North and South Muiron Islands lie within the Exmouth Sub-basin of the Carnarvon Sedimentary Basin and are structurally a continuation of the Cape Range Peninsula. In Section 1.1.3 they are classified as offshore island type 2. They are low, dome-shaped, limestone islands separated by a deep, navigable channel. Their western shores face the prevailing swells and are characterised by low limestone cliffs fronted by wave-swept sandy beaches and intertidal rock platforms covered by algal turf and thin sheets of sand. Their eastern shores comprise sand beaches backed by low dunes. To the south-east, Sunday Island is an example of the offshore islands composed of Pleistocene ooid limestones and Holocene sands, classified in Section 1.1.3 as island type 3.

To the west of the islands the sea floor slopes away to the shelf edge some 30 km seaward. The reef-front slope beyond the edge of the intertidal rock platforms is deeply dissected by a prominent spur and groove system, usually with prolific coral growth, at least on the spurs. Beyond the reef slope the sea floor is rough with irregular limestone rock and coarse sand patches. Soft and hard corals grow on the exposed areas of hard rock. Structurally the reef-front zone of these windward reefs is similar to the equivalent zone of the Ningaloo Reef along the western side of the Cape Range peninsula.

The eastern shores are less exposed to the prevailing wind and swell and are characterised by gently sloping sand with numerous patch reefs and coral bommies. To the east and south the sea floor levels out, with moderately level, muddy, soft substrates which form part of the trawling grounds of the Exmouth Gulf prawn trawl fishery.

Marine flora and fauna

The islands are important seabird nesting rookeries, most notably of the Wedge-tailed Shearwater. Green turtles nest on the beaches.

The inshore reef fishes around South Muiron Island were sampled by Mr J.B. Hutchins of the WA Museum in June 1977. He recorded over 330 species of fish from a limited period of collecting. His field report (WA Museum unpublished file note) observes that in terms of abundance and diversity, the inshore fish fauna is very similar to that of the Ningaloo Reef. Fairly comprehensive collections of fishes have also been made from the nearby trawl grounds.

There have been no systematic surveys of the marine habitats, flora or invertebrate fauna of the shores and surrounding waters of the Muiron Islands. One of the Working Group members (BRW) has made cursory inspections and collections of invertebrates at several intertidal and sublittoral sites around South Muiron Island. The sublittoral coral reef fauna and habitats of the west side seem to be much the same as those of the reef-front zone of Ningaloo Reef. The patch reef and sandy sea-bed habitats of the more sheltered eastern side are comparable to those of the deeper parts of the back-reef and lagoon of Ningaloo Reef.

Of particular interest are the intertidal rock platforms along the western shores of the islands. They are similar in structure to the rock platforms at North West Cape in the Ningaloo Marine Park, and are similarly wave-swept and covered with an algal turf. This habitat type is a feature of the Western Australian west coast south of Cape Cuvier (a different biogeographic zone) but is uncommon in the tropics. The only other comparable rock platforms on the Pilbara coast are on the west side of Barrow Island and the north sides of Kendrew and Legendre Islands in the Dampier Archipelago (see 3.11.2 (i) and 3.6).

Recreation

The islands are bleak, waterless, sparsely vegetated and severely wind swept. There have been several proposals in the past for establishment of accommodation and facilities for recreational fishermen on the islands. Access from the nearby port of Exmouth is easy and accommodation and support facilities are readily available there.

Nevertheless, as the tourism industry of Exmouth develops, increasing day-use of the islands and their surrounding marine resources is inevitable, especially for recreational fishing and SCUBA diving. There are already anecdotal accounts of deterioration of the fish stocks in the area, reputedly due to over-fishing. Local people have put the argument to members of the Working Group that tighter controls on recreational fishing in the Ningaloo Marine Park have led to an increase in fishing pressure at the Muirons. Some form of increased management of recreational fishing may be necessary at the Muirons to ensure continuity of this socially and economically important activity.

There is potential for development of commercial nature and dive tours to these islands from the tourist town of Exmouth. Seabird and turtle nesting provide a particularly interesting spectacle, in season, although visits by groups of people must be carefully controlled to avoid disturbing the animals.

Previous recommendations

There have been no previous recommendations for declaration of marine protected areas at the Serrurier Islands.

An IUCN report (Hatcher, 1988) recommended that "due to the similarity between the marine faunas of the islands and the Ningaloo area" the Muiron Islands should be added to the Ningaloo Marine Park.

Working Group recommendations

The waters around the islands and reefs of the Serrurier group are representative of the offshore marine habitats of the western Rowley Shelf. They also have potential as a resource for recreation and tourism.

Due to increasing use of the marine resources of the waters around the Muiron Islands there is a need for increasing management, that is, facilitating access while protecting the environment and its living resources. Reservation of the area as marine park is one means of providing a basis for management.

Accordingly the Working Group recommends:

> "1. Serrurier Island Group
> "a) That an area of waters encompassing Flat, Serrurier, Bessieres, Round and Table Islands and Hood Reef, Black Ledge and Bowers Ledge be considered for reservation for the purposes of public recreation and protection of marine flora and fauna.
>
> "b) That an integrated Management Plan be developed for both the island Nature Reserve and the surrounding marine reserve, with provisions for recreational fishing and for camping ashore during those seasons when seabirds and turtles are not nesting.
>
> "2. Muiron Islands
> That an area of the waters encompassing the Muiron and Sunday Island group be considered for reservation for the purposes of public recreation and protection of marine flora and fauna, subject to:
>
> > "a) a survey of the marine flora and fauna and habitats surrounding the Muiron Islands and comparison with those of the Ningaloo Marine Park.
> > "b) a study on the impact of current and anticipated future recreational fishing on fish stocks around the islands and a report produced on options for management, including the option of reserving the area as marine park."

3.11. Barrow-Monte Bello Complex (Map III-8)

The Barrow, Lowendal and Monte Bello Islands, lie approximately 120 km west-north-west of Dampier. They lie within the Barrow Sub-basin, an offshore trough of the Carnarvon Sedimentary Basin separated from the inner part of the North West Shelf by the Flinders Fault. Barrow Island itself consists of Tertiary and Quaternary limestones while the Monte Bello and Lowendal groups comprise Pleistocene limestones. Together they stand on an elevated sublittoral limestone platform, with the Monte Bellos separated from the others by a transverse channel of moderate depth.

The islands of these groups are reserved either as Nature Reserve or Conservation Park although Barrow Island and the Lowendal Islands are leased to petroleum companies under the powers of the Petroleum Act, 1937, for the development of oilfields. There are petroleum exploration tenements over much of the area.

To the north and west of the Barrow-Lowendal-Monte Bello system lie deeper waters of the continental shelf edge. To the south and east are the shallower waters of the shelf. The area is subjected to occasional extreme cyclonic weather and strong current flows. Spring tidal range is between 3 and 3.5 m.

The island complex lies within the offshore zone discussed in Section 1.1.1. The marine habitats of this group are more oceanic than those of the coastal waters closer to the coast, with less turbid water. The islands, together with the sublittoral ridge on which they stand, comprise a geomorphological and ecological unit which is unique on the coast and may be regarded as a major distinctive coastal type. There is at least one gastropod endemic to the sand substrate habitat of the Barrow-Lowendal-Monte Bello group, the direct-developing volutid *Amoria macandrewi.* Such endemicity may indicate that the sublittoral ridge has been isolated from other marine ecosystems for some time.

Within this geomorphological unit a variety of marine ecosystem types are represented (see Part 1, 3.7). Over much of its surface the sublittoral ridge is dominated by algal beds and sand habitats on the limestone pavement. The sands are well-sorted and moderately coarse-grained where there is water movement due to wave action or currents, but fine and muddy in the shallows of sheltered areas such as off the eastern shore of Barrow Island. Wide intertidal muddy sand flats, with an abundant and diverse infauna, are a significant feature of the eastern side of Barrow. A particularly good example of this type of habitat occurs in Bandicoot Bay at the southern end of the island.

Coral growth is extensive in the less muddy areas and there are well developed coral reefs along the western front of the group, most notably west and south of the Monte Bellos and at Biggada Reef on the west side of Barrow. There are large *Porites* bommies and other massive coral colonies in the channels and along the ridge between Trimouille Island and the Lowendal Islands. These reefs have not been surveyed and their species composition is unknown (see notes on corals at the Monte Bellos in Section 3.11.1).

There are sandy beaches and rock platforms on the western side of Barrow and small mangals in sheltered bays at several locations in the group. The shallow, structurally complex lagoons of the Monte Bellos are a unique feature of the group.

The Barrow Sub-basin is the site of an established oilfield, with both island and off-shore production wells, storage tanks and pipe-lines. The intertidal sand flat, rock platform, coral reef, mangal and lagoonal habitats of the area are particularly vulnerable to oil spills and the Working Group believes that there is a need for a marine management plan covering the whole area, aimed at protecting the significant marine habitats and flora and fauna.

Three marine protected areas are recommended, one covering the northern end of the system, ie. the waters surrounding the Monte Bellos and the others consisting of small areas on the western side and southern end of Barrow Island.

3.11.1. Monte Bello Islands

The WA. Museum carried out a survey of the marine habitats and biota of the Monte Bellos in 1993 for the Department of Conservation and Land Management but the completed results of that project were not available in time for incorporation in this report. Nevertheless some observations of the survey team are noted.

History

The English ship *Tryal* was wrecked on what are now known as the Tryal Rocks just north of the Monte Bello Islands in 1622 and the crew spent seven days on the islands before sailing to the East Indies. The islands were named by the French Baudin Expedition which passed by in 1801. British hydrographic surveys were made in 1818 (King, 1827) and 1840 (Stokes, 1846). The report by Stokes includes notes on the islands' natural history. The first detailed biological survey was done by P. D. Montague in 1912 (Montague, 1914). Sheard (1950) published a note on a visit to the islands.

In 1952 and 1956 the Monte Bello Islands were used as a nuclear weapons testing site by the British Government. For this purpose the islands and surrounding waters were declared a prohibited area under the control of the Australian Department of Defence (Special Undertakings Act, 1952). They remained under Commonwealth control until 1992 when control was returned to the State. Several reports on the terrestrial and marine flora and fauna were published following surveys associated with the weapons-testing program (see Burbidge 1971 and Deegan 1992 for references).

In 1966 West Australian Petroleum Pty. Ltd. drilled an exploratory oil well on Trimouille Island. Naturalist W. H. Butler visited the Monte Bellos at about that time.

Two visits were made to the Monte Bellos by officers of the Fisheries and Wildlife Department in 1970 and 1971, resulting in a report on the islands' flora and fauna and recommendations for future management (Burbidge, 1971). One of those recommendations was for action to eliminate feral cats from the islands.

Between 1903 and 1913 a pearling lease was held over waters in the Monte Bellos by a Mr Thomas Haynes. Campbell Island was reserved at that time for the "Water Pearling Industry" and remnants of Haynes' buildings and other structures may still be seen there. Haynes also collected mollusc specimens which were the substance of a published report (Iredale, 1914). A contemporary pearling lease exists over waters between Hermite and Campbell Islands.

In the context of the negotiations between the State and Commonwealth Governments prior to the return of the Monte Bello Islands to State jurisdiction, the Department of Conservation and Land Management prepared an unpublished draft Management Plan for the islands (pers. comm. Dr Keith Morris). A summary of marine resources and bibliography was prepared for the Department by Deegan (1992).

Tenure

While under the control of the Commonwealth the Monte Bello Islands had the status of vacant Crown Land. The agreement between State and Commonwealth authorities relating to the return of the area to the State included arrangements for reservation and management of both lands and waters of the archipelago as conservation reserve under State legislation.

The islands of the Monte Bellos were reserved on 7 July, 1992 as Conservation Park (Reserves Nos. 42196 and 42197) extending to low water level and vested in the National Parks and Nature Conservation Authority (Government Gazette, pp 3083-3084). At the same time an existing Land Act Reserve (No. 13517) for the purposes of "Water Pearling Industry" over Campbell Island was cancelled (Government Gazette: p. 3084).

Petroleum Exploration Permit EP 358 overlays the islands and waters of the Monte Bellos. The Harriet oilfield (production licence TL/1) overlaps the south eastern fringe of the area.

Two small portions of North West Island and Trimouille Island are excised from the Conservation Park and are leased to the Commonwealth for the operation of a lighthouse.

Geomorphology

The Monte Bellos are the most seaward and remote of all the Rowley Shelf islands except for the Rowley Shoals themselves. Their physiography has been described by Deegan (1992).

The Monte Bello Islands represent the island type 3 referred to in Section 1.1.3. They are low lying and include 95 islands larger than 50 metres in length and 170 smaller islets and stacks. The largest island is Hermite (970 ha.), followed by Trimouille (450 ha.), North West (120 ha.), Alpha (115 ha.) and Blue Bell (64 ha.). They are composed of Pleistocene limestones and calcareous and ferruginous, cross-bedded sandstones, capped in places with consolidated or active sand dunes with elevations up to 40m. Most islands are bare rocky terrain without any beaches.

Except for North-West and Trimouille, the medium to large-sized islands in the group have sinuous, convoluted coastlines. Many are long and very narrow and all exhibit the effects of erosive forces of strong currents. The central chain of islands from Ah Chong northwards is a relict of what was, in Pleistocene times, a continuous landform which has been subsequently eroded to a multitude of islands of varying size. The extremely convoluted coastline of the modern islands provides not only attractive scenery but also varied habitats for intertidal and nearshore fauna and flora. In contrast, North-West and Trimouille Islands are composed of accumulated sands derived from beach growth and from aeolian-formed parabolic dunes.

Most of the shorelines are rocky but there are some sandy beaches.

Coral Reefs

The main (barrier) reef, which is about 12 km long, forms the seaward border of the archipelago on the western or windward side, with a wide discontinuity in the south where several patch reefs occur. The reef-front slope is not steep and has no distinct "spur and groove" development. There is a wide reef flat but it has no distinct crestal area and is composed largely of consolidated coral rock slabs, interspersed with sand and some accumulations of loose boulders. There are several large breaks in

the reef forming deep channels. Tabular *Acropora* corals grow profusely along the edges of the channels.
There is a structurally complex back reef system with many patch reefs among and around the islands, separated by the maze of channels, banks, sublittoral pavements, and lagoons. The complex back-reef complex appears to have developed on a previous karst landscape and is similar in structure to some areas in the Abrolhos. On the eastern side of the archipelago there are many patch reefs but no reef flat or rampart comparable to that of the western side.

At the southern end of the archipelago, south of Hermite Island, there is a different coral reef structure. Here many small patch reefs have developed over a broad, shallow, sublittoral, limestone rock pavement which extends south to the Lowendal and Barrow Island groups. The rock pavement is cut by several deep channels. Except for the patch reefs the pavement is covered for the most part by algal turf and shallow deposits of sand. The back-reef is influenced by the strong west-flowing currents and is structurally controlled by previous karst landforms similar to those of the northern area.

The extensive development of barrier reef, back-reef, patch reef, pavement patch reef and lagoonal habitats in such close proximity is a feature of the Monte Bello group without parallel in Western Australia.

Within the Monte Bello complex there are many shallow lagoons and bays and a maze of narrow channels. There are two main lagoons, one between the central island chain and the western barrier reef, and the other between the island chain and Trimouille Island. The waters of the lagoons are turbid and have extensive areas of sand substratum. The channels mostly run between the islands of the central chain. They also have turbid water but, because of strong currents that flow through them, they have mostly coarse sand and rubble substrates and extensive exposures of limestone pavement where scouring occurs.

Within the bays protected from severe wave action and tidal scouring, there are extensive intertidal flats composed of fine sand with low organic content. Some of the bays have simple mangals.

Flora and fauna
The Monte Bello Islands and surrounding waters have several distinctive features which together make the area unique and valuable for conservation. P. L. Montague visited the islands in 1912, collected both terrestrial and marine specimens, and subsequently published a report (Montague, 1914). Some of his specimens were later described and named by other workers so that the Monte Bellos are the type locality of several species. Since the early visit by Montague several surveys of the terrestrial flora and fauna of the Monte Bello Islands have been carried out (see Burbidge, 1971 for summary and references).

According to Burbidge (1971) and Morris *et al.* (1988) the nuclear tests have had no appreciable effects on the terrestrial flora and fauna of the islands. Regular radiological monitoring since 1962 has demonstrated that there is no significant residual radioactivity likely to be of concern to visitors in most parts of the islands although certain localities should remain as prohibited areas for prolonged visits.

Terrestrial fauna and flora
Two species of marsupial (Spectacled Hare Wallaby and Golden Bandicoot) inhabited the Monte Bello Islands until early this century when they became extinct, probably as a result of feral cat predation or drought. There is considerable potential for re-establishing these threatened species on the islands if cats and rats can be eradicated.

Marine flora and fauna
The islands are particularly important as habitat for marine species. At least 2 species of marine turtle (Green and Hawksbill) nest on the beaches. Twenty six species of seabird and waders have been recorded from the islands (Serventy & Marshall, 1964; Burbidge, 1971). Seabirds which nest on the islands include the Crested Tern, Caspian Tern, Pied Oyster Catcher, Sooty Oyster Catcher, Osprey, White Breasted Sea Eagle, Beach Curlew and Wedge-tailed Shearwater.

The maze of shallow channels, lagoons, and both sandy and silty bays provide an extraordinary range of substrate, depth, turbidity, current, and wave exposure conditions. Some habitats are heavily influenced by the dominant westerly currents surging through gaps and passages in the islands and reefs, while others are relatively sheltered from the currents. The structural variety of the system creates exceptional habitat diversity.

Hill (1955) recorded 28 species of fish from the Monte Bellos in a report on the natural history of the islands based on studies during preparations for the 1952 nuclear weapons tests. The recent WA Museum survey recorded 457 species of fishes, a number greater than that known from the Dampier Archipelago and almost as large as the number recorded from Ningaloo Reef (G. R. Allen, pers. comm.).

Until recently, study of the marine invertebrates had been cursory (Iredale, 1914, Preston, 1914 and Robson, 1914 on molluscs; Rathburn, 1914 on crustaceans). Even though the recent WA Museum survey was brief, it has provided the first extensive information on the invertebrate fauna of the archipelago. The survey recorded 141 species of scleractinian corals, making a total of 150 species now known from the area. It was observed that the coral community at the Monte Bellos is characteristic of moderately clear conditions and is similar to that known from the Dampier Archipelago (L.M. Marsh, pers. comm.). The molluscan fauna is particularly noteworthy, judging from the results of the Museum survey which collected 595 species, making a total of 633 species now recorded from the Monte Bellos (F. Wells, S. Slack-Smith & C.W. Bryce, pers. comm.). This high diversity is interpreted as a result of the extremely varied habitats. In particular, the large expanse of semi-lagoons and intertidal sand flats with their variety of sand habitats were found to support a high diversity of burrowing, filter-feeding bivalves.

Associated with the sand and mudflats in the bays there are numerous areas of mangal ranging in size from isolated mangrove trees to more than 15 hectares. These are scattered throughout the islands in sheltered embayments and are particularly prevalent on Hermite Island. At least four species are present (*Avicennia marina, Rhizophora stylosa, Ceriops tagal, Bruguiera exaristata*).

Algal Flats
Extensive algal beds occur on the sublittoral pavements, especially in the southern part of the Monte Bello complex. There is no information on the species composition of these communities but a high diversity is certain.

Recreation
Although the Monte Bellos are distant from the mainland, there are many excellent anchorages in the archipelago for even quite large vessels. Several charter boats operate fishing, diving and shell-collecting tours there. Small private vessels frequently visit the islands and commercial fishing boats often anchor there for rest and recreation periods.

There is little scope for development of holiday accommodation on these low, sparsely vegetated islands, which are quite lacking in surface water. More bleak "desert islands" would be hard to imagine. Yet there is no doubt that the extraordinary landscape, human history, natural history, and underwater scenery are extremely interesting and attractive. It seems likely that the archipelago will become increasingly popular as a destination for sea-borne visitors seeking a maritime experience in remote and environmentally severe circumstances.

Previous recommendations
Burbidge (1971) recommended that Hermite Island, the largest in the group, should be declared a Class A nature reserve and that the other islands in the group be declared Class A reserves for conservation and tourism. Burbidge was the first to recommend that surrounding waters be made a marine park. In 1975 the EPA (System 8, rec. 8.2) made similar recommendations for the islands, except that it proposed that (with the exception of Hermite) they be reserved for the purpose of "Recreation and Conservation of Flora and Fauna". The EPA did not mention marine park.

An IUCN report (Hatcher, 1988) recommended a marine ecological survey of the area.

3.11.2. Barrow Island

Tenure

Barrow Island is a Class A Nature Reserve extending to the low water mark, and is vested in the National Parks and Nature Conservation Authority (Reserve No. 11648). Middle Island and Boodie Island immediately south of Barrow together form a Class C Nature Reserve vested in the National Parks and Nature Conservation Authority.

Initial development of the Barrow Island oilfield by Western Australian Petroleum Pty. Ltd. (WAPET) was authorised by a special Act of State Parliament (Act No. 85 of 1966). Subsequently, under the provisions of the Petroleum Act, 1937 (replaced by the Petroleum Act, 1967-87) WAPET was granted a lease over Middle Island and most of Barrow Island for the development of an oilfield. The lease was renewed for a further 21 years in 1988. Boodie Island is not included in the lease. WAPET Production Licenses TL/3 and L10 cover most of the island and surrounding waters; Boodie Island and the south west corner of Barrow, plus the waters to the south-west and south, are covered by oil Exploration Permit TP/2.

Under the terms of its lease the company maintains a workforce on the island and controls access. An environmental protection and nature conservation program is in place and strict measures are taken to ensure compliance. The company supports research on the flora and fauna of the island and adjacent waters.

Geomorphology

The geomorphology of Barrow Island is summarised in an Environmental Review submitted to the Environmental Protection Authority by WAPET in 1989.

The east coast of Barrow has low cliffs of Pleistocene coastal limestone fronting stony and muddy intertidal flats which are hundreds of metres wide in some places. Wave action is slight on the east coast. The west coast is rugged, deeply dissected, with high, Miocene limestone cliffs. It is subjected to relatively strong wave action. Wide rock platforms are cut into the shore in many sectors, alternating with long sandy beaches. At the southern end of the island there is a major embayment known as Bandicoot Bay.

Flora and fauna

Barrow Island is one of Australia's most important conservation reserves. It is a refuge of several threatened native mammal species. Through co-operation between the State Government and WAPET appropriate environmental management of the island habitats, flora and fauna is assured.

In practical terms, through control of access, the significant conservation values of the island's shore-line environment are also protected. Nevertheless, the Working Group believes that there would be advantage in reserving two areas of water adjacent to the island for conservation purposes.

(i) *West coast*

At Turtle Bay near the mouth of Biggada Creek on the west side of Barrow Island, there is a small but significant fringing coral reef. It extends in an arc for about 1 km northwards from the cliff base at the southern end of the bay, enclosing a shallow lagoon. The coral grows on a limestone base. It is emergent at its southern end where it joins the shore but submerged at its northern end. Its outer edge has a dense cover of living coral and there are groups of coral heads in the lagoon. There has been no systematic collecting of the coral or other marine fauna, although Hatcher (1988) gives a list of coral genera collected there.

North of Turtle Bay, along a stretch of shore known by WAPET as "John Wayne Country", there is a section of cliffs fronted by beach and wave-swept, limestone rock platform. The platform is covered with a thick algal turf. There has been no sampling of its flora or fauna. Nevertheless, this habitat type is very poorly represented in the proposed marine reserve system of the Pilbara and the Working Group is confident that there are adequate grounds for reserving a section of it. Similar rock platforms occur commonly along the mid-west coast of Western Australia south of Cape Cuvier but they are in a different biogeographic zone. In the tropical zone of the North West Shelf the equivalent structures found on inner shelf island and mainland shores are subject to less wave action and greater turbidity. Wave-swept rock platforms in semi-oceanic conditions occur only on the west

side of Barrow and the Muiron Islands, and perhaps the north side of Kendrew and Legendre Islands in the Dampier Archipelago.

The wide sandy beach of Turtle Bay is a major nesting site of the Green Turtle (*Chelonia mydas*).

(ii) *South-eastern sheltered sand flats*
At the southern end of Barrow Island there is a wide embayment known as Bandicoot Bay in which there is an excellent example of the oceanic intertidal sand flat habitat. The bay is protected from the prevailing westerly ocean swell by the South End Peninsula and by Middle and Boodie Islands, although passages between the islands and the peninsula permit circulation of oceanic water into the bay. Consequently there is a range in sediment type with coarser sands in the west grading to muddy sands in the eastern portion, similar to the muddy flats typical of the eastern shore of Barrow.

In 1966 a field party from the WA Museum and Smithsonian Institution (Washington) intensively studied the intertidal and shallow sublittoral invertebrate fauna of this area. The very large collections obtained are now lodged with the two museums. Several new species have been described from this material. The burrowing fauna is both abundant and diverse. Because of the range of substrate type and water circulation conditions there is a variety of micro-habitats and community types.

The Working Group noted that WAPET presently prohibits staff from shelling and fishing in this area except at three small points (two on South End and one at Stokes Point). However, access to these waters by people from the mainland or elsewhere cannot be controlled in this way. If the area was declared a nature reserve such activities would be prohibited automatically. If it was declared a marine park, recreational fishing would be permissible, subject to regulation.

The Working Group also noted that the WAPET oilfield extends over Bandicoot Bay and that there are several production wells within the proposed marine reserve. As the Company's rights to develop the oilfield are already established under the authority of the Petroleum Act, declaration of the reserve would not impede such operations in the area. The effect of reservation would be to provide a legal basis for prohibition of fishing and shell-collecting, and for control of access to these waters by the marine park management authority.

Recreation
Public access to Barrow Island is prohibited under the terms of the WAPET lease. Company workmen are permitted to recreate (fishing and swimming) on the shore, subject to strictly enforced conditions. As the WAPET lease will remain in force for the foreseeable future there are no prospects for public recreation or tourism on this island.

Previous recommendations
Previous recommendations by the Fisheries and Wildlife Department (Burbidge, 1971) and the Department of Conservation and Environment (Conservation Reserves for WA, 1971) for reservation of the Monte Bello Islands for conservation and recreation have been put into effect by declaration of the Monte Bello Conservation Park (Government Gazette, 7 July, 1992).

The Fisheries and Wildlife Department recommendations (Burbidge, 1971) also included the following: "That some of the waters surrounding the islands be declared a marine reserve - a possible area might be all the waters within half a mile of Hermite and Campbell Islands." The Department of Conservation and Environment (1971) made no reference to marine reserves at the Monte Bellos.

The IUCN report on coral reefs of the world (Hatcher, 1988) described and noted the significance of the Monte Bello coral reefs and recommended a "full marine ecological survey", and that "some degree of protection be afforded" to the area. The same report (pp. 8-9) briefly described the Biggada coral reef on the western side of Barrow Island and recommended a detailed study to determine its significance.

Working Group recommendations

While noting that the Barrow-Monte Bello-Lowendall island complex comprises a distinct coastal type with very significant conservation values, the Working Group considers that appropriate protection and management can be achieved by reservation of parts of the area, combined with designation of the remainder as an environmentally sensitive area needing special management.

Accordingly the Working Group recommends:

"1. Monte Bello Marine Park

"a. that the waters encompassing the Monte Bello Islands, southwards to the channel separating the group from the Barrow-Lowendal groups, be declared a Class A marine reserve for public recreation and protection of flora and fauna, ideally with boundaries located at the limit of State territorial waters along the western and northern sides and following the edge of the sublittoral ridge on the eastern side;

"b. that the present pearl oyster lease within the marine reserve continue but that the issue of any further leases, or approval for the expansion of the existing lease, be subject to careful review taking account of possible environmental impacts.

"2. Barrow Island

"a. Biggada Reef - that a stretch of the western coast of Barrow Island between Cape Malouet and Cape Poivre, encompassing Turtle Bay, the Biggada coral reef, and a section of rocky shore, be considered for reservation for protection of marine flora and fauna. The precise seaward, northern and southern boundaries should be determined in consultation with WAPET after further study of the coastal flora and fauna and marine habitats of the area;

"b Bandicoot Bay - that an area east of South End, Middle Island and Boodie Island to a line southward from Stokes Point and encompassing Bandicoot Bay, be considered for reservation for protection of marine flora and fauna. The precise boundaries should be determined in consultation with WAPET after further study of the flora and fauna and marine habitats of the area."

A REPRESENTATIVE MARINE RESERVE SYSTEM FOR WESTERN AUSTRALIA

Report of the Marine Parks and Reserves Selection Working Group

PART IV

MARINE RESERVES ON THE WEST COAST

CONTENTS

PART IV: MARINE RESERVES ON THE WEST COAST

1. INTRODUCTION

In accordance with common usage by contemporary biogeographers the term "West Coast" refers to the north-south section of the Western Australian coast between North West Cape and Cape Leeuwin. (Hatcher, 1991 used the term "Leeuwin Province" for this zone.) It spans a distance of almost two thousand kilometres and 12 degrees of latitude, covering the latitudinal transition from the tropical to the warm temperate climatic zones. The Tropic of Capricorn crosses the coast just south of North West Cape. The West Coast sector conforms with one of the biogeographic zones described in the Council of Nature Conservation Ministers working paper on marine protected areas (CONCOM, 1985).

The West Coast is the most populous section of the Western Australian coast, with metropolitan Perth and two regional cities, Geraldton and Bunbury, located on its shores. Coastal waters and their living resources in the proximity of those centres are subject to intensive recreational use. The West Coast is also the site of important fisheries and offshore petroleum potential.

Several areas of the West Coast have very high conservation values. Shark Bay is a World Heritage Area. Ningaloo Reef is one of Australia's most extensive coral reef systems. The species-rich coral reefs of the Houtman Abrolhos are the most southerly in the Indian Ocean, being situated well south of the so-called "coral province" of the tropic zone, and are of extreme scientific interest.

A number of marine parks and a marine nature reserve have already been declared in this sector - Ningaloo Marine Park, Shark Bay Marine Park, Hamelin Pool Marine Nature Reserve, and Marmion, Shoalwater Islands and Swan Estuary Marine Parks in the metropolitan area. Nevertheless, the existing West Coast marine reserve system does not adequately represent its flora and fauna and recreational resources and the Working Group considered additional areas which may be worthy of reservation for conservation and recreational purposes.

The West Coast comprises a natural unit for the purposes of this study. North West Cape and Cape Leeuwin are regarded as boundaries between major biogeographic provinces. The marine flora and fauna and coastal geomorphology of the West Coast are moderately well studied and the Working Group was able to distinguish a series of major distinctive coastal types which formed the basis for division of the coastline into natural sectors. The habitats, biotic communities and recreational resources of each of these sectors were considered, leading to recommendations of areas worthy of consideration for reservation, supplementing the existing marine reserves.

The Working Group is aware that petroleum exploration permits exist over some of the coastal waters of the West Coast, including some of the areas identified here as being worthy of reservation for conservation and recreation purposes. These have been noted where they occur but they have not influenced this reserve selection process which is based on biological and geomorphological criteria and considerations of public recreation values. The needs of the petroleum industry and constraints which may be imposed by reservation would be addressed before any reserve proposal was taken further and when management plans were formulated.

1.1. Coastal geomorphology

The West Coast features a wide range of coastal landforms. Taken together with the climatic transition from tropical to temperate and the effects of ocean currents, coastal geomorphology has a profound influence on habitats of flora and fauna, and on human activities as well. The rich marine resources of the West Coast, including the western rock lobster and recreational fisheries, are dependent on the complexity of the nearshore marine habitats, especially those formed by the complex reef and island topography of the inner continental shelf.

The continental shelf of the West Coast is relatively narrow. At the northern end of this sector, just south of North West Cape, the shelf is merely 40 km wide. The seabed consists primarily of carbonate sands. Two distinct shelf areas are recognised, the Dirk Hartog Shelf in the north and the Rottnest Shelf in the south. Collins (1988) has described the sediments and history of the Rottnest Shelf. The two shelves represent seaward extensions of the two major Phanerozoic sedimentary basins fringing the western margin of the

continent, that is the Carnarvon Basin and the Perth Basin, lying along the western margin of the Yilgarn Craton and separated from it by ancient faults.

Both basins have great depths of sediment, mainly marine, and the process of deposition is on-going, forming coastal plains along the western margin of the continent. During the Pleistocene there was a series of marine transgressions and regressions across the surface of the coastal plains relating to the global cycle of interglacial and glacial conditions and changing sea levels. The succession of marine and wind blown sediments resulting from these events left remnants along the coastal lands of both basins and on the seabed along the inner part of the continental shelf.

In the last interglacial period of the Pleistocene, when sea level was close to its present position, an extensive dune system was formed along the coast which was subsequently consolidated to produce an aeolianite known as the Tamala Limestone. Today this limestone and its associated quartz sands form ridges of coastal limestone and chains of elongate ridges on the seabed offshore. Interfingered with the Tamala Limestone at many locations along the central part of the West Coast, is a coral reef and shell limestone known as the Rottnest Limestone, also deposited in the Late Pleistocene. Superimposed upon these Pleistocene limestones there is usually a thin veneer of Holocene sands (Safety Bay and Becher Sands) which may or may not be stabilised by vegetation.

Thus, the shores along much of the West Coast, particularly its southern section, essentially comprise a narrow ribbon of medium to fine, calcareous sandy deposits of Holocene age abutting or overlying Pleistocene limestones. Regional and local heterogeneity of coastal landform has been produced by variations of physical forces acting on the accumulation of these sediments. Searle *et al.* (1988) and Semeniuk *et al.* (1989) have identified several discrete geomorphic units of the coast according to the character of their sediments.

There are four important exceptions to this generalised account of the West Coast:

i) At the northern end of the sector marine Miocene limestones dominate the coastal geology. Pleistocene and Holocene limestones and sands form a surficial cover along most of the shore but the Miocene limestones outcrop along the shore at several locations as far south as Red Bluff (Map IV-2).

ii) At Shark Bay there is a wide surficial sheet of Pleistocene and Holocene dune deposits accumulated on low anticlinal ridges of Tertiary limestone on the western part of the Carnarvon Basin (Playford, 1990). The western dune ridges have consolidated to form the Tamala Limestone as elsewhere along the West Coast but this is a high energy shore and the limestones have eroded and formed continuous high cliffs. The sea has invaded behind the western barrier dune ridges and flooded the low-lying land behind producing the vast, sheltered shallows of Shark Bay and Hamelin Pool.

iii) At Kalbarri near the boundary between the Carnarvon and Perth Basins, the Tumblagooda Sandstone of Silurian age outcrops at the coast forming high cliffs.

iv) At the southern end of the Perth Basin, an outlier of the Yilgarn Craton known as the Leeuwin Block, consisting mainly of Proterozoic gneissic rocks, forms the extreme south western margin of the continent, separated from the Perth sedimentary basin by the Dunsborough Fault.

With this geological background, the Working Group has recognised 12 major distinctive coastal types along the seaward shores, as the first step in the selection of a representative marine reserve system on the West Coast, according to the methodology described in Part I. From north to south these are as follows (see Index to Maps IV).

1. ***Ningaloo Reef.*** The coast from North West Cape to Gnarraloo Bay is formed mostly of Pleistocene limestones and Holocene sands superimposed on the margin of an anticline of Miocene limestone. There is a protective barrier-fringing coral reef of great complexity and with a species-rich coral reef community. This is one of Australia's major coral reef systems. The reef is almost continuous and off-shore in the northern part but becomes an interrupted fringing reef in the southern part. There are no rivers in this sector although a number of seasonal storm creeks drain into the lagoon from the arid hinterland.

2. ***Red Bluff to Point Quobba*** . This is a high energy, rocky shore with low to high Pleistocene or Miocene limestone cliffs exposed to the westerly winds and swells. There are two semi-sheltered bays behind (east of) Red Bluff and Cape Cuvier respectively. Narrow intertidal rock platforms are dominated by algal growth. There is a small coral reef in a small impounded lagoon behind a protective limestone reef at Point Quobba.

3. ***Western shores of the Shark Bay outer islands and Edel Land Peninsula (Zuytdorp Cliffs).*** These are high energy, rocky shores with high Pleistocene limestone cliffs exposed to westerly winds and swells. Narrow intertidal rock platforms are dominated by algal growth. There are some coral colonies in tidal pools but no coral reefs except at the sides of the channels between the islands where there is less wave action.

4. ***Eastern shores of Shark Bay-Hamelin Pool.*** The eastern side of Shark Bay is a low energy shore of low relief with a mono-species mangal, wide tidal and supratidal flats, and a very large offshore carbonate bank. The extreme southern portion bordering Hamelin Pool is hypersaline and has extensive growth of stromatolites. Two major seasonal rivers (Gascoyne and Wooramel) enter the sea on this coast and have formed large deltas.

5. ***Inner inlets and peninsulas of Shark Bay-Hamelin Pool.*** The sheltered shores within Shark Bay consist of narrow beaches and low Pleistocene limestone or sandy cliffs. Seagrass meadows and carbonate sand banks dominate the sublittoral zone. There are no coral reefs. Some inlets are hypersaline.

6. ***Kalbarri*** . This is a short stretch of coast of moderately high energy with high Silurian sandstone cliffs which are strongly bedded and terraced. The intertidal rock platforms are dominated by algal growth and there are no coral reefs. The Murchison River enters the sea here and has a small estuary.

7. ***Abrolhos.*** This is an off-shore, shelf-edge unit comprising a series of coral limestone platforms and islands with prolific contemporary coral reef development. Seaward margins of the platforms are algal dominated with extensive growth of kelp in the sublittoral zone. Coral reef development occurs on the leeward margins and in the channels. There are intertidal rock platforms and some seagrass meadows. This coral reef complex is an outlier of the Indo-West Pacific coral reef province. It is one of Australia's most significant coral reef systems and is very different in structure and species composition to the Ningaloo Reef.

8. ***Kalbarri to Port Denison.*** The shore is of moderate energy and is relatively straight with sandy beaches and occasional Pleistocene limestone headlands and offshore reefs. Small parabolic dunes abut and in some places overlie the coastal limestones. Kelp dominates the sublittoral zone on the limestone reefs. Seagrass meadows are moderately developed in sheltered lagoons and banks. Small and species-poor coral reefs occur at several localities. The coast features Late Pleistocene fossil coral reefs and a number of small estuaries (Chapman, Irwin and Greenough Rivers).

9. ***Port Denison to Whitfords***. The shore is similar to that north of Port Denison but there is extensive development of offshore limestone reefs protecting elongate lagoons and more frequent small limestone islands. There are large erosional scallops into the coastal limestones as well as discrete, accretionary cuspate forelands. Wide intertidal rock platforms are developed below the larger limestone headlands and around some of the islands. Kelp dominates the sublittoral zone on the limestone ridges. Seagrass meadows dominate the lagoons and banks behind the protective offshore reefs. There are no coral reefs although coral communities are common in sheltered lagoons. There are two small estuaries (Hill and Moore Rivers). Semeniuk *et al.* (1989) distinguished two coastal types within this sector, based on dune structure and sedimentation details, with the boundary between them located at Wedge Island.

10. ***Whitfords to Bunbury.*** This sector has a range of coastal types and complex near-shore bathymetry with prominent sublittoral limestone ridges parallel to the coast, two major embayments with deep basins (Cockburn and Warnbro Sounds), many small, offshore emergent rocks and three large limestone islands (Rottnest, Carnac and Garden) , and three large estuaries (Swan, Peel-Harvey and Leschenault). The open ocean shores have moderate exposure to wave action and consist of long sandy beaches and some cliffed limestone headlands with wide, algal dominated, intertidal rock platforms.

Kelp dominates the sublittoral zone on the limestone ridges. Seagrass meadows dominate the sublittoral zone in the offshore inter-ridge lagoons. There are no coral reefs although coral communities are common and there is extensive growth of *Pocillopora damicornis* in sheltered situations at Rottnest Island and the reefs off Whitfords. Semeniuk *et al.* (1989) distinguished two coastal types along this coast, based on dune structure and sedimentation details, with the boundary located at Cape Bouvard.

11. ***Geographe Bay***. The coast from Bunbury to Dunsborough is a wide, arcuate, north-facing embayment. It is a low to moderate energy shore consisting mainly of beach fronted by gently sloping shallows and backed by a Holocene dune system. Long-term Holocene sediment accretion has resulted in outward growth of the shore face and development of successive beach ridges which have blocked natural drainage from the hinterland, forming fresh to brackish lagoons behind the ridges. The seabed is dominated by very extensive seagrass meadows and rock substrates.

12. ***The Leeuwin Block***. The south west corner of Western Australia is formed by a north-south aligned, elevated block of igneous rocks representing an outlier of the Proterozoic Yilgarn Craton, projecting north and south as Cape Naturaliste and Cape Leeuwin respectively. Its eastern boundary is the Dunsborough Fault marking abrupt changes of geology and coastal type at Dunsborough and Flinders Bay. The western face of the Ridge is a high energy shore with arcuate sandy beaches between high gneissic rock headlands. The lower intertidal and sublittoral zones are dominated by kelp. The gneisses do not erode to form rock platforms but there are boulder shores and large tide pools in sheltered places. In some areas Pleistocene dune limestone overlies the gneisses and may be eroded to form steep cliffs with flat intertidal rock platforms at sea level, comparable to those of the central west coast. On the leeward (eastern) sides of Cape Naturaliste and Cape Leeuwin there is less exposure to ocean swells and more sheltered conditions prevail.

Estuaries

In addition to the above major distinctive coastal types along the seaward shores of the West Coast, there is a number of estuaries.

The two large seasonal rivers entering the eastern side of Shark Bay form large deltas but not estuaries.

The most northerly estuary on the West Coast is that of the Murchison. From there southwards to the Moore River there is a series of small estuaries. Most of the rivers have the bulk of their catchments in the semi-arid hinterland or are very short with small catchments. The Murchison Estuary is of the riverine type (that is the tidal waters flood the lower reaches of the river channel and there is no wide basin development) and it is permanently open to the sea although there is an entrance bar. The Hutt, Bowes, Buller, Chapman, Irwin and Hill Estuaries are also of the riverine type but they are seasonally closed. Estuaries of the Greenough and Moore Rivers are of the lagoonal type and are seasonally closed. Very little is recorded of the flora and fauna of these central West Coast estuaries but, given the small size and seasonally closed condition of most of them, it is unlikely that they possess diverse communities. The possible exception is the Murchison which warrants study.

On the lower West Coast there are three large estuaries, the Swan, Peel-Harvey, and Leschenault, all of which are permanently open to the sea. The Swan and the Peel portion of the Peel-Harvey have wide basins. The Harvey portion of the Peel-Harvey Estuary and the Leschenault Estuary are large, elongate basins formed in interbarrier depressions (ie. between Pleistocene limestone ridges). The rivers which serve these estuaries have rather large catchments within a moderately high rainfall zone. Their annual salinity cycles are extreme in that they flood with sea water (at least in their lower reaches) during the dry summer months and are scoured with fresh water during the winter rainy season. For this reason they are somewhat inhospitable habitats for aquatic organisms and their flora and fauna are depauperate. Nevertheless, in summer they are significant nursery areas for a number of marine fishes and crustacea and support important commercial and recreational fisheries. They are also very important feeding areas for migratory wading birds. All three of these large estuaries currently suffer from eutrophication of varying severity.

1.2. Marine flora and fauna

Scientific study of the marine environment of Western Australia's West Coast began before European settlement. The Baudin Expedition of 1801-03, sponsored by the French Academy of Science, made extensive collections of marine fauna along this coast, most notably in Shark Bay. Following establishment of the Swan River Colony by the British nearly thirty years later, additional material was supplied to European scientists. The German *Gazelle* expedition in 1874-76 visited Shark Bay and collected marine specimens including some corals (Studer, 1878) and in 1894 fisheries biologist W. Saville-Kent collected and studied corals at Shark Bay and the Houtman Abrolhos (Saville-Kent, 1897).

In the 20th Century, marine research intensified on the West Coast, following establishment of research and tertiary education institutions at the metropolitan centre of Perth. The State Fisheries Department and the CSIRO Divisions of Fisheries and Oceanography established marine research laboratories in Perth. A considerable body of information has now accumulated on physical and biological features of the West Coast marine environment.

North West Cape and Cape Leeuwin are points where significant changes in coastal marine flora and fauna take place. The changes are a consequence of several interacting factors including climate, geomorphology and physical aspects of habitat, ocean currents, and geological history. Between these capes the West Coast is a zone of overlap between two biogeographic provinces, the tropical Northern Australian Region and the temperate Southern Australian Region (Wilson & Gillett, 1971; Wilson & Allen, 1987).

On the North West Shelf north-east of North West Cape the marine flora and fauna are wholly tropical (see Parts I and III). Biogeographically that area belongs to the Northern Australian Region which is a sub-unit of the vast tropical Indo-West Pacific Region. In stark contrast, the southern coast east of Cape Leeuwin belongs to the temperate Southern Australian Region and has a very different flora and fauna (see Parts I and V). The differences are due not only to contemporary environmental conditions but also to the different geological histories of the two regions (Wilson & Allen, 1987). The northern (tropical) and southern (temperate) floras and faunas have had different evolutionary origins.

Along the West Coast the tropical marine flora and fauna give way to temperate species and many species reach their limits of range. Coral reefs and mangals, the two ecosystems which most characterise coastal zones of the tropics, flourish on the Pilbara coast but dwindle away down the West Coast. In the vicinity of Fremantle on the central West Coast the composition of the marine fauna is almost balanced between tropical and temperate species, with temperate species slightly more numerous.

The extent to which tropical species and tropical ecosystems penetrate to higher latitudes on the West Coast is apparently very sensitive to climatic and oceanographic changes. The central section of the West Coast has been subject, through the Pleistocene Period, to oscillations in climate and, consequently, in the balance of temperate and tropical flora and fauna. During warmer Pleistocene interglacial periods, the tropical zone (and the Northern Australian Faunal Region) extended much further south than it does today (Kendrick *et al.* , 1991). For example, although the Abrolhos is the present limit of coral reef development, there are Late Pleistocene fossil coral reefs as far south as Rottnest Island.

There is also evidence that in contemporary times the West Coast is highly dynamic in respect of marine species distributions. For example, some tropical species of fish, echinoderm and mollusc, having planktonic larvae capable of wide dispersal by ocean currents, are known to occasionally establish populations at southern locations within the temperate zone, far beyond the "normal" limit of their ranges. The warm, southerly-flowing Leeuwin Current carries the larvae of tropical animals from the north which may establish populations at places such as the West End of Rottnest Island and Cape Naturaliste (Hutchins, 1991). Dispersal of some tropical animals even extends around Cape Leeuwin and into the Great Australian Bight in years when the Leeuwin Current flows strongly (Maxwell & Cresswell, 1981). Some of these outlying, southern populations appear to be "permanent" and capable of reproductively sustaining themselves (eg. the cowry *Cypraea caputserpentis* at Rottnest). Others appear to be transient and incapable of reproduction in these cooler southern conditions, depending on constant replenishment from the north. But the Leeuwin Current is erratic from year to year so that southern populations of tropical species with short life-cycles are highly unstable and subject to periodic local extinction.

Although communities of marine plants and animals on the West Coast mostly comprise a mixture of northern (tropical) and southern (temperate) species, there is an endemic element as well. Examples are the Western rock-lobster (*Panulirus cygnus*) and the Dhufish (*Glaucosoma hebraicum*). Some of these endemics are strictly confined to the West Coast. Others extend onto the South Coast beyond Cape Leeuwin. The origins of these endemics are varied. Many of them appear to be Pleistocene derivatives from Indo-West Pacific genera, perhaps arising from populations isolated by oscillation of climate. Others are relicts of the ancient faunas of the Tertiary. In the latter category is the gastropod *Campanile symbolicum* , the sole living survivor of the family Campanilidae which flourished in the tropical Sea of Tethys during the Tertiary. This "living fossil" is a conspicuous species in the intertidal and shallow sublittoral communities of the south-west coast.

This situation of progressive change from one major biogeographic province to another along a two thousand kilometre stretch of coast is relevant to the reserve selection process in that seemingly similar habitats located a few degrees of latitude apart are likely to support communities of quite different species composition. For a reserve system to approximate "representativeness" it is necessary for it to include a series of reserves along the length of the coast that, together, represent the transition from the tropical to temperate biota.

It must be emphasised that reservation of an area close to the geographical limit of a tropical species or community does not guarantee its long-term protection if it depends on recruitment by means of dispersal from populations in unprotected "upstream" areas. This relates to the inter-connectedness of marine ecosystems discussed in Part I. In this situation marine reserves are not, by themselves, enough and must be complemented by strong environmental protection measures for the whole coast.

An account of certain marine community types of special significance on the West Coast follows.

Corals and Coral Reefs

The transition from tropical to temperate biota along the West Coast is no better illustrated than by the distribution of corals and coral reefs. Hatcher (1991) has discussed the importance of the Leeuwin Current in establishing and maintaining the coral reefs of the West Coast.

At the extreme northern end of the West Coast, just north of the Tropic of Capricorn, is Ningaloo Reef, one of Australia's most significant coral reef systems. It is about 260 kilometres long and is part barrier reef and part fringing reef, with a wide range of coral reef habitats and a high diversity of corals and associated species. From this reef 217 species of hermatypic corals in 54 genera are recorded (Veron & Marsh, 1988). Coral growth is luxuriant in many localities. The reefs are built on a Pleistocene limestone structure along the western side of the Cape Range anticline. Their existence relates to the proximity of the continental shelf edge in that area and the clear oceanic water with minimal terrestrial run-off. It is likely that the reef community is constantly replenished by recruits delivered by the Leeuwin Current from outer reefs and shelf-edge atolls of the North West Shelf.

There are no coral reefs in Shark Bay but coral communities are found in the channels between Bernier and Dorre Islands and in South Passage. Within Shark Bay itself coral communities are poorly developed.

After Ningaloo the only major coral reefs on the West Coast are at the Abrolhos. These reefs comprise four groups of islands and coral banks near the shelf-edge about 60 km offshore between latitudes 28° 16' and 29°. Stokes (1846), who surveyed these waters, noted that ".. the Abrolhos, with the exception of Bermuda, is the place farthest removed from the equator where coral formation is found." While later studies have found that to be not quite accurate, it is certainly true that the Abrolhos coral reefs lie in exceptionally high latitudes making them of great scientific interest.

Living corals flourish on the leeward slopes of the Abrolhos reef platforms with a diverse coral fauna. A total of 184 species of coral belonging to 42 genera are so far recorded (Veron & Marsh, 1988). The modern coral reefs of the Abrolhos grow as a veneer on a foundation of Late Pleistocene coralline limestone. They are less extensive than their Late Pleistocene antecedents. During that time there was coral reef development along the seaward edges of the platforms but today those areas are dominated by the kelp *Ecklonia* (Wilson & Marsh, 1979) and reef development is confined to the leeward slopes and the sides of the channels and "blue holes". The oceanographic and climatic factors which sustain these unusual reefs are discussed by Collins *et al.* (1991) and Hatcher (1991).

Some tropical coral species which are tolerant of cooler conditions maintain populations as far south as Cape Naturaliste (a few even beyond that) but they occur as isolated colonies and do not form "coral reefs". Tabular corals of the genus *Acropora*, usually dominant among the reef-building species in the tropics, are particularly abundant at the Abrolhos and occur as isolated colonies as far south as Jurien Bay, mostly in lagoons between offshore limestone reefs. A branching coral, *Pocillopora damicornis,* is very common in dense colonies at many localities on the West Coast as far south as Rottnest Island. Massive corals of the genera *Favites, Goniastrea* and *Turbinaria* are a feature of sheltered bays at least as far south as Cape Naturaliste. In Geographe Bay, on the leeward side of Cape Naturaliste, fourteen species of corals belonging to seven genera are recorded living on the rocky sea floor among seagrasses and small macroalgae.

Mangroves

Mangal habitat is well developed in the northern half of the West Coast sector although the number of species of mangrove tree is greatly reduced in comparison with the Pilbara coast. In the extreme north of the sector in the Ningaloo Marine Park three species of mangrove, *Avicennia marina, Rhizophora stylosa* and *Bruguiera exaristata*, form small but important mangals. Further south in Shark Bay there are extensive mangals but they are solely *Avicennia.* Small, remnant *Avicennia* mangals also occur at the Abrolhos and in Leschenault Inlet. The decline of the mangal ecosystem from north to south in the West Coast transition zone matches closely that of coral reefs.

Seagrasses

A general description of Western Australian seagrasses and seagrass meadows is given in Part I, Section 3.7.4. In the southern part of the State seagrasses form conspicuous ecosystems. Seagrass meadows comprise one of the most important marine ecosystems in the region. They usually have a very large biomass and may stretch without interruption for many kilometres along the coast.

Seagrass meadows provide habitat for a large number of other organisms and play an important part in the food webs and cycling of nutrients of coastal waters (see Part I, Section 3.7.4). In the southern portion of the West Coast they have great commercial significance because of their importance to the western rock lobster fishery. Following their planktonic development, rock lobsters at the puerulus developmental stage settle on reefs near seagrass meadows. Adult rock lobsters forage in nearby seagrass meadows, feeding on detritus, plant material and associated fauna (Joll & Phillips, 1984).

Within the boundaries of the West Coast sector there are 22 species in nine seagrass genera (Kirkman & Walker, 1989). Six of the species are regarded as tropical while the others are temperate to cool temperate species. The dominant genera of the southern West Coast seagrass meadows are *Posidonia* and *Amphibolis.* The dominant species is *Posidonia sinuosa.*

Southern Western Australia could be said to be the centre of distribution of the genus *Posidonia* with eight species in the region, reducing to one east of St Vincent Gulf in South Australia and one north of Shark Bay. *Amphibolis* is represented by two species - *A. griffithii*, which ranges from Kalbarri to South Australia and *A. antarctica* which ranges from Exmouth southwards and east to Bass Strait.

Generally, the seagrass meadows of the West Coast south of Shark Bay grow in lagoons within a sheltering coastal reef system, mostly at depths from low tide level to 20 m. Most species and the densest meadows grow on soft, sandy substrata on shallow banks between reefs. Species of two genera grow on rocks and one of these, *Thalassodendron pachyrhrizum,* is only found on rocky substrata. Both this species and *Amphibolis antarctica* grow down to depths of 30 m where there is suitable substrate.

Unlike other parts of Australia, estuarine seagrasses are rare in southern Western Australia because most of the estuaries are small and subjected to wide seasonal changes in salinity. There are usually bars across their entrances which restrict exchange of water with the sea. The main exception to this is the Swan Estuary which has quite extensive seagrass meadows consisting of *Zostera mucronata* and *Halophila sp.* in its lower reaches.

Seagrass meadows may be hundreds of years old. They are occasionally disturbed by high intensity storms which "blow out" the seagrass. The original seagrass vegetation of the blowout areas, usually predominantly *Posidonia sinuosa,* may be subsequently revegetated by other species, such as *Heterozostera tasmanica, Halophila* or *Amphibolis,* but these are less able to withstand storms and the blowouts become areas of considerable change. The original *Posidonia sinuosa* association may take tens of years to return, if it does

at all (Kirkman and Kuo, 1990). The decline of seagrass beds in Cockburn Sound has been described by Cambridge & McComb (1984).

Algae and Algal Beds

A general description of Western Australian algae and algal beds has been given in Part I, Section 3.7.3. The algal flora of the warm temperate coast south of the Abrolhos is very diverse, although this element of the Western Australian flora has been little studied. There is even less information about the marine algae of the northern shores of the West Coast but it seems that the tropical zone is not rich in taxa. The most comprehensive studies of West Coast algae have been done at Rottnest Island (Huisman & Walker, 1990) and Shark Bay (Kendrick *et al.*, 1990).

Seaweeds are most conspicuous on the fringing rock platforms and inshore rocky reefs along the southern West Coast. The small kelp *Ecklonia radiata* is the dominant species, at least in the southern part of the West Coast south of Kalbarri and the Abrolhos. *Sargassum* species are also important in terms of biomass during the warmer months of the year (Kirkman, 1984). Beds of these algae may dominate rocky habitats in the shallow sublittoral zone along the West Coast but there is no development of massive algal beds on the scale of those seen in the cool temperate areas of south-eastern Australia.

Many species of green and red algae make up a high diversity in algal bed ecosystems on rocky shores. Many also grow as epiphytes on seagrasses (Kendrick *et al.*, 1988) and these may make up a high proportion of the biomass in seagrass meadows, particularly when the dominant seagrass is *Amphibolis*. The epiphytes on *Amphibolis* can make up more than three times the biomass of this seagrass.

The distribution of most of the seaweeds found between North West Cape and Cape Leeuwin is not known. North of Geraldton there appears to be a transition from the southern temperate flora to a tropical one, comparable to distribution patterns described above for marine fauna. The effects of sea temperature and ocean currents on the distribution of algae on the West Coast have been described by Walker (1991).

In the temperate waters of the southern West Coast there are not many herbivores which feed directly on algae. The most notable are two species of the fish genus *Kyphosus* (Buffalo Bream), one of which feeds on brown algae while the other feeds on a variety of red algae. Probably the most important role played by algae in coastal ecosystems is the production of detrital material for nutrient recycling. Organic detrital material from algal beds is a major element in the food of rock lobster along the West Coast (Joll & Phillips, 1984).

Rocky Shore Communities

Rocky shore habitats have been described in general terms in Part I, Section 3.7.2. Two quite distinct types occur on the West Coast and there are significant differences in the invertebrate community types inhabiting them and the zonation patterns which they establish on the shore.

North of Cape Naturaliste rocky headlands between beaches and sandy bays are composed of limestones (or sandstones in the case of the Kalbarri sector) which are commonly eroded into near-horizontal rock platforms in the intertidal zone. Limestone rock platforms are a significant feature of the West Coast. Platforms eroded into the Late Pleistocene Tamala Limestone, the most common type, tend to be deeply notched along their inner margins between high and low water levels, and have a distinctive vertical zonation of benthic invertebrates and algae. The strongly bedded Silurian Tumblagooda Sandstone at Kalbarri tends to be terraced below the sea cliffs and zonation patterns are different.

Zonation of flora and fauna on intertidal rock platforms eroded into Tamala Limestone has been described in detail at Rottnest Island by Hodgkin *et al.* (1959) and at Carnac Island by Marsh & Hodgkin (1962). Similar species communities and patterns of intertidal distribution occur on limestone rock platforms at least as far north as Geraldton. Little is known of the equivalent rocky shore faunas further north but it may be assumed that temperate species are replaced by tropical ones.

In the south along the Naturaliste-Leeuwin coast, rocky shores are predominantly constructed of Proterozoic gneissic rocks with rounded boulders and relatively smooth rock slopes, although there are areas where limestone rock platforms overlay the igneous-metamorphic base. The gneissic shores lack development of rock platforms. In sheltered areas, particularly on the northern sides of rocky headlands, boulder fields and large pools provide rich habitats for a diverse flora and fauna. There has been no detailed study on their flora and fauna or on the zonation patterns of those shores.

Marine Mammals

The Australian Sea Lion (*Neophoca cinerea*) is sparsely distributed from the Abrolhos to South Australia with a total population of probably less than 5 000. It is declared to be a specially protected species under the Western Australian Wildlife Conservation Act. The West Coast population numbers about 1 000 animals. Most of the limestone islands with lee side beaches, from the Abrolhos to Shoalwater Bay, are used as haul-out sites by the sea-lions. Breeding colonies occur on the Abrolhos, the Beagle Islands, North Fisherman Island and Buller Island. The largest breeding colony is on the Beagle Islands. On the West Coast the sea-lion has a 17-18 month breeding cycle that is not synchronous among the breeding colonies (Gales *et al.*, 1992). The long-term security of this animal on the West Coast is questionable. Most of the haul-out sites and the breeding colonies are subject to increasing human interference and there is some question about increasing competition between humans and the sea-lions for food resources.

There is a significant population of the Bottlenose Dolphin (*Tursiops truncatus*) along the West Coast although the population size is unknown. These animals frequently interact with humans and do so regularly at three West Coast localities, Monkey Mia in Shark Bay, Shoalwater Bay and Bunbury.

Two species of whale, the Southern Right Whale (*Eubalaena australis)* and the Humpback (*Megaptera novaeangliae)* also frequent the shores of the West Coast. Since the cessation of commercial whaling both species appear to be recovering from their earlier perilously low numbers. The Right Whales breed in sheltered bays of the south west coast. The Humpbacks pass by twice a year on their migrations between their summer Southern Ocean feeding grounds and their winter North West Shelf breeding areas. The migrating pods of Humpbacks have already attracted attention from the tourist industry as they make an attractive spectacle when they pass close enough to shore to be approachable.

1.3. Tourist potential

Marine-based tourism is well established on the West Coast. There are a number of cities and large provincial towns on this coast, often near significant coastal and estuarine attractions. There are five marine parks already declared within the region. Ningaloo Marine Park is recognised as a major recreation and tourism resource in the north west of the State. Commercial tourism activities associated with the park form a significant part of the local economy. Shark Bay Marine Park is part of a World Heritage Area. Marmion and Shoalwater Islands Marine Parks service the urban population of the Perth metropolitan area. In addition, management authorities have been established for the Peel-Harvey and Leschenault Inlets which are extensively used for recreation. All of these areas are destined to become increasingly important tourist and recreational destinations.

1.4. Fisheries

The section of coastal waters between North West Cape and Cape Leeuwin supports the majority of Western Australia's commercial and recreational fishing activities.

The western rock-lobster (*Panulirus cygnus*) fishery is the largest and most important of the region's 14 marine and three estuarine commercial fisheries. The annual average catch of 10 500 tonnes is worth in excess of $240 million. The majority of the fishing takes place between Kalbarri and Mandurah and out to a depth of 160 m.

The most important prawn and scallop trawl fisheries are concentrated in Shark Bay, primarily in the area east of Bernier and Dorre Islands. Further south, the Abrolhos Islands and Mid-west Trawl Fishery and the South-West Inshore Trawl Fishery also take western king prawns and saucer scallops.

One of the more important West Coast finfisheries is the Shark Bay Snapper Fishery. This extends from Shark Bay to the southern boundary of the Ningaloo Marine Park. The fishery takes an average annual catch of 520 tonnes. Another important fishery is the West Coast Purse Seine Fishery which targets mainly pilchard and scaly mackerel. Sharks and demersal finfish are also widely targeted by gillnet and longline operators off the West Coast. In more protected, inshore waters, such as the southern parts of Shark Bay and off the Perth metropolitan area, beach-seining and mesh-netting for a variety of finfish support a number of vessels.

Roe's abalone constitutes an important fishery along the lower West Coast. Other invertebrate fisheries include mussel culture in Geographe Bay and Warnbro and Cockburn Sounds, blue manna crab fishing in Warnbro Sound, deep water crab fishing on the outer shelf, and octopus fishing.

The Swan-Canning, Peel-Harvey and Leschenault estuaries each support long-standing, limited entry fisheries, with 11, 27, and 11 operators respectively. They took a total catch of 458 tonnes in 1991. The key target species include sea and yelloweye mullet, cobbler, whiting, blue manna crabs and prawns.

Recreational fishing is a popular activity on the West Coast. Key target species include western king and school prawns, blue manna crabs, abalone, rock lobster and a variety of finfish, notably Australian herring, Australian salmon, tailor, whiting, snapper, and WA jewfish. A major review of Western Australia's recreational fisheries was conducted in the late 1980s resulting in the publication of the document "The Future for Recreational Fisheries - Issues for Community Discussion" (Fisheries Department, 1990).

2. EXISTING MARINE RESERVES

On the West Coast five Marine Parks and one Marine Nature Reserve have already been declared under the CALM Act, and one marine reserve has been declared under special legislation. The Commonwealth National Parks and Wildlife Conservation Act has been used to extend the boundaries of one of the State Marine Parks (Ningaloo) seaward to include Commonwealth waters.

2.1. Ningaloo Marine Park (Map IV-1)

Area 224 000 ha.

Ningaloo Reef extending 260 km along the western side of the Cape Range Peninsula is one of Australia's major coral reef systems.

In its report, *Conservation Reserves in Western Australia*, (1975, System 9), the EPA recommended that the Ningaloo Reef Tract should be declared an aquatic reserve, vested in the National Parks Board. The EPA recommended that the reserve should extend from North West Cape to Point Anderson and from 40 m above high water mark to the 100 m isobath. The 100 m isobath is about 5 nautical miles offshore near North West Cape but off Point Anderson the continental shelf is much wider and the 100 m isobath is nearly 30 nautical miles offshore.

The State Government formed a Working Group in 1978 which produced a draft management plan (May, Lenanton & Berry, 1983). The plan included recommendations that the reserve be a marine park, that the southern boundary be located at Amherst Point rather than Point Anderson, and that the park should extend around North West Cape to include Bundegi Reef at the mouth of Exmouth Gulf. It also recommended that the seaward boundary be set at approximately 10 nautical miles from shore rather than at the 100 m isobath which was considered to be inappropriate. A 10 nautical mile seaward boundary encompasses Commonwealth waters. The revised boundaries were proposed so that "the ecological integrity of the living resources could be secured". The report added that "the area of sea and land within these boundaries incorporates all major habitat types, would maintain the integrity of the proposed Marine Park as a viable ecological unit and is necessary for holistic and integrated management." These recommendations were adopted in principle by the State Government.

Following passage of the Conservation and Land Management Act 1984 with its provision for declaration of marine parks, and after further public consultation, the inner portion of Ningaloo Marine Park was gazetted under State legislation in 1987. The outer portion was declared under the Commonwealth National Parks and Wildlife Conservation Act 1975 later in the same year.

Integrated management plans for the State and Commonwealth parts of the marine park were produced and adopted in 1989 and are now in force.

Together with the adjacent Cape Range National Park, Ningaloo Marine Park has already become an important recreational resource and a primary attraction for the tourism industry. Dive and Whale Shark tours and fishing charters operate from the towns of Exmouth and Coral Bay. An interpretive centre has been established within the national park. With its rich and easily accessible coral reef and unique coastal scenery, this reserve complex will certainly become one of the best known and most valuable conservation reserves in Australia.

2.2. Shark Bay Marine Park (Map IV-2)

Area 748 735 ha

In its report, *Conservation Reserves in Western Australia* (1975, System 9) the EPA recommended that the waters of Shark Bay be reserved for a range of purposes. Subsequently the State Government appointed a consultative committee and an inter-departmental task force to carry out a regional planning study for Shark Bay. The matter of marine reserves was one of the issues considered in that study. The final report, the *Shark Bay Region Plan* was adopted by the Government in June 1988. It recommended declaration of a multiple-use marine park over much of Shark Bay, and a marine nature reserve at Hamelin Pool. The Shark Bay Marine Park was gazetted in 1990.

Shark Bay is a very large, shallow embayment, open to the north, with narrow inlets separated by long, slender peninsulas. It is the only major embayment on the West Coast between Exmouth Gulf and Cockburn Sound. Bernier, Dorre and Dirk Hartog Islands form the western boundary of the bay. A summary of the Bay's geomorphology is given by Playford (1990) and the hydrology by Logan & Cebulski (1970).

The seabed is typically composed of calcareous sands with vast areas of dense seagrass meadows. For the most part the shores of the inlets are sand beaches although there are some rocky shores. The eastern shore of the Bay, south of Carnarvon, has a very low profile backed by wide supratidal samphire flats, a fringe of mangroves, and an enormous near-shore calcareous sand bank. Tidal sand flats and extensive subtidal sand banks are a feature of the bay. The sheltered, low energy shores of Shark Bay are recognised as major distinctive coastal types in Section IV - 1.1 (western and central shores type 5; eastern shore type 4).

The seagrass meadows and the calcareous sand banks of Shark Bay are among the world's most extensive. These both provide habitats for rich communities of macrophytic algae, fishes and invertebrates.

Other features of the marine environment with high conservation value include the most southerly resident populations of dugong and green turtle, the internationally famous Bottlenose Dolphins of Monkey Mia, and important nursery areas for several valuable recreational and commercial fisheries.

Shark Bay also has great historical significance, including for the history of Australian marine science. The French "Baudin Expedition" of 1801-03 was a major scientific event of that period and Shark Bay was one of its most important study areas. Shark Bay was also a principal site of the German "Hamburg Expedition" of 1905. In recent years there has been renewed research activity in Shark Bay. A recent report of the France-Australe Bicentenary Committee contains a collection of recent works and references to previous publications (ed. Berry *et al.*, 1990).

Together with equally significant terrestrial values, the features of the Shark Bay marine environment are considered to be of such importance that the whole area is now a World Heritage Area.

Management plans are being prepared for the marine and terrestrial reserves of Shark Bay by the Department of Conservation and Land Management.

2.3. Hamelin Pool Marine Nature Reserve (Map IV-2)

Area 132 000 ha.

This marine reserve was declared at the same time as the Shark Bay Marine Park, and as a result of the same planning and public participation processes. It is also included within the Shark Bay World Heritage Area.

Hamelin Pool is the innermost of the Shark Bay inlets. Its waters are almost isolated from the rest of the bay by a sill of sand across its mouth, that is the Faure Sill. As a result of isolation and the high evaporative rates, the water of the inlet is hypersaline. The inlet has an impoverished but highly specialised flora and fauna.

The unique character of the Hamelin Pool marine environment has produced two features of immense scientific interest. These features - growth of stromatolites and the development of Holocene coquina deposits - have been extensively described and discussed in the scientific literature (references in Logan & Cebulski, 1970; Playford, 1980; Playford, 1990).

There is little recreational activity and no commercial fishing in Hamelin Pool. However, the stromatolites and coquina deposits are an attraction for visitors and inspection sites are provided.

A management plan is being prepared by the Department of Conservation and Land Management.

2.4. Marmion Marine Park (Map IV-7)

Area 9 350 ha.

This park was gazetted in 1987. It is a heavily used marine reserve along the northern shores of the Perth metropolitan area. It was originally recommended by the EPA in its System 6 report (1983, recommendation M10). However, following an intensive public participation program culminating in publication of the proceedings of a public seminar (Ottaway & Humphries, 1986), a larger reserve was declared than was originally proposed.

The Marmion Marine Park is representative of the Whitfords to Bunbury sector, that is major distinctive coastal type 10. It features sandy beaches and Tamala Limestone rock platforms along the shore, backed by Quindalup Dunes, and with a succession of near-shore limestone reefs. Marmion Reef is the largest of the reefs, protecting a shallow area known as the Marmion Lagoon with extensive seagrass meadows and a series of emergent rocks and submerged rock platforms. The reefs are deeply undercut and cavernous and there is a rich wall fauna of invertebrates which provide a colourful underwater spectacle. Most marine plants and animals in the park are of temperate origin but there are some tropical stragglers, including a dozen or so corals. Useful references may be found in Ottaway & Humphries (1986) and Moore (1987).

Marmion Marine Park is extensively used by recreational fishers. The sheltered waters, accessibility and spectacular underwater scenery ensure that scuba diving is also a popular activity. Several commercial dive and whale watching tours operate from the Hillarys Boat Harbour. The beaches between Trigg and Mullaloo are popular swimming and surfing locations.

A management plan was approved in January 1992 (Pobar *et al.*, 1992) and remains in force. It zones the majority of the park for General Use. Three small areas are zoned as Sanctuary areas and one as a Recreation area.

2.5. Swan Estuary Marine Park (Map IV-7)

Area 340 ha.

The entire Swan Estuary is a Management Area declared under the powers of the Swan River Trust Act 1988. The marine park reserved and vested in the National Parks and Nature Conservation Authority, consists of three separate, small areas of the Estuary. The reserve was gazetted in 1990. At the time of writing this report the Department of Conservation and Land Management had begun preparation of a management plan, in collaboration with the Trust.

The three parts of the marine park are located at Milyu on the South Perth foreshore (95 ha.), Alfred Cove (190 ha.), and Pelican Point (40 ha.). They were the subjects of the EPA System 6 recommendations M60, M61 and M62 respectively. They are all intertidal and shallow sublittoral flats and were reserved primarily as habitat for migratory waterbirds.

2.6. Shoalwater Islands Marine Park (Map IV-7)

Area 6 545 ha.

The Shoalwater Islands Marine Park was declared in 1990 over the waters between Cape Peron and Becher Point, encompassing Shoalwater Bay and Warnbro Sound. At the time of writing this report the Department of Conservation and Land Management had begun preparation of a management plan.

The EPA System 6 report (1983) considered this area, noting the proximity of the educational and recreational facilities at Cape Peron and its "high value in the teaching of ecological principles". Recommendation 101.4 proposed that "a study of the area be commissioned by the Environmental Protection Authority with the aim of establishing a Marine Reserve to be managed for the purpose of conservation." The survey was duly carried out and the results published (Gordon, 1986).

The original area proposed for reservation included mainly the reef habitats off Cape Peron and surrounding the limestone islands and rocks extending southwards to The Sisters off Becher Point. After further

consideration, the marine park was declared over a larger area so as to include the extensive seagrass meadows and the deep basin of Warnbro Sound.

The reef areas are typical of the West Coast near-shore systems of the Whitfords to Bunbury sector identified in Section 1.1 as distinctive coastal type 10. They are rich in macroalgae and benthic invertebrates and provide habitat and refuge for a wide variety of reef fishes. The reefs are deeply undercut and cavernous and there is a colourful wall fauna of suspension-feeding invertebrates. In these respects the reef habitats of this park are similar to those of the Marmion Marine Park. However, the wide sandbanks with dense seagrass meadows (especially near Point Mersey and Becher Point) and the deep central basin of Warnbro Sound are distinctive features.

The Warnbro Sound basin is similar in origin and character to that of Cockburn Sound, with a mud bottom at 15-20 m depth and steep sides. The Cockburn Sound basin has a distinctive benthic fauna (Wilson *et al.*, 1978) but that area is now polluted by heavy industry. Although it has not been surveyed in detail there is evidence that the Warnbro Sound basin has similar benthic communities (Wilson, unpublished information). It remains the only pristine habitat of this type on the West Coast.

The islands and rocks in the park are important seabird nesting sites. Of particular significance is the Little Penguin rookery on Penguin Island. Australian Sea-lions also use some of the islands as haul-out and resting areas. Both these animals feed within the marine park and there is some question whether they are competing with recreational and commercial fishing for the same resource.

Recreational fishing is a popular activity within the marine park. The sheltered waters and clean sand beaches are also popular swimming, sailing and diving areas. Commercial boat tours operate among the islands. The hinterland of this area is quickly becoming urbanised and the intensity of recreational use of the park is rapidly increasing.

2.7. Rottnest Island Reserve (Map IV-7)

This reserve includes the waters surrounding Rottnest Island for a distance of 800 m offshore. The aquatic reserve was declared as part of the Rottnest Island Reserve under the powers of the Rottnest Island Authority Act 1987, and includes the waters, seabed and subsoil. The purpose of the reserve includes public recreation and protection of flora and fauna and the natural environment. It is managed by the Rottnest Island Authority in collaboration with the Fisheries Department.

Although the marine part of the Rottnest Island reserve is neither a Marine Park nor a Marine Nature Reserve, it serves the same purposes and must be considered to be part of the State marine reserve system. However it is unclear whether it is subject to Government policies on marine parks and reserves in respect of mining, petroleum exploration and other activities.

Reservation of the waters around Rottnest followed a recommendation (C45) of the EPA's System 6 report of 1983. The recommendations actually proposed:

> "C45.2 That the EPA commission a study of the waters off Rottnest Island, especially those from (and including) Eagle Bay to Fish Hook Bay and from Salmon Point to Phillip Rock, with the aim of establishing Marine Reserves to be managed for the purpose of scientific research and education."
>
> "C45.3 That, subject to the implementation of C45.2, management plans be prepared for the Marine Reserves."

The intent of the EPA recommendation was that the two marine areas identified as being of particular interest should be managed for the purposes of scientific research and education. The appropriate reserve category to match those purposes would be Marine Nature Reserve. However, the same management control could be achieved by zoning areas for scientific and education purposes under the proposed management plan. Although the Rottnest Island Authority Act has no provisions for zoning controls the Authority has sufficient powers to declare areas for specific purposes and to regulate accordingly.

Bradshaw (1990) published a lengthy bibliography of Rottnest Island. Geomorphologically, the Island is representative of the major distinctive coastal type identified between Whitfords and Bunbury (type 10). The marine environment is characterised by limestone shores, with cliffs and intertidal rock platforms, and sandy beaches in the bays between the headlands. The near-shore areas have complex limestone reef systems which are deeply undercut and cavernous. The rock platforms support a rich invertebrate fauna (Hodgkin *et al.*, 1959) which has been the subject of research and teaching programs by the University of Western Australia and other educational institutions for many years. Features of particular interest include the presence of a number of tropical species on the rock platforms at West End and a "reef" of the coral *Pocillopora damicornis* at Parker Point. There is a rich flora of marine algae which has a close affinity with the marine flora of southern Australia but includes a tropical element (Huisman & Walker, 1990). The reefs of Rottnest are the type locality of many species of algae. At the eastern end of the island there are extensive seagrass meadows. It is for these reasons that the EPA identified these areas as having particular interest making them worthy of reservation for research and education.

Rottnest Island is an extremely valuable recreation and tourist resource. As well as general recreational activities it has great value as a site for environmental education, as noted by the EPA. This applies to both the terrestrial and the marine environment. Balancing the need for public access to the natural resources of the island and its waters with the need to ensure adequate environmental protection is no easy task. The living marine plants and animals and their habitats at West End and the south eastern end of the island identified by the EPA as having particular importance are particularly vulnerable to human interference. The Working Group considers that providing special protection through zoning for those areas is both necessary and urgent.

3. RECOMMENDATIONS FOR MARINE RESERVES ON THE WEST COAST.

As with other Parts of this report, the first division of the West Coast for the purposes of reserve selection was based on recognition of major distinctive coastal types using geomorphological criteria. A total of twelve types was recognised (see IV.1.1). Marine and estuarine habitats characteristic of each coastal type were then considered, as far as they were known. The objective was to select areas as candidates for reservation which contain the greatest variety and best examples of the characteristic habitats of each coastal type. Superimposed upon this was consideration of the transition from tropical to temperate flora and fauna from north to south along the coast. Also taken into account were conservation and recreation features of specific value such as Sea Lion breeding sites and outstanding underwater scenic areas for use by recreational divers and commercial dive tour operators. The existing marine reserves were considered as well as the new areas proposed in this section as worthy of consideration for reservation so that the reserve system as a whole will be representative of the West Coast marine environment.

Previous, unimplemented recommendations of the EPA (Conservation Reserves for Western Australia, Systems 9, 5, 6, and 1), the Shark Bay Region Plan (1988), and the Abrolhos Islands Planning Strategy (1989), are incorporated within the following recommendations of the Working Group.

3.1. Ningaloo Reef - Southern Extension (Map IV-1)

The coast south of North West Cape to Gnarraloo Bay is a major distinctive coastal type characterised by the development of a barrier-fringing coral reef. Most of this coast has already been reserved as the Ningaloo Marine Park (see Section 2). This part of the report considers the remaining part of Ningaloo Reef, that is the coast from Amherst Point to Gnarraloo Bay.

Tenure
The adjacent land is pastoral lease. Offshore, Petroleum Exploration Permit WA-229-P abuts most of the State territorial sea boundary of the proposed extension.

Geomorphology
This southern part of Ningaloo Reef is a continuation of the reef type found between Coral Bay and Amherst Point. The shore consists mainly of long sandy beaches with occasional low limestone cliffs and headlands, and a discontinuous fringing coral reef.

Flora and fauna
There is little information on the flora and fauna although inspection of aerial photographs and limited anecdotal information suggest that coral growth is prolific, at least in the back reef habitats in the small lagoons at several locations.

It is assumed that the communities of plants and animals are generally like those found within the park further north. However, there is a progressive change in the species composition of the reef communities along the length of Ningaloo Reef. Many tropical species common in the northern part of the park do not extend into the southern parts. Conversely, some southern temperate and West Coast endemic species present in the southern parts do not extend to the northern end of the park. For example, the western rock lobster (*Panulirus cygnus*) which is the basis of the West Coast rock lobster fishery as far north as Shark Bay, occurs in small numbers at the southern end of Ningaloo Reef but is rare north of Coral Bay. The endemic West Coast turbinid gastropod *Turbo (Marmarostoma) pulcher* is abundant as far north as about Gnarraloo Bay but is replaced by its congener *T. (M.) argyrostomus* further north on the Ningaloo Reef.

Previous recommendations
None.

Working Group recommendation:

"Consideration should be given to a southern extension of the State portion of the Ningaloo Marine Park encompassing the State Territorial Sea as far as Gnarraloo Bay so as to include the full length of the Ningaloo Reef.

"The Commonwealth Government authorities should be consulted so that consideration may also be given to the seaward extension of the park beyond the limits of the State Territorial Sea adjacent to this proposed southern addition, as is the case with the existing park."

3.2. Red Bluff to Point Quobba (Map IV-2)

Between the coral coast of Ningaloo Reef and the mangal coast of Carnarvon and the eastern shores of Shark Bay, the coastline is mainly rocky and exposed to open ocean swells. This coastal type is not found to the north and the Working Group considers that it represents a major distinctive coastal type. The "high energy" rocky shores along the western sides of Bernier, Dorre and Dirk Hartog Islands and on the mainland coast of the Edel Land Peninsula have many features in common (see Section IV.1.1).

Tenure
The hinterland from 40 m above high water mark is pastoral lease. At Point Quobba a small area of reef and lagoon has been declared closed as waters under the Fisheries Act.

Geomorphology and climate
The climate is arid and there are no streams entering the sea. The coast comprises low to high limestone cliffs. In the northern portion of this sector, between Red Bluff and Cape Cuvier, the limestone is of Miocene age (Cape Range Group). Both these headlands have high sea cliffs, providing some protection to shallow bays on their eastern sides. South of Cape Cuvier to Point Quobba the cliffs are lower and comprised of the Late Pleistocene Tamala Limestone. The two limestones weather slightly differently along the shore with rock platforms best developed in the Tamala Limestone.

At the base of the cliffs there are rock platforms at various heights above low water level. For the most part the rock platforms are narrow (just a few metres wide) but south of Cape Cuvier there are some more than 50 m wide with shallow tide pools. The higher platforms have perched splash pools above high water level. Wave action is high and the shore may be said to be a "high energy " coast.

In the semi-protected bay to the east of Cape Cuvier a ship-loading facility has been constructed servicing the nearby salt works. There is a boulder shore on the leeward (eastern) side of the headland and the bay has moderately shallow water.

Extending south from Point Quobba there is a short rock platform and reef enclosing a shallow lagoon with a small coral reef.

Flora and fauna
Within the Quobba lagoon the coral reef has a moderately species-rich marine fauna.

North of Point Quobba the narrow limestone rock platforms constitute a habitat type which is uncommon in the northern half of the West Coast. Similar shores occur further south on the western sides of the Shark Bay islands. There is no information on the flora and fauna which inhabit these rocky shores. From inspection of aerial photographs the reef flats appear to bear an algal turf. Given the location it may be expected that the species are primarily tropical which would make them of considerable interest.

Further study is needed to determine whether the rock platforms have sufficiently distinctive flora and fauna to warrant reservation or extension of the closed waters of the Fisheries Act, or whether this habitat type and its biota are a repetition of those found along the western sides of the outer islands of Shark Bay.

Recreation
Access is relatively easy to the southern part of the area under consideration, that is, in the vicinity of Point Quobba, and it is extensively used for public recreation. The lagoon is a safe and attractive site for swimmers

and divers. The blowholes on the point are also a popular attraction. Fishing from the shore is the main activity. Further north toward Cape Cuvier and between that headland and Red Bluff there are few access tracks and public access is very limited.

Previous recommendations
There are no previous recommendations for declaration of marine reserves on this section of the coast.

Working Group recommendations

> "The area at Point Quobba presently gazetted as closed waters under the Fisheries Act should be reserved for the protection of marine flora and fauna, specifically for the small coral reef community in the lagoon.
>
> "The rocky shores between Point Quobba and Red Bluff should be considered for reservation as a marine reserve, subject to a survey of the habitats, flora and fauna of the shore. The survey should be done in conjunction with the recommended survey of the similar habitats along the high energy shores on the western sides of Bernier, Dorre and Dirk Hartog Islands."

3.3. Shark Bay Marine Park - Bernier, Dorre and Dirk Hartog Islands Extensions (Map IV-2)

The existing Shark Bay Marine Park and contiguous Hamelin Pool Marine Nature Reserve together comprise the largest marine protected area in Western Australia. Their features are described briefly in Section 2. This Section considers proposed extensions to encompass the shores of Bernier and Dorre Islands and the western shores of Dirk Hartog Island.

Tenure
Bernier and Dorre Islands are Class "A" Nature Reserves vested in the National Parks and Nature Conservation Authority. Dirk Hartog Island is a pastoral lease with several small areas of freehold. The Shark Bay Region Plan (adopted by the State Government in June 1988) recommended that there should be consultation with the lessees of the Dirk Hartog pastoral lease with the objective of eventually reserving Dirk Hartog Island as National Park.

The waters along the eastern shores of Dirk Hartog Island are included within the existing Shark Bay Marine Park.

The three islands and adjacent waters are included within the Shark Bay World Heritage Area.

Geomorphology and climate
The climate of the Shark Bay region is arid. There is no surface water on the islands and no streams enter the western side of Shark Bay.

Bernier, Dorre and Dirk Hartog Islands comprise a series of elongate islands forming the seaward boundary of Shark Bay, over a distance of almost 80 kilometres. There is a narrow channel known as South Passage separating Dirk Hartog from the mainland, a wide pass known as Naturaliste Channel between Dirk Hartog and Dorre Islands, and a narrow pass between Dorre and Bernier Islands.

The three islands belong to the landform known as the Edel Province, a continuation of the mainland landform of Edel Land south of Steep Point. They consist of Pleistocene aeolianite limestones (Tamala Limestone) overlain by Holocene sand dunes. The dunes of Bernier and Dorre are low but there are much higher dunes on Dirk Hartog, some of them mobile.

Two very different coastal habitats are represented on the shores of the outer Shark Bay islands. The leeward eastern shores are relatively sheltered with moderate exposure to wave action. The windward western shores are very exposed with high wave action.

All three islands lie entirely within the "oceanic water mass" of Shark Bay (Logan & Cebulski, 1970). That is, their surrounding water has normal oceanic salinity levels, unlike the metahaline and hypersaline waters of inner parts of the Bay.

(i) *Leeward shores*
The waters along eastern the shores of Dirk Hartog Island are within the existing Marine Park.

The eastern sides of Bernier and Dorre Islands are exposed to only moderate wave action. Along these eastern shores there are shallow bays with curved beaches between headlands of low limestone cliffs which are rarely more than 2-3 m high. The cliffs are usually undercut by erosion between high and low tides. There are occasional narrow rock platforms in the intertidal zone. Offshore east of Bernier Island there is a sublittoral sand sill with a steep seaward slope beginning at about the 6 m contour. There is a similar narrow sand sill on the north-eastern side of Dorre Island but at the south-eastern end of that island there is a wide bank extending several kilometres seaward.

(ii) *Windward shores*
The western sides of all three islands are exposed to strong wave action. They are characterised by high cliffs to 270 m. The tops of the cliffs are travertinised and often have abrupt, undercut edges. The hard travertine cap is covered by perched dunes in some places. Commonly there are steep scree slopes of limestone boulders and rubble below the cliff edges. Narrow rock platforms are cut into the bases of the cliffs along most of these shores. The platforms are of various heights, frequently above high water level. They have many splash pools. There are a few narrow, steep beaches of coarse sand and limestone rubble perched between the bottom of the scree slopes and the rock platforms.

These high energy, rocky shores with their Tamala Limestone cliffs and narrow rock platforms are a feature of the western face of the Edel Province and are regarded by the Working Group as a major distinctive coastal type. On the mainland south of Steep Point (ie. the Edel Land Peninsula) the cliffs are quite high and are known as the Zuytdorp Cliffs after the Dutch ship wrecked there in 1712. Similar though less spectacular cliffs occur on the mainland north of Carnarvon between Point Quobba and Red Bluff.

Flora and fauna
The marine biological communities of Bernier, Dorre and Dirk Hartog Islands are profoundly influenced by the coastal geomorphology and exposure to the open ocean. Two major, very different community types may be distinguished, the leeward seagrass and sand bank communities of the eastern shores, and the windward rock platform communities of the western shores, with intermediate conditions in the channels between the islands.

French naturalists of the "Baudin Expedition" (1801-03) landed on Bernier and Dorre Islands and collected marine animals around their shores. These specimens are preserved in the national natural history museum in Paris and some of them are the original types of species described by Lamarck and other French scientists in the early 19th century. The German "Hamburg Expedition" collected extensively in Shark Bay in 1905.

During the 1980s officers of the Western Australian Museum collected invertebrate specimens at a number of localities around Bernier, Dorre and Dirk Hartog Islands, but not from the high energy rock platforms of the windward shores (Marsh, 1990; Slack-Smith, 1990). An account of Shark Bay bivalved molluscs (Slack-Smith, 1990) includes a list of species from the "oceanic water mass", many of those records being based on specimens collected by that author from island localities and now preserved in the collections of the Western Australian Museum.

Shark Bay has a depauperate coral fauna (Marsh, 1990). The major sites of coral growth occur in the intermediate zones between the windward and leeward shores, that is on the sides of the channels between the islands and between Dirk Hartog Island and the mainland, where there is some shelter from wave action but close proximity to the open sea. The main coral sites are at the southern end of Bernier Island, the northern end of Dorre Island, and on the northern side of South Passage at the southern end of Dirk Hartog Island (the latter being within the existing Shark Bay Marine Park). Elsewhere corals occur as scattered colonies, the diversity of *Acropora* species tending to decrease and the diversity of *Turbinaria* tending to increase at the more sheltered, inner (eastern) ends of the channel entrances. There are very few corals in the metahaline waters, and none in the hypersaline waters further within the Bay. Although the high energy windward shores along the western sides of the islands have not been investigated there is evidence that they do not support any significant coral reefs or coral communities (Marsh, 1990).

Marsh (1990) recorded 55 species belonging to 23 genera of hermatypic corals from Bernier and Dorre Islands. On the western side of Cape Couture at the southern end of Bernier Island there is a coral-covered

platform, at depths of 1-2 m, with "gardens" of staghorn and tabular *Acropora.* On the eastern side of Cape Couture there is a small coral reef with 20-30% cover of living coral, principally *Montipora* spp., tabular *Acropora* , and faviids.

At Cape Boullanger on the northern end of Dorre Island there is a reef extending northwards into the channel which supports a diverse coral fauna. East of this, near the entrance to the bay in Disaster Cove, there is a coral community on a rock substrate with a 10-20% coral cover, principally *Turbinaria* spp., *Montipora* spp., and faviids.

Although these coral reefs and coral communities are small and only moderately species-rich, they lie in the path of the Leeuwin Current and they may be a significant source of larvae contributing recruits to populate the reefs of the Abrolhos further south.

Shark Bay contains the largest known seagrass meadows in the world and seagrass may be regarded as the dominant organism in the Bay (Walker, 1990). Twelve species are present, the most abundant being *Amphibolis antarctica.* Several are temperate species at the northern limit of their geographic range, eg. *A. antarctica* and *Posidonia australis*. Others are tropical species (eg. *Cymodocea angustata*) at the southern end of their range.

The sand sills and banks east of Bernier and Dorre Island support significant seagrass meadows. These meadows occur within the "oceanic water mass" of the Bay, unlike the salinocline, metahaline and hypersaline conditions prevailing at most other Shark Bay locations where seagrass meadows dominate (Logan & Cebulski, 1970). The Bernier and Dorre banks and seagrass meadows are significant winter feeding areas for the Shark Bay dugong population (Paul Anderson, pers. comm.).

There is no information on the marine flora and fauna of the islands' windward shore rock platforms or sublittoral zone. Inspection of aerial photographs indicates that the rock platforms are covered with an algal turf and that brown algae dominate the sublittoral zone. There is likely to be a fauna of molluscs and other invertebrates on the platforms and in the perched splash pools. Whether these communities are dominated by tropical species or have a proportion of southern temperate species is unknown.

Given the biogeographically intermediate position of this section of the coast it has considerable scientific interest. A survey of the flora and fauna of the rock platform habitats on the high energy coasts of the mainland between Red Bluff and Point Quobba, the outer Shark Bay islands, and the Edel Land Peninsula would provide critical biogeographic information which is currently lacking and assist selection of the most suitable section for reservation.

Fisheries

The important prawn and scallop trawl fisheries of Shark Bay operate to the east of Bernier and Dorre Islands but beyond the 6 m isobath and impinge little on the seagrass meadows. There are significant commercial and recreational scale-fish fisheries close to shore along both the eastern and western sides of Bernier, Dorre and Dirk Hartog Islands. Commercial and recreational fishing for snapper by hand-line occurs in the shallows around the islands, most notably in Naturaliste Channel and around Koks Island just north of Bernier. Other reef and pelagic fish are also taken in those areas. The recreational fishery includes charter boat operations sailing from Carnarvon and Denham. Commercial rock lobster fishing by potting occurs along the western shore of Dirk Hartog Island, and to a lesser degree along the western shores of Bernier and Dorre Islands.

Recreation and tourism

The main recreational activity in the vicinity of the islands is fishing which is discussed above. Bernier and Dorre Islands are too far offshore for access by most people seeking other aquatic recreational pursuits. Because of their extremely high conservation values and the vulnerability of the several endangered mammals surviving there to fire and introduced plants and animals, access to these two islands is restricted. Dorre Island is a prohibited area. Landing on Dirk Hartog Island requires the permission of the lessees. If that island becomes a national park public access for recreation will be encouraged, but in that event recreational activities would be likely to concentrate on the eastern shores which are already within the Shark Bay Marine Park and are not the subject of this report.

Previous recommendations
The Shark Bay Region Plan proposed (p. 79, 5.5.3 (2)) the establishment of a multiple use marine park at Shark Bay specifying certain special areas which should be included. Among these were "the waters east of Bernier and Dorre Islands below the high water mark to the 6 m isobath". The purpose was " to protect the shallow water marine environment adjacent to the islands, particularly the seagrass banks which are important dugong habitats". Although other areas recommended for reservation have now been declared marine park (see Section 2) this portion of the Region Plan's recommendations has not yet been implemented.

The Shark Bay Region Plan also proposed (p. 80, 5.5.3 (4)) that "the high energy marine environments west of Bernier and Dorre and Dirk Hartog Islands should be investigated for possible Marine Park status in consultation with the Fishing Industry". This recommendation has not yet been implemented.

Working Group recommendations

"1. The Working Group endorses Shark Bay Region Plan recommendation 5.5.3 (2) (p. 79) that the waters east of Bernier and Dorre Islands should be added to the Shark Bay Marine Park.

"The Working Group notes that the 6 m isobath recommended as the seaward (eastern) boundary in the Shark Bay Region Plan may be difficult to implement and suggests that a series of straight lines approximating that isobath and incorporating the seagrass banks would be more practical.

"The Shark Bay Region Plan did not propose northern and southern boundaries for this addition to the marine park. As an interim measure, pending further consideration of also adding the "high energy" shores along the western sides of the islands (see rec. 2), the Working Group suggests that the northern boundary should be located at the northern tip of Bernier Island and the southern boundary at the southern tip of Dorre Island.

"2. The Working Group endorses the Shark Bay Region Plan recommendation 5.5.3 (4) that the high energy marine environments west of Bernier, Dorre and Dirk Hartog Islands should be surveyed and an assessment made of their value as an addition to the Shark Bay Marine Park. The survey should be done in conjunction with one of the exposed rocky shores of the section of mainland between Red Bluff and Point Quobba.

"In the event that the results of the survey of the western high energy environments indicate that the western shores of the islands should be added to the Shark Bay Marine Park, the Working Group suggests that there would be practical advantage in extending these additional areas around the northern and southern ends of Bernier and Dorre Islands respectively."

3.4. Kalbarri (Map IV-3)

This section lies within the major distinctive coastal type between Kalbarri and Port Denison (see Section 1.1).

Tenure
The Kalbarri Townsite occupies the hinterland in the northern portion of this sector. South of this to Bluff Point, a distance of about 12 kilometres, the Kalbarri National Park extends to the shore.

Geomorphology and climate.
South of the Zuytdorp Cliffs of Edel Land there is an abrupt change of geology and coastal type. The Mesozoic sandstone cliffs adjacent to the Kalbarri National Park also comprise rocky shore habitats but they take different form and are here regarded as a separate major distinctive coastal type.

The climate is semi-arid. One of Western Australia's longest rivers, the Murchison, enters the sea at Kalbarri but its flow is seasonal.

Flora and fauna
There is very little information about the flora and fauna of the rocky shores of this area. It is a high energy shore and access to the rock platforms is difficult except at low tide in unusually light weather conditions. However, it is known that the platforms are covered with an algal turf and that many southern temperate species of marine plant and animal occur here at the northern end of their geographic range. Small coral colonies occur in the outer reef platform pools.

Similarly, there is no information on the flora and fauna of the Murchison Estuary. It is possible that the estuary is depauperate but whatever is there will be of interest as this is the most northerly of the temperate estuaries in the State.

Fisheries
Kalbarri is an important centre for the rock lobster fishery. A number of boats operate from the mouth of the estuary and fish the waters north and south, including close inshore along the Kalbarri Cliffs.

Recreation
The scenic and wildlife attractions of the adjacent country, the quality of the beaches at the mouth of the estuary, and the protected waters of the estuary itself make this coast a popular recreational destination. Fishing from the rocks and beaches and in the estuary are popular recreational activities.

Previous recommendations
None.

Working Group recommendation
Although there is so little information about the flora and fauna of this sector, the geographic location at the centre of the West Coast, the distinctiveness of the coastal geomorphology and rocky shore habitats, and the fact that the Murchison Estuary is the most northerly of the temperate estuaries in Western Australia led the Working Group to recommend as follows.

> "Consideration should be given to reservation of the marine areas adjacent to the Kalbarri National Park and the Kalbarri township, seawards for a distance of 1 nautical mile, and encompassing the tidal waters in the mouth of the Murchison River, for the purposes of public recreation and the protection of flora and fauna."

3.5. Port Gregory to Port Denison (Maps IV-3,5)

Although the sector of the central West Coast between Port Gregory and Port Denison is included within major distinctive coastal type 8, the Working Group was not able to identify any one portion of it as worthy of reservation by reason of its representativeness. However, two small areas warrant special attention for specific reasons. One of these is a small area at Port Gregory, significant because it contains Western Australia's most southerly coral reef on the mainland coast. The other is a small area south of Greenough where research on the western rock lobster has been carried out over many years.

3.5.1 Port Gregory (Map IV-3)

Tenure
The land adjacent to the area under consideration is a gazetted townsite.

Geomorphology
For the most part the coastline north and south of Port Gregory consists of sand beaches backed by Pleistocene dunes. At Port Gregory there is a low headland of Pleistocene aeolianite. A wide wave-cut rock platform has formed, connected to the shore at the southern end but with a shallow lagoon behind it in the northern part.

Flora and fauna
The intertidal rock platform has a cover of algal turf and macro-algae, and a rich invertebrate fauna. There are seagrass meadows in the lagoon and in the deeper offshore areas. In the lagoon immediately behind the rock platform, where there is constant water flow but protection from the main force of the swells, there is a small coral community. Veron & Marsh (1988) record 37 coral species of 13 genera at this locality. The genus *Acropora* is represented by eight species.

Recreation and commercial fishing
The lagoon is popular for swimming and a launching site for recreational fishers. It is also an anchorage for commercial fishing vessels.

3.5.2. Seven Mile Beach (Map IV-5)

This is a very small area about 1 km long and extending to 400 m offshore, located about 10 km north of Port Denison, which receives special attention here because of its long-term importance as a research area.

Tenure

The taking of rock lobster by any means in the small research area is prohibited pursuant to Sections 9 and 11 of the Fisheries Act (Government Gazette No. 88, 9 September, 1988). This was done to protect the area as a rock lobster research site.

Geomorphology and physical features

The beach is backed by Holocene dunes. There is an outer fringing reef of Pleistocene limestone and patchy limestone reefs within 400 m of the shore, some of which are exposed at extreme low tide. The patchy distribution of the reefs allows considerable wave energy to reach the shore, particularly at high tide.

Flora and fauna

Most of the patch reefs are covered by the seagrasses *Amphibolis antarctica* and *A. griffithii*. Those reefs exposed at extreme low tide are colonised by a mixture of the seagrasses *Halodule uninervis*, *Heterozostera tasmanica, Halophila ovalis* and a variety of turf algae. Between the reefs there are small sand blowouts and seagrass meadows dominated by *Halophila ovalis, Heterozostera tasmanica,* and *Syringodium isoetifolium* and the alga *Caulerpa cactoides*. Off-shore, beyond 400 m, the large brown algae *Ecklonia radiata, Scytothallia dorycarpa* and *Sargassum* sp. dominate the sublittoral zone. The seagrass *Thalassodendron pachyrhizum* is also prolific there, in shallower water than is usual for this species. The most southerly known locality of *Halodule uninervis* is at Port Denison just a few kilometres south of this location.

The area is of special note as a nursery site for the western rock lobster. Its inshore patch reefs are probably the best representatives of this habitat type along the West Coast. The juveniles settle among the seagrasses and large numbers live under the patch reef ledges. For this reason the area was selected as a research site by the Western Australian Fisheries Department and CSIRO Division of Fisheries and has been used for that purpose since the 1960s. Beach and bottom profiles have been drawn and the reefs have been accurately mapped in detail. Permanent transects through the seagrass meadows have been established. Research on the feeding, settling and migration of the western rock lobster is ongoing at this site. Many research findings basic to understanding the biology of this important commercial species have been published.

Previous recommendations

None.

Working Group recommendations

"1. Consideration should be given to the reservation of the reef and lagoon at Port Gregory for protection of marine flora and fauna, particularly the coral reef. Further study is needed to determine appropriate northern and southern boundaries.

"2. Consideration should be given to the reservation of the reefs and lagoons at Seven Mile Beach for protection of marine flora and fauna and scientific study. The reserved area should cover at least the area closed to rock lobster fishing under the powers of the Fisheries Act."

3.6. Houtman Abrolhos (Map IV-4)

The Houtman Abrolhos is a complex of islands, reefs and lagoons lying near the shelf-edge off the mid-west coast between latitudes 28 and 29° S. The Working Group believes that, of all the marine areas of the Western Australian coast, the Abrolhos is perhaps the most significant for its natural resource, nature conservation, historical and recreational values, and the most worthy of reservation.

On the criteria used by the Working Group in the reserve selection process, the Abrolhos scores very highly on every count. It qualifies as a major distinctive coastal type because it is unique - there are no other coral reefs of this type anywhere in the world. In biological terms it is representative in the sense that it represents itself - there are no other communities of marine animals which equate to those of the Abrolhos. It scores very highly in terms of habitat diversity and species richness, with a unique blend of tropical and temperate species. It is one of Australia's most important seabird breeding areas. It contains some of

Australia's most significant historic sites. It has magnificent underwater scenery and considerable potential for the development of nature-based tourism, especially dive tours. It is also the site of an extremely important rock lobster fishery and has been the subject of intensive marine research.

Because of the inter-connectedness of the various ecosystem units at the Abrolhos it is essential that the entire reef complex and surrounding waters be reserved and managed as an integrated ecosystem.

Recognising the potential conflict between these different interests, in 1988 the Western Australian Government appointed the Abrolhos Task Force to undertake a planning study, and the Abrolhos Islands Consultative Council (AICC) to ensure local input to recommendations and their implementation. The planning study culminated in publication of the Abrolhos Islands Planning Strategy in 1989. The AICC has since initiated a review of the Planning Strategy recommendations relating to selection and management of marine reserves within the Abrolhos.

It is important that marine reserves declared there be seen in the broader context of the Statewide marine reserve system proposed in this report. For this reason, while acknowledging the responsibility of the AICC and taking account of the fact that Working Group members have considerable experience and knowledge of the Abrolhos, it is appropriate that the Working Group expresses its views on marine reserves in the area as part of this report.

The following, much abbreviated descriptive notes are drawn from the Abrolhos Islands Planning Strategy, other technical publications, and the personal research experience of Working Group members.

Tenure

The islands of the Abrolhos are at present a Class A reserve (20253) vested in the Minister for Fisheries for the purposes of conservation of flora and fauna, tourism and purposes associated with the fishing industry. The reserve extends to low water mark.

The islands are surrounded by State Territorial Waters for a distance of 3 nautical miles from established baselines. These waters are declared a special fishing area for rock lobsters (Zone 'A') under the Fisheries Act. Two areas, one at Morning Reef in the Wallabi Group and one at Half Moon Reef in the Southern Group, are declared historic shipwreck sites under the Maritime Archaeology Act.

There are no current oil exploration tenements over the area of State Territorial Waters and the islands of the Abrolhos.

Geomorphology

The Abrolhos comprises a series of shelf-edge carbonate platforms situated at the northern end of the Rottnest Shelf. They have very great scientific interest in terms of interpretation of Quaternary climatic and geological history and development of coral reefs. The evolution, form and geological structure of the Abrolhos islands and reefs have been described by several authors in various contexts (Teichert, 1947; Fairbridge, 1948; Wilson, 1977; France, 1985; Hatcher Research Associates, 1988; Collins *et al.,* 1991; Collins *et al.*, 1993). Eisenhauer *et al.*, 1993) determined Holocene sea-levels from dating of coral cores taken in the Easter Group.

There are three major platforms, North Island and the Wallabi Group comprising the most northerly, Easter Group in the centre, and Pelsaert (or Southern) Group the most southerly. They are separated by Middle and Zeewijk Channels of about 40 m depth. Each of the platforms consists of a central area composed of Last Interglacial (Pleistocene) coral reefs about which leeward Holocene coral reefs have developed (Collins *et al.*, 1993).

The Easter Group and Pelsaert Group platforms have a more or less triangular form, reminiscent of atolls, with prominent seaward reefs, central lagoonal areas, and leeward back-reef complexes. The North Island-Wallabi Group platform "lacks the geomorphological organisation of the other island groups" (Collins *et al.*, 1991) and is dominated by large islands. Well developed lagoonal sand sheets are prominent in the Easter and Pelsaert groups. In the eastern parts of these two groups a conspicuous feature is the development of deep, roughly circular pits of varying diameter in the reef platforms, known as "blue holes". Determining the origin of these structures has been problematical. At one time they were thought to be remnants of a karst topography (collapsed caves and solution pipes) formed when the limestone platforms were elevated above

sea level during the Pleistocene glacial periods. Recent drilling has shown that they are developed in deep (over 26 m in the Easter Group) deposits of Holocene sediment and that they are depositional, not erosional, structures (Collins *et al.*, 1993).

The greatest area of the platforms now lies below high water mark but there are emergent islands and cays of diverse make-up and structure. The central portions of many of the reef platforms have emergent, flat-topped, so-called "high rock islands" (France, 1985) consisting of coralline limestone remnants of earlier reef platforms which stood at a slightly higher level (3-4 m) than the contemporary reef flats. They are usually deeply notched in the intertidal zone around their periphery and may have superficial ridges of coral sand and rubble. In the Wallabi Group the two large islands have a base of Late Pleistocene (Last Interglacial) reefal limestone overlain by bedded grainstones and aeolianites, sometimes with a mantle of Holocene dunes. These are the highest islands in the Abrolhos with the dunes rising to as high as 50 m. The eastern (leeward) margins of the platforms have composite islands which also have a Pleistocene reef limestone base overlain by Holocene coral shingle and sand.

During the last Pleistocene interglacial period there was extensive coral reef development at the Abrolhos, including along the seaward margins of the platforms. After interruption of coral growth during the Last Glacial, coral reef formation began again about 10 000 years ago (Collins *et al.* , 1993). Today coral reef growth is confined to the leeward shores and the sides of the channels. Nevertheless, modern coral growth is prolific.

Flora and Fauna

Both the terrestrial and marine flora and fauna of the Abrolhos are remarkable in several respects. During the last Pleistocene glacial period these reef platforms were limestone highlands along the coast. At that time they were populated by the plants and animals inhabiting the mainland coast.

After sea level rose some 7 000 years ago the highest points of the platforms became islands and the wide, lower portions became submerged reefs. Some residual mainland plants and animals survive on the highest islands (West and East Wallabi) including the Tammar wallaby, a number of reptiles, and the threatened plant *Eucalyptus oraria*, as relict populations. Newly emergent composite islands and cays, formed during the Holocene from sand and shingle thrown up by storms, have been colonised by plants and animals capable of crossing the water barriers from the high islands and the mainland.

With the warmer climate the Leeuwin Current redeveloped bringing warm water and the larvae of tropical marine animals from the north and re-establishing coral reefs and associated communities on the submerged reef platforms. Thus, the living and fossil floras and faunas of the Abrolhos provide a record of the momentous events of the late Pleistocene and early Holocene periods which have shaped our contemporary environment. It is partly for this reason that the islands and surrounding reefs of the Abrolhos have such great scientific importance.

Coral Reefs

The Abrolhos coral reefs are the most southerly in the Indian Ocean, lying far south of the tropical, so-called "coral zone". They are by far the richest in terms of habitat and coral species diversity of any high latitude reefs in the world. At present 184 species of coral belonging to 42 genera are recorded from the Abrolhos (Veron & Marsh, 1988). It appears that the corals at the Abrolhos are relatively slow-growing (Crossland, 1981) as might be expected at such a high latitude. The reef communities are also unusual in that they include a significant number of temperate species as well as tropical species and in some areas seaweeds dominate rather than corals (Wilson & Marsh, 1979; Hatcher, 1985). The competitive interactions of the seaweeds and corals on the Abrolhos reefs are of great interest to marine ecologists (Crossland, 1981; Johannes *et al.*, 1983; Hatcher & Rimmer, 1985).

Reef habitats are diverse at the Abrolhos. In a report commissioned by the Abrolhos Task Force for the Abrolhos Islands Planning Strategy, Hatcher Research Associates (1988) recognised 16 community types in 6 primary groups. Corals are not dominant in all of these. The most diverse and prolific growth of corals occurs in the low energy, leeward, back-reef habitats, along the sides of the channels and around the blue holes. Unlike reefs of similar structure in the tropics, there is only poor development of coral reef communities along the seaward reef-fronts at the Abrolhos.

Plant communities and filter feeding animal communities (sponges and ascidians etc.) are also important elements in the Abrolhos reef complex. The high energy seaward reefs are dominated by algae, most notably by the kelp *Ecklonia* and a fucoid of the genus *Sargassum.* There is evidence that organic detritus originating in these kelp beds and swept over the seaward reefs into the lagoonal and back-reef communities is a major factor in the high biological production of the Abrolhos reefs. Another plant community of great importance at the Abrolhos is seagrass meadow. These are best developed in the shallows on the northern sides of West and East Wallabi Islands. Rich filter-feeding communities are best developed on the seabed in the channels and lagoons.

Hatcher (1991) has discussed the importance of the Leeuwin Current in establishing and maintaining the coral reefs and associated communities at the Abrolhos. It delivers nutrients, warm water, and the larvae of tropical organisms from source areas further north. By the same process the Abrolhos reefs are a source of marine larvae carried even further south. The occurrence of tropical animals, including many corals, along the West Coast as far south as Rottnest and Cape Naturaliste is undoubtedly a consequence of this process. It follows that protection of the Abrolhos reef communities is important not only for their own sake but also for maintenance of the tropical element in the marine fauna along the Western Australian coast further south.

Mangals
There is only one species of mangrove present at the Abrolhos, *Avicennia marina.* It forms small mangals on sheltered shores throughout the islands. Apart from the remnant mangal, composed of the same species, in Leschenault Inlet, these are the most southerly mangals in Western Australia. There have been no studies on their associated fauna and ecology.

The Abrolhos mangals have special significance as habitat of the Lesser Noddy Tern and their preservation is essential for the continued breeding of this threatened bird.

Seabirds
The Abrolhos are considered to be among the most significant seabird breeding areas in the world (Fuller *et al.*, 1981).

The eastern Indian Ocean subspecies of the Lesser Noddy Tern (*Anous tenuirostris melanops*) is known to nest only at the Abrolhos (Morley, Wooded and Pelsaert Islands) where 39 000 breeding pairs have been counted (pers. comm. Andrew Burbidge and P. Fuller, May, 1993). A noddy recently reported breeding in small numbers at Ashmore Island may be this species (Stokes & Hinchey, 1991). The Red-tailed Tropic Bird (*Phaethon rubricauda)* formerly nested on Pelsaert Island. One bird was recorded incubating there in 1989 (R. Goodale & K. Coate, pers. comm.). Both these birds are threatened species under the Western Australian Wildlife Conservation Act.

The following seabirds breed at the Abrolhos (the Abrolhos support the largest Western Australian breeding colonies of the first nine species):

- Wedge-tailed Shearwater (*Puffinus pacificus)* - more than 1 million breeding pairs (pers. comm. A. Burbidge & P. Fuller, May, 1993);
- Little Shearwater (*Puffinus assimilis);*
- White-faced Storm Petrel (*Pelagodroma marina);*
- White-bellied Sea Eagle (*Haliaeetus leucogaster);*
- Common Noddy (*Anous stolidus);*
- Caspian Tern (*Hydroprogne caspia);*
- Crested Tern (*Sterna bergii);*
- Roseate Tern (*Sterna dougallii);*
- Fairy Tern (*Sterna nereis);*
- Eastern Reef Egret (*Egretta sacra);*
- Bridled Tern (*Sterna anaethetus*);
- Pied Cormorant (*Phalacrocorax varius);*
- Pacific Gull (*Larus pacificus);*
- Sooty Oyster Catcher (*Haematopus fuliginosus);*
- Osprey (*Pandion haliaetus).*

With this impressive list of breeding seabirds it is clear that the islands of the Abrolhos deserve special protection and management for nature conservation. Reservation of the surrounding waters and introduction of management objectives including protection of seabird feeding areas and the maintenance of buffer areas around the rookeries are also warranted.

Marine Mammals and Reptiles
The Australian Sea Lion (*Neophoca cinerea*), an animal declared to be in need of special protection under the Wildlife Conservation Act, is present in small numbers in the Abrolhos. This is close to the species' northern limit of range. There is evidence that the Sea Lion was once more abundant at the Abrolhos than it is today (O'Loughlin, 1969). In recent surveys in the Easter Group up to 43 animals were counted, mostly single bulls and small groups of cows and juveniles (Gales *et al.*, 1992). Breeding occurs on the islands with pupping taking place during July in 1989.

The Green Turtle (*Chelonia mydas)* has been recorded on North Island and may breed there.

Fisheries
The most important industry at the Abrolhos is the rock lobster fishery. It is a limited entry fishery and the Abrolhos is classed as a separate fishing area (Zone 'A') for the purposes of administration. Just over 200 boats are licensed to fish there, employing about 490 fishers. The fishing season runs from March 15 to June 30 and during this period many of the fishers live on certain of the islands. The rock lobsters are caught in pots set on the sea floor. Current estimates place the egg production from the Abrolhos rock lobster population at approximately 50% of the total egg production of the Western Australian population.

An important scallop fishery operates in the Abrolhos area, mostly on the sandy seabed east of the reefs. This too is a limited entry fishery. It engages about 30 trawlers, employing about 100 people. Wetlining is also a significant activity, engaging about 30 boats and employing over 50 fishers. Snapper, Jewfish, Baldchin Groper and other reef dwellers are the main target species.

Because of its distance offshore, the Abrolhos at present supports only a small recreational fishery. The extent of the amateur catch is not known.

Recreation
Access to the Abrolhos for tourism and recreational purposes is at present limited to guests of fishers holding permits to live on the islands, passengers on charter vessels or aircraft, and visitors on private launches and yachts. There are no accommodation or other facilities for tourists at the Abrolhos. Camping on the islands is prohibited. For these reasons, and the distance offshore, recreational and tourist use of the Abrolhos is at present very limited.

Nevertheless, there is considerable scope for development of nature-based tourism at the Abrolhos, both marine and terrestrial. The seabird rookeries, rich intertidal reef flats, magnificent coral reef dive sites, excellent fishing, and the historical sites on some of the islands hold many attractions for environment-conscious tourists.

The Abrolhos Islands Planning Strategy proposed that the islands should not be developed for tourist accommodation at this time and that the main form of tourism and recreation at the Abrolhos should continue to be boat based, augmented by aerial tours. An exception to this would be development of a field study facility on one of the islands, probably Beacon Island in the Wallabi Group, for use by educational environment and nature tour groups. Otherwise emphasis should be placed on developing day use sites in carefully selected areas, allowing visitors access to historic sites, bird observation points and other places of natural and cultural interest. This would include moorings in safe anchorages for overnight stays by charter vessels and at popular dive sites to avoid damage to coral growths.

Previous recommendations
There have been several reviews and reports on management of the Abrolhos prior to the above-mentioned Planning Strategy, notably a report by the WA Museum on the flora and fauna of the Wallabi and Easter Groups (Wilson, 1977), a report published by the Geraldton Mid-West Regional Development Committee (1982), and the proceedings of a workshop held by the Australian Marine Sciences Association (Hatcher & Walker, 1984).

The final report of the Abrolhos Islands Planning Strategy was received by the Government in 1989 and referred back to the AICC for further advice on implementation. Since then the AICC has prepared proposals for an Abrolhos Islands Aquatic Reserve covering the State waters surrounding the islands. The report was endorsed by the Government in November 1993.

The 1989 Planning Strategy recommended that those islands which are used as a base for the fishing industry should remain vested in the Minister for Fisheries and continue to be used for that purpose but that the remaining islands should be declared national park vested in the National Parks and Nature Conservation Authority for conservation of flora and fauna and recreation. This would allow appropriate management of the seabird rookeries and other conservation values of the islands and the development of day use sites for nature-based tourism.

The Planning Strategy also recommended that the State Territorial Waters surrounding the Abrolhos should be declared an aquatic reserve under Section 30 of the Fisheries Act, but with three enclaves declared marine park under the Conservation and Land Management Act. The three proposed enclaves are a portion of Morning Reef in the Wallabi Group, the eastern reef complex of the Easter Group, and the north-eastern portion of the lagoon and back reef of the Pelsaert Group.

This strategy, in effect, proposes reservation of the whole area as a multiple-use reserve. However, the areas designated principally as fishing zones, and the areas designated principally as conservation-recreation zones would be reserved separately under different legislation and managed by different agencies, that is the Fisheries Department and the Department of Conservation and Land Management respectively. Integrated management of the whole ecosystem would be achieved with the advice of the AICC and collaboration between the two management agencies.

The Planning Strategy selection of the three enclaves for marine park reservation was based, in part, on a habitat map produced by consultants to the Abrolhos Task Force (Hatcher Research Associates, 1988). The criteria used included a variety of environmental, economic and social factors and gave high values to:

- areas of highest diversity and richest growth of corals;
- areas of highest sensitivity to disturbance;
- areas which incorporate a range of habitats.

In accordance with the first two of these selection criteria, the three areas proposed for reservation as marine park all feature rich coral growth and are located in low energy, leeward reef positions which are most sensitive to disturbance. They include some of the richest coral growth and the best dive sites in the Abrolhos, eg. the area known as "The Maze" in the Easter Group. However, the Working Group has studied the Task Force habitat map and believes that, in respect of the third of the criteria listed above, these three areas are not adequate. They do not represent the range of marine habitats of the Abrolhos. Most notably they do not include areas of the seaward reefs which are dominated by algal growth, or areas dominated by seagrass meadows. The Working Group also considers that the three proposed marine park enclaves do not provide adequately for recreational activities in the Abrolhos.

To date none of the Planning Strategy and AICC recommendations for an aquatic reserve and marine parks in the Abrolhos have been implemented.

Working Group recommendations

The Working Group had difficulty in reaching a satisfactory degree of consensus in respect of its recommendations for the Abrolhos. The view that these islands, reefs and waters have the highest possible scientific and conservation value and that they should be managed as an ecological entity was unanimous. There was also unanimity that the three enclaves proposed in the Abrolhos Islands Planning Strategy to be managed primarily for conservation and recreation purposes do not adequately represent the habitats of the Abrolhos, or fairly provide for recreational users. A strong view was expressed that the whole area of State Territorial Waters at the Abrolhos should be reserved as marine park, noting that present legislation would not preclude commercial fishing within the park. However, after long debate the following recommendations were agreed.

> "In keeping with the high scientific, historic, recreational and conservation values of the Abrolhos islands and reef complexes, and the high value of the rock lobster fishery and other fisheries, the entire area to the

limit of State Territorial Waters should be reserved and managed as a multiple-use area. This should be done as a high priority.

"Management of fisheries, tourism, education and scientific research should be integrated with measures to protect the area's natural and cultural values so that an appropriate balance between these activities is maintained.

"Ideally, given the inter-connectedness of the island, reef and open water ecosystems, the entire Abrolhos area should be managed as a single ecosystem unit.

"The Working Group proposes that areas selected specifically for protection of marine flora and fauna and public recreation could be made more representative of the Abrolhos marine habitats and flora and fauna, and with better provision for public recreation, by the following amendments to the Planning Strategy recommendations:

i) addition of an area encompassing the seaward rock platform and seagrass meadows on the west and north of West Wallabi and East Wallabi Islands;
ii) extension of the proposed marine park around Beacon Island to include the whole of Morning Reef;
iii) extension of the proposed Pelsaert Group marine park to include a section of the seaward reef-front habitat of Half Moon Reef and the lagoon west of Pelsaert Island."

3.7. Beagle Islands (Map IV-5)

This section of the central West Coast represents the northern portion of major distinctive coastal type 9 (see Section 1.1). It contains most of the typical habitat types and shares many features with the area of the coast centring on Jurien Bay. However the Beagle Islands sector possesses some unique geomorphological features and has special conservation values.

Tenure
The Beagle Islands are a Class "A" Nature Reserve. They are roughly 5 nautical miles offshore. The waters within a radius of 3 nautical miles around the islands are State Territorial Sea. The inner part of that circle intercepts the north-south line representing the limit of the State Territorial Sea described 3 nautical miles from the mainland shore. Thus, most of the reef areas considered in this section fall within the coastal area under State jurisdiction but some of the areas north and south of the Beagle Islands are outside State limits and within Commonwealth waters.

There are at present no petroleum exploration tenements over the area of the continental shelf under discussion in this section.

Geomorphology
The shore of this sector has a generally north-south alignment and consists of arcuate beaches backed by cuspate dunes. There are several small rocky headlands composed of Tamala Limestone.

The offshore bathymetry is moderately complex with north-south aligned limestone reefs, some of which break in moderate seas. The most conspicuous offshore feature is the Beagle Island complex, consisting of three limestone islands surrounded by reef shallows. A shallow sand bank (3-4 m depth) runs from the island complex to the mainland.

A feature unique to the sector is the presence of several scour or drainage channels running from the mainland across the sea floor on the inner part of the continental shelf. These are not evident on available bathymetric charts but are readily apparent on satellite imagery. Their origin is unknown.

There are no rivers entering the sea within this sector.

Marine flora and fauna
There is very little information on the marine flora and fauna of this section of the West Coast. There have been no surveys and no comprehensive collecting has been done there. However, from aerial photography and satellite imagery it is evident that there are very extensive seagrass meadows in the inter-reef lagoons and on the large sand bank inshore of the Beagle Islands.

There are anecdotal reports of extensive coral growth around the Beagle Islands, including tabular *Acropora*, but these have not been confirmed.

The Beagle Islands are nesting areas for seabirds, notably the Bridled Tern, Roseate Tern, Pied Cormorant and Wedge-tailed Shearwater. The Osprey, White-bellied Sea Eagle, White-faced Storm Petrel, Caspian Tern and Silver Gull also nest there in small numbers.

The Beagle Islands are the site of the West Coast's largest breeding colony of the Australian Sea Lion (Gales *et al.*, 1992). Up to 200 animals have been counted there at any one time. In the 1989 breeding period 79 pups were counted on these islands. These figures suggest that protection of this breeding colony is of the utmost importance as the species is in limited numbers on the West Coast and is declared to be in need of special protection.

Fisheries
The reefs of this sector are important areas for the rock lobster fishery. There are several small fishing settlements along this stretch of coast and the town of Leeman is located just to the south. Recreational fishing is limited.

Recreation
There is poor access to most of this coast, except at the small fishing settlements. The Beagle Islands are remote and difficult to land on and they are rarely visited.

Previous recommendations
None

Working Group recommendations
Although limited information is available on the marine habitats and flora and fauna of this part of the central West Coast, the Working Group concluded that it has many of the characteristics of the region and some particularly important features, most notably the very extensive seagrass meadows and the Beagle Islands Sea Lion breeding colony. The scour channels across the seagrasses in the northern part of the sector are worthy of further investigation.

In order to provide adequate protection to the Sea Lion colony, the Working Group considers that the waters surrounding the Beagle Islands should be made a buffer zone by reservation for the protection of marine flora and fauna. Given the importance of the seagrass meadows along the adjacent coast, the Working Group also believes that consideration should be given to the declaration of a multiple-use reserve along that coast and suggests that this should extend about 30 kilometres from Knobby Head to a point just north of Leeman. When taken together with the proposed marine reserve in the Jurien sector this would reserve about 16% of the Port Denison to Whitfords coastal type and adequately represent the marine habitats and biota of the West Coast.

Accordingly the Working Group recommends as follows:

> "Consideration should be given to the reservation of State Territorial waters surrounding the Beagle Islands and along the adjacent mainland between Knobby Head (29° 39') and a point just north of Leeman (29° 55'), for the purpose of protection of marine flora and fauna, with accommodation made for the continuance of the rock lobster fishery."

3.8. Jurien (Map IV-6)

This section of the central West Coast is regarded by the Working Group as typical of the region (major distinctive coastal type 9 - see Section 1.1) and contains excellent examples of all its characteristic habitat types. It shares many features with the Beagle Islands sector.

Tenure
The State coastal baseline in this area is drawn between the major headlands and islands so that the 3 nautical mile limit of the State Territorial Sea lies well offshore and all the reef structures described below are within the area under State jurisdiction.

Essex Rocks and Sandland, Favorite, Boullanger, Whitlock and Escape Islands are Class "A" Nature Reserves. The mainland shore adjacent to the area under consideration has a variety of purposes and vesting including townsite (Jurien), private, foreshore reserve for public recreation or public utilities, and nature reserve.

The coastal areas under consideration are abutted by offshore Petroleum Exploration Permit WA-228-P.

Geomorphology

The shore of this sector has a generally north-south alignment and consists of arcuate beaches backed by cuspate dunes with several prominent sandy tombolas or dune-covered promontories and several rocky headlands composed of Tamala Limestone.

The near-shore bathymetry is complex. Inside the 20 m isobath there is a series of prominent, elongate, offshore limestone reefs, more or less parallel to the shore, protecting inshore lagoons. Many of the reefs break in moderate weather, some are exposed at low tide and some bear emergent rocks and islands. There is a series of medium sized limestone islands (Sandland, Favorite, Boullanger, Whitlock, Escape, Cervantes) which have well developed intertidal rock platforms, at least on their seaward sides.

The most conspicuous of the headlands is North Head which has moderate cliffs, wide rock platforms at sea level with deeply undercut intertidal notches, and small pocket beaches. Green Head, further north, is very similar. Below low tide level the reefs are frequently deeply undercut and extensive underwater cave systems are common.

Jurien Bay is the major embayment within distinctive coastal type 9 of the West Coast. It has developed as an erosional scallop into the interbarrier zone behind prominent offshore limestone reefs (see Semeniuk *et al.*, 1989, fig. 11). It is wide, arcuate and westward-facing. Ronsard Bay further south is of similar but less pronounced character.

The two principal sand promontories, Island Point and Thirsty Point, are developed behind protective near-shore islands. Constructed by the same sedimentary processes, there are shallow sand banks connecting near-shore islands and reefs to the mainland, most notably behind Favorite Island, Boullanger Island, Booker Rocks, Emu Rocks and North Ronsard Rocks. These are normal to the shore and tend to break up the inshore lagoon system. However, moderately deep basins (12-14 m) remain between the sand banks in several locations. Two of the inshore basins are completely enclosed by the banks with restricted bottom circulation to the open sea. One of these is in Jurien Bay behind Favorite Island opposite the marina. The other is south of Island Point, behind the Essex Rocks and Three Breaks Reef complex.

The Hill River reaches the coast within this sector. It has a small estuary of the riverine type with a permanently closed entrance.

Flora and fauna

There has been no thorough survey of the marine flora and fauna of this sector although there is some information giving the impression that the biota is both rich and diverse.

The dominant organisms are the seagrasses which form dense meadows on the shallow banks and at the bottoms of the lagoons. Both species of *Amphibolis,* unidentified species of *Posidonia, Halophila ovalis, Syringodium* sp. and *Heterozostera tasmanica* are recorded. It is likely that, when studied, the seagrass flora will prove to be species-rich. There is no detailed information on the zoophytes and epiphytes living on and associated with the seagrasses although some species characteristic of this habitat (eg. the molluscs *Phasianotrochus irisodontes, Cantharidus lepidus, Ctena bella* and *Wallucina icterica)* are known to be abundant and it can be assumed that the seagrass community is diverse. Kelps dominate the sublittoral zone where there are rock substrata. Rock platforms bear thick coverings of algal turf.

Sand substrata between the seagrass meadows on the sand banks support a rich infauna of bivalves and other invertebrates. These include four species of irregular echinoids (sand dollars and heart urchins) including *Ammotrophus arachnoides* which is otherwise not known north of Fremantle. The deep basins between the sand banks are likely to have a different benthic fauna but they have not been investigated.

North Head within this sector and Green Head a few kilometres further north are very similar habitats. There is no information on the relative richness of the respective plant and animal communities of these

two rocky headlands and it is assumed that North Head adequately represents this type of habitat for the West Coast. There has been some scientific collecting on the rock platforms and sublittoral rock habitats around Whitlock Island which are especially rich in invertebrate species. A number of endemic South West molluscs are at or close to their northern end of range in this area, eg. *Campanile symbolicum, Turbo jourdani, Haliotis scalaris.* This is the type locality of the rare endemic cowry *Cypraea (Zoila) venusta* . It is the centre of the West Coast and most of the West Coast endemic species are present on and among these reefs. Assessment of the species composition of the molluscan fauna indicates that temperate species dominate although there is a significant proportion of tropical species (Wilson, unpublished data). Limited scientific collecting has revealed 18 species of echinoderm from the reefs in this region and more could be expected (L.M. Marsh, pers. comm., May, 1993).

The well developed sublittoral rock and cave walls of this sector have an especially rich fauna of attached, suspensory feeding animals such as ascidians, sponges and gorgonian and hydrozoan corals. These communities are extremely colourful and provide a magnificent spectacle for recreational divers. They are a feature of the West Coast yet remain virtually unstudied.

There are no coral reefs in this sector but individual coral colonies of 14 species belonging to 11 genera have been recorded, some of them common, in the shallows of sheltered areas behind the offshore reefs (Veron & Marsh, 1988). This includes 2 species of *Acropora* (*A. hyacinthus* and *A. millepora).* With the exception of a few colonies of *A. yongei* recorded at Rottnest, these are the most southerly Western Australian records of living *Acropora.*

Seabirds and Mammals
Like most of those along the central West Coast, the small islands and rocks of this sector are breeding areas for a variety of seabirds.

Sandland Island is an important nesting area for the Crested Tern and Pied Cormorant. Other birds recorded breeding there are the Little Pied Cormorant, Wedge-tailed Shearwater, White-faced Storm Petrel, Eastern Reef Egret, Osprey, Silver Gull, and Caspian Tern.

The other particularly important seabird islands in this sector are the three small islets comprising the Essex Rocks. Large numbers of Bridled Tern, Little Shearwater and Pied Cormorant nest there. Also recorded are Wedge-tailed Shearwater, Eastern Reef Egret, Pied Oystercatcher, Silver Gull, Pacific Gull, Caspian Tern, Crested Tern, White-faced Storm Petrel and Osprey.

Favorite Island is an important nesting area for the Little Shearwater. Other seabirds recorded nesting there are the Wedge-tailed Shearwater, White-faced Storm Petrel, Pied Cormorant, Osprey, Pied Oystercatcher, Silver Gull, Pacific Gull and Caspian Tern.

Boullanger and Whitlock Islands are important nesting sites for the Fairy Tern. Numbers of Pied Cormorant nest on Boullanger and numbers of Bridled terns on Whitlock. Also nesting in this island group are the Wedge-tailed Shearwater, Little Shearwater, White-faced Storm Petrel, Osprey, Pied Oystercatcher, Silver Gull, Pacific Gull and Caspian Tern.

In spite of their small size, Boullanger and Whitlock Islands support populations of the Dibbler (*Parantechinus apicalis*), a native marsupial once common in the South West but now threatened with extinction.

Sandy beaches on most of the islands in this sector are used to some extent by Australian Sea Lions. Of particular importance is Sandland Island, near North Head, where numbers of juveniles are often present (G. Pobar pers. comm., May, 1993). None of the islands in this sector are known breeding sites.

Fisheries
Jurien Bay is a major centre for the rock lobster fishery. A number of boats operate from Jurien. The relatively protected bay is an important anchorage for the fleet and a serviced marina has been constructed. South of Island Point there is a commercial mussel farm. Proposals are current for the location of fish cage farms in the area as well.

Recreation
Jurien town has a population of over 800 residents and is becoming a centre for tourist access to the hinterland as well as for maritime recreation. There is some potential for developing dive tour and marine oriented nature-based tourism activities. A whale-watching tour operated from Jurien during the 1992 Humpback migration season. However, public access to the islands disturbs the seabirds and Sea Lions which nest and rest there and such activities must be carefully managed. The populations of the Dibbler on Boullanger and Whitlock Islands are especially vulnerable to disturbance.

Previous recommendations
None.

Working Group recommendations
Having considered the limited available information on the marine habitats and flora and fauna of the central West Coast, the Working Group concluded that a section about 26 km long encompassing Jurien Bay has excellent potential as a multiple-use marine reserve representing the regional environment, when taken together with the Beagle Islands sector. As indicated previously, the two areas represent about 16% of the Port Denison to Whitfords coastal type.

The Jurien sector has complex bathymetry with well developed reef systems, emergent rocks and islands, extensive sand banks with dense seagrass meadows, rocky shores with wide rock platforms, several deep semi-enclosed basins, and abundant and diverse marine flora and fauna. Consideration was given to a stretch of coast further south, adjacent to the Nambung National Park, but that area has less complex geomorphology and less diverse marine habitats.

The Working Group is aware that the rock lobster fishery makes extensive use of this area but believes that is compatible with reservation for multiple-use purposes under existing legislation (see Part I).

Accordingly the Working Group recommends as follows:

> "Consideration should be given to reservation of the State Territorial waters between latitudes 30° 12' and 30° 26', encompassing Sandland Island, North Head, Jurien Bay, Island Point, Boullanger, Whitlock and Escape Islands and Booker Rocks, for the purposes of protection of marine flora and fauna and public recreation. The Jurien Boat Harbour should be excluded."

3.9. Shoalwater Islands Marine Park - Garden Island and Carnac Islands Extensions (Map IV-7)

The waters of Shoalwater Bay and Warnbro Sound, were declared Class "A" Marine Park in May, 1990 (see Section IV, 3.2). This section deals with a proposed extension of the marine park seawards to the limit of the State Territorial Sea and northwards to encompass the waters around Carnac Island and the western shore of Garden Island.

A bibliography of environmental studies in the southern metropolitan waters was published by Cary & Ryall (1992).

Tenure
The boundaries of the existing marine park are shown on Map IV-7.

Carnac Island is a Class "A" Nature Reserve (No. 26646). Garden Island is Commonwealth territory managed by the Department of Defence. Point Peron is a recreation reserve vested in the Minister for Sport and Recreation for recreation and education. The islands of Shoalwater Bay and Warnbro Sound within the existing marine park are Class "A" nature reserves except Penguin which is a Class "A" reserve for recreation and camping.

The waters on the western side of Garden Island are under the control of the Department of Defence. A section of the coastal waters between Collins and Callista Points has been gazetted under the Fisheries Act as a research area for use by CSIRO.

Geomorphology
The coast of this area is representative of major distinctive coastal type 10 (see Section 1.1). The geomorphology of the existing Shoalwater Islands Marine Park has been briefly described in Section 2.6. The areas proposed below for addition to the marine park have the following features.

The western shore of Garden Island is exposed to moderate wave-action and comprises long sandy beaches between limestone headlands, although there are several semi-protected bays at the northern end. Wide, intertidal rock platforms are cut into the fronts of the headlands and there are numerous shallow reefs and some rock islets close to shore. Carnac Island is almost surrounded by low limestone cliffs and intertidal rock platforms, but there is a beach on the eastern side. A shallow sand sill, known as Parmelia Bank, connects Carnac Island to the mainland and forms the northern side of the Cockburn Sound basin.

Offshore, west of Garden and Carnac Islands, there is a series of limestone ridges on the seabed, generally trending parallel to the coast. These are the remains of consolidated Pleistocene dune systems formed during periods of low sea level. The ridges are deeply undercut and cavernous. Between them there are sandy gutters. The largest of the ridges is Five Fathom Bank, approximately five kilometres offshore. This bank is one of the major structural features of the central West Coast.

Flora and fauna
The intertidal flora and fauna of the Carnac Island rock platforms have been described in detail by Marsh & Hodgkin (1962). These communities are species-rich but lack the high proportion of tropical species present in the comparable intertidal rocky shore communities of Rottnest Island. The Carnac and Garden Island rock platform communities may be considered as representative of this habitat type on the central West Coast.

The seagrass meadows of Parmelia Bank are exceptionally dense and prolific. They represent one of the best examples of this community type on the West Coast.

There has been no survey of the flora and fauna of the offshore submerged limestone ridges. Nevertheless, several of the Working Group members have dived there and report that reef surfaces exposed to sunlight bear very dense growths of macroalgae and seagrass and that the shaded ledges and cave walls bear prolific growths of suspensory-feeding invertebrates. There are large areas of seagrass meadow in the sandy gutters between the ridges.

Fisheries
The offshore limestone ridges are the habitat of rock lobster and this area is an important fishing ground of the rock lobster fishery, the vessels operating from Fremantle and Rockingham. Recreational fishers also make extensive use of this area.

Previous recommendations
See Section 2.6 for details of the existing Shoalwater Islands Marine Park and its boundaries.

In the System 6 report (1983) the EPA recommended that "a study be commissioned by the Environmental Protection Authority with the aim of establishing a Marine Reserve to be managed for the purposes of conservation and education" around Carnac Island, showing boundaries (Fig. 35) encompassing Shag, West, South West and Flat Rocks. This recommendation has not been implemented.

Working Group recommendations
The Working Group notes the increasing recreational use of the waters off Carnac and Garden Islands and the importance of these areas for research and environmental education. Although no study of the Carnac Island area has been carried out as recommended by the EPA, the Working Group believes that sufficient is known of the marine communities and recreational activities in the area to justify reservation. However, there would be merit in extending the marine reserve southward to link with the existing Shoalwater Islands Marine Park and providing added protection to the western shores of Garden Island. The Working Group also believes that the representativeness of the reserve would be greatly increased if its seaward boundary was located at the limit of the State Territorial Sea, thus incorporating a section of the submerged limestone ridge known as Five Fathom Bank.

Accordingly the Working Group recommends as follows.

> "Consideration should be given to the extension of the Shoalwater Islands Marine Park seaward to the limit of the State Territorial Sea, northward along the western shores of Garden Island and Carnac Island, and for 1 nautical mile east of Carnac Island, returning to Beacon Head on the north-eastern corner of Garden Island."

3.10. Peel-Harvey Inlet (Map IV-8)

The Peel-Harvey Inlet is one of the three large estuarine systems on the West Coast. There are two distinct parts of the complex which have rather different structure, known as Peel Inlet and Harvey Estuary. (Note the local convention of calling one an inlet and the other an estuary. They are both estuarine and equally definable as inlets.)

The Peel-Harvey system is at present subject to severe eutrophication resulting mainly from input of nutrients from farming lands in the catchments. It is also one of Western Australia's most important recreational areas, the site of significant recreational and commercial fisheries, and an internationally important waterbird and wetland habitat.

Because of these social, economic and environmental values the Government has invested heavily in an attempt to correct the pollution problem. This effort includes construction of a second, artificial channel to the sea which will increase the tidal flushing of the estuary and many detailed studies of the physical and biological features of the area leading to proposals for management (Hodgkin *et al.*, 1980; Peel-Harvey Study Group, 1985 (a) and 1985 (b); Hodgkin et. al., 1985; EPA Bulletin **363**, 1988; Waterways Commission Report No. **27**, 1992). There have also been several symposia on the subject (D.C.E. Bulletins No. **136**, 1983; No.**160**, 1984; No. **195**, 1985).

This account will not attempt to summarise the wealth of information to be found in the above publications. The following brief notes relate specifically to the possible reservation of estuarine areas.

Tenure

Pursuant to the provisions of the Waterways Conservation Act 1976 (see Part I) the Government established the Peel Inlet Management Authority in 1977 and declared the Peel Inlet and Harvey Estuary a Management Area. The Authority has overall responsibility for protection and management of the inlet, in collaboration with other State and Local Government authorities with statutory responsibilities in the area.

Public land around the periphery of the inlet has a variety of vestings. Near the entrance to Peel Inlet there are extensive supratidal samphire flats and two low islands, Creery and Channel, which were recently declared nature reserves. In the delta of the Serpentine and Murray Rivers there are many islands with a variety of vestings. One of these, Ballee Island, is reserved as "national park" vested in the Shire of Murray. On the eastern and southern shores of Peel Inlet itself there is a nature reserve (No. 4990). On that side of the inlet there are extensive mud and sand flats that are exposed at low tide. A large part of Austin Bay is intertidal and is a nature reserve (No. 28087) declared under the Land Act. Most of the land bordering the eastern side of the southern end of Harvey Estuary is nature reserve (Nos 23756. 2738, 24739).

The whole of the Peel-Harvey Estuary, and the surrounding nature reserves (ie. excluding private lands) is included within the Peel-Yalgorup Wetland of International Importance on account of its very high value as habitat for waterbirds. Listing of the wetland was proposed by the Western Australian Government in February 1990 and it is now included in the List of Wetlands of International Importance under the RAMSAR Convention to which Australia is a signatory. Listing imposes on the State an obligation to ensure that the environment is adequately protected against changes that may be detrimental to its function as wetland habitat.

Geomorphology
Accounts of the physical features of the estuary are given in Hodgkin *et al.* (1980) and Hodgkin *et al.* (1985).

Peel Inlet is a wide saucer-shaped basin with a narrow channel to the sea. It has a central portion about 2 m deep surrounded by shallow and intertidal flats which are very wide on the eastern and southern sides and grade into supratidal samphire flats and marshes. The Murray and Serpentine Rivers flow into the north-eastern corner and have formed a large delta.

Harvey Estuary is an elongate barrier estuary formed behind Pleistocene dune ridges, discharging to the sea through Peel Inlet. It has a central channel, also about 2 m deep, bordered by shallow sand flats, principally along the eastern side where they grade into supratidal samphire flats and marshes. The Harvey River flows into the southern end of the estuary forming a prominent delta.

The eastern side of Peel Inlet and the southern end of Harvey Estuary have wide intertidal mudflats and slope gently upwards to wide samphire flats and marshes.

The Mandurah Channel through which the estuary discharges to the sea was partly barred at the mouth and partly occluded at its inner end by delta flats and samphire islands. These barriers and the narrowness of the channel restricted tidal flow. The channel has recently been deepened by dredging to remove these barriers as part of the estuary management program. A second, artificial channel (the Dawesville Cut) has been constructed through the barrier dunes at Dawesville, near the point where the Harvey Estuary joins Peel Inlet. This is intended to increase tidal flushing and assist in removal of excess nutrients by tidal flow.

Prior to these channel works tidal amplitude seldom exceeded 0.1 m. Water level within the estuary may vary over a greater range than this as a result of weather conditions. Salinity in the estuary ranges from nearly fresh in winter to hypersaline in summer (up to 50 ppt). The lowest summer salinities occur at the southern end of Harvey Estuary. Even though it is so shallow, stratification of the estuary occurs when the rivers flood. The Dawesville Channel is expected to increase tidal amplitude within the estuary and reduce the annual range in salinity so that, on average, conditions will be more like that of seawater (Hodgkin *et al.*, 1985).

Flora and fauna
The aquatic flora and fauna of the estuary is depauperate, largely as a result of the severe salinity regime.

There are no extensive seagrass meadows in Peel-Harvey inl*et al*though three seagrass species are present. *Zostera mucronata* grows in a small area near the present channel entrance. *Ruppia megacarpa* is common in the shallows and *Halophila ovalis* is common in the deeper areas (Hillman, 1985). It is believed that *Ruppia* and *Halophila* were once the dominant plants in the estuary, with the former most abundant in Harvey Estuary (Hodgkin *et al.*, 1985). Since about 1960, with the development of the eutrophication problem, macroalgae and planktonic algae have displaced them.

The principal macroalgae in the estuary are benthic species of *Cladophora, Ulva* and *Chaetomorpha* and the epiphytic *Enteromorpha*.

Supratidal flats, especially well developed along the eastern and southern shores of Peel Inlet and the southern shores of Harvey Estuary, are vegetated with *Sarcornia, Juncus krausii* and other marsh plants.

Wells & Threlfall (1981) recorded only 13 species of molluscs in the estuary, of which five true estuarine species are dominant. Nevertheless, in terms of biomass some of these are of utmost importance (Wells *et al.*, 1980). Two tiny estuarine molluscs, the bivalve *Arthitica semen* and the gastropod *Hydrococcus brazieri* and several of the estuarine polychaetes are extremely abundant on the tidal flats and provide the bulk of the food for wading birds. Marine invertebrates and estuarine species with marine affinities are restricted mainly to the vicinity of the entrance channel and the deeper parts of the estuary which are less subject to freshwater inundation (Wells *et al.*, 1980).

The fish fauna of Peel-Harvey Estuary has been described by Lenanton (1974a) and Chalmer & Scott (1984). The latter authors list a total of 33 species of fish from the two portions of the estuary.

The Peel-Harvey Estuary is the most important area in southern Western Australia in terms of the total numbers of waterbirds which feed there (Jaensch, 1993). Over 110 000 birds were recorded there in 1977. A total of 67 species of waterbird have been recorded in the estuary. For some of these species the largest populations recorded in the south-west are from this estuary, eg the Little Egret (*Egretta garzetta)* and the Royal Spoonbill (*Platalea regia)*. More than 60,000 Banded Stilts (*Cladorhynchus leucocephalus)* were counted there in 1977. It was largely for these reasons that the Peel-Harvey Estuary was listed as a Wetland of International Importance under the RAMSAR Convention in 1990.

Effects of the Dawesville Channel and other management programs
At various stages in the development of eutrophication, macroalgae and planktonic algae have bloomed and created severe fouling problems in the estuary. Since 1980, spring and early summer blooms of the planktonic nitrogen-fixing algae *Nodularia* have created even greater fouling problems. Although these algae normally play a necessary role in the nutrient cycling and food chains of the estuary, their blooms have become such a problem that the estuarine ecosystem is now in danger of complete collapse. Mass mortalities of fish, crabs and other invertebrates in the estuary have become a common event as a result of deoxygenation of the deeper waters during *Nodularia* blooms.

The present catchment management program, dredging the Mandurah Channel and construction of the new Dawesville Channel, are intended to reduce nutrient enrichment and eutrophication and restore the estuary to a healthy condition. However, these actions will do more than that. By making the estuary more marine they may entirely change the nature of the ecosystem (Hodgkin *et al.*, 1985). The possible effects of these changes on the estuarine biota have been discussed by several authors in DCE Bulletin **195** (1985). *Nodularia,* which cannot tolerate high salinity, may no longer be subject to periodic blooms. Species diversity is likely to increase as more marine species invade the estuary. Fluctuations in abundance are likely to decrease as the range of salinity is reduced and the periods of freshwater inundation become shorter. Periodic mass mortality of fish and invertebrates will be less frequent. Seagrasses may become more abundant (although in the short term there may be a return to *Cladophora* blooms). These changes are likely to have overall positive effects. On the possible down side, it is likely that the biomass of benthic estuarine invertebrates on the tidal flats will be reduced (Chalmer & Hillman, 1985). This may have an adverse effect on the waterbird population (J. Lane pers. comm.). A concern has also been raised that the increased tidal range may have adverse effects on vegetation and bird nesting sites around the periphery of the wetland.

Fisheries
The Peel-Harvey Estuary supports the largest commercial and recreational estuarine fishery in Western Australia.

Recreation and tourism
The Peel-Harvey Estuary is one of Western Australia's most important recreation areas servicing the metropolitan Perth community as well as people living in the district. It is the major tourist attraction of the district (Waterways Commission Report No. **27**, 1992). Details of recreational activities and commercial tourism in the area are described in the Mandurah Tourism Development Plan. Most of these activities concentrate in the northern parts of Peel Inlet and the western shores of the Peel and the Harvey Estuary.

Previous recommendations
The EPA System 6 Report (1983) recommended that three areas within the Peel-Harvey system should be declared aquatic reserves:

> C 50.3 "That the area of water surrounding Reserve C8185 [Creery Islands] at the entrance to Peel Inlet be declared an Aquatic Reserve and vested in the WA. Wildlife Authority."
>
> C 50.5 "That the area of water to the west of Reserve B4990 be declared an Aquatic Reserve and vested in the WA. Wildlife Authority."
>
> C 51.3 "That the area of Harvey Estuary south of the "Ford" be declared an Aquatic Reserve and that the Reserve be vested in the WA. Wildlife Authority."

More recently (1993, EPA Bulletin 695) the EPA considered the potential environmental impacts of a proposal to develop a canal estate on land adjacent to the proposed aquatic reserve but did not refer to its earlier recommendation (C 50.3).

It should be noted that, in respect of recommendation C 50.5, the recommended area abuts the northern side of the former Austin Bay Nature Reserve No. 28087 (now part of the extended Reserve 4990) which covered the intertidal flats of the south-eastern side of Austin Bay. In effect C 50.5 would extend that reserve northwards to encompass all the shallows on the eastern side of Peel Inlet. Aquatic reserve status was recommended because it includes an area of subtidal waters which cannot at present be reserved under the Land Act.

All three areas were recommended as aquatic reserves because at that time there was no provision for declaration of marine nature reserves. The Conservation and Land Management Act 1984 provides that an aquatic reserve under Section 30 of the Fisheries Act may not be declared for any purpose which could be met by declaration of the area as a marine park or marine nature reserve under the Conservation and Land Management Act. In keeping with the intent of the System 6 recommendations the appropriate reserve category for the three proposed areas under present legislation is marine nature reserve, with vesting in the National Parks and Nature Conservation Authority, the successor of the WA Wildlife Authority.

In its Peel Inlet Management Program 1992, the Peel Inlet Management Authority (Waterways Commission Report No 27, 1992) recommended as follows (page 40, recommendation 20): "Support the implementation of the System 6 Recommendations C 50 and C 51 and provide technical advice concerning these areas if appropriate."

However, this recommendation is not entirely consistent with area recommendation A 91 of that Management Program (page 87) which refers to the same area as System 6 area C 51 but reads:

> "Create a Conservation Reserve south of a line between Island Point and Herron Point. Incorporate all of the Harvey Estuary south of this line into the reserve. Vest reserve in the WWC [Waterways Commission] until Peel-Harvey Regional Park is established. CALM to prepare a management program."

This last recommendation cannot be implemented under present legislation. Reserves vested in the Waterways Commission must be declared under the Land Act but subtidal lands cannot be declared under that Act. Vesting of the subtidal areas in question in the Waterways Commission would require special legislation or an amendment to the Land Act.

Working Group recommendations

Notwithstanding the present polluted condition of the Peel-Harvey estuary, the Working Group believes that parts of this estuary have very high value as habitat for waterbirds, including migratory waders whose protection is subject to international treaties, and warrant reservation as an added protection measure. Changes to the estuarine ecosystem following the opening of the Dawesville Channel are likely to be, on the whole, beneficial although the effects on waterbird feeding, roosting and nesting habitats will need to be carefully monitored.

The recreational and fishing activities in the Peel-Harvey Estuary are at present adequately controlled under the authority of the Peel Inlet Management Authority and the Fisheries Department. Accordingly the Working Group:

> "1. Endorses the recommendations in the EPA System 6 report for the reservation of three areas within Peel-Harvey Inlet, namely:
>
> - the waters surrounding the Creery Islands at the entrance to Peel Inlet (C 50. 3);
> - the waters and intertidal lands in the eastern part of Peel Inlet and south of the Yunderup, adjacent to Nature Reserve No 4990 delta (C 50.5);
> - the waters of Harvey Estuary south of a line between Herron Point and Island Point (51.3)
>
> for the purpose of protection of flora and fauna, specifically for the protection of waterbirds and their habitats.

"2. Suggests that the lower reaches of the Harvey River as far upstream as the southern boundary of Nature reserve No. 23756 should be included within the reserved area.

"3. Notes that, under present legislation subtidal waters reserved for this purpose must necessarily be declared marine nature reserve and vested in the National Parks and Nature Conservation Authority.

"4. Notes that the Peel-Harvey Estuary is a declared management area under the control of the Peel Inlet Management Authority and recommends that a review of legislation be undertaken to find the most effective management structure to ensure collaboration between the several Government agencies and Statutory Authorities which would have responsibility for management of areas of the inlet declared marine nature reserve under the CALM Act."

3.11. Leschenault Inlet and Estuary (Map IV-9)

The Leschenault estuarine system is the most southerly of the three large West Coast estuaries. Its southern end is the site of rapid urban and industrial development associated with the regional centre and port of Bunbury. Its shores, and to some extent its waters, have been modified by that development. Nevertheless, the Leschenault Estuary and Inlet comprise an important estuarine system for public recreation, tourism and conservation, and as a nursery area for marine fishes and crustaceans.

This unit, now comprising two parts, was previously a single estuary known as the Leschenault Inlet. The original outlet to Koombana Bay was closed in 1951 and a new one, known as The Cut, constructed through the Leschenault Peninsula opposite the Collie River. The mouth of the Preston River was realigned in 1968-69. Substantial land reclamation at the south western end of the estuary relating to the development of the Inner Bunbury Harbour in 1971 resulted in the isolation of the waters of that area from the rest of the system, with its own artificial outlet to Koombana Bay. That small lagoon is now known as Leschenault Inlet and the larger area as Leschenault Estuary.

Tenure

The waters of the Leschenault Inlet and Estuary, and the lower reaches of the Collie and Preston Rivers and their tributaries comprise a declared Management Area under the Waterways Conservation Act with management authority devolved from the Waterways Commission to the Leschenault Inlet Management Authority.

The land surrounding the estuary and inlet has a variety of vestings, summarised in the Leschenault Waterways Management Program, 1992 (Waterways Commission Report No. 26). The majority of the natural and reclaimed land around Leschenault Inlet is reserved for public use or leased for uses associated with the Port of Bunbury. The southern foreshore of Leschenault Estuary is mostly subject to the zoning scheme relating to the port, while its eastern and northern shores are mostly reserved for public uses. The western shore, that is the inner shore of the Leschenault Peninsula, is Conservation Park vested in the National Parks and Nature Conservation Authority for protection of flora and fauna and public recreation.

Geomorphology and hydrology

Leschenault Inlet is so modified that it is not appropriate to classify it as any natural type. It should be regarded as an artificial lagoon but with remnants of its natural features and retaining important conservation values. Water depth is generally about 3 m but there are emergent muddy sand banks along the northern and eastern shores. A portion of Anglesea Island (a mud island with mangroves) remains at the eastern end of the Inlet.

Leschenault Estuary is a barrier estuary (type 2a of Hesp, 1984) very like the Harvey Estuary except that it has its own (now artificial) outlet to the sea. Klemm *et al.* (1987) have compared the physical features of Leschenault with those of the Peel-Harvey Estuary. The geomorphology of Leschenault has been described by Semeniuk & Meagher (1981) and LeProvost *et al.* (1983). It is a long, narrow lagoon between dune limestone ridges, separated from the sea by the Leschenault Peninsula, now with an artificial channel near its southern end. Water depth varies from 0.3 m on the peripheral muddy sand flats up to 3 m in the central channel. In some areas the peripheral intertidal flats grade up to supratidal samphire and sedge flats.

Tidal range (both astronomic and barometric) is about 0.3 m, sufficient to achieve thorough flushing of the estuary.

Two major rivers, the Collie and the Preston, enter the south-eastern side of the estuary. The Collie has a well developed delta but the entrance of the Preston has been realigned and greatly modified. Although the upper part of the estuary has no rivers it receives significant freshwater discharge from drainage and seepage.

As a result of the efficient artificial channel and the upstream damming of the Collie River, the waters of the estuary are now less brackish than they were (Hodgkin & Smith, 1971; Semeniuk & Meagher, 1981). Like the other highly seasonal southern Western Australian estuaries which are permanently open to the sea, Leschenault oscillates between marine conditions in summer, to brackish conditions in winter. In summer evaporation produces local areas of hypersalinity. Being relatively remote from the outlet channel, the upper part of the estuary tends to be subject to a greater seasonal range in salinity but less daily variation than the southern parts.

Flora and fauna

The most southerly occurrence in Western Australia of mangroves occurs on Anglesea Island in Leschenault Inlet. At this location there is a small mangal consisting of one species, *Avicennia marina.* The fact that these trees have persisted through such drastic modification of their habitat is remarkable. However, whether they are reproductive has not been studied and the long-term survival prospect of this community is in question. Another small mangal of the same species occurs on the western side of the Leschenault Estuary.

The seagrass *Halophila ovalis* covers much of the floor of the estuary in water less than 2 m deep (Hodgkin & Smith, 1971; Meagher, 1971). *Ruppia megacarpa* and *Heterozostera tasmanica* are common on the sandy flats along the eastern side and *Zostera mucronata* is present near the entrance channel.

The brown alga *Hormophysa triquetra* is a significant macrophyte, especially along the eastern and northern shallows where it may dominate over *Halophila* . The dominant green alga is *Chaetomorpha linum* which is most common on the northern flats. The red alga *Gracilaria* sp. is widely distributed throughout the estuary.

Spring and early summer blooms of macrophytic and planktonic algae do not appear to be a problem in this estuary at this time.

Much of the foreshore vegetation of the Leschenault Estuary has been heavily modified since European settlement. The shore itself commonly has a fringe of *Juncus.* Extensive samphire flats occur along the southern shores, merging into *Melaleuca* and *Casuarina* woodlands. Similar vegetation once dominated the northern shores but much of this has been cleared.

The fish and aquatic invertebrate fauna of the estuary have been studied by Meagher (1971), Wells & Threlfall (1981), LeProvost *et al.* (1983), Chalmer & Scott (1984) and Van de Wiele (1987).

The number of benthic species of invertebrate is greatest close to the channel where the salinity varies least from that of seawater, that is in the southern part of the estuary. Fewer species occur in the northern part of the estuary where freshwater persists for longer periods. The suite of common mollusc, polychaete worm and small crustacean species in Leschenault Estuary is the same as that in the Peel-Harvey and Swan Estuaries (Wells & Threlfall, 1981; LeProvost *et al.*, 1983). For example, the bivalved molluscs *Arthritica semen, Spisula trigonella, Tellina deltoidalis* and *Anticorbula amara,* the gastropods *Hydrococcus brazieri,* the polychaetes *Ceratonereis erythraeensis, Haploscolopus kerguelensis* and *Prionospio* sp., and the amphipod *Paracorophium* are extremely abundant on the peripheral sand flats and at times form a dense biomass, especially in the northern part of the estuary (Van de Wiele, 1987). Figures published by LeProvost *et al.* (1983, Table 7) indicate that the densities of benthic species in Leschenault Estuary are of the same order of magnitude as those in comparable habitats in the Peel-Harvey and Swan Estuaries.

The estuary is an especially important nursery area for the blue manna crab *Portunus pelagicus* (Meagher, 1971).

The fish fauna of Leschenault Estuary includes over 40 species, listed by LeProvost *et al.* (1983). The distribution of fish species in the estuary shows similar patterns to the invertebrates, the largest number of species being present near the channel (Chalmer & Scott, 1984). Although few of the fishes in the estuary breed there, the high production of seagrass, algal and invertebrate biomass during spring and summer provides food to support nursery areas for a number of fishes including whiting, bream, mullet, tailer, flathead, cobbler and flounder.

According to a report by Ninox Wildlife Consulting (1989), the Leschenault Estuary is less important for waterbirds than other West Coast coastal estuaries and lagoons in terms of the total numbers of birds counted. Nevertheless, it is an important summer refuge and feeding area for some species during the summer months when many wetlands elsewhere dry out. In the Ninox report 62 waterbird species are recorded. It is a crucial feeding area for the Great Egrets which breed at nearby Morangeral Swamp. Other birds which occur in large numbers include the Little Egret, Grey Plover, Bar-tailed Godwit, Great Knot and Black Swan. Large numbers of Australian Pelican feed in this estuary.

The most important part of the estuary for waterbirds is the northern area, both the intertidal flats and the supratidal samphire flats. The high biomass of invertebrates and the seagrass *Halophila ovalis* in the shallows of that area provide the birds with abundant food at a critical time of the year. The equivalent habitats on the south eastern side in the vicinity of the Preston River mouth are also of importance for the same reasons.

Recreation

Leschenault Estuary is a popular site for boating and fishing during the summer months. There are several boat launching ramps within the estuary although the shallow waters limit the use of power boats. Water skiing is prohibited. Crabbing by wading across the shallows and using hand nets is a traditional activity in the estuary.

Previous recommendations

In its System 6 Report (1983) the EPA made several recommendations for management and pollution control of Leschenault Estuary (Recommendation C66) but did not recommend reservation of any of the intertidal or subtidal areas.

Recommendation C68 of the EPA's System 6 Report deals with Anglesea Island and the land and waters along the northern side of the Leschenault Inlet. The recommendation was that the remains of the island and a portion of the adjacent land on the north shore should be reserved for conservation of flora and fauna and vested in the WA Wildlife Authority, and that "the area of water, as shown in Figure 47, be added to ..." the reserve. It is difficult to interpret the illustration given because of the subsequent reclamation in that area. The southern foreshore with its small piers was not included.

The Leschenault Inlet Management Authority in its 1992 Management Program (Waterways Commission Report No. 26, pp. 33-34)) discussed the matter of vesting subtidal areas for the conservation of flora and fauna which, at present, can only be done under the CALM Act with vesting in the National Parks and Nature Conservation Authority. It concluded that "it will be necessary to amend the Land Act to enable Land Act reserves to be created below low water mark" and recommended that this be done.

The Management Program went on to recommend that three aquatic areas be reserved for "conservation of flora and fauna and protection of the environment". These were:

- The northern estuary above Waterloo Head;
- Vittoria Bay (Turkey Point to Pelican Point, including the Preston River mouth);
- The Leschenault Inlet affected by System 6 Recommendation C68.

It also recommended that, after amendment of the Land Act as above, "the appropriate agencies for vesting" should be identified. No reasons were given why the three areas should not be reserved under the existing CALM legislation with vesting in the National Parks and Nature Conservation Authority.

Working Group recommendations
Although Leschenault Inlet and Leschenault Estuary have been considerably disturbed and modified by urban and industrial development, the Working Group believes that they retain important values for both public recreation and conservation.

The present arrangement whereby these waterways are managed by the Leschenault Inlet Management Authority under the authority of the Waterways Conservation Act is entirely satisfactory as a means to protect and manage those values and there would be nothing to be gained by reservation of the whole estuary and inlet as marine park.

Nevertheless, as an added protection there would be merit in reserving the most important areas for conservation of flora and fauna, notably the important waterbird areas and the mangrove areas, specifically for that purpose. These are correctly identified in the 1992 Leschenault Waterways Management Program.

Accordingly the Working Group recommends as follows:

"The following areas should be reserved for the protection of aquatic flora and fauna and waterbird habitat:
(i) Leschenault Inlet;
(ii) two areas of Leschenault Estuary:
  a) the northern estuary above Waterloo Head, and
  b) Vittoria Bay (Turkey Point to Pelican Point, including the Preston River mouth).

"The most appropriate reserve category is marine nature reserve. Management should be carried out in collaboration with the Leschenault Inlet Management Authority."

3.12. Geographe Bay - Cape Leeuwin (Map IV-10)

The area considered here encompasses two major distinctive coastal types, the low profile, low energy, sandy shores of Geographe Bay and the high profile, high energy, rocky shores of the Naturaliste-Leeuwin Ridge (see Section 1.1). They are considered together because they are contiguous and could form a single management unit. At the southern end of the sector the estuary of Hardy Inlet forms another contiguous but distinctive coastal type which could also be managed as part of the same unit but it falls within the South Coast Sector and is best considered with other South Coast estuaries. Hardy Inlet will be dealt with in Part V.

The State Planning Commission initiated a planning study of the Leeuwin-Naturaliste Ridge. Stage 1 of that project culminated in the Leeuwin-Naturaliste Planning Study released for public comment in August, 1987. The report noted the significance of the marine environment and marine flora and fauna but did not consider or recommend declaration of marine reserves.

Tenure
The foreshore of Geographe Bay is largely private land with a narrow fringe of beach front reserved for public purposes and vested in the respective local authorities. The townsite of Busselton occurs at the centre of the sector.

The status of the foreshore along the Naturaliste-Leeuwin coast is varied. Much of it is national park vested in the National Parks and Nature Conservation Authority. There are townsites at Dunsborough, Cowaramup Bay, Prevelly and Flinders Bay.

Sugarloaf Rock at Cape Naturaliste, Hamelin Island in Hamelin Bay and St. Alouarn Island off Cape Leeuwin are Class "A" Nature Reserves. A number of other rocks and islets along the coast are Vacant Crown Land.

Geomorphology and physical features
The Leeuwin Block is a raised horst, separated from the sunkland of the Perth Basin by the Dunsborough Fault. It has an elevation of up to 200 m and is also referred to as the Leeuwin-Naturaliste Ridge. The Leeuwin Complex consists of intensely deformed plutonic igneous rocks, mainly granite and gneiss (Peers, 1975; Myers, 1990). To the west of it lies the Yallingup Shelf, an area of shallow basement extending to the continental slope.

At Dunsborough the Proterozoic granites and gneisses give way to the Quaternary calcareous sand beaches of Geographe Bay. The Bay is gently arcuate with low foredunes (Quindalup Dunes) forming a barrier between the sea and a series of interdunal lagoons and marshes. A number of small rivers enter the lagoons but are barred from the sea by dunes. The Vasse-Wonnerup lagoons have locks at their outlets and are managed as artificial freshwater wetlands although previously (prior to the 1930s) they were barred estuaries. (Although these lagoons have high conservation value as waterbird habitat they are not regarded as estuarine and parts are already declared as nature reserve under the Land Act.)

At the western end of Geographe Bay, between Dunsborough and Busselton the shore is relatively sheltered but east of Busselton, as the bay curves northward, the shore becomes progressively more exposed to the prevailing westerly winds and swells. The seabed is gently shelving and consists of Holocene sediments over Pleistocene limestones and clays. The sediments have been described by Searle & Logan (1978). A record of older Pleistocene shorelines is preserved as limestone ridges parallel to the present beach, both onshore and offshore.

A conspicuous feature is the Dunn Bay sandbar a few hundred metres offshore between Dunsborough and Quindalup. This structure is actively growing. It is now partly emergent at high tide and cuts off a shallow lagoon between it and the beach. Further east, by contrast, the beach is eroding and artificial groynes have been constructed to control regression of the shore.

The granites and gneisses of the Leeuwin Complex are eroded by the sea to form sloping rock faces on exposed headlands and rounded boulder fields in more sheltered situations. There are coarse sand beaches between the headlands. At several locations along the western side of the Leeuwin Block (eg. Yallingup, Hamelin Bay), Quaternary aeolianite limestones have been deposited over the granites and gneisses, sometimes with considerable thicknesses. These tend to form limestone cliffs along the shore, fronted with intertidal limestone rock platforms. Thus the shore of this sector is quite complex with a range of very different habitats.

There is one small estuary on the Leeuwin-Naturaliste coast at the mouth of the Margaret River. It is of the barred riverine type (Hesp, 1984). Elsewhere there are many freshwater springs along the shore, especially where the aeolianite-granite junction occurs near shore level. Caves are also common in that situation.

In summer the cool West Australian Current flows northward along this shore and sweeps around into Geographe Bay. But in late summer and winter the Leeuwin Current flows southwards off the West Coast. In some years it reaches as far south as Cape Leeuwin, "turns the corner" and flows across the face of the South Coast. This current has a major impact on the marine environment of the Leeuwin-Naturaliste coast. Autumn and winter sea temperatures at Cape Naturaliste are usually 2-3 degrees higher than in Geographe Bay.

Flora and fauna

Geographe Bay

The flora and fauna of Geographe Bay are of temperate affinity although there is a significant endemic West Coast element and some tropical species. Much of the seabed in the Bay is a sand plain. The benthic community of the inner part of the Bay is dominated by monospecific stands of the seagrass *Posidonia sinuosa* with smaller areas of other seagrasses, most commonly *Amphibolis griffithii* and *A. antarctica* (Walker *et al.*, 1987). The Geographe Bay seagrass meadows are the most extensive on the West Coast, except perhaps for those in Shark Bay. Seagrass meadows are known to occur to depths of at least 45 m and have been observed by remotely controlled video camera and from LANDSAT™ imagery (Kirkman, pers. comm.).

Limestone ridges paralleling the shore are a common feature of the seabed, especially in the western part of the bay. They are low (rarely more than 1 m high) and often undercut with ledges and cavities. These ridges provide hard substrates for macroalgae and suspensory-feeding invertebrates such as sponges and ascidians. Two species of seagrass, *Thalassodendron pachyrhizum* and *Amphibolis antarctica* grow attached to these hard substrates. At the western end of the bay, ie. west of the Dunsborough Fault between Cape Naturaliste and Dunsborough, there are seabed outcrops of granite and gneiss providing a different type of hard substrate for benthic macroalgae and invertebrates.

There is a rich epiphytic flora of algae and fauna of invertebrates associated with the seagrass meadows. This community type is very distinctive and characteristic of southern Western Australia. Small trochid gastropods are a dominant feature. Several invertebrates are specifically adapted to this habitat, eg. two small chitons of the southern Australian endemic genus *Stenochiton* which are elongate and live attached to the blade-like fronds of *Posidonia.* The seagrass meadows also serve as important nursery areas for commercially valuable fishes and crustaceans.

Corals are common as individual colonies growing on rock substrata, especially at the western end of Geographe Bay (presumably because of the influence of the Leeuwin Current). Veron & Marsh (1988) list 14 species of seven genera from the area. These include four species of *Turbinaria,* one of which forms very large, foliose coralla up to 4 m in diameter. In Eagle Bay, quite close to shore, there are several dome-shaped coralla of *Turbinaria* sp. which are 3-4 m high making a real spectacle for scuba divers. Two endemic West Coast species, *Coscinaraea marshae* and *Symphyllia wilsoni* , are locally very abundant on rocky ridges at 15-20 m.

Leeuwin-Naturaliste
There has been no published description of the marine flora and fauna of the Leeuwin-Naturaliste coast although scientific collections have been made in the area. The biota is essentially of temperate affinity but there are significant West Coast endemic and tropical elements.

The rock slopes and limestone rock platforms are usually covered with an algal turf. Kelp and lesser macroalgae dominate the sublittoral zone. Small areas of seagrass, notably *Amphibolis antarctica,* grow in tide pools. This vegetation supports a rich epiphytic invertebrate fauna. Grazing gastropods and chitons generally keep the algae cropped low in the intertidal zone. The abalone *Haliotis roei,* the limpets *Patella laticostata* and *Patelloida alticostata,* and the turbinid *Turbo torquatus* are conspicuous examples. These animals may be in vast numbers at their respective levels in the intertidal zone. But it is the cryptic invertebrate fauna which exhibits the greatest species diversity on these rocky shores. The rock fissures and undersides of stones are habitats for a wealth of small species.

Although the communities of plants and animals on these rocky shores are predominantly of temperate affinities, a notable feature is the presence of a number of tropical species. Whether these populations of tropical species are reproductive and self-sustaining or rely on recruitment from the north via the Leeuwin Current is unknown. The matter is well illustrated by the cowry genus *Cypraea*, which has both temperate and tropical species represented in the fauna. There are three endemic southern species present in the rock pools, *C. (Notocypraea) piperita declivis, C. (N.) pulicaria* and *C. (Austrocypraea) reevei.* These subgenera are endemic to the Southern Australian Region. There is one endemic West Coast species, *C. (Cribrarula) fallax,* which belongs to an Indo-West Pacific subgenus. In addition there are several tropical Indo-West Pacific species, the most common being *C. caputserpentis,* with *C. vitellus, C. cernica* and *C. helvola* of more uncommon occurrence. This mixture of temperate and tropical species is typical of the fauna of this section of the coast, reflecting the geographic location at the margins of the Southern Australian and Indo-West Pacific Regions and the influence of the Leeuwin Current.

Fisheries
There are small trawl and purse-seine fisheries in Geographe Bay. Commercial offshore hand lining for bottom-living fish such as dhufish and snapper, supports several operators from the ports of Bunbury, Busselton and Augusta. Rock lobster boats also operate from these ports although this is near the southern limit of the western rock lobster fishery. Beach netting for Australian Salmon is an important fishery at several locations along the Leeuwin-Naturaliste coast.

Recreational fishing is one of the major attractions in this sector, contributing significantly to both the local lifestyle and the regional tourism industry. The fishing may be from small boats in near-shore waters or from the rocks and beaches.

Recreation and tourism
This is one of Western Australia's most rapidly developing recreational and tourism regions. The coastal scenery is outstanding. The importance of recreational fishing has already been noted. The large swells and excellent breaks at many localities along the Leeuwin-Naturaliste coast, eg. at Yallingup and Margaret River, provide some of the world's best surfing and national and international surf competitions are regularly held there. Geographe Bay and the leeward sides of Cape Leeuwin (Flinders Bay) and Cape Naturaliste (Bunker

Bay, Eagle Bay, Meelup and Dunsborough), on the other hand, are sheltered shores with high quality beaches and very clear water providing safe family swimming and water sports.

There is considerable potential for development of recreational diving and commercial dive tours, especially in the clear and sheltered waters of Geographe Bay. The coral bommies at Eagle Bay and colourful invertebrate growth on the Busselton jetty pilings are already popular dive sites.

The hinterland of the Leeuwin-Naturaliste Ridge also has many attractions such as wineries, caves and forests.

With this wide range of attractions the Leeuwin-Naturaliste National Park has become one of the State's most intensively used parks and much of the use focuses on the coast and maritime recreational activities.

Previous recommendations

In its consideration of the Leeuwin-Naturaliste Ridge (recommendation 1.4) in the Conservation Reserves in Western Australia - System 1 report (1976), the EPA made no recommendations relating to marine reserves.

Following a substantial public participation program relating to management of the Leeuwin-Naturaliste National Park, the Department of Conservation and Land Management produced a Management Plan (1989, number 13) which included consideration of the marine environment and recommended as follows:

> "Action 15.1: Marine areas adjacent to the Leeuwin-Naturaliste Ridge should be investigated to ascertain their suitability for declaration as a Marine Park.
>
> "Action 15.2: Any Marine Parks in this area should be zoned for multiple use.
>
> "Action 15.3: The declaration of the National Park to the Low Water Mark will give National Park Rangers jurisdiction over the intertidal zone. Suitable regulatory arrangements should be made to ensure the protection of these areas from over-exploitation."

The CALM Management Plan noted that "areas of high conservation value include Yallingup Reef, Cape Naturaliste, Cosy Corner, Hamelin Bay, the Indicators and Cape Leeuwin."

Working Group recommendations

Although there has been no investigation of the Leeuwin-Naturaliste coast, the Working Group believes that there is already sufficient information to support a recommendation for declaration of a marine reserve. These are shores of two very distinctive coastal types with outstanding public recreational potential, a wide range of habitats and very high conservation values.

The Working Group agrees that the areas identified in the Leeuwin-Naturaliste Management Plan have high conservation value but considers that it would be unwise to select only these for reservation. Other areas are known to be of similar importance, for example the sheltered rocky shores of Flinders Bay and the leeward side of Cape Naturaliste, and the near-shore sublittoral area between Bunker Bay and Dunsborough where there is spectacular underwater scenery and prolific growth of tropical corals. Given the high public recreational use of the Leeuwin-Naturaliste National Park and its coast, as well as its high conservation value, there would be merit in declaring the whole sector a multiple-use marine park. Commercial fishing is also important and would be provided for by management programs under the control of the Fisheries Department.

The major distinctive coastal type represented by the sandy beaches, sheltered waters and vast seagrass meadows of Geographe Bay is also worthy of representation in the State's marine reserve system. The densest seagrass meadows, most prolific coral growth, best underwater scenery and most used areas for recreation are located at the western end of the bay in the lee of Cape Naturaliste. As this area is contiguous with the distinctive rocky coast of the Leeuwin-Naturaliste Ridge there would be merit in extending the proposed marine park eastwards, perhaps as far as Vasse, to encompass a portion of the Geographe Bay distinctive coastal type.

The Working Group believes that a multiple-use marine park encompassing the shores of the Leeuwin-Naturaliste Ridge and the western end of Geographe Bay would become one of Australia's most significant recreation and conservation marine reserves. Accordingly the Working Group recommends as follows:

"1. Consideration should be given to the reservation of the State Territorial waters adjacent to the Leeuwin-Naturaliste National Park as a multiple-use reserve for protection of marine flora and fauna and public recreation, with provision made for the continuance of commercial fishing.

"2. That in the north the reserve should extend around into Geographe Bay as far as Vasse so encompassing the Dunn Bay sand bar, the best of the Bay's seagrass meadows, and the areas with most prolific coral growth.

"3. That in the south the reserve should extend around Cape Leeuwin to encompass Flinders Bay and the Seal and Sea Lion colonies on the offshore rocks. (The reserve should also include the Hardy Inlet estuary - see Part V.)."

A REPRESENTATIVE MARINE RESERVE SYSTEM FOR WESTERN AUSTRALIA

Report of the Marine Parks and Reserves Selection Working Group

PART V

MARINE RESERVES ON THE SOUTH COAST

CONTENTS

PART V: MARINE RESERVES ON THE SOUTH COAST

1. INTRODUCTION

This section deals with that area of Western Australia generally known as the South Coast, extending from Cape Leeuwin to the South Australian border. Broadly speaking the South Coast has an east-west orientation, facing the Southern Ocean, covering a distance of about 1 500 km and spanning 14 degrees of longitude. It lies entirely within the temperate climatic zone and corresponds to one of the biogeographic zones described in the Council of Nature Conservation Ministers working paper on marine protected areas (CONCOM, 1985).

The South Coast is sparsely populated. There are several coastal towns, including the regional centre of Albany. Most of the coastal land is national park, nature reserve or recreation reserve. The scenery of much of this coast is outstanding, both above and below the water. Although present levels of maritime recreational activities are moderate and localised, there is potential for significant development of the recreational and commercial tourism resources of these coastal waters and a case can be made for the reservation of several marine areas for that public purpose.

A bibliography for the natural environment of the Albany region (extending from Denmark to the Fitzgerald River National Park) has been prepared for the Heritage Council of Western Australia (Livesey, 1993).

The marine flora and fauna of the South Coast are poorly known. The biota is similar to that of South Australia and Victoria and reference must be made to the taxonomic literature of those States in order to identify many of the species. In recent years there has been some collecting of the marine fauna of the area by Western Australian Museum staff and helpful reference collections exist in that institution. However, with the exception of the estuarine biota, there have been very few ecological studies on the South Coast. For this reason the Working Group was obliged to base its assessment of areas worthy of reservation for conservation purposes mainly on geomorphological features and the assumption that areas representative of shore geomorphology are likely to be also representative of the biota.

1.1. Coastal geomorphology

The continental shelf along this section of the coast is relatively narrow, the shelf edge being as close as 35 km from shore. It is a high energy coast with heavy swells generated by the Roaring Forties wind belt in the Southern Ocean. Along the open ocean shores, south-facing headlands and beaches are exposed to strong wave action for much of the time. Sheltered conditions prevail in inlets and estuaries but most of the bays are wide and open to the prevailing winds and swells.

Exposed open ocean shores
The types of open ocean shore evident on the South Coast relate to the geology and geological history along the southern margins of the Yilgarn Craton and the sedimentary basins to the south, east and west of it. For our purpose they can be considered in four categories.

(i) *Perth Basin - Cape Leeuwin to Point D'Entrecasteaux*
At the western end of the South Coast sector, between Cape Leeuwin and Black Head just west of Point D'Entrecasteaux, the coast is formed by the southern boundary of the Scott Coastal Plain, the southernmost portion of the Perth Basin (Cockbain, 1990). It is separated from the Leeuwin Block in the west by the Dunsborough and Busselton-Alexander Bridge Faults and from the Yilgarn Craton and Albany-Frazer Oregon in the east by the Darling Fault. The Darling Fault crosses the coast at Black Head.

The hinterland is relatively low-lying with Quaternary sands overlying Cretaceous sediments. The shore itself consists of a wide, curving beach, more than 80 km long, and trending NW-SE. It is backed by a Holocene dune field. The beach is almost continuous, interrupted only at Black Point where there is an outcropping of the Bunbury Basalt. The basalt here forms unusual rocky shores, including columnar cliffs and boulder fields (see Cockbain, 1990, p. 516, fig. 4-158).

(ii) *Shores of the Albany-Frazer Oregon - Point D'Entrecasteaux to Israelite Bay*
The southern margin of the Yilgarn Craton is fringed by the Albany-Frazer Oregon, a zone of intense Proterozoic tectonic activity, and is characterised by granites and high-grade gneisses with some doleritic intrusions and very uneven landforms (Myers, 1990). High points of the Proterozoic land surface form hills inland, high headlands at the coast, and islands offshore. Inland, depressions in the ancient land surface are filled by flat-lying Eocene sediments of the Bremer Basin but at the coast there are fringes of Pleistocene aeolianites and Holocene dunes between the granitic or gneissic headlands.

The result of these geological structures is a ruggedly scenic coastline characterised by a repeated pattern of long, arcuate sandy beach backed by dunes (some of which are mobile) located between high, cliffed granitic, doleritic or metasedimentary headlands. The coast shares some features with that of the Leeuwin-Naturaliste Ridge. The headlands, many of which are over 300 m high, are often multiple with small lunate bays and beaches between the projecting units. The most exposed parts of the headlands, facing south and south-west, are either cliffed or fronted by steep slopes which are swept by swell surge. The south-eastern sides of the headlands, adjacent to the next wide bay and beach, are exposed to lesser wave action and tend to have granitic or gneissic boulder fields along the shore.

In the eastern part of this sector, between Esperance and Israelite Bay, much of the Proterozoic land surface of the Oregon lies below present sea level so that its high points form the Recherche Archipelago of granitic and gneissic islands. Similar but smaller and fewer islands also occur along the whole of this shore.

As well as active dune fields backing the long arcuate beaches, there are frequently perched dunes on the Proterozoic headlands. In many places older perched dunes have consolidated and formed aeolianite limestones as a fringe or rim above the Proterozoic rocks. In a few cases the aeolianites have considerable thickness and extend down to sea level where they are eroded to form limestone rock platforms between high and low tide levels.

Limestone also forms as beach rock below the surface along many of the long beaches. Frequently, the beach rock surfaces are exposed by erosion and form intertidal rock platforms, especially at the eastern ends of the beaches. Limestone shores, presumably of this origin, are a notable feature of the coast between Hopetoun and Esperance. In that area there are series of narrow limestone reefs paralleling the shore, apparently representing different positions of the shore at periods of different sea level during the Pleistocene and Holocene. A dramatic example occurs on the western side of Shoal Cape where there are three limestone ridges, one forming the shore and two forming offshore reefs, with deep gutters between them.

Thus, the open ocean rocky shores of this section of the South Coast provide a variety of habitats for marine plants and animals, including the wave-swept granitic and gneissic slopes of the headlands, the boulder fields and pools of the less exposed sides of the headlands, and the limestone rock platforms and reefs. Commonly, the headland shores are "steep to", dropping off steeply into relatively deep water, meeting the sandy sea floor at depths of 20-30 m. Vertical sublittoral rock walls are common. Offshore granitic and gneissic reefs are very common and these too usually have steep or even vertical walls. Along jointing cracks and dolerite intrusions, erosion often forms precipitous underwater canyons.

The beaches of the open ocean in this section are exposed to heavy surf and are generally of coarse-grained sand. They provide suitable habitat for only a few specialised plants and animals. Intertidal sand flats occur only in protected corners and are never very extensive. The wide bays tend to slope gently from the surf zone into the sublittoral and there is usually extensive development of seagrass beds beyond the action of the surf.

(iii) *Bremer Basin*
The larger part of this sedimentary basin lies offshore on the continental shelf but onshore elements of it infill depressions on the Proterozoic land surface between Point D'Entrecasteaux and Israelite Bay (Hocking, 1990). The infill sediments are marine deposits of Eocene age. They meet the coast at several places east of Albany (Hassell Beach, Cheyne Bay and Doubtful Island Bay) but are usually covered

there by Quaternary dunes and the shores are long sandy beaches. The only outcrop of the Eocene rocks on the shore is at Cheyne Bay where a section of the Pallinup Siltstone forms low cliffs. These rocks are easily eroded and the shore there features a boulder field below the cliffs.

(iv) *Eucla Basin - Israelite Bay to Eucla*
This is a large sedimentary basin extending into South Australia and forming the shores of the Great Australian Bight. The onshore surface deposits consist of Tertiary limestones overlain along much of the coast with a veneer of Quaternary limestones, calcareous soils and dunes (Hocking, 1990). The edge of the Tertiary limestones forms a conspicuous escarpment and the Quaternary deposits have built up below this to form the Roe Plain. These features give rise to two distinctive coastal types.

The escarpment forms the shore of the Bight east of Eucla in South Australia and for a short section between Twilight Cove and west of Point Dover on the Western Australian side of the border. There the Tertiary limestones form precipitous cliffs, with either a narrow rock platform or boulder field at sea level. Where there are irregularities in the shore-line, there may be narrow fringes of beach. Elsewhere the Quaternary deposits form a shore comprising long sandy beaches backed by high dunes. In both shore types the sea bed shelves gradually seaward with little relief.

On the basis of these geomorphological features, primary and secondary divisions of the South Coast open ocean shores into major distinctive coastal types is possible (see Index to Maps V). These are:

1. southern coast of the Perth Basin (Cape Leeuwin to Black Head) - wide, arcuate beach with a shelving shore and heavy surf;
2. shores of the Albany-Frazer Oregon (Point D'Entrecasteaux to Cape Arid) - wide bays with arcuate beaches and high granitic or gneissic headlands. Within each segment there is a repeated sequence of coastal type:
   (a) long, wide bay and beach, with shallow shelving shore, often with perched dunes or limestone cliffs and exposed limestone rock platforms at sea level (usually at the eastern end of the bay);
   (b) high granitic or gneissic headland exposed to the open ocean swells with wave-swept slopes, steep-to shores, cliffs and sometimes small lunate bays between the projecting elements of the headland;
   (c) eastward-facing, semi-exposed shore with granite or gneissic boulders and tide pools;
3. Great Australian Bight - shores of the sedimentary Eucla Basin which are either:
   (a) long, curved beach with dunes; or
   (b) high limestone cliffs.

A distinctive coastal type of limited extent occurs at Black Point where there is an outcrop of Bunbury Basalt, and another occurs in Cheyne Bay where there is an outcrop of Pallinup Sandstone, both rock types forming shores of different character to rocky shores elsewhere on the South Coast.

Inlets and estuaries
Many of the bays on the South Coast are wide and provide little protection from the prevailing winds and swell. The major exception is the King George Sound-Princess Royal Harbour-Oyster Harbour complex (Wells, 1990). These three basins are depressions of the Proterozoic land surface now flooded by the sea. Princess Royal Harbour is an almost landlocked, shallow marine inlet which is not fed by any major rivers or streams. Oyster Harbour, on the other hand, has two major rivers entering it which contribute large volumes of freshwater, at least during the winter months, and it may be regarded as an estuary.

Along the western part of the South Coast there are many small rivers entering the sea and forming estuaries at their mouths. A general description of Western Australia's southern estuaries may be found in section 3.7.6. of Part I of this report. Detailed descriptions of the South Coast estuaries have been published by Dr E. P. Hodgkin and associates in a series of Environmental Protection Authority Bulletins (see reference list).

The estuaries west of Albany have catchments in forested and agricultural lands with relatively high rainfall (greater than 1000 mm/ann.). East of Albany there is a sharp decline in rainfall. The rivers there are short and small and have catchments in semi-arid agricultural lands. East of Cape Arid there is no surface runoff and no estuaries. Because of the climatic regime South Coast estuaries are all seasonal, saline and freshwater conditions alternating. Some of the smaller estuaries on the South Coast, especially those in the drier eastern areas, may actually dry up in summer. Because of this extreme variation in salinity they form harsh aquatic environments.

Physiographically, the South Coast estuaries are of two types, riverine and lagoonal (Hesp, 1984). They may be further classified as "permanently open", "seasonally open" and "semi-permanently closed" (see Part I, section 3.7.6.).

Oyster Harbour is unusual in that it is a large lagoon with a permanently open mouth. Only the upper part of this lagoon is greatly influenced by freshwater flow from the rivers entering it, the lower part being almost permanently marine (McKenzie, 1962, 1964). The other large South Coast lagoonal estuaries which have permanently open mouths are the Hardy and Nornalup-Walpole Inlets. Both of these have an entrance bar which retards tidal flow of sea water.

Broke Inlet is a seasonally open lagoonal estuary. Its entrance bar is breached every year when the rivers flood and closes again when river flow ceases. Wilson Inlet is naturally a seasonally open estuary of the same type but it is artificially opened every year as a measure for flood control in the catchment.

The most easterly lagoonal estuary is Culham Inlet near Hopetoun. In this century it has opened only once or twice and it could be regarded as a salt lake. Recently, increased clearing in the catchment and unusually heavy rainfall have resulted in flooding and the entrance bar has been breached. A permanent spillway has now been constructed at the entrance bar and it is anticipated that it will once again convert this system to a "saline lake".

The small riverine estuaries east of Albany are all of the semi-permanently closed type. They have small catchments and their bars are breached only after exceptionally heavy rainfall.

1.2. Marine flora and fauna

Although there has been some collecting of marine plants and animals by individual scientists at many localities on the South Coast, only two areas have been studied or surveyed in any detail.

King George Sound is an important site in the history of science. Because of its magnificent harbour and access to fresh water, it was visited by many of the early voyages of exploration. The French ships of the *Baudin* (1801-03) and *Astrolabe* (1826) expeditions spent some time there and their naturalists made extensive collections of the marine life. Consequently King George Sound is the type locality for many southern Australian marine species, especially molluscs, described by 19th century French scientists. The British survey ship *Investigator* commanded by Matthew Flinders spent four weeks in the sound (December 1801 - January 1802) and botanist Robert Brown collected many terrestrial plants in the area. Charles Darwin visited the sound briefly aboard the *Beagle* (1836), but apparently made no scientific observations. The German "Hamburg Expedition" (1905) collected marine invertebrates at a number of sites in King George Sound and the nearby inlets. Most recently an international marine biological workshop was held in the area, resulting in the publication of a number of important papers on the taxonomy, ecology and physiology of local marine plants and animals (Wells *et al.*, 1990; 1991). The Western Australian Environmental Protection Authority is presently engaged in a long term study of Princess Royal Harbour in the context of concern about the increasing pollution of its waters.

Cape Leeuwin is sometimes regarded as the position of a boundary zone between the temperate Southern Australian Biogeographic Region and the subtropical West Coast Overlap Zone (Wilson & Gillett, 1971; Wilson & Stevenson, 1977; Wells, 1980; Wilson & Allen, 1987). It can be argued that Cape Naturaliste is a more meaningful position for a biogeographical boundary than Cape Leeuwin, if the nature of the rocky shore habitats along the Leeuwin-Naturaliste coast are taken into account. Irrespective of precisely where the boundary is located, many species of marine flora and fauna are distributed across the southern coast of Australia from Bass Strait to the vicinity of the Leeuwin-Naturaliste coast and no further. A few northern species of tropical origin have distributional ranges which extend around Cape Leeuwin and along the South Coast. The influence of the Leeuwin Current is paramount in this, as described in section 1.2 of Part IV.

And finally there is a significant south-west endemic species element in the marine biota, many of them relics of the Tertiary Tethyan Province. Most of the endemic species have distributions which straddle the transition between the Southern Australian Region and the West Coast Overlap Zone, and live on both sides of Cape Leeuwin. One endemic gastropod of Tethyan origin is *Diastoma melanioides*, the sole living survivor of the family Diastomatidae, which lives in the seagrass beds on the South Coast of Western Australia east of Albany.

Corals are generally regarded as tropical animals although there are four species endemic to the southern coast of Australia (Veron & Marsh, 1988). In addition, five tropical species extend down the West Coast and onto the western part of the South Coast. Of these, three species of the genus *Turbinaria* cover extensive areas in King George Sound and the Recherche Archipelago.

Rocky shore faunas

Perhaps the most conspicuous marine habitats of the South Coast are the rocky shores. Intertidal communities at several South Coast localities were described by Hodgkin (1960) but otherwise there has been little study of these rocky shore communities. Granitic and gneissic slopes exposed to heavy wave action are usually rather smooth and populated with moderate to large numbers of gastropod molluscs, barnacles and macrophytes showing distinct vertical zonation. A greater diversity of species, both plant and animal, occurs in the more sheltered corners of the headlands where there are boulder fields in the intertidal and sublittoral zones.

A feature of the South Coast is the spectacular rock wall fauna of the deeper sublittoral zone. The sublittoral slopes of the exposed headlands and islands usually drop off steeply to considerable depths (as much as 40 m) before reaching the sandy sea floor. Vertical rock walls and narrow canyons are common. To depths of 20 m or so these rock surfaces are usually dominated by macrophytes, but below this sponges, ascidians and coelenterates grow in high density anywhere there is a hard substrate. They provide a very colourful display. To date there has been no study of this rock wall fauna.

Seagrass beds

Seagrass beds are extensively developed along the South Coast although there is very little known of their diversity. The genus *Posidonia* dominates both as a meadow-forming seagrass and as fringing and clumped patches. *P. australis* and *P. sinuosa* are the main meadow-forming species but *P. robertsonae* also forms well-defined meadows. Edges and blowouts usually harbour *Amphibolis* species. The smaller plants *Halophila australis* and *Heterozostera tasmanica* also often grow in disturbed areas and blowouts.

The South Coast may be the centre of distribution of the genus *Posidonia.* In addition to the dominant species noted above, *P. ostenfeldii, P. denhartogii* and *P. kirkmanii* are found in large quantities in some bays but their respective habitat preferences are not known. All the *Posidonia* species flower and produce fruit in summer. It is believed that some seagrass species grow to depths of at least 45 m along the South Coast. The plants are well adapted to large swells as they have deep, well developed rhizomes. The "ostenfeldii" group (*P. ostenfeldii, P. denhartogii, P. robertsonae* and *P. kirkmanii)* have rhizomes which grow vertically downwards and hence the above-ground plants appear as clumps. The "australis" group tend to spread horizontally at a rate less than 2 cm/year. *Thalassodendron pachyrhyzium* has been found as drift but not growing. It is expected that it lives attached to rocky substrates.

Associated with the seagrasses there is a rich and diverse fauna. Seagrass communities in King George Sound and Princess Royal Harbour have been described in detail (Kirkman *et al.*, 1991; Walker *et al.*, 1991; Hutchings *et al.*, 1991; Wells *et al.*, 1991).

Algae and algal beds

Along the South Coast the dominant alga is the small kelp *Ecklonia radiata* which often forms dense beds in the shallow sublittoral zone. Other common brown algae include *Cystoceira, Scytothallia, Cystophora* and *Hormosira banksii.* Conspicuous green algae are various species of *Caulerpa*. The reds are represented by many cool temperate species. Generally speaking, the limestone reefs afford more protection and a better surface for attachment of algae than the granitic or gneissic rocks.

Estuarine flora and fauna

South Coast estuaries are depauperate in terms of diversity of plants and animals due to their strongly seasonal nature and the extreme hydrological conditions that result, although biological production and population density of tolerant species may be very high when conditions are favourable. Most of the estuaries are becoming progressively degraded as biological environments as a result of nutrient enrichment and sedimentation and increased frequency of flooding following extensive clearing in their catchments. An exception is Broke Inlet whose catchment lies entirely within forested land.

There is only a handful of obligate estuarine species (ie. aquatic species found in estuaries but not in marine or freshwater habitats) in the South Coast biota. Most of the animals present in the seasonally open estuaries are opportunistic marine invaders which enter with tidal inflows in early summer when the flow of freshwater decreases. Some of these species are subject to mass mortalities when the next winter floods scour the estuaries with freshwater. Even in the permanently open Hardy and Nornalup-Walpole Inlets the entrance bars restrict summer tidal flow, winter scouring is severe, and species diversity is consequently limited. In the case of the semi-permanently closed estuaries, marine species invade on those occasions when the bars open and a progressive decline in species diversity follows after the bars reclose.

Obligate estuarine molluscs on the South Coast include the gastropods *Hydrococcus brazieri, Salinator fragilis, Tatea preissii* and *Hydrobia buccinoides* and the bivalves *Fluviolanatus subtorta, Xenostrobus inconstans* and *X. securis*. Among the marine mollusc species which normally inhabit protected bays and inlets and invade the estuaries when conditions are suitable are the bivalves *Arthritica semen, Katelysia scalarina, K. peroni, Spisula trigonella, Mytilus edulis planulatus, Wallucina assimilis, Macomona deltoidalis, Soletellina donacioides, Sanguinolaria biradiata, Iris crenata* and *Theora lubrica,* and the gastropods *Nassarius burchardi, N. pauperatus, Liloa brevis* and *Philine* species. Some of this second group of molluscs may maintain populations within the estuaries for several years even if the bars remain closed. Fossil beds containing shells of these and other marine species are commonly found around the shores of the estuaries, providing evidence that seasonal conditions during earlier times in the Holocene and Pleistocene were rather less extreme than at present.

The tube worm *Ficopomatus enigmaticus* is found in most of the estuaries wherever there are hard substrates. Other common polychaetes are *Capitella capitata, Scoloplos simplex, Ceratonereis aequisetes, Neanthes vaali, Prionospio* cf. *cirrifera* and *Polydora* sp. Two species of benthic amphipod, *Melita* sp. and *Paracorophium* sp., are commonly present. The estuarine crab *Halicarcinus ovatus* is also usually common, especially in beds of the mussel *Xenostrobus*. The shrimp *Palaemonetes australis* seems to be everywhere. Two marine crustaceans, the blue manna crab, *Portunus pelagicus* and the barnacle *Balanus amphitrite,* invade the larger estuaries when the bars open but neither is capable of surviving prolonged winter flooding. The crab moves out of the estuaries to avoid such flooding while the fixed barnacle suffers mass mortality. Empty barnacle shells are frequently seen on rocks and timber, evidence of the transient success of this animal.

With the exception of some atherinid and gobiid species, few fishes breed in the South Coast estuaries. The most notable of those which do are the black bream and the cobbler which are target species of both the commercial and recreational fisheries. Blue-spotted flathead and southern sea garfish breed in Wilson Inlet (and possibly Nornalup-Walpole Inlet). However, there are many species which enter the estuaries from the sea as juveniles and use them as nursery areas (Lenanton, 1974a; 1974b; 1984;

Lenanton & Hodgkin, 1985). Large numbers of juveniles of fishes, such as mullet and whiting, which enter the estuaries when they are open to the sea and establish flourishing populations become isolated from the sea after the bars close again. Such populations may flourish in the semi-permanently closed estuaries for several years following breaching of the entrance bars.

Plankton blooms occur in early summer in the South Coast estuaries, developing in wedges of saline water that penetrate upstream as the summer progresses. The majority of zooplankton species are the larvae of marine species and are the source of recruitment to the estuarine fauna. However, there are a few truly estuarine planktonic animals. The most ubiquitous of these is the copepod *Gladioferens imparipes*. Also recorded are the copepods *Sulcanus conflictus, Acartia tranteri , A. clausi* and *Oithona nana*. Nearer the entrances these are usually replaced by more marine copepods such as *Gladioferens inermis*. Small medusae of the genus *Australomedusa* are also common.

Ruppia megacarpa is the only submerged aquatic plant that commonly occurs in South Coast estuaries. It is a dominant plant in the basins of the lagoonal estuaries and lower reaches of most of the riverine estuaries. It grows on sand in the shallows and is an important food resource for Black Swans. Other seagrasses occur mainly in the lower parts of those estuaries which are permanently open. For example, in Oyster Harbour the three marine seagrasses *Posidonia sinuosa, P. australis* and *Amphibolis antarctica* are common in the marine parts of inlet, *Halophila australis* occurs sparsely there, and *Heterozostera tasmanica* is found near the entrance. Only *Zostera mucronata* lives in the upper part of the inlet (near the mouth of the Kalgan River). In Hardy Inlet, *Z. mucronata* occurs in the lower reaches. *Halophila australis* is reported from Hardy Inlet. A newly described species, *Halophila glabra,* lives along channel banks of that estuary during summer and autumn. *Heterozostera* is recorded from Nornalup/Walpole Inlet but is not common there.

Seagrasses are vulnerable to reduced light intensity. This detrimental condition may be caused by turbidity or eutrophication which produces increased density of phytoplankton and epiphytes. Seagrass communities of many of the South Coast estuaries show evidence of decline caused by these forms of pollution (Hodgkin & Clark, 1990).

There is a variety of macroalgae and filamentous algae in the South Coast estuaries. Brown algae are not common except for *Hormosira banksii* and *Cystophyllum muricatum* in the marine parts of Oyster Harbour, and *Cystoseira trinoides* which has been found on rocks at the entrance of Nornalup Inlet. Green algae dominate most of the vegetation, including species of *Polyphysa, Cladophora, Chaetomorpha, Enteromorpha and Vaucheria.* The stonewort *Lamprothamnium papulosum* is common in most estuaries. Some of these algae are subject to spring blooms and eutrophication and may smother the seagrasses.

Marine mammals

Humpback whales (*Megaptera novaeangliae)* and sperm whales (*Physeter catodon*) occur off the South Coast but are not commonly seen in near-shore waters. However, the southern right whale (*Eubalaena australis*), once hunted to near extinction, is presently staging a recovery and is being seen more and more frequently in coastal waters along the South Coast. The humpback and southern right whales are both threatened species under the Western Australian Wildlife Conservation Act.

A monitoring program of the southern right whale begun in 1978 has shown a steady increase in the South Coast population of this animal (Bannister, pers. comm.) now estimated to number at least 81 animals. Females use the sheltered bays as birthing and nursery areas. Cows with calves may often be seen very close to shore in August and October. Several localities have recently become popular "whale watch" sites. Perhaps the best of these is Point Ann in the Fitzgerald River National Park. An observation platform has been erected at that spot and it is frequently used by tourists, including the commercial tourism industry.

Two species of pinniped use South Coast islands as resting and breeding sites. These are the Australian Sea Lion (*Neophoca cinerea)* and the New Zealand Fur-seal (*Arctocephalus forsteri*). Both are classified as specially protected species under the Western Australian Wildlife Conservation Act. The sea lions feed in the shallows and are frequently seen along the shores of the South Coast, but the fur seals feed

in the open ocean and are not commonly seen except at the breeding colonies during the breeding season. A baseline survey has recently been undertaken to determine the population size and locate the breeding colonies of these animals.

1.3. Tourist potential

The South Coast has a number of popular tourist destinations although most visits relate to the scenic attractions of the coast and to date marine-based tourism is not well developed. Beach fishing is very popular and there is a small diving fraternity. Some charter boats operate dive tours, for example in the Recherche Archipelago and King George Sound. The quality of the fishing, diving and seascapes is such that there is scope for development of a marine-based tourism industry.

1.4. Fisheries

The South Coast between Cape Leeuwin and the WA/SA border supports the State's major commercial finfisheries and some important recreational fisheries.

The Demersal Gillnet and Demersal Longline fishery, primarily for gummy (*Mustelus anarcticus*), whiskery (*Furgaleus macki*) and dusky or bronze whaler (*Carcharhinus obscurus*) sharks and demersal scalefish, is the largest offshore fishery of the South Coast. This fishery, which extends offshore to the 200 m isobath, is managed in two zones, Zone 1 extending around Cape Leeuwin and eastwards to Cliffy Head, and Zone 2 from Cliffy Head to the WA/SA border. In Zone 2, 25 full-time and 29 supplementary access license holders landed 1080 tonnes of shark and 160 tonnes of scalefish during 1991-92. Over the past few years some of these operators have moved further offshore to target deepwater spurdog sharks (*Squalus spp.*) and scalefish such as the blue-eyed trevalla (*Hyperoglyphe antarctica*).

Scalefish are targeted by a group of line fishers (including drop and longliners) operating principally from Albany and Esperance. Key species include deepwater fishes such as leatherjackets (*Monocanthidae* spp.), hapuka (*Polyprion oxygeneios*) and grey-banded rock cod (*Epinephelus septyemfasciatus*), together with species that can be taken closer inshore such as bight redfish (*Centroberyx gerradi*) queen snapper (*Nemadactylus valenciensi*) and blue groper (*Achoerodus gouldii*).

South Coast trawl fisheries are managed by State and Commonwealth agencies. The Commonwealth manages trawling seaward of the 200 m isobath and in the Great Australian Bight east of 125°. The South Coast Demersal Trawl Fishery extending offshore to the 200 m isobath between Cape Leeuwin and 125°E is managed under State jurisdiction. The target species are demersal finfish such as queen snapper, bight redfish, boarfish (*Pentacerotidae* spp.) and deepwater flathead (*Platycephalus conatus*). Presently 4 vessels have access to this fishery. The area of the Recherche Archipelago between 121° 30' E and 123° 30' E, and offshore to 34° 20' S, is excluded from general trawl fishing. However the waters of the archipelago are seasonally open (April 1 to November 30) to endorsed vessels to fish only for scallops (*Pecten* sp.). At present there are two endorsed scallop vessels. They also have access to the Commonwealth Bight Trawl Fishery for scallops in shelf waters between 125°E and 129°E.

Purse-seining, primarily for pilchard (*Sardinops neopilchardus*), is the most important inshore finfish fishery. It is managed in four zones on the South Coast, the most important being the Albany Zone which includes the King George Sound fishery where 22 vessels took a total of 4 255 tonnes in 1992.

Other nearshore resources that historically support commercial fisheries, and now also support increasingly important recreational fisheries, are stocks of Australian salmon (*Arripis ruttaceus*) and Australian herring (*A. georgianus*). At present 21 commercial teams have access to these fisheries on nominated South Coast beaches. The most westerly beach is at Windy Harbour and the most easterly at Trigalow on the western end of Doubtful Island Bay. Beach seines are used to catch salmon while fixed

"G" (trap) nets and sometimes beach seines are used for herring. In 1993 totals of 2 006 tonnes of salmon and 532 tonnes of herring were taken by these limited entry fisheries.

Abalone is one of the most valuable nearshore resources harvested off the South Coast. Commercial abalone operations are managed in two zones, on either side of Shoal Cape (120°E). There is a closed area restriction in Flinders Bay. Six divers have access to the eastern zone and eight to the western zone. They take three species of abalone, Roe's (*Haliotis roei)*, greenlip (*H. laevigata)* and brownlip (*H. conicopora)*.

Rock lobster fishing is also an important coastal activity which is managed as two separate fisheries, each extending to the limit of the territorial sea as the offshore boundary. The Augusta-Windy Harbour fishery is located west of 116°E, and the Esperance fishery located between 120°E and 125°E. In 1991-92, 13 vessels caught 36 tonnes of western rock lobster (*Panulirus cygnus)* in the Augusta-Windy Harbour zone and 9 vessels caught 45.7 tonnes of southern rock lobster (*Jasus edwardsii)* in the Esperance zone. The viability of the Augusta-Windy Harbour fishery is enhanced by capture of deep water crabs and a variety of scalefish.

Several of the South Coast estuaries (but not including Hardy Inlet) also support important commercial fisheries managed as a single, limited entry fishery. During 1992, 61 fishing units had access to this fishery. Commercial fishers can operate in all of the South Coast estuaries although netting is specifically prohibited in Wellstead, Torbay, Nornalup-Walpole and Nannarup inlets. Finfish targeted by the estuarine fishery west of Albany include King George whiting (*Sillaginodes punctata)*, Australian herring, garfish (*Hyporhamphus melanochir)*, trevally (*Pseudocaranx dentex*), cobbler (*Cnidoglanis macrocephalus)*, flathead (*Platycephalus speculator)*, leatherjacket (*Monocanthid* spp.), yelloweye mullet (*Aldrichetta forsteri)*, sea mullet (*Mugil cephalus*) and black bream (*Acanthropagrus butcheri)*. East of Albany catches are dominated by black bream and to a lesser extent the two mullet species. Small catches of blue manna crabs (*Portunus pelagicus*) and squid are taken in some estuaries. The bivalve mollusc *Anadara trapezia* is taken exclusively from Oyster Harbour.

Hardy Inlet is managed as a separate, small, limited entry estuarine fishery. During 1992 three units had access to this fishery. The key species are King George whiting, western yellowfin whiting (*Sillago schomburgkii)*, black bream, yelloweye mullet, sea mullet and tarwhine (*Rhabdosargus sarba)*.

There is an important offshore tuna fishery (mainly for southern bluefin tuna *Thunnus maccoyii*) operating from the major South Coast ports. It is managed by the Commonwealth.

A 1987 Australian Bureau of Statistics survey of recreational fishing estimated that 13.5% of about 284 000 recreational anglers operated in the South Coast region in 1986-87. About 73% of these were shore-based. The most sought after species would have been Australian herring. Other key species would have included whiting and Australian salmon. Offshore species taken by boaters would include queen snapper, bight redfish, samsonfish (*Seriola hippos*), breaksea cod (*Epinephelus armatus)*, blue groper and sharks.

Netting is another important recreational activity in this region. It is mostly undertaken in estuaries for such species as sea mullet, yelloweye mullet, Australian herring, and black bream. Recreational netting in WA is currently under review. Some rock lobster potting, squid jigging and diving for abalone also occur in the region.

2. EXISTING MARINE RESERVES

There are no existing marine reserves on the South Coast.

3. RECOMMENDATIONS FOR MARINE RESERVES ON THE SOUTH COAST.

Four primary geomorphological areas distinguishable in the South Coast region are described in section 1.1. One of these, the Bremer sedimentary basin, has only minor outcrops on the shore. The other three exhibit very different types of shore topography and provide a useful first division of the South Coast into major distinctive coastal types. Two of them may be further subdivided on geomorphological criteria. Estuaries are an important feature of the South Coast and these too may be classified into a range of types according to their geomorphology and hydrological conditions. The following recommendations of the Working Group attempt to take all these factors into account.

Previous, unimplemented recommendations of the EPA report on Conservation Reserves for Western Australia, Systems 12 (1975), 2 and 3 (1976) and the CALM *South Coast Regional Management Plan* (1991) are incorporated within the following recommendations of the Working Group.

3.1. Hardy Inlet (Map V-1)

In Part IV section 3.12, it is recommended that consideration be given to inclusion of an area east of Cape Leeuwin encompassing Flinders Bay and nearby offshore rocks within a Leeuwin-Naturaliste marine reserve. Such a reserve would include the waters seaward of the mouth of the Hardy Inlet. Consideration of the inlet was deferred to this Part because it is necessary to assess its recreation and conservation values in the context of the suite of South Coast estuaries. Nevertheless, should both the marine areas east of Cape Leeuwin and the estuarine areas of Hardy Inlet be reserved they should be managed as a single unit.

Hardy Inlet is the downstream basin of the Blackwood River estuary. This recommendation actually refers to the entire Blackwood estuary and not merely to its inlet. Only a brief account of the estuary and its flora and fauna is given here. Details may be found in a comprehensive report, with references to earlier publications, by Hodgkin (1978).

Tenure

The townsite of Augusta occupies the land on the western side of the inlet near its mouth. The Scott National Park and freehold land occupy the eastern shore. Upstream from the town there is freehold land on both sides of the estuary but beyond Alexandra Bridge most of the shores are State Forest.

Geomorphology and hydrology

The estuary of the Blackwood may be classified as a seasonal, permanently open estuary. Like the other large estuaries on the South Coast it is subject to weak tidal flow in summer and scouring with freshwater during winter floods. It has a catchment of about 23 000 km^2, much of it within an area of relatively high rainfall. The upper Blackwood River catchment lies in agricultural lands on the Yilgarn Craton. After crossing the Darling Fault the river flows westwards across the Perth Basin until it is impeded by the Leeuwin-Naturaliste Block. It then turns south and runs more or less along the fault zone that forms the junction of the Leeuwin-Naturaliste Block and the Perth Basin, entering the Southern Ocean east of Cape Leeuwin.

The Blackwood is one of the two large estuaries on the South Coast which are permanently open to the sea. It consist of two parts, a pair of downstream basins and a long upstream riverine section. The wide lower basin is the part known as Hardy Inlet which opens to the sea via a rather long and narrow entrance channel. Two lagoons, the Deadwater and Swan Lake, open into the eastern side of the entrance channel near the mouth. There are two shallow bays further upstream known as West Bay and North Bay. The smaller upper basin, into which the Blackwood and Scott Rivers discharge, is called Molloy Basin. It is almost filled by Molloy Island.

The original position of the mouth of the estuary was at its present location but the bar silted up during the period from 1925 to 1930 and the mouth moved to a new position about 2 km to the east. The Deadwater was formed during that period as the entrance channel. The bar was cut in 1945,

returning the mouth to its old position, the Deadwater remaining as a narrow lagoon. Swan Lake was originally a freshwater lagoon but became salty when it was connected to the Deadwater. Both areas are now saline lagoons relatively little affected by winter flooding and they contribute significantly to the productivity of the estuary.

The riverine parts of the estuary are unusually long. Tidal water flows upstream in the Scott River for a distance of about 8 km. The Blackwood is tidal to a point upstream from Warner Glen Bridge, a distance of more than 30 km beyond Molloy Basin.

Tidal exchange is dampened by the entrance bar. Astronomic tides in the inlet have a maximum range of only 70 cm. However, other factors (notably barometric pressure) also influence water level and the extreme range of water level may be as great as 1.3 m (Hodgkin, 1978). Mean sea level in winter may be as much as 30 cm higher than the mean summer level. There is also a build-up of flood water during winter which raises the level of water in the basins as well as in the riverine parts of the estuary.

Much of the area of the basins consists of shallow banks or "marginal platforms" at less than 1 m depth. Large areas of these are exposed at low tide and there are rush islands in the highest parts of them. Thus, although the inlet is wide, it actually holds little water compared with the other basin estuaries on the South Coast. There are clearly defined channels 2-8 m deep. The main channel extends into Molloy Basin, around the west side of Molloy Island and up the riverine part of the estuary as far as Warner Glen Bridge. That portion of it within the inlet was dredged in 1956 and again in 1973.

Flora and fauna

The most prominent aquatic plant in the estuary is the seagrass *Ruppia maritima.* This species is tolerant to a remarkably wide range of salinity and survives in the estuary throughout the year. It is now particularly abundant in the Deadwater. Another seagrass, *Zostera mucronata,* is confined to the lower part of the inlet where low salinity is experienced only briefly in winter. *Halophila glabra,* which may be Australia's first known annual seagrass, is found along the channel banks from near the mouth to Molloy Island.

The bottom fauna of the inlet is rather diverse compared with that of other South Coast estuaries. All the obligate estuarine species are present (see section 1.2). A number of marine invaders also appear to be permanent residents in at least the marine end of the inlet (Hodgkin, 1978). As might be expected with a permanently open estuary, the list of non-resident invaders is relatively long. These include many kinds of fishes that enter the estuary as larvae and establish large populations, eg whiting, herring, mullet, tailor, mulloway, tarwhine and many others much sought by both amateur and professional fishers.

The mud banks of the inlet are widely used by waterbirds, including migratory birds, as feeding areas in the summer months. The numbers present, however, are not as great as at some other estuaries. The Deadwater and Swan Lake are especially important areas for Black Swan and a variety of ducks which consume large quantities of *Ruppia.*

Recreation and tourism

Augusta has become an important holiday centre. It is popular because of its scenic and historic attractions and its proximity to first-rate fishing areas, caves, wine-growing areas and surf beaches. Hardy Inlet is an important component of the local attractions. As expansion of the town and tourism activities continues, the natural environment, especially the estuary, will come under increasing pressure.

Previous recommendations

In its report on conservation reserves on the South Coast (System 2, 1976) the EPA did not consider Hardy Inlet, although in the context of community debate at about the same time on a proposal to mine mineral sands on the eastern side of the inlet it directed that there be a study of the ecology of the estuary. This was to include an assessment of the multiple uses of the estuary for a range of recreational, conservation and commercial purposes. This was done and resulted in the report by

Hodgkin (1978) which has been the main source document for the Working Group in its considerations.

Working Group recommendations
The Working Group notes the high recreational values of Hardy Inlet and the upper parts of the Blackwood Estuary and the fact that increasing activity in the area places increasing stresses on its biological resources. The estuary is one of the two large estuaries on the South Coast which are permanently open to the sea and it supports a relatively large diversity of aquatic species of plants and animals. Although the basin is wide, the volume is relatively small and there will be an increasing need to manage human activities, especially fishing, so that the aesthetic and biological values of the estuary are maintained.

Accordingly the Working Group recommends that:

> "The estuary of the Blackwood River, including the Deadwater, Swan Lake, Hardy Inlet, Molloy Basin and the tidal parts of the Scott and Blackwood Rivers be considered for reservation as a marine reserve for dual recreation and conservation purposes.
>
> "The estuarine reserve should be continuous with the eastern portion of the proposed Leeuwin-Naturaliste marine reserve." [See Part IV]

3.2. D'Entrecasteaux (Map V-1)

With the exception of a few small enclaves, the coastal lands between Black Point and the mouth of Broke Inlet comprise the D'Entrecasteaux National Park. The coastal marine and estuarine environments are diverse along this sector but, for management reasons, the Working Group decided to treat it as a unit.

Tenure
Along most of the open ocean shore of this sector the D'Entrecasteaux National Park extends to the low water mark.

The small inlets of the Donnelly, Warren, Meerup and Gardner Rivers and Doggerup Creek are wholly or partly encompassed by the D'Entrecasteaux National Park. At the mouth of the Gardner River on the eastern shore there is a reserve (No. A15776, 283.3 ha) vested in the Shire of Manjimup.

Broke Inlet lies almost entirely within the D'Entrecasteaux National Park. Almost the entire catchment of the Shannon River is reserved within the Shannon National Park. There is a small townsite and a Shire reserve (No. 19787, 40.5 ha) at Camfield on the eastern shore. There are some residences and holiday huts at Camfield but otherwise there are no residential areas near the shores of the inlet or in the catchment.

There is difficulty in determining the present status of at least two of the small inlets under the Land Act. Although the bars of the Warren, Meerup and Doggerup inlets may be breached in some winters, allowing seawater to flood the lower reaches of the rivers, they are not tidal in any sense and it is here assumed that they are presently reserved within the national park. However, the inlets of the Donnelly and the Gardner Rivers are tidal in the sense that, for the brief period when the bars are open, seawater enters and there may be tidal flow upstream, at least in a wedge of saline water along the bottom below the freshwater. The boundary of the national park is the "low water mark" but it is problematical whether the deeper portions of the estuaries should be considered to be "below low tide" simply because they are seasonally flooded with seawater. The distinction between tidal and not tidal is quite arbitrary in cases like this. A legal opinion is needed to determine whether these water bodies are already part of the national park.

Geomorphology and hydrology
From the point of view of coastal geomorphology this stretch of coast may be divided into distinct western and eastern portions. The western portion from Black Point to Black Head is a straight, wide,

90 km long beach forming the southern shore of the Perth Basin. Black Head is the position of the Darling Fault and the coast east of it is characterised by rocky headlands alternating with arcuate bays, typical of the coastal margin of the Proterozoic Albany-Frazer Oregon.

The sector has one large estuary, Broke Inlet which is of the seasonally open, basin type, and several small inlets in the mouths of the Donnelly, Warren, Meerup, Doggerup and Gardner Rivers, some of which may be flooded with tidal water for brief periods in early summer. Of the latter, only the Donnelly and Gardner may be considered to be "tidal" in any sense and possible candidates for reservation under the CALM Act.

For the purposes of this report it is convenient to distinguish the following coastal areas within the sector:

(i) Black Point;
(ii) surf beaches of the Perth Basin;
(iii) alternating rocky headlands and arcuate beaches of the Albany-Frazer Oregon;
(iv) Broke Inlet as a representative of a large, seasonally open, basin type of estuary;
(v) Donnelly and Gardner Inlets as representatives of the seasonally open, riverine type of estuary.

Although Black Head has geological significance as the point where the Darling Fault crosses the coast, the Working Group concluded that coastal waters at neither this location nor off the rocky headlands of Point D'Entrecasteaux and Cliff Point have particular merit as candidates for reservation. No further reference will be made to those areas. However, each of the other areas in the above list has features of special interest and they are considered separately below.

3.2.1. Black Point

Tenure

The promontory known as Black Point is at the western end of the D'Entrecasteaux National Park which extends to the low water mark.

Geomorphology

The promontory interrupts the otherwise continuous stretch of wide beach forming the southern shore of the Perth Basin. It is a high headland of the Bunbury Basalt, and is one of the most extensive outcrops of this rock type. At the shore the outcrop has eroded into high cliffs with narrow rock platforms, large tide pools and boulder fields at sea level. Columnar and pillar formations are both present. It is assumed that the rocks extend into the sublittoral zone.

Flora and fauna

No information is available on the marine flora or fauna at this locality. However, the type of rocky shore is unusual and undoubtedly provides a variety of habitats for marine life.

Recreation

The locality is remote and access difficult. Some use is made of the shore as a recreational fishing site.

Previous recommendations

None.

Working Group recommendations

Noting that the promontory is unique in its geology and landforms and that the shore above low water mark is within the D'Entrecasteaux National Park, the Working Group recommends that:

> "a survey of the marine habitats adjacent to Black Point be conducted and an assessment made of their value for conservation purposes, with a view to consideration being given to reservation of the area as a marine reserve for the conservation of marine flora and fauna."

The Working Group considered that there would be merit in extending the proposed reserve west or east to include a section of the wide beach characteristic of the southern shore of the Perth Basin. However, not all of the hinterland of those areas is presently included within the national park and it

was concluded that a representative portion of that coastal type would be better selected further east (see section 3.2.2).

3.2.2. Warren Beach

This section refers to a 20 km stretch of shore between the mouth of the Donnelly River and Black Head. The D'Entrecasteaux National Park comprises the hinterland for almost its entire length.

Geomorphology

The sector represents the straight, wide beach coastal type characteristic of the southern shores of the Perth Basin. It is backed by Quaternary dunes. The shore faces directly into the prevailing south-westerly wind and swell and is exposed to continuous heavy surf. The beach face is steep, almost reflective, and consists of coarse quartz sand. The surf zone exhibits a two bar system, that is an outer parallel-bar disparative system and an inner transverse bar-and-rip system, with attendant mega-cusp horns and bays on the beach face (McLachlan & Hesp, 1984). Beyond the surf zone the seabed is gently shelving.

Flora and fauna

McLachlan & Hesp (1984) recorded accumulations of diatoms (comprising only a single species - *Anaulus birostratus)* in the surf zone at this beach. Similar surf zone diatom blooms in other areas are known to support rich beach communities, especially of filter feeding bivalves.

Little information is available on the marine biota of this area. With exposure to such strong wave action, species diversity is unlikely to be high. McLachlan & Hesp (1984) failed to find any "large macrofauna organisms" burrowing in the beach face, in spite of the presence of diatom blooms, and interpreted this as probably due to the unsuitable, coarse-grained substrate. Nevertheless, it may be assumed that plant and animals are present, representing the surf beach and sandy substrate near-shore communities of the Southern Australian Region.

Recreation

The coast of this sector is remote with few access points. Very limited use is made of the beach by recreational fishers.

Previous recommendations

None.

Working Group recommendations

Although species diversity is unlikely to be high in this habitat, it is representative of a coastal type and ecosystem not otherwise represented or proposed in the South Coast marine reserve system. The Working Group recommends that:

> "State coastal waters adjacent to the D'Entrecasteaux National Park between the mouth of the Donnelly River and Black Head be considered for reservation for the conservation of marine flora and fauna and their habitats."

3.2.3. Broke Inlet

Broke Inlet is the only South Coast estuary, in fact the only one in southern Western Australia, with little development around its shores and virtually none in its catchment so that it remains almost unaffected by human activity.

The estuary and its flora and fauna have been described in some detail by Hodgkin & Clark (1989b) and only a brief summary is given here.

Geomorphology and hydrology

Broke Inlet is an elongate lagoonal estuary fed mainly by the Shannon River. The catchment of Broke Inlet and its rivers lies within the highest rainfall area of the south west with an annual average of about 1 300 mm. Most of the rain falls in the winter months but summer rain is sometimes experienced.

Broke is a seasonal estuary, the bar being closed for much of the year. It has brackish water in summer, rarely more than half the salinity of sea water. The bar is wide, consisting of marine sands which build up to as high as 1.8 m above sea level in summer. It is breached naturally in most years by winter floods, usually between June and September, and remains open until December or January. The dates of opening and closing vary, depending on the time and volume of the winter floods. There have been dry years when it has not opened. Sometimes fishermen have artificially opened the bar.

The main river is the Shannon which is 47 km long and rises in the forested hills of the Shannon National Park. It enters the western end of the inlet where it forms a small delta. Two small, short rivers, the Forth and the Inlet Rivers, enter from the east where they arise in swampy plains.

Broke Inlet lies in a depression of the Proterozoic landscape behind a field of Holocene coastal dunes. The basin is about 15 km long and 2 to 3 km wide. It has an area of 48 km^2. The entrance channel is 3.5 km long and nowhere more than 250 m wide. Its northern shore is steep and cliffed but the southern shore is low and sandy. The entrance appears to be slowly eroding its way northwards. The position and depth of the channel varies.

The basin is shallow with an average summer depth of 1.5 m but there are several deeper areas with depths of 3 to 4 m. These deeper basins are separated by wide sand banks which may be exposed at low tide or when water level is low for other reasons. When the bar is open the inlet is tidal but the astronomic tidal range is only about 10 cm. Barometric pressure effects are believed to produce water level changes as great as 30 cm. During winter floods the water level in the inlet may be as much as 2 m above sea level. It is this build-up of flood water in the inlet which breaches the bar and scours the entrance channel.

The rivers entering the inlet are tidal for only short distances upstream, the Shannon for about 3 km from its mouth.

The shallow sand banks within the inlet are composed of fine, yellow, siliceous sand. The sediment at the bottom of the deeper basins is fine sandy mud or black gelatinous mud. Along the northern and eastern shores of the inlet there are rocky outcrops with sandy beaches between, rising to vegetated dunes. The south-western shore has a narrow beach backed by swamp with paperbark trees. There are two moderately large islands in the inlet and several islets and emergent rocks.

Flora and fauna

The aquatic flora and fauna of Broke Inlet is depauperate. The river water entering the estuary is low in nutrients and biological productivity is not great. The dominant plants are the seagrass *Ruppia megacarpa,* the stonewort *Lamprothamnion papulosum*, the red alga *Polysiphonia* and the green alga *Cladophora.* Only the handful of obligate estuarine benthic animal species are normally present throughout the year. Invasion of other invertebrates sometimes occurs in spring when the bar is open but few survive the subsequent winter.

Hodgkin & Clark (1989b) list 17 commercial species of fish at Broke Inlet. Most of these are temporary invaders. Because the bar usually closes rather early in summer, only early-breeding fish species are able to colonise the estuary in most years. Fishes that breed in spring, summer and autumn such as the King George whiting, yellow-finned whiting and tarwhine, invade the inlet only in those rare years when the bar remains open until late in the season. This is one reason Broke Inlet is a less popular fishing locality than Nornalup/Walpole and Wilson Inlets where the bars are permanently open or open until mid-summer. There is both commercial and recreational fishing in the inlet but it is of limited extent.

Recreation

Broke Inlet is relatively little used for recreational purposes. Fishing and some windsurfing and canoeing are the most common activities. Access to the inlet is limited. Easy access is available only to the Camfield townsite on the eastern shore via Broke Inlet Road. There is a boat launching site at that locality. The Education Department has a camp facility at Camfield which is occasionally used for school groups on nature-oriented study camps.

Previous recommendations
In its report on Conservation Reserves in Western Australia (1976, System 2), the EPA recommended declaration of a South Coast national park, to include the land surrounding Broke Inlet and the catchment of the Shannon River. This has now been done, the parks being called the D'Entrecasteaux and Shannon National Parks. In making that recommendation the EPA did not explicitly recommend that the inlet be reserved although this was clearly implied by the following recommendation:

> "2.3 (7) until legislation is enacted to allow conservation reserves to include submarine lands, the Fisheries Act be employed to protect the Broke and Walpole-Nornalup Inlets and the Director of Fisheries and Wildlife be made responsible for their protection;".

The Shannon and D'Entrecasteaux National Park Management Plan (CALM Management Plan No. 6, 1987) recommends that Broke Inlet should be gazetted as a marine park.

Working Group recommendation
Broke and Wilson Inlets are similar in many respects. Both are large, lagoonal estuaries which are seasonally open. However, while the catchment of Broke lies within a conservation reserve, that of Wilson Inlet lies largely in agricultural lands. Broke Inlet has every chance of remaining in virtually pristine condition without eutrophication while Wilson Inlet is already eutrophic. Although Wilson Inlet has a richer flora and fauna than Broke, its status as a biological environment is less secure. For catchment management reasons as well as management of the estuary, the Wilson Inlet bar is artificially opened every year. Access to Wilson Inlet is considerably greater than to Broke and it is more extensively used for recreation. Management of Wilson Inlet and recreational use of it is presently under the control of the Wilson Inlet Management Authority, empowered by the Waterways Conservation Act.

The Working Group concluded that there would be little point in reserving Wilson Inlet for conservation purposes as it is now subject to such intensive human impact. As the inlet is already controlled by the Management Authority, neither would there be any advantage in reserving it for recreational purposes. For conservation purposes Broke Inlet is a better choice as an example of the large, lagoonal, seasonally-opened estuary because it is likely to remain in natural condition. Because of its isolation within the national park, Broke also offers the prospect of management to preserve its present peaceful character and use for passive recreation.

Accordingly the Working Group recommends that:

> "Broke Inlet and the tidal parts of the Shannon, Forth and Inlet Rivers be reserved for recreation and conservation and their management integrated with that of the D'Entrecasteaux National Park."

3.2.4. Donnelly and Gardner Inlets

Geomorphology and hydrology
Each of these rivers has a small, riverine estuary at its mouth, described by Hodgkin & Clark (1989b). There are no lagoons. The mouth of the Donnelly River is barred by the build-up of sand but opens seasonally following winter floods. While the bar is open the river is tidal for a distance of about 12 km upstream. The sea water intrudes beneath the surface freshwater and there may be little, if any, mixing. The Gardner River has a rock bar at the mouth which remains open all year, although the bar impedes penetration of sea water except during the summer period when there is very little river flow. The catchments of both rivers lie largely within forested land although the headwaters arise in agricultural land.

Flora and fauna
As might be expected given the highly seasonal nature of the environment the aquatic flora and fauna of both inlets are depauperate. The marine seagrass *Ruppia megacarpa* and the stonewort *Lamprothamnium* are sometimes present. Even the suite of obligate estuarine benthic animals is represented by only a few species (see Hodgkin & Clark, 1989b). Only the Donnelly has significant fish populations and is fished with any regularity.

Previous recommendations
None.

Working Group recommendation
The Working Group considers that the inlets of the Donnelly and Gardner Rivers have considerable scientific and recreational value and should be managed as part of the surrounding D'Entrecasteaux National Park. It is unclear whether these areas are already included within the national park. Accordingly the Working Group recommends that:

> "Legal advice should be taken on the status of the tidal parts of the Donnelly and Gardner Rivers and if they are not already reserved within the D'Entrecasteaux National Park under the Land Act, consideration should be given to reserving them under the Conservation and Land Management Act for conservation and recreational purposes."

3.3. Walpole-Nornalup (Map V-1)

The Walpole-Nornalup estuarine system consists of two connected lagoons, that is Nornalup and Walpole Inlets, and the tidal reaches of the Deep, Frankland and Walpole Rivers. The estuary has been described by Hodgkin & Clark (1988a) and Smith *et al.* (1990).

Tenure
In 1972 the Government gazetted the Walpole-Nornalup National Park under the Land Act as a Class A reserve and included the inlets within the park. But it was later discovered that areas below low tide cannot be reserved under that Act and that inclusion of the tidal waters of the inlets within the park was not valid. When the marine reserves provisions of the CALM Act were introduced the Government directed that the inlets be reserved as marine park under the powers of this legislation. This has not yet been done.

Nornalup Inlet is entirely surrounded by the Walpole-Nornalup National Park. A small area of the park on the north-eastern shore of Nornalup Inlet is leased to the Coalmine Beach Sailing Club. The south-eastern shore of Walpole Inlet is also national park but the north eastern shore is occupied by the Walpole townsite and the north-western shore is a recreation reserve vested in the Shire of Manjimup.

The tidal parts of the Frankland and Deep Rivers are also contained within the national park except for a portion of the former in the vicinity of the Nornalup townsite.

Geomorphology and hydrology
Walpole-Nornalup is a relatively large lagoonal estuary which has two basins and a permanently open entrance. It lies between forested, granitic hills fringing the Albany-Frazer Oregon and the high Pleistocene dunes of the coast. It consists of two basins which together cover an area of about 13.2 km^2. Walpole Inlet is connected to the much larger and deeper Nornalup basin by a narrow channel between steep granite headlands. The entrance channel from the sea into Nornalup Inlet lies against a granite headland on its western side and the sand dunes which flank Bellanger Beach on its eastern side. The ocean bar limits tidal flow but it is always open and the estuary is always tidal.

Both the Deep and Frankland Rivers have well-defined channels, rather large deltas and discharge over shallow sand banks into Nornalup Inlet. The channels have been dredged and the rivers are navigable for some distance upstream. Their upper catchments are in agricultural lands but for much of their length they flow through State forest or national park. Rainfall in the catchment is high, with an annual fall of up to 1 400 mm near the coast.

Deep River is tidal for a distance upstream of about 6 km and the Frankland for about 12 km. The much smaller Walpole River is tidal for only a very short distance. Except for the dredged channels, Walpole Inlet is shallow with depths less than 1 m. There are shallow sand banks around the perimeter of Nornalup Inlet which shelve steeply to a central basin between 3 and 5 m deep.

The salinity regime in the estuary was studied in some detail by CSIRO from 1944 to 1951 (for references see Hodgkin & Clark, 1988a). Throughout the summer the salinity of the water in both inlets is approximately that of seawater. Marine water of oceanic salinity also penetrates far upstream in the two larger rivers during summer. In winter, when the rivers flood, a thermocline develops and the fresh water flows downstream over salty water which usually remains in the deeper parts. The saline bottom water may become deoxygenated under those conditions.

Flora and fauna

As may be expected, this permanently open estuary has a relatively rich flora and fauna. The seagrasses *Ruppia megacarpa* and *Heterozostera tasmanica* both occur in Nornalup Inlet, the latter mainly near the entrance channel. A brown alga, *Cystoseira trinodes,* is common on rocks around the shore. Green algae of the genera *Chaetomorpha* and *Cladophora* are abundant on the muddy flats, and the green alga *Acetabularia calyculus* is common, living attached to stones and shells in the shallows. The epiphytic algae *Chaetomorpha billardieri* and *Monosporus australis* sometimes overgrow the *Ruppia,* although there is no evidence of eutrophication.

The estuarine copepod *Gladioferens imparipes* dominates the plankton of the riverine parts of the estuary but also occurs abundantly in the inlets. The marine euryhaline copepod *Acartia tonsa* is the dominant plankter in the higher salinities of the inlets. Hodgkin & Clark (1988) list other copepods taken in plankton samples within the estuary.

All of the South Coast obligate estuarine invertebrate animals occur in the estuary and there is a larger number of marine invaders than is found in any other estuary in the region (except Oyster Harbour). A faunal list is given in Hodgkin & Clark (1988a).

The fish fauna also is relatively diverse. Many species targeted by recreational fishers are present, often in large numbers, including most of the common inshore marine species. Nornalup Inlet in particular is a popular location for recreational fishing. Net fishing is prohibited.

Recreation

Ablone *et al.* (1990) summarised recreational use of the Walpole-Nornalup National Park.

The Walpole-Nornalup estuary is surrounded in many places by tall forest. It is scenically and aesthetically one of Western Australia's most spectacular estuarine environments (Hodgkin & Clark, 1988). Much of its shore remains in its natural condition and the waters are unpolluted. For these reasons the Walpole-Nornalup National Park has long been a popular area for recreational pursuits, with the inlets as a central focus. Boating and especially fishing are among the most common recreational activities. Sailing from the Coalmine Beach Sailing Club attracts visitors as well as local people. Windsurfing is becoming another popular watersport on the inlets.

The Walpole-Nornalup National Park Management Plan notes the current rate of increase in the number of visitors to the park, including those indulging in water sports, with the corresponding need for increased management to prevent degradation of the environment.
Management of boat launching sites is seen to be of particular concern. Prevention of pollution and conservation of fish stocks are also important.

Previous recommendations

Although in its report on Conservation Reserves in Western Australia (1976, System 2) the EPA did not specifically recommend marine park status for the Walpole-Nornalup Inlets, it recommended as follows:

> "(7) until legislation is enacted to allow conservation reserves to include submarine lands, the Fisheries Act be employed to protect the Broke and Walpole-Nornalup Inlets and the Director of Fisheries and Wildlife be made responsible for their protection;".

The CALM Walpole-Nornalup National Park Management Plan (Smith *et al.*, 1990) noted that the Minister for the Environment had directed that the inlets should be reserved under the CALM Act and that declaration of the marine park was "expected to occur early within the life of this [management] plan".

Working Group recommendations
The Working Group believes that the Walpole-Nornalup estuarine system has very high conservation and recreational values. Although in size it is similar to Broke and Wilson Inlets, it is quite different in that it is naturally permanently open to the sea. It is the only permanently open lagoonal estuary on the South Coast and, apart from the partly estuarine Oyster Harbour, it has the most diverse estuarine flora and fauna of any estuary in the region. It also has outstanding scenic qualities and is largely surrounded by National Park.

The Working Group notes that in 1972 the Government included Walpole-Nornalup Inlets within the national park until it was discovered later that this was not possible under the Land Act. Accordingly the Working Group recommends that:

> "declaration of Walpole and Nornalup Inlets and the tidal parts of the Deep, Frankland and Walpole Rivers as marine park be implemented as a matter of high priority, and its management integrated with that of the surrounding national park."

3.4. William Bay (Map V-2)

Tenure
William Bay National Park extends to the low tide mark in the area under consideration.

Geomorphology
This is a granite shore with beaches alternating with smooth rock surfaces. There is a chain of large, near-shore boulders and rock islets protecting the beaches and deep pools from the full force of the swells. This type of situation is uncommon on the South Coast where most open ocean rocky shores are exposed to heavy wave action.

Flora and fauna
There is very little information about the marine flora and fauna at this locality. However, the sublittoral habitats are diverse with extensive tide pools and boulders. A diverse flora and invertebrate fauna is certain to occur there. The locality is the type locality for the gastropod (cowry) *Cypraea hadnightae.* Seagrasses, mainly species of *Posidonia* and *Amphibolis,* grow in most of the sheltered areas in the lee of the islets.

Recreation
This is one of the South Coast's most attractive sections of coast, particularly because of its relatively protected waters suitable for swimming, diving and fishing. It is of such scenic quality that photographs of it often appear in tourist promotion and other publications.

Previous recommendations
None.

Working Group recommendation
Noting the high scenic and recreational values of the locality and its likely diverse marine flora and fauna representative of the South Coast rocky shore habitat, the Working Group recommends that:

> "the State waters adjacent to the William Bay National Park be surveyed and assessed for their conservation values, with a view to possible reservation as a marine reserve for dual conservation and recreation purposes."

3.5. West Cape Howe (Map V-2)

Tenure
West Cape Howe National Park extends to the low water mark along most of the coast under consideration. At the eastern boundary of the park, that is at the western end of Torbay (Port Harding), there is a Shire reserve at the shore.

Geomorphology
This section of the coast is one of a series of repeated geomorphic units characteristic of the western part of the South Coast (see section 3.1) with Torbay Head as its central feature. It is a high doleritic promontory with perhaps the State's most dramatic sea cliffs exposed to the full force of the Southern Ocean swells. Its extremity is the southernmost point of Western Australia. To the west, between West Cape Howe and Knapp Head, there is a long, curved sandy beach backed by high Pleistocene dunes. The sea floor fronting the western beach is gently shelving but the shore of the promontory is steep-to, dropping off very steeply into deep water. On the eastern side of the promontory there is a series of small, deep, arcuate bays with narrow beaches below very steep hill slopes. Further north within Torbay the force of the swells decreases and the shore comprises boulders with some semi-protected tidal pools. Two small islets, Migo and Richards, protect a channel and boat anchorage.

Flora and fauna
No information is available on the marine flora and fauna of the shore. Inspection of aerial photographs reveals a wide range of rocky shore habitats from those with maximum exposure to ocean swells, to semi-protected pools and boulders. There are dense algal beds in the shallows on the eastern side of the promontory, especially in the shelter of the two small islets. Deeper waters offshore in the western part of Torbay support extensive seagrass beds. The aerial photographs suggest the presence of similar seagrass beds beyond the surf zone off the beach west of West Cape Howe.

Recreation
There are spectacular views from the headland although four wheel drive is necessary to gain access. Access is available to the shore on the eastern and western sides of the headland. Both areas are popular with local people for beach and rock fishing. The small, deep bay on the eastern side is one of the most popular dive sites in the Albany district, with access to deep water from the shore. The water is exceptionally clear and the rock wall fauna is extremely rich and colourful. The beach at the Shire reserve in Torbay is popular as a family swimming area and boat launching site. Until now this headland has had little attention from tourists because of its relative remoteness and inaccessibility.

Previous recommendations
None.

Working Group recommendations
Noting the high scenic values of the shore, the ready access to deep water and magnificent underwater scenery, and the variety of habitats and likely high diversity of marine flora and fauna, the Working Group recommends that:

> "consideration be given to reservation of the State waters adjacent to the West Cape Howe National Park as a marine reserve for the purposes of conservation of flora and fauna and recreation, with the possible inclusion of the western part of Torbay adjacent to the Shire reserve."

3.6. King George Sound - Princess Royal Harbour (Map V-2)

King George Sound and the two related inlets, Princess Royal Harbour and Oyster Harbour, comprise one of the principal landform features of the South Coast. Albany, the South Coast regional centre and principal port, is located on these shores.

Tenure
Land use around the shores of this area is complex with townsites, shire reserves, freehold land and national parks. The waters of King George Sound, Princess Royal Harbour and Oyster Harbour are under the control of the Albany Waterways Management Authority.

Geomorphology
A general account of the geomorphology of the Sound and inlets is given in section 1.1. King George Sound is a marine gulf, Princess Royal Harbour an enclosed marine inlet, and Oyster Harbour partly a marine inlet and partly an estuary. The waters are presently under study by the EPA and other government agencies in view of concern about eutrophication of the inlets.

King George Sound is protected from the southerly winds and swells by Flinders Peninsula which terminates at Bald Head. The southern side of the Peninsula is very exposed and features high granite and limestone cliffs. The Sound is open to the east although there are two high islands in the entrance, Michaelmas and Breaksea, both of which are nature reserves. The depth of the Sound ranges from 10 to 35 m. The deepest part is a basin at 30-35 m in Frenchman Bay west of Seal Island. A sublittoral rocky ridge connects Michaelmas Island to the northern shore of the mainland west of Herald Point and there is a chain of deep reefs west of that island.

Princess Royal Harbour is cut off from King George Sound by Vancouver Peninsula with only a narrow entrance channel. The inlet is silted and very shallow except for a small basin on the northern side just inside the entrance where the port of Albany is located. There are wide muddy sand banks around its periphery.

Oyster Harbour is similar to Princess Royal Harbour but has two rivers, the King and the Kalgan, entering it on the north side. These render the northern part of the inlet an estuary. The entrances to both inlets are permanently open and there are strong tidal flows in and out. Princess Royal Harbour and Oyster Harbour are both eutrophic while King George Sound is oligotrophic.

Flora and fauna

As noted in section 1.2, King George Sound and the two inlets were collecting sites for several early expeditions and many marine species were originally described from there. There has been a number of ecological studies in the area in more recent years, outlined by Wells (1990). McKenzie (1962) described the environment and fauna of Oyster Harbour. Roberts & Wells (1980) described the marine and estuarine molluscan faunas. An international marine biological workshop held in the area in 1988 resulted in publication of a range of important papers on the biology of the sound and the two inlets (Wells *et al.*, eds., 1990; 1991). These included detailed studies on seagrass beds and their associated fauna (Kirkman *et al.*, 1991; Walker *et al.*, 1991; Hutchings *et al.*, 1991; Wells *et al.*, 1991), spatial distribution of intertidal rocky shore invertebrates (Britton *et al.*, 1991; McMahon & Britton, 1991), foraging by opisthobranchs (Jensen, 1991), resource partitioning by intertidal snails on sand flats (Morton & Britton, 1991). Also included were taxonomic accounts of some groups of invertebrate animals in the area.

From the early and modern accounts it is clear that there is a wide range of habitat in the Sound and the two inlets. These range from open ocean marine, through protected marine inlet to estuarine. There are both limestone and granite rocky shores, intertidal mud and sand flats, deep reefs, and deep basins with fine sand and mud substrates. As a consequence this area has an exceptionally rich and diverse marine and estuarine flora and fauna.

Seagrass beds are dense and rich in plant and animal species, especially on the sandy sills on each side of Vancouver Peninsula and bordering Middleton Bay. However, the seagrass beds in Princess Royal Harbour and Oyster Harbour have suffered serious depletion in recent years as a result of eutrophication (Bastyan, 1986; Kirkman, 1987). In Frenchman Bay seagrasses grow down to 17 m. The meadow-forming species *Posidonia sinuosa* covers the largest area but along the shallow edges *P. australis* is the first seagrass seen. *P. kirkmanii* is common at Gull Rock and along the north eastern shores of King George Sound. *P. roberstsonae* is common along blowout edges and inside blowouts. Both species of *Amphibolis* occur throughout King George Sound. *Halophila australis* and *Heterozostera tasmanica* are transient members of the seagrass communities between years of large storms and years with few storms.

The intertidal sand flat faunas of Princess Royal Harbour and Oyster Harbour support diverse communities of burrowing invertebrates (Roberts & Wells, 1980; Wells & Roberts, 1980) and are of special significance as this habitat type is now of such rare occurrence on the South Coast. A notable species is a population in Oyster Harbour of the bivalved mollusc *Anadara trapezia,* a relic of former times when the species had a much wider geographical range. It is a common species in Pleistocene shell beds in southern Western Australia. The species is common in south-eastern Australian estuaries

today but in Western Australia it now lives only in Oyster Harbour where it is the subject of a small fishery.

The rocky sublittoral ridge between Herald Point and Michaelmas Island has a rich and diverse fauna of attached, suspensory-feeding invertebrates, especially sponges, and associated animals. A seagrass, *Thalanodendron pachyrhizum* , grows in large quantities along this ridge. The steep-to, rocky shores of Michaelmas and Breaksea Islands also have a rich and extremely colourful wall fauna below the algal zone (that is below about 15 m).

The deep basin in Frenchman Bay has a fine sand floor with a rich burrowing invertebrate fauna.

Fisheries

An account of the fish fauna of Princess Royal Harbour and Oyster Harbour can be found in Lenanton (1974). Pilchard is the most abundant species harvested in the area. It is taken by purse-seine in King George Sound and to a lesser extent in Princess Royal Harbour. Other key species, taken by beach-seine and gill net within the area, include Australian herring, leatherjackets, cobbler, yellowtail scad, flathead, King George whiting and garfish.

Bonito and Nanarup Beaches, located east of King George Sound, are important beaches for the Australian salmon fishery. Commercial fishing for Greenlip abalone (*Haliotis laevigata*) occurs off Flinders Peninsula and in King George Sound.

Recreation

The protected and semi-protected waters of the Sound and both inlets are extensively used by local people for recreation, including boating, fishing and diving. There are boat ramps at several locations. Larger vessels use the port in Princess Royal Harbour. Commercial dive tours operate from Albany, taking divers to the exceptionally scenic areas in the vicinity of Michaelmas and Breaksea Islands. Whale-watching tours also operate from Albany. The lee side of Flinders Peninsula is particularly suited for snorklers and beginners. Torndirrup National Park, which occupies much of Flinders Peninsula, has outstanding scenery and is heavily used by sightseers.

Previous recommendations

None.

Working Group recommendations

The Working Group recognises that King George Sound, Princess Royal Harbour and Oyster Harbour are extensively used for port and recreational purposes and that the two inlets show evidence of environmental degradation. Nevertheless, these areas are of such biological importance that reservation of some parts of them for conservation purposes should be considered. There might also be merit in reservation of some parts to protect and promote recreational activities, especially diving.

Of particular importance are the seagrass beds on either side of Vancouver Peninsula and in Frenchman Bay. The sheltered deep basin in Frenchman Bay is also a rare feature on the South Coast. These areas are of special value for both conservation and recreation. The rocky sublittoral ridge and reefs in the vicinity of Michaelmas and Breaksea Islands have special attractions for recreational divers, including the commercial dive tour industry. Although similar underwater scenery and flora and fauna occurs further east around Cape Vancouver, the King George Sound sites are much more easily accessible to vessels from Albany.

Accordingly the Working Group recommends that:

"1. the western shore of Vancouver Peninsula in Princess Royal Harbour, and the eastern shore of that Peninsula in King George Sound as far east as Flat Rock, and extending seaward as far as Seal Island to include the waters of Frenchman Bay, should be considered for reservation as a marine reserve for the purposes of conservation of flora and fauna and recreation;

"2. a survey be conducted of the deep ridge and reefs in the vicinity of Michaelmas and Breaksea Islands, together with a survey of the waters around Cape Vancouver, to assess their relative underwater scenic

values and merits as dive sites, with a view to selecting areas to be reserved for conservation and recreation use."

3.7. Cape Vancouver to Bald Island (Map V-2)

This section of the South Coast has outstanding coastal scenery and a wide range of open coast habitats with high conservation values.

Tenure
The Cape Vancouver peninsula is reserved as a Class A Nature Reserve (No. 27956) notable as a refuge for the Noisy Scrub-bird and other threatened birds. Bald Island is also an important Class A Nature Reserve (No. 25869) which is especially important as an island refuge for the Quokka and the site of an introduced population of the Noisy Scrub-bird. Between the two is the Mount Manypeaks ridge incorporating the Waychinicup National Park (No. 25865 and 27502) and a Class A Nature Reserve (No. 36028). Thus, all but a few kilometres of the coast in the section under consideration is reserved for conservation or conservation and recreation purposes.

Geomorphology
This section of coast is a fine example of the repeated sequence of arcuate beach between granite headlands which is a prominent feature of the western part of the South Coast (section 1.1).

Mount Gardner (399 m) and Mount Manypeaks (565 m) are two of the high points on the South Coast. Mount Gardner forms a large, granitic promontory, terminating at Cape Vancouver, and connected to the mainland by a low, sandy isthmus. It would have been a high island when sea level was only a few metres higher than it is today. The southern side of the isthmus is the windward side. The shore there consists of a long, curved, surf beach backed by Pleistocene dunes and a fringe of eolianite limestone cliffs. At sea level, especially at the eastern end, there is extensive beach rock development and the formation of intertidal limestone rock platforms. The northern side of the isthmus, fronting onto Two Peoples Bay, faces east and is less exposed to the southern swells. It too has an arcuate beach and a backing of Pleistocene dunes but there is less surf and no limestone. The bay is gently shelving with a sandy floor.

Mount Manypeaks is the high point on an east-west granitic ridge facing the Southern Ocean and forming a stretch of very rugged, steep-to shore with almost no access. The ridge is breached near its centre by the steep valley of the Waychinicup River which has a small but unique inlet at its mouth. The inlet is very narrow and flanked by steep granite hills. Its entrance is permanently open and sea water penetrates a short distance upstream until it is blocked by a series of rock bars. The upper portion of the inlet is estuarine. The high granite ridge terminates in the east at Bald Island, separated from a granitic headland between Mermaid and Lookout Points by a narrow and deep channel. Beyond Lookout Point the coast turns north again to Hassell Beach, the high granite giving way to another long, curved beach backed by Pleistocene dunes.

Although the sea floor slopes gradually out to 20 m in Two Peoples Bay and off Hassell Beach, elsewhere there is a rather steep slope. The granitic shores of Cape Vancouver, Bald Island and the Manypeaks ridge drop off very steeply to 50 m within 1 or 2 km from the shore. These steep-to shores are characterised by spectacular vertical rock walls in the sublittoral zone. There are reports of a deep underwater canyon off the mouth of the Waychinicup River which may be a continuation of the river valley.

Flora and fauna
The gently sloping, relatively protected seabed of Two Peoples Bay has extensive seagrass meadows of *Posidonia* and *Amphibolis* spp. There is no information on their floristic composition or the composition of their associated fauna. However it would be safe to assume that the seagrass community is rich in both density and species.

Little is known of the rocky shore flora and fauna of this shore. The steep granite shores of Cape Vancouver, the Manypeaks ridge and Bald Island are exposed to very heavy wave action. The intertidal

biota there is not diverse but well represents the flora and fauna of exposed South Coast granitic shores. The limestone rock platforms on the southern side of the Mount Gardner isthmus have not been studied but, although they provide a rather different habitat, are probably constantly abraded by sand in the heavy surf and not rich in species.

The intertidal fauna of the rocky spit at South Point at the southern end of Two Peoples Bay has been well sampled by biologists. The western side of the spit is relatively protected from the swells and consists of a field of boulders and tide pools extending down into the sublittoral zone. This is a habitat rich in macrophytic algae and invertebrate animals. There is an assemblage of molluscs, crustaceans and echinoderms typical of South Coast sheltered rocky shores. Juvenile Roe's abalone (*Haliotis roei)* are abundant and the endemic relict gastropod *Campanile symbolicum* is very common. Seagrass meadows begin at a depth of 2-3 m, beyond the limit of the boulders. They are sparse with a shoot density of about 9-11/m. The meadow-forming species *Posidonia sinuosa* is the dominant seagrass but *P. robertsonae* covers large areas. *Amphibolis* spp, *Heterozostera tasmanica* and *Halophyla australis* are also present. There is a similar feature with a similar flora and fauna in the equivalent position at Cheyne Beach, at the southern end of Hassell Beach. Habitats of this type are rare on the rugged South Coast.

An unusual geomorphic feature, with an unusual flora and fauna, is the Waychinicup Inlet. The sheltered rocky shores have many tide pools and loose boulders providing invertebrate habitats. In the estuarine shallows near the head of the inlet there are dense seagrass beds of *Posidonia australis* and muddy sand flats with diverse flora and fauna. There is nothing else quite like this on the South Coast. The most similar would be parts of Oyster Harbour.

On open ocean shores the rock slopes are densely vegetated with macrophytic algae down to depths of 15-20 m. Below that depth macrophytes give way to a very diverse community of attached, suspensory-feeding invertebrate animals including sponges, ascidians and coelenterates. Sublittoral vertical walls and undercuts where there is shade are also densely covered with a wall fauna of sedentary invertebrates.

Several of the emergent rocks and islands on this section of the coast are important haul-out and breeding colonies of Australian Sea Lions and New Zealand Fur Seals. The most important of these are Coffin Island and Bald Island. Bald Island is also an important breeding area for the Little Penguin (*Eudyptula minor).*

Fisheries

Pilchard is the most abundant species harvested (by purse-seine) from the inshore waters between Cape Vancouver and Bald Island. Betty's Beach, midway between these points, is one of the most productive salmon fishing beaches on the South Coast. Greenlip abalone are taken commercially around Cape Vancouver and Bald Island. The demersal line-fish resource of this region is fished by recreational fishers operating mainly by small craft launched from Albany and Cheyne Beach.

Recreation

Local people use this area for fishing and diving but it is relatively remote and it has not yet become a popular tourist area. There is little access to the shore. The Two Peoples Bay Nature Reserve is a "prohibited area" except at the beach on the north side of the promontory where there is a picnic area and a boat launching site. There is another picnic area and boat launching site at the northern end of the bay at North Point. A track gives access to the head of the Waychinicup Inlet but only very small boats can be launched there. The only other point of access is at Cheyne Beach at the south end of Hassell Beach where there is a reasonable anchorage and a launch site.

Because of limited access, the shore and its flora and fauna are relatively pristine. Anecdotal evidence was given to the Working Group that the fish fauna around Cape Vancouver and Bald Island remains very rich with little evidence of depletion of the large and vulnerable species like Blue Groper and Queen Snapper. Local dive tour operators and abalone divers claim that locations like Coffin Island off Cape Vancouver and Bald Island, with their deep drop-offs (to 50 m in some places), spectacular rock walls and exceptionally clear water are among the best dive sites known on the South Coast. They are

relatively easily reached in good weather from the boat launching sites in Two Peoples Bay and Cheyne Beach.

Previous recommendations
None.

Working Group recommendations
Noting the wide variety of coastal types and habitats that are represented, the relative remoteness and lack of access to the shore and the degree of protection that provides, and the value of the inshore waters for public recreation, especially fishing and diving, the Working Group recommends that:

> "the State coastal waters between the western boundary of the Two Peoples Bay Nature Reserve and Lookout Point, including the tidal waters of Waychinicup Inlet and encompassing Bald Island, be considered for reservation as a marine reserve for conservation of flora and fauna and recreation."

3.8. Fitzgerald Biosphere Reserve (Map V- 3)

This section deals with the marine environment of the coast adjacent to the Fitzgerald River National Park and the estuarine environments of several small inlets within the park boundaries. A published management plan for the park (1991, CALM Management Plan No. 15) contains relevant information about the coastal features.

Tenure
The Fitzgerald River National Park consists of two Class A reserves, one (No. 31738) being a 700 m wide strip of land along the coast between Gordon and Culham Inlets, extending to the low tide mark and including a small near-shore islet known as Red Island. The national park is a Biosphere Reserve under the UNESCO Man & the Biosphere Program.

Beyond the southern end of the park, that is at the southern end of Doubtful Islands Bay, there is a prominent granitic headland, terminating in Point Hood and two small islands called the Doubtful Islands. The headland, which forms the eastern side of Bremer Bay, is Shire reserve and freehold land but the two islands are Class A Nature Reserve (No. 23516).

The Fitzgerald River National Park extends to the low water mark and the status of those inlets entirely encompassed by it is difficult to determine. As the inlets are merely flooded with sea water on rare occasions, they are hardly classifiable as "tidal" so that it can be argued that they are, by definition, included within the national park. Gordon Inlet in the west and Culham Inlet in the east form part of the boundary of the park but the location of that boundary remains ambiguous because a "low water mark" is not definable.

Geomorphology
The Fitzgerald River National Park is characterised by rolling hills and a range of higher hills, the Mount Barren Ranges. The hills are formed of metasediments of the Albany-Frazer Oregon known as the Mount Barren Group. Low parts of the landscape are filled with Eocene sediments. The Mount Barren Range lies along the coast in the eastern part of the park, forming rugged rocky shores with precipitous cliffs. Outcrops of the Mount Barren Group occur at Point Charles and Point Ann, producing high, prominent headlands. Between the headlands of the Mount Barren Range east of Dempster Inlet and Point Charles, between Point Charles and Point Ann, and between Point Ann and Point Hood, there are wide, arcuate beaches backed by Pleistocene dunes.

The seabed south of Point Hood and the Doubtful Islands drops off steeply to 50 m within 1 km of the shore but in Doubtful Islands Bay there is a gradual slope and the 50 m contour is 10-15 km offshore.

Between Point Hood and Hopetoun there is a series of inlets either contained within the Fitzgerald River National Park or bordering it. From west to east these are the Gordon, St Mary, Fitzgerald, Dempster, Hamersley and Culham Inlets. They are no longer estuaries in the conventional sense, being open to the sea on rare occasions when there are exceptional floods and the bars are breached (Hodgkin

& Clark, 1990a). Nevertheless they are considered here as they sometimes support estuarine and marine flora and fauna. Detailed descriptions of these inlets have been published by Hodgkin & Clark (1990).

While acknowledging that the inlets within and bordering the Fitzgerald River National Park lie at the edge of the definition of estuary, for the present purpose they are considered to fall within the category of semi-permanently closed estuary (see Part I, section 3.7.6). The inlets have formed where the river mouths are trapped in depressions behind rocky headlands or coastal dunes. If they were permanently closed they would be classified as saline coastal lagoons. Culham Inlet could perhaps be so regarded. The rivers that feed the inlets are saline and tend to flow intermittently. In summer some of the inlets become hypersaline as a result of evaporation or even dry out.

Gordon Inlet has a small lagoon about 4 km long but there is a meandering riverine portion extending 13 km from the mouth. The lagoon is shallow, probably not much more than half a metre below mean sea level. The entrance sand bar is low and breaks at intervals of about 3-5 years. The eastern shore of the lagoon forms the boundary of the national park and the western shore is a shire reserve.

St Mary Inlet is the smallest of the series. It is only 1 km long and 250 m wide. It has a very shallow lagoon and is filled with sediment to about mean sea level. It has a low sand bar at the entrance that breaks only in those years of unusually heavy rainfall and then remains open for only a few weeks.

Fitzgerald Inlet is the largest of the series. It has a lagoon about 6 km long and 1.5 to 2 km wide, lying in a valley of Pallinup Sandstone with cliffed shores at several locations. There is a narrow inlet channel barred by low dunes. The lagoon is very shallow, that is seldom more than 1 m, and the floor is at about mean sea level. Water level in the lagoon may build up to nearly 2 m during a heavy winter flood, before the bar bursts and the water is released. The bar does not stay open for more than a few weeks. The inlet dries completely in prolonged dry periods.

Dempster Inlet is a small elongate lagoon, about 4 km long, lying in a valley of metamorphic schists. It is fed by small streams that rise within the park. The floor of the lagoon is silted to about mean sea level. The entrance channel is narrow and there is a high sand bar. There are no records of the frequency of opening but it does not seem to be often.

Hamersley Inlet lies in a deep valley between metamorphic rocks. Its upper reaches lie in a meandering gorge and the lagoon has rocky shores. Overall the inlet is about 7 km long but it is narrower than the Fitzgerald. It is deeper than any other of the series with the lagoon floor at about 2 m below mean sea level near the mouth. It dries completely only rarely. The sand bar at the entrance has broken only about seven times since 1923, that is an average of about once in ten years.

Culham Inlet is a wide, shallow coastal lagoon cut off from the sea by a stable coastal dune system. Its western shore abuts the steep slopes of East Mount Barren in the park. Its eastern shore is lower and bordered by Shire reserve and agricultural land. The inlet is fed by the Phillips and Steere Rivers, both of which are saline. There are rich fossil beds around the lagoon showing that it was a true estuary during the Holocene. The inlet is now so shallow that it dries up completely during prolonged dry periods. It fills with saline river water in most winters. The last time the bar is known to have broken naturally was in 1849 (Hodgkin & Clark, 1990a) but it was opened artificially in about 1920 and again in 1993 following heavy floods.

Flora and fauna

There is very little information about the marine flora and fauna along this stretch of coast. The metasedimentary rocks of the Mount Barren Group form rocky shores of rather different type to the granite shores more typical of the South Coast but there have been no surveys of their flora and fauna. Aerial photographs indicate that there is extensive development of seagrass beds beyond the surf zone in Doubtful Island Bay but again no information about their floristic composition or associated fauna is available.

The steep-to shores of Point Hood and the Doubtful Islands are reported to be spectacular dive sites with vertical sublittoral walls and prolific growth of attached invertebrates and large fish populations. Doubtful Island Bay is an important beach for the Australian salmon and Australian herring fisheries.

Southern Right Whales are frequently seen in Doubtful Island Bay during winter and spring. The highest reported numbers of this whale have been from the vicinity of Point Ann (Bannister, pers. comm.). The Doubtful Islands are important breeding colonies of Australian Sea Lions and New Zealand Fur-seals.

The inlets within and bordering the Fitzgerald River National Park are very depauperate in terms of aquatic flora and fauna, as might be expected in view of their semi-permanently closed condition. However, when the bars break and seawater floods the lagoons many marine animals invade them and may survive there for brief periods.

The seagrass *Ruppia megacarpa* and the stonewort *Lamprothamnium* establish in most of the inlets when salinity conditions are favourable. Some of the obligate estuarine invertebrates are present. Black bream survive throughout the year in deeper riverine pools. Sea mullet and a few other marine fishes that enter while the entrances are open may also survive for some months and grow to fishable size, especially in Hamersley Inlet. At those times they are fished by both commercial and recreational fishers. The commercial fishers make the point that if these fish are not taken they die anyway when the water becomes unsuitable for them and a valuable resource is wasted.

Recreation

The coastline of the Fitzgerald River National Park is classified by CALM for management purposes as having high or moderate scenic value. The central area of the park is a wilderness zone without access for vehicles. Vehicle access to other parts of the shore is sited to minimise visual impact. Consequently the scenic quality of this very beautiful section of the South Coast will be maintained.

Most park visitors are sightseers. Recreational fishers use vantage points on the accessible rocky shores and beaches but the intensity of use is low. There is a boat launching site at the southern end of Doubtful Island Bay.

The inlets within and bordering the Fitzgerald River National Park are an important element in the scenic value of the park. Dempster Inlet lies within the wilderness zone of the park and Fitzgerald and Hamersley within natural environment zones. The park is becoming increasingly used for recreational purposes.

Previous recommendations

The EPA made no recommendations regarding the marine areas adjacent to the Fitzgerald River National Park or the inlets within the park boundaries in its report on Conservation Reserves in Western Australia (1976, System 3).

In the CALM Management Plan (1991, No. 15) for the Fitzgerald River National Park it was recommended that the Gordon, St Mary, Fitzgerald, Dempster and Hamersley Inlets be declared marine reserves. It was also recommended that commercial fishing be permitted in Gordon and Hamersley Inlets but not in Fitzgerald, Dempster or St Mary Inlets.

Working Group recommendations

While acknowledging the lack of information about the marine flora and fauna on the shores of the Fitzgerald River National Park, the Working Group believes that reservation of the coastal waters adjacent to the park would have merit for recreation and management reasons. With limited access to the shore, significant human impact on the marine flora and fauna is unlikely. Reservation would be consistent with the principal uses of the coastline, that is sight-seeing and recreational fishing, and a logical extension of the International Biosphere Reserve status of the coast.

The importance of Doubtful Island Bay as a nursery area for Southern Right Whales is in itself a reason for reservation. Assuming that care is taken to avoid interference with the whales, the existing

commercial Australian Salmon fishery would be readily accommodated within marine park management programs.

The Working Group notes the greater public access to the coast on the north side of Point Hood and the presence there of housing but believes that there is a case for extending the proposed marine reserve to encompass the Doubtful Islands and Point Hood providing additional protection to the Sea Lion and Fur Seal colonies and adding a significant area of rocky shore to the reserve.

The small inlets of the Fitzgerald River National Park, impoverished though they are in terms of aquatic flora and fauna, nevertheless represent a type of semi-permanently closed "estuary" peculiar to the eastern part of Western Australia's South Coast. They have considerable scenic merit and contribute significantly to the scenic and recreational values of the Fitzgerald River National Park and to the integrity of the status of the area as an International Biosphere Reserve. Culham Inlet is hardly claimable as an estuary at all and it is now highly modified by human activity and has less value as a potential reserve for either conservation or recreational purposes.

For the above reasons the Working Group recommends that:

> "the area of State coastal waters between the mouth of Gordon Inlet and the mouth of Culham Inlet, that is the coast adjacent to the Fitzgerald River National Park, should be considered for reservation as a marine reserve for conservation of flora and fauna and recreation, and that it should be added to the Fitzgerald Biosphere Reserve;
>
> "consideration also be given to reservation for the same purposes of the southern part of Doubtful Island Bay encompassing the Doubtful Islands and Point Hood;
>
> "legal opinion be obtained on the status of Gordon, St Mary, Fitzgerald, Dempster and Hamersley Inlets and if they are judged to be 'tidal' and therefore excluded from the national park as declared under the Land Act, consideration should be given to reservation of them as marine reserves under the CALM Act and that their management be integrated with that of the national park."

3.9. Stokes Inlet (Map V-4)

The section of the coast here under consideration is adjacent to the Stokes National Park encompassing Margaret Cove, Dunster Castle Bay and Fanny Cove and includes Torradup and Stokes Inlets. The geomorphological and biological features of the inlets were described by Hodgkin & Clark (1989a) and are summarised here.

Tenure

The national park extends to the low water mark. Stokes Inlet is entirely surrounded by the national park but the extreme upstream part of Torradup Inlet lies beyond the park's northern boundary. As in the case of the inlets enclosed within the Fitzgerald River National Park, there is question whether Torradup and Stokes Inlets are "tidal" and therefore excluded from the national park by the terms of the Land Act.

Geomorphology and hydrology

The repeated sequence of granitic rocky headlands alternating with arcuate beaches backed by Quaternary dunes is represented along the coast of the Stokes National Park by three units. The headlands here are low and not as scenically spectacular as those in the western part of the South Coast. The largest is Shoal Cape at the western end of Fanny Cove. Similar but much smaller headlands form the western ends of Dunster Castle Bay and Margaret Cove. Fanny Cove is moderately protected from ocean swells except during easterly weather.

The southward-pointing toe of the Shoal Cape headland is exposed to heavy wave action on both its western and eastern sides. Its shores are typical of exposed granitic shores with smooth, wave-swept rock slopes.

West of Shoal Cape the shore is beach and Quaternary limestone. For a distance of over 1 km immediately west of the headland the beach is protected from the ocean swells by three parallel, near-shore limestone reefs. The reefs appear to be formed of old beach rock deposits and to represent previous positions of the shore. The two inner reefs break the surface but the top of the outer one is several metres deep. There are deep channels between the three reefs and between the inner reef and the shore. The outer channel has a maximum depth of over 25 m. The inner sides of the reefs are deeply undercut and cavernous and there are underwater scree slopes of limestone slabs. Similar offshore limestone reefs occur further west but are less continuous and provide less protection to the shore.

Torradup Inlet, formed at the mouth of the Torradup River, is the most easterly of the South Coast riverine estuaries. It is small, being about 3.5 km long and nowhere more than 200 m wide, with an area of about 0.4 km^2. Most of the inlet is shallow with marginal sand flats and depths of 2 m in the narrower parts. It always holds water, which may be almost fresh when the river flows and is probably seldom much more salty than sea water. The entrance bar breaks every year but remains open only briefly, for about a week.

Stokes Inlet is the most easterly of the South Coast lagoonal estuaries of moderate size. It is only arguably an estuary. It may be classified as of the lagoonal, semi-permanently closed type. The inlet lies in a deep valley and is fed by the Lort and Young Rivers, both of which are saline. Although the rivers arise in agricultural lands, the lagoon is entirely encompassed by the park. It has an area of about 14 km^2. It has relatively deep water and is not known to dry out. The entrance channel has a depth of up to 10 m. The entrance sand bar may be as much as 2 m high and breaks infrequently. It remained closed for the thirty year period to 1967 but since then has opened on average at about 5 year intervals. The more frequent opening in recent years appears to relate to the clearing of much of the catchment and the resulting increased flooding. Salinity in Stokes Inlet is rarely less than that of sea water. Even winter flood water is brackish and evaporation in summer may raise the salinity to hypersaline levels. There is some evidence of minor nutrient enrichment derived from the catchment.

Flora and fauna

Very little information is available on the marine flora and fauna of this shore. Inspection of aerial photographs indicates that the gently shelving seabed, especially in the coves, has dense *Posidonia* and *Amphibolis* seagrass beds but little is known of their floristic composition or associated fauna.

The Working Group was given reports from abalone divers and commercial shell collectors that the channels between the limestone reefs west of Shoal Cape are the habitat of an extremely rich and diverse invertebrate and fish fauna. This is consistent with the physical nature of the habitat.

The aquatic biota of Stokes Inlet is impoverished. The seagrass *Ruppia megacarpa,* the stonewort *Lamprothamnium* and the attached green alga *Polyphysa peniculus* are the dominant plants and all may be abundant in suitable water conditions. The suite of obligate estuarine invertebrates normally found in South Coast estuaries is present. In addition a number of marine invader invertebrates have been recorded. A species present in this inlet but not recorded in inlets further west is the inland salt lake snail *Coxiella sp.* Black bream are permanent residents in the inlet but during the years following opening of the bar a number of marine fishes establish there, including Australian herring, pilchard, yelloweye mullet, sea mullet, King George whiting, cobbler, tarwhine and many others.

The aquatic flora and fauna of Torradup Inlet is even more impoverished than that of Stokes. The only invertebrates recorded (Hodgkin & Clark, 1989a) are the bivalves *Arthritica semen* and *Sanguinolaria biradiata,* a salt lake gastropod *Coxiella* sp., and an unidentified polychaete worm.

Recreation

The Stokes National Park has high scenic qualities but it is remote and as yet it is not a popular tourist destination. Yet the coastal vegetation and scenery is of high quality and fishing in the inlet and on the coast is excellent. Increasing use of the park and the inlet for recreational purposes may be expected in future.

Fanny Cove is used mostly by local people as a camping and fishing location. Boats may be launched there. Although little used at present, the western side of Shoal Cape has considerable potential as a recreational diving site with the protection from the swells provided by the near-shore limestone reefs.

Previous recommendations
None.

Working Group recommendations
The repeated sequence of rocky headland-beach present on this section is representative of the South Coast except that the headlands are low and without high cliffs. The near-shore limestone reefs which are a common feature at the eastern ends of the bays east of Hopetoun are very well represented here. The deep channels between the reefs on the western side of Shoal Cape are a unique feature and undoubtedly provide habitat for a diverse marine flora and fauna. The coast has excellent potential for sightseeing, recreational fishing and diving which would add significantly to the recreational opportunities of the Stokes National Park.

Stokes and Torradup Inlets have high conservation values as representatives of the South Coast semi-permanently closed lagoonal and riverine estuaries. Stokes is the most easterly of the lagoonal inlets of any size. It has relatively deep water and does not dry out. Undoubtedly for that reason, it supports a more diverse aquatic flora and fauna than other estuaries of similar type further west. The inlet has high scenic value and is an important element of the scenic quality of the surrounding national park. It also has considerable value for its recreational fishing.

The Working Group recommends that:

> "State coastal waters adjacent to the Stokes National Park, encompassing Margaret Cove, Dunster Castle Bay and Fanny Cove, and including the tidal parts of Stokes Inlet and Torradup Inlet, be considered for reservation as a marine reserve for the purposes of conservation of flora and fauna and public recreation, and managed in conjunction with the national park."

3.10. Recherche Archipelago (Map V-4)

The Recherche Archipelago is one of the major features of the South Coast, stretching for a distance of more that 200 km and including many islands. The port of Esperance, located in Esperance Bay at the western end of the archipelago, is the district centre.

Tenure
Most of the islands of the archipelago are incorporated in a Class A Nature Reserve (No. 22796). Woody Island in Esperance Bay is a Class B Nature Reserve. Cape Arid National Park and Cape Le Grand National Park include the shores of most of the adjacent mainland. All the nature reserves and the national parks extend to the low water mark.

Several of the outer islands lie beyond the State three mile limit (that is three nautical miles from the baseline). They are State territory and therefore each is surrounded by its own area of State waters.

Geomorphology
The islands of the archipelago represent the high points of the Proterozoic land surface (Albany-Frazer Oregon) now flooded by the ocean. Most of the islands are exposed to high or moderate wave action from all directions and there are few safe anchorages or landings. In form and character the islands resemble the granitic headlands of the mainland coast. Their high rocky promontories have smooth, steep sides sloping into the sea in the most exposed areas. More sheltered shores have boulders and tide pools. Between some of the headlands there are arcuate beaches backed by low dunes or granite hill slopes.

The depth of the sea floor within the archipelago averages about 40 m. Most of the islands are within the 50 m bathymetric contour although the outer islands rise from depths of 70 m or more. Typically

the rocky shores are steep-to with an abrupt change in substrate where the rock slopes meet the sandy floor. There are many vertical rock walls in the sublittoral zone.

Flora and fauna

The only studies of the marine flora and fauna of the archipelago were published over 30 years ago by members of the Australian Geographical Society Expedition. There is little other information available. Inspection of aerial photographs indicates that there are extensive seagrass beds in the bays but there is no information on their floristic composition and associated flora and fauna. *Posidonia sinuosa* has been collected from individual clumps as deep as 47 m in the Archipelago.

Recreational divers and commercial abalone divers and shell collectors have informed the Working Group that the upper parts of the rock slopes, that is above about 20 m, are dominated by macrophytic algae but below that depth there are spectacular growths of attached invertebrates, most notably sponges and coelenterates. Fish communities are very diverse and even the vulnerable residential species like Blue Groper and Queen Snapper are abundant.

Many of the islands and emergent rocks in the archipelago are haul-out sites and breeding colonies of Australian Sea Lions and New Zealand Fur Seals. The breeding colonies include the largest in the State for both species. There are also important nesting areas for the Little Penguin on several of the islands.

Fisheries

The lower rock slopes of the islands are an important Zone 1 area for the greenlip and brownlip abalone which are fished commercially.

Gummy shark, and to a lesser extent whiskery shark and dusky shark (bronze whaler), are extensively fished by demersal gillnet and longline in these waters. The waters of the archipelago also support a large proportion of the fishery for the southern rock lobster. A small demersal trawl fishery for saucer scallops also operates seasonally within the area. There is a regionally important, developing, purse-seine fishery for pilchard.

Recreation

Because of the remoteness of these islands, the paucity of safe anchorages and the difficulty of landing ashore, they are not well suited for recreational use. With one exception they are reserved exclusively for nature conservation and, although landing is not prohibited, camping on the islands is approved only for special purposes. The exception is Woody Island where shore accommodation is available. Nevertheless, the waters around the islands provide excellent opportunities for fishing and quite spectacular sites for diving and the archipelago is becoming increasingly used for those purposes, including commercial dive tours.

Previous recommendations

None.

Working Group recommendations

While acknowledging the paucity of information about the marine flora and fauna of the Recherche Archipelago, the Working Group believes that reservation of these waters can be justified on the grounds that habitats are diverse and that added protection would be provided for the Sea Lion, Fur Seal and seabird colonies. Protection of areas for the purposes of recreational diving and development of the commercial dive tour industry can also be justified.

However, with the limited information available, the Working Group was unable to identify parts of the Archipelago which are particularly worthy of reservation. It was concluded that selection of specific areas would be unwise and that reservation of the entire area as a multiple-use marine reserve is warranted. Subsequent surveys in the course of preparation of a management plan would identify areas of particular importance for conservation, recreation and commercial fishing and appropriate zoning would resolve potential conflicts between these activities.

Accordingly the Working Group recommends that:

> "the waters of the Recherche Archipelago between Butty Head in the west and Israelite Bay in the east, extending to the limit of the State Territorial Sea, including the areas of State waters surrounding the outer islands but excluding the Port of Esperance, should be considered for reservation as a marine reserve for multiple purposes including conservation of flora and fauna and public recreation."

3.11. Twilight Cove (Map V-5)

The section of the coast considered here takes in the western shores of the Great Australian Bight, extending approximately 50 km east and west of Twilight Cove.

Tenure
The adjacent coast is a Class A Nature Reserve (No. 27632) which extends to the low tide mark.

Geomorphology
Geologically the area lies within the Eucla Basin and straddles the two major coastal types characteristic of the shores of that sedimentary basin. In the east the shore is beach backed by high, often mobile Pleistocene dunes, including the Eyre Sandpatch. In the west the shore is formed by the Baxter Cliffs, high limestone cliffs with narrow, limestone rock platforms, boulder fields or narrow beaches at their base. They are similar to the Nullarbor Cliffs on the South Australian side of the border. The sea floor along this stretch of coast is gently shelving and relatively featureless.

Flora and fauna
There is very little information about the marine flora and fauna of this area. Inspection of aerial photographs indicates that there are extensive seagrass beds off the beach, protected by coastal limestone reefs. The seagrass meadows consist mainly of *Amphibolis* but their associated fauna has not been determined. Nothing is known of the rocky shore biota along the base of the Baxter Cliffs.

The Little Penguin has been reported nesting at sites along the coast in the vicinity of Twilight Cove, the only mainland breeding area known for this species in Western Australia. There have also been reports of a breeding colony of the Australian Sea Lion on rocks at the base of the Baxter Cliffs (pers. comm. B. Haberley). The colony is small but it too is the only record of the species breeding on the mainland.

Fisheries
No significant use is made by commercial fishers of this area. The shallow coastal limestone reefs and seagrass beds between Twilight Cove and Eucla are currently being considered as a protected nursery area for the commercially important gummy shark.

Recreation
This is a very remote part of the coast with limited access. It is used only rarely by sight-seers and recreational fishers.

Previous recommendations
None. However, it should be noted that the South Australian Government has proposed the establishment of a marine reserve at the Head of the Bight extending as far west as the Western Australian border.

Working Group recommendations
This section of the coast is selected for consideration by the Working Group because it represents the two coastal types characteristic of the shores of the Eucla Basin and not because it has any known special conservation or recreation values. The Working Group recommends that:

"a survey of the coast between about 50 km east and west of Twilight Cove should be conducted to assess the value of the area as a marine reserve for the protection of marine flora and fauna and coastal landforms."

A REPRESENTATIVE MARINE RESERVE SYSTEM FOR WESTERN AUSTRALIA

Report of the Marine Parks and Reserves Selection Working Group

Summary of Recommendations

PART I: INTRODUCTION

The introductory section contains no Working Group recommendations.

PART II: MARINE RESERVES IN THE KIMBERLEY AND THE SAHUL SHELF

RECOMMENDATIONS FOR MARINE RESERVES ON THE KIMBERLEY COAST

Cambridge Gulf (Map II-1)

Working Group recommendations

Noting the high biological diversity of the Cambridge Gulf estuary, especially in the eastern mangals and nearby areas, the unique character of the estuary in terms of its geomorphic and biological community structure, and the importance of the system as a contributor to the biological productivity of Bonaparte Gulf, the Working Group believes that there is a good case for reserving this area for nature conservation.

After some consideration the Working Group decided not to recommend extending the reservation to the NT border because, although the fringing mangals and supra-tidal flats of that shore are a significantly different coastal type to those of Cambridge Gulf, they are not likely to support a diverse flora and fauna and not likely to need management for public recreation purposes.

The Working Group recommends that:

> "the eastern side of Cambridge Gulf, east of a line between White Stone Point on Lacrosse Island and Nicholls Point on Adolphus Island, and encompassing the False Mouths of the Ord, together with the waters of the tidal portion of the East Arm of the Ord, be considered for reservation for the conservation of marine flora and fauna and protection of mangal habitat. At the mouth of the Gulf the reserve should extend seaward to the limit of State territorial waters and eastwards from Cape Domett for a distance of approximately 15 km."

Londonderry (Map II-2)

Working Group recommendations

It is acknowledged that the following recommendations are based almost solely on photo-interpretation and accounts of the scenic quality of the coast. Field studies will be needed to confirm the high values of the seagrass, reef and mangal habitats before these recommendations proceed and boundaries are decided.

The Working Group endorses the earlier recommendations, though noting that there is no category for marine national park in the current legislation. Given the high recreational and tourism potential of the area the most appropriate reserve category would be marine park.

The eastern and western extent of the proposed marine reserve is problematical. In the west, because of the configuration of the Drysdale Estuary, it is not possible to limit the marine reserve to the waters contiguous with the proposed national park. It will be necessary to extend the reserve westwards along the southern shores of the estuary which are Aboriginal reserve land. The western

boundary of the marine reserve could be located along a line running northward from Red Bluff and through West Governor Island so including the north eastern part of Napier Broome Bay.

Limiting the marine park to the waters contiguous with the national park in the east would exclude Lesueur Island, the estuary of the King George River and the spectacular King George Falls. As the falls are an important feature in potential recreational use of the park and Lesueur Island and its surrounding reefs have high conservation values, the Working Group believes that consideration should be given to including these areas within the marine reserve.

The eastern and western sides of the proposed marine reserve abut Aboriginal Reserve land and it will be necessary for the boundaries to be discussed with the relevant Aboriginal communities.

The Working Group recommends that:

> "Western Australian coastal waters west and north of the Cape Londonderry Peninsula, including the estuaries of the Drysdale and King George Rivers and extending eastwards as far as Cape Rulhieres, should be reserved for the purposes of public recreation and the conservation of flora and fauna."

Vansittart Bay - Admiralty Gulf (Map II-3)

Working Group Recommendations

Although information on the flora and fauna of this remote part of the Kimberley coast is sparse, the Working Group believes that four marine areas within the area warrant consideration as candidates for reservation and recommends as follows:

> "1. Vansittart Bay
> Noting the accounts of the high recreational potential, marine habitat variety and abundant marine fauna, that there be a biological survey of waters of Vansittart Bay with a view to selecting an area or areas for reservation for conservation of marine flora and fauna and public recreation. The area surveyed should include the waters south of the Eclipse Islands and Mary Island.
>
> "2. Port Warrender
> The Working Group endorses the earlier recommendation of Burbidge et. al. (1991) that a marine reserve be declared in the waters adjoining the proposed national park at the mouth of the Lawley River. However, as there is no category for marine national park, the reserve should be marine park or marine nature reserve. In view of the high nature conservation value of the area and the limited potential for public recreation, the appropriate category would be marine nature reserve.
>
> "The area considered for reservation should be south of a line eastward from Walsh Point upstream in the tidal rivers of the Lawley Estuary as far as the limit of tidal waters, thus including both the Walsh Point and Lawley mangals.
>
> "3. Mitchell River
> Consideration should be given to reservation of the Mitchell River Estuary for the purpose of conservation of marine flora and fauna. The area considered should include the waters of Walmesly Bay south of Pickering Point and extend upstream to the limit of tidal waters.
>
> "4. Long Reef
> The Working Group recommends that there be geological and biological surveys of Long Reef and that reservation be considered at a later date."

Prince Frederick Harbour - Saint George Basin (Map II-4)

Working Group recommendations

The Working Group has not considered the marine habitats surrounding the many nearshore and offshore islands of this sector because there is such little information about them. Further study may show that the waters around the outer islands, eg. Montalivet and Maret Islands, may warrant reservation. However, the Working Group believes that there are sufficient grounds for reservation of the two marine gulfs in the sector and recommends as follows:

"The recommendations of the EPA and Burbidge et al. (1991) that the waters of Prince Frederick Harbour and Saint George Basin should be reserved should be implemented, except that there is no category of marine national park. The appropriate designation to meet the intent of those recommendations would be marine park.

"The Working Group suggests that the seaward boundaries of the two marine reserves should be varied from those of the earlier recommendations. In the case of Prince Frederick Harbour the boundary should be across York Sound between Cape Torrens and Augereau Island. In the case of Saint George Basin the boundary should be across Brunswick Bay between High Bluff and Cape Wellington, incorporating the waters of Hanover Bay. These boundaries include portions of the more open ocean marine habitats and can be precisely located for management purposes."

Montgomery Islands (Map II-5)

Working Group recommendations

With very little information available the Working Group is not in a position to do more than endorse the earlier recommendations of Burbidge et al., primarily on the grounds that a known habitat of the dugong is worthy of protection. However, the extensive intertidal and subtidal rock and sand flats constitute an unusual feature on the Kimberley coast and it is probable that they support a diverse flora and fauna. The hunting of dugong in the area by Aborigines is not necessarily incompatible with marine reserve status, provided that the dugong population is monitored and the numbers of animals taken are at sustainable levels.

Accordingly the Working Group recommends that:

"The waters surrounding the Montgomery and High Cliffy Islands should be considered for reservation for the conservation of flora and fauna, with provisions made for a sustainable level of dugong hunting by Aborigines.

"The Working Group suggests that the outer boundary of the marine reserve should be located at a suitable bathymetric contour around the banks and reefs."

Walcott Inlet and Secure Bay (Map II-5)

Working Group recommendations

The Working Group endorses the recommendation of Burbidge et al. (1991) for the reservation of the waters of Walcott Inlet. As there is no category of marine national park the appropriate category of reserve in keeping with the recreational use of the surrounding national park would be marine park.

The Working Group noted the extensive and unusual mangal system and scenic values of Secure Bay and believes that it should be added to the proposed marine park. Marine park status would not necessarily be incompatible with future use of this feature for the generation of tidal power.

The Working Group was also impressed by George Water and Doubtful Bay as likely crocodile and bird habitat and by the extensive mangal there, although there is little information about those areas. Further studies should be undertaken to identify the most important areas of these inlets for nature conservation purposes and reservation of them should be considered at a later date. Preference given here to Walcott Inlet and Secure Bay as a marine park representing the enclosed inlet environment of this section of the coast is based on the fact that Walcott is surrounded by proposed national park.

Accordingly the Working Group recommends that:

"1. The tidal parts of Walcott Inlet and Secure Bay should be considered for reservation for the purposes of public recreation and the conservation of flora and fauna, with the seaward boundaries being across the entrances at Yule Entrance and The Funnel respectively.

"2. There be a survey of the habitats, flora and fauna of George Water and Doubtful Bay and assessment made of the natural values of these areas and consideration given to reservation of them or parts of them, for the conservation of flora and fauna."

Buccaneer Archipelago (Map II-6)

Working Group recommendations

The Working Group endorses the proposals that the waters of the Buccaneer Archipelago be declared marine park and zoned for multiple use according to a management plan developed in collaboration with the Aboriginal community.

After considering the proposed boundaries, the Working Group believes that the values of the marine park would be greatly enhanced by extending the boundaries to include Cygnet Bay in the west and Talbot Bay in the east. The Working Group's preferred boundaries are indicated in Map II-6.

The presence of pearl culture leases and operations within the area of the proposed marine park is noted. Providing that this industry is managed with due care for the many sensitive natural values of the marine environment, the Working Group considers that this activity would be compatible with multiple-use marine park status.

The Working Group recommends that:

"The waters of the Buccaneer Archipelago, including Cygnet Bay in the South West and Talbot Bay in the east, should be considered for reservation as a multiple-use marine park."

Oceanic Coral Banks and Islands (Map II-7)

Working Group recommendations

The Working Group endorses the earlier recommendations for declaration of marine reserves around both Adele and Browse Islands. It is noted that, in the case of Adele, the surrounding reef extends beyond the limit of State jurisdiction. As it is an integral part of the coral platform reef and ecosystem it is important that the whole reef be reserved. The Working Group suggests that the State authorities liaise with the Commonwealth with a view to securing reservation under Commonwealth legislation of those parts of the reef under Commonwealth jurisdiction and subsequent joint management of the whole marine reserve.

The Working Group also believes that consideration should be given to the reservation of Scott Reef. Although part of the reef is under State jurisdiction and part under Commonwealth jurisdiction, the Working Group believes that the reef complex should be managed as one unit, with appropriate collaboration between the State and Commonwealth management agencies.

The Working Group recommends that:

"1. Consideration should be given to reservation of the State waters surrounding Browse and Adele Islands and Scott Reef.

"2. The relevant Commonwealth authorities should be approached with a suggestion that those areas of Scott Reef and the reef around Adele Island which are under its jurisdiction, should be reserved under Commonwealth legislation so that the State and Commonwealth areas can be managed as ecologically integral units."

PART III: MARINE RESERVES ON THE CANNING AND PILBARA COASTS AND THE ROWLEY SHELF

RECOMMENDATIONS FOR MARINE RESERVES ON THE PILBARA AND CANNING COASTS AND THE ROWLEY SHELF

West Coast of Dampierland (Map III-1)

Working Group Recommendations

1. Pender Bay - Cape Borda:

"(i) that a survey be carried out of the supratidal, intertidal and shallow sublittoral marine habitats and flora and fauna of the Cape Borda-Pender Bay system and the Sandy Point-Beagle Bay system;

"(ii) that, as an outcome of the survey, an area of the coast be selected for declaration as a marine reserve for public recreation and protection of flora and fauna, to represent the V-shaped bay systems characteristic of the Canning coast."

2. Lacepede Islands:

"that there be a survey of the intertidal and shallow sublittoral marine habitats and reef platforms surrounding the Lacepede Islands, and an assessment made of their suitability as a marine reserve for the conservation of flora and fauna."

Roebuck Bay - Lagrange Bay (Map III-2)

Working Group Recommendations

As a designated RAMSAR wetland, Roebuck Bay is an obvious candidate for reservation. As well as its status as bird habitat it includes a large mangal of very unusual structure and exceptionally well-developed mudflats. The Working Group endorses the earlier recommendation of Burbidge *et al.* (1991) that a marine park be declared in Roebuck Bay but believes that further work is needed to define the most appropriate boundaries. From an ecological and management point of view, limiting the park to the intertidal flats is not appropriate. It would be preferable to reserve the whole waters of the bay and such parts of the adjacent hinterland which directly contribute to its ecosystem functions, ie. the tidal creeks and supra-tidal flats.

Also, the Working Group considers that boundaries should be set north and south of those recommended in the 1991 report. The rocky shore of Gantheaume Point has particular conservation values in terms of its invertebrate marine fauna and the presence of dinosaur footprints. Inclusion of that area within the marine reserve would help resolve the management problems that prevail there and increase the habitat diversity of the reserve. The southern boundary recommended by Burbidge *et al.* at Sandy Point would be undesirable as the Roebuck Bay coastal geomorphic continues southwards to Cape Villaret.

For these reasons the Working Group suggests that the Marine Park should include a larger area than that recommended by Burbidge *et al.* (1991), while noting that the Port of Broome would need to be excluded.

The proposed Roebuck Bay Marine Park should be managed specifically for the protection of habitat for migratory birds and the ecosystems upon which they depend. Nevertheless, the Working Group believes that the current level of commercial, recreational and subsistence fishing in Roebuck Bay is compatible with that management objective.

The Working Group was also impressed by the features of Lagrange Bay which is perhaps the best example on the coast of the dune-ridge bay coastal type. It has an exceptionally wide range of habitats and biotic assemblages and an extremely rich marine fauna including many of the North West Shelf endemic species.

Accordingly the Working Group recommends as follows:

1. Roebuck Bay Marine Park:

"(a) That the waters of Roebuck Bay be reserved as Marine Park for public recreation and protection of flora and fauna.

"The marine park should exclude an area (whose precise limits will need to be defined) encompassing Broome Harbour.

"The Working Group suggests that the boundaries could be from the north side of Gantheaume Point to Cape Villaret and from High Water Mark to the limit of the Territorial Sea but further study and discussion will be needed on this aspect.

"(b) That foreshore areas not already reserved behind High Water Level adjacent to the central and southern parts of the park, should be added to the marine park by reservation under the Land Act. This action is pivotal for successful integrated management. The shoreward boundaries of this proposed reserve have not been fully determined but they should encompass those coastal areas of pastoral leases which are an integral part of the drainage and geomorphological systems of the coast."

2. Lagrange Bay

"That there be further study of the flora, fauna and habitats of the coastal waters, tidal creeks and supra-tidal flats between Cape Latouche Treville and Cape Bossut including Lagrange Bay, and an assessment made of the present commercial and recreational uses of these areas, with a view to the selection of the most suitable sections for reservation for the purposes of public recreation and protection of flora and fauna."

Eighty Mile Beach (Map III-3)

Working Group recommendations

"1. While noting that the whole of Eighty Mile Beach receives environmental recognition as a RAMSAR Wetland of International Importance, the Working Group recommends that a section be reserved for the protection of marine flora and fauna and the habitat of migratory shorebirds. The area reserved should include the tidal flats and the 40 metre strip of land above high tide level, ie. it should extend at least from low tide level to the boundary of the adjacent pastoral leases.

"2. The Working Group recommends that consideration should also be given to the reservation of an area of coastal waters seaward of low tide level, preferably to the limit of State waters, as a buffer to the beach reserve.

"3. Noting that the RAOU study of Eighty Mile Beach is not yet complete, the Working Group recommends that a decision on which section should be reserved should be deferred until it is possible to accurately identify the areas of most importance to migratory shorebirds, although preliminary indications are that it should be a section in the vicinity of Anna Plains."

Keraudren (Map III-4)

Working Group Recommendations

"1. That there be a survey of the marine habitats and flora and fauna of the mainland coast between Cape Keraudren and Spit Point, with special attention given to the mangals and sand/mud flats, and that an assessment be made of their regional significance with a view to selecting the most diverse and representative area for consideration as a marine reserve.

"2. The Working Group endorses the EPA recommendations for the declaration of North Turtle Island as a Class A reserve for the conservation of flora and fauna and recommends that the waters surrounding the island, from the Low Tide Mark to the limit of State waters, be also reserved for protection of seabirds, turtles and their habitats, and marine flora and fauna generally.

"3. The Working Group endorses the EPA recommendations for the declaration of Bedout Island as a Class A reserve for the conservation of flora and fauna and recommends that the waters surrounding the island, from Low Tide Mark to the limit of State waters, be also reserved for the protection of seabirds and marine flora and fauna generally."

Depuch (Map III-5)

Cowrie Beach

Working Group Recommendations

In view of the lack of information about the marine flora and fauna of the mangals and nearshore waters of the coast in the Depuch sector, the Working Group has not been able to recommend any particular areas for reservation which would represent coastal type 3 and these habitat types within the region. Further photo-interpretation work and field surveys are needed before this is possible.

Cowrie Beach is a special case. The Working Group considers that reservation of the beach and hinterland is urgently needed to support protection of the very important Flatback Turtle rookery. Not much would be gained by including the waters in front of the beach within the reserve. However, there is good reason for including the tidal waters of Cowrie Creek which is a small but significant, self-contained mangal unit.

Declaration of the coastal lands as a CALM Act marine nature reserve or Land Act nature reserve would have the disadvantage that recreational fishing and camping could not be permitted. There would be procedural advantages, however, in declaring the intertidal zone and the 40 m strip as marine park under the CALM Act or the Land Act, vested in the NPNCA, thus allowing recreational fishing to continue, subject to careful management to avoid interference with the turtle breeding activities.

Accordingly the Working Group recommends that:

"1. That a survey should be carried out of the mangal and nearshore marine habitats of the coast between Cape Thouin and Cape Lambert so that one or more parts of it may selected for reservation to represent coastal type 3 and protect nearshore marine and mangal habitats and their flora and fauna.

"2. That the stretch of shore of Cowrie Beach and West Cowrie Beach, extending from the boundary of the adjacent pastoral lease to the Low Tide Mark, but including the tidal waters of Cowrie Creek, be reserved and vested in the NPNCA, for the purpose of public recreation and protection of flora and fauna.

"3. That the breeding success of the Flatback Turtles at this site be monitored and any necessary steps be taken to ensure that predation of the adults and young and other forms of disturbance are kept to a minimum."

Dampier Archipelago (Map III-6)

Working Group recommendations

The Working Group had no difficulty in agreeing that the waters of the Dampier Archipelago warrant reservation but the determination of boundaries for such a reserve was problematical. There is potential for pollution of the waters in the vicinity of the industrial and harbour facilities of Dampier and the western side of the Burrup Peninsula and in the shipping lane which bisects the Archipelago through Mermaid Sound, and potential for conflict between management objectives of the port-industrial developments and conservation.

For these reasons the Working Group concluded that a Dampier Archipelago marine reserve should exclude the inner portion of Mermaid Sound and the functional area of the Port of Dampier. The park would then comprise two primary sectors, connected on the northern side. The western part would encompass Rosemary, Malus, Enderby, Eaglehawk, West Lewis and the western and northern shores of East Lewis Islands. The eastern part would include the northern tip of the Burrup Peninsula, Conzinc, Dolphin, Angel and Gidley Islands, the island complex and waters north of Gidley I., Hamersley Shoal, and Legendre, Hauy and Delambre Islands. The Working Group considers that the waters of Nickol Bay are not an integral part of the Archipelago ecosystem and does not propose that they should be included in the reserve, except for the area across the top between Dolphin, Hauy and Delambre Islands.

The Working Group considers that the area proposed to be included in the reserve, while avoiding the principal shipping lanes and industrial areas, adequately represents the coral reef, mangal and sand and mudflat habitats of particular importance in the Archipelago, and that it provides good buffers for the turtle and seabird nesting sites on the islands. It also contains the most important recreational areas worthy of management and long term preservation.
The suggested boundaries are straight lines between easily identifiable points in the seascape wherever possible. In the case of the eastern sector, a suitable western boundary for management purposes could be the eastern limit of the prohibited anchorage area, between Conzinc Island and the western tip of Hamersley Shoal, where the gas pipeline is laid. This would include the important coral communities on the rock slopes of Conzinc and other small islands.

Accordingly the Working Group recommends that:

"...the waters of the Dampier Archipelago, excluding the Port of Dampier, be reserved for the purposes of public recreation and protection of flora and fauna, and that the seaward boundary should be the limit of the State Territorial Sea."

Cape Preston (Map III-7)

Working Group recommendations

The mangals, muddy intertidal flats and extensive shallows east and west of Cape Preston are species-rich and undoubtedly contribute significantly to the energy budget of the coastal waters in the region. The varied marine habitats are diverse and represent the mainland coast of the central Pilbara, especially coastal type 10, so that the area is an excellent candidate for setting aside as a marine conservation reserve.

The area considered here is close to the eastern part of Regnard Bay which is suggested for inclusion within the proposed Dampier Archipelago marine park (section 3.6 - see Map III-6). A case can be made for a single marine reserve extending from the Archipelago to Cape Preston and encompassing

all the waters of Regnard Bay, combining within the one reserve major examples of coastal types 9 and 10. For this reason the recommendations of this section should be considered together with those for section 3.6.

After some consideration the Working Group decided not to propose inclusion of the Fortescue inactive delta in the proposed marine reserve. This coastal type is repeated further south in the Robe River delta (section 3.8). However, if the boundaries of the marine park proposed within that sector do not include the Robe delta, inclusion of the Fortescue delta within the proposed marine reserve at Cape Preston should be reconsidered.

Accordingly the Working Group recommends:

"1. That the section of coastal waters between Gnoorea Point and James Point, encompassing South West Regnard Island, Preston Island, Preston Spit and Carey Island, be considered for reservation for the purposes of protection of mangal habitat, prawn and fish nursery areas, turtle nesting and feeding areas, and marine flora and fauna generally.

"Alternatively, consideration could be given to extension of the proposed Dampier Archipelago Marine Park (section 3.6) westwards to encompass all the waters of Regnard Bay and North Regnard, South West Regnard, Preston and Carey Islands.

"Extension westwards to include the inactive delta of the Fortescue River should be considered if the inactive delta of the Robe River is not included in the reserve of the Robe-Cane sector.

"2. That the 40m strip of vacant Crown Land between High Water Mark and the boundary of the adjacent pastoral leases be added to the Marine Park by reservation under the Land Act."

Robe (Map III-8)

Working Group recommendations

Although available information and inspection of aerial photographs clearly indicate that this sector contains many significant geomorphological and biological features, the Working Group was not able to recommend any particular section of it for reservation because of the lack of adequate information. Field survey work is needed to establish which areas most adequately represent the variety of geomorphology, habitats, flora and fauna that are present.

However, the Working Group noted that the nearshore islands of the northern part of the sector, that is between Sholl and Yammadery Islands, have recently been collectively designated as the xxx Nature Reserve (see Map III-8). Should the results of field surveys indicate that the northern part of this sector contains geomorphology, habitats, flora and fauna suitably representative of the sector, there would be merit in selecting the waters surrounding those islands for designation as a marine reserve.

Therefore the Working Group recommends:

"1. That there should be a survey of the marine habitats, flora and fauna of the Robe mangal and adjacent nearshore waters to identify areas of particular conservation value in terms of mangal habitat, prawn and fish nursery areas, dugong and turtle feeding areas, and marine flora and fauna generally.

"2. That, unless the results of the survey indicate that the most desirable areas for marine conservation are elsewhere within the sector, consideration should be given to the declaration of the waters surrounding the islands designated as the Great Sandy Island Nature Reserve and encompassing the Robe mangal south to the Cane River, including the inactive delta of the Robe River.

"3. That the strip of land between the High Water Mark of the area selected for designation as marine reserve and the boundary of the adjacent pastoral lease, should be added to the reserve."

Exmouth Gulf (Map III-9)

Working Group recommendations

The distinctive eastern mangal and adjacent coastal waters of the gulf already receive a measure of protection under the Fisheries Act. Marine reserve status would enhance that protection. Reservation of the supra-tidal flats between the mangal and the hinterland would be essential to ensure adequate management of the mangal and coastal habitats of the marine reserve. Although they represent a different mangal type, the mangals of Gales Bay and the Bay of Rest should be included in the reserve. By extending the reserve north along the south-western shore to a point in the vicinity of Learmonth a section of the very different habitats of the western shore would be included. Reservation of a small section of the coastline near Exmouth would then adequately represent the western shore habitats.

Accordingly the Working Group recommends:

"1. That the nearshore waters on the eastern and south-western sides of Exmouth Gulf be considered for reservation for the protection of mangal habitat, prawn and fish nursery areas, turtle and dugong feeding areas, and coastal marine fauna and flora generally, and for recreational fishing and such commercial fishing and mariculture as may be consistent with the former purposes.

"2. Boundaries:
(a) that the north-eastern limit of the proposed marine reserve should be located at Locker Point and the south-western limit in the vicinity of Learmonth;

"(b) that the marine area reserved should extend from the High Water Mark seaward to about the 10 m bathymetric contour, or some suitable straight lines approximating that contour;
"(c) that the 40 m strip of vacant Crown Land between the adjacent pastoral leases and High Water Mark should be added to the marine reserve by reservation under the Land Act, together with such portions of the adjacent pastoral leases as will produce simple, clearly definable boundaries.

"3. That the EPA 1975 recommendations for declaration of islands in the area as nature reserves should be implemented as soon as possible. The Working Group is of the view that all the island nature reserves should be designated as Class A."

West Pilbara Offshore Islands (Maps III-8, 9)

Working Group recommendations

The waters around the islands and reefs of the Serrurier group are representative of the offshore marine habitats of the western Rowley Shelf. They also have potential as a resource for recreation and tourism.

Due to increasing use of the marine resources of the waters around the Muiron Islands there is a need for increasing management, that is, facilitating access while protecting the environment and its living resources. Reservation of the area as marine park is one means of providing a basis for management.

Accordingly the Working Group recommends:

"1. Serrurier Island Group
"a) That an area of waters encompassing Flat, Serrurier, Bessieres, Round and Table Islands and Hood Reef, Black Ledge and Bowers Ledge be considered for reservation for the purposes of public recreation and protection of marine flora and fauna.

"b) That an integrated Management Plan be developed for both the island Nature Reserve and the surrounding marine reserve, with provisions for recreational fishing and for camping ashore during those seasons when seabirds and turtles are not nesting.

"2. Muiron Islands
That an area of the waters encompassing the Muiron and Sunday Island group be considered for reservation for the purposes of public recreation and protection of marine flora and fauna, subject to:

"a) a survey of the marine flora and fauna and habitats surrounding the Muiron Islands and comparison with those of the Ningaloo marine Park.
"b) a study on the impact of current and anticipated future recreational fishing on fish stocks around the islands and a report produced on options for management, including the option of reserving the area as marine park."

Barrow-Monte Bello Complex (Map III-8)

Working Group recommendations

While noting that the Barrow-Monte Bello-Lowendall island complex comprises a distinct coastal type with very significant conservation values, the Working Group considers that appropriate protection and management can be achieved by reservation of parts of the area, combined with designation of the remainder as an environmentally sensitive area needing special management.

Accordingly the Working Group recommends:

"1. Monte Bello Marine Park
"a. that the waters encompassing the Monte Bello Islands, southwards to the channel separating the group from the Barrow-Lowendal groups, be declared a Class A marine reserve for public recreation and protection of flora and fauna, ideally with boundaries located at the limit of State territorial waters along the western and northern sides and following the edge of the sublittoral ridge on the eastern side;

"b. that the present pearl oyster lease within the marine reserve continue but that the issue of any further leases, or approval for the expansion of the existing lease, be subject to careful review taking account of possible environmental impacts.

"2. Barrow Island
"a. Biggada Reef - that a stretch of the western coast of Barrow Island between Cape Malouet and Cape Poivre, encompassing Turtle Bay, the Biggada coral reef, and a section of rocky shore, be considered for reservation for protection of marine flora and fauna. The precise seaward, northern and southern boundaries should be determined in consultation with WAPET after further study of the coastal flora and fauna and marine habitats of the area;

"b. Bandicoot Bay - that an area east of South End, Middle Island and Boodie Island to a line southward from Stokes Point and encompassing Bandicoot Bay, be considered for reservation for protection of marine flora and fauna. The precise boundaries should be determined in consultation with WAPET after further study of the flora and fauna and marine habitats of the area."

PART IV: MARINE RESERVES ON THE WEST COAST

RECOMMENDATIONS FOR MARINE RESERVES ON THE WEST COAST

Ningaloo Reef - Southern Extension (Map IV-1)

Working Group recommendation:

"Consideration should be given to a southern extension of the State portion of the Ningaloo Marine Park encompassing the State Territorial Sea as far as Gnarraloo Bay so as to include the full length of the Ningaloo Reef.

"The Commonwealth Government authorities should be consulted so that consideration may also be given to the seaward extension of the park beyond the limits of the State Territorial Sea adjacent to this proposed southern addition, as is the case with the existing park."

Red Bluff to Point Quobba (Map IV-2)

Working Group recommendations

"The area at Point Quobba presently gazetted as closed waters under the Fisheries Act should be reserved for the protection of marine flora and fauna, specifically for the small coral reef community in the lagoon.

"The rocky shores between Point Quobba and Red Bluff should be considered for reservation as a marine reserve, subject to a survey of the habitats, flora and fauna of the shore. The survey should be done in conjunction with the recommended survey of the similar habitats along the high energy shores on the western sides of Bernier, Dorre and Dirk Hartog Islands."

Shark Bay Marine Park - Bernier, Dorre and Dirk Hartog Islands Extensions (Map IV-2)

Working Group recommendations

"1. The Working Group endorses Shark Bay Region Plan recommendation 5.5.3 (2) (p. 79) that the waters east of Bernier and Dorre Islands should be added to the Shark Bay Marine Park.

"The Working Group notes that the 6 m isobath recommended as the seaward (eastern) boundary in the Shark Bay Region Plan may be difficult to implement and suggests that a series of straight lines approximating that isobath and incorporating the seagrass banks would be more practical.

"The Shark Bay Region Plan did not propose northern and southern boundaries for this addition to the marine park. As an interim measure, pending further consideration of also adding the "high energy" shores

along the western sides of the islands (see rec. 2), the Working Group suggests that the northern boundary should be located at the northern tip of Bernier Island and the southern boundary at the southern tip of Dorre Island.

"2. The Working Group endorses Shark Bay Region Plan recommendation 5.5.3 (4) that the high energy marine environments west of Bernier, Dorre and Dirk Hartog Islands should be surveyed and an assessment made of their value as an addition to the Shark Bay Marine Park. The survey should be done in conjunction with one of the exposed rocky shores of the section of mainland between Red Bluff and Point Quobba.

"In the event that the results of the survey of the western high energy environments indicate that the western shores of the islands should be added to the Shark Bay Marine Park, the Working Group suggests that there would be practical advantage in extending these additional areas around the northern and southern ends of Bernier and Dorre Islands respectively."

Kalbarri (Map IV-3)

Working Group recommendation

Although there is so little information about the flora and fauna of this sector, the geographic location at the centre of the West Coast, the distinctiveness of the coastal geomorphology and rocky shore habitats, and the fact that the Murchison Estuary is the most northerly of the temperate estuaries in Western Australia led the Working Group to recommend as follows.

"Consideration should be given to reservation of the marine areas adjacent to the Kalbarri National Park and the Kalbarri township, seawards for a distance of 1 nautical mile, and encompassing the tidal waters in the mouth of the Murchison River, for the purposes of public recreation and the protection of flora and fauna."

Port Gregory to Port Denison (Maps IV-3,5)

Seven Mile Beach (Map IV-5)

Working Group recommendations

"1. Consideration should be given to the reservation of the reef and lagoon at Port Gregory for protection of marine flora and fauna, particularly the coral reef. Further study is needed to determine appropriate northern and southern boundaries.

"2. Consideration should be given to the reservation of the reefs and lagoons at Seven Mile Beach for protection of marine flora and fauna and scientific study. The reserved area should cover at least the area closed to rock lobster fishing under the powers of the Fisheries Act."

Houtman Abrolhos (Map IV-4)

Working Group recommendations

The Working Group had difficulty in reaching a satisfactory degree of consensus in respect of its recommendations for the Abrolhos. The view that these islands, reefs and waters have the highest possible scientific and conservation value and that they should be managed as an ecological entity was unanimous. There was also unanimity that the three enclaves proposed in the Abrolhos Islands Planning Strategy to be managed primarily for conservation and recreation purposes do not adequately represent the habitats of the Abrolhos, or fairly provide for recreational users. A strong view was expressed that the whole area of State Territorial Waters at the Abrolhos should be reserved as marine park, noting that present legislation would not preclude commercial fishing within the park. However, after long debate the following recommendations were agreed.

"In keeping with the high scientific, historic, recreational and conservation values of the Abrolhos islands and reef complexes, and the high value of the rock lobster fishery and other fisheries, the entire area to the limit of State Territorial Waters should be reserved and managed as a multiple-use area. This should be done as a high priority.

"Management of fisheries, tourism, education and scientific research should be integrated with measures to protect the area's natural and cultural values so that an appropriate balance between these activities is maintained.

"Ideally, given the inter-connectedness of the island, reef and open water ecosystems, the entire Abrolhos area should be managed as a single ecosystem unit.

"The Working Group proposes that areas selected specifically for protection of marine flora and fauna and public recreation could be made more representative of the Abrolhos marine habitats and flora and fauna, and with better provision for public recreation, by the following amendments to the Planning Strategy recommendations:

i) addition of an area encompassing the seaward rock platform and seagrass meadows on the west and north of West Wallabi and East Wallabi Islands;
ii) extension of the proposed marine park around Beacon Island to include the whole of Morning Reef;
iii) extension of the proposed Pelsaert Group marine park to include a section of the seaward reef-front habitat of Half Moon Reef and the lagoon west of Pelsaert Island."

Beagle Islands (Map IV-5)

Working Group recommendations

Although limited information is available on the marine habitats and flora and fauna of this part of the central West Coast, the Working Group concluded that it has many of the characteristics of the region and some particularly important features, most notably the very extensive seagrass meadows and the Beagle Islands Sea Lion breeding colony. The scour channels across the seagrasses in the northern part of the sector are worthy of further investigation.

In order to provide adequate protection to the Sea Lion colony, the Working Group considers that the waters surrounding the Beagle Islands should be made a buffer zone by reservation for the protection of marine flora and fauna. Given the importance of the seagrass meadows along the adjacent coast, the Working Group also believes that consideration should be given to the declaration of a multiple-use reserve along that coast and suggests that this should extend about 30 kilometres from Knobby Head to a point just north of Leeman. When taken together with the proposed marine reserve in the Jurien sector this would reserve about 16% of the Port Denison to Whitfords coastal type and adequately represent the marine habitats and biota of the West Coast.

Accordingly the Working Group recommends as follows:

"Consideration should be given to the reservation of State Territorial waters surrounding the Beagle Islands and along the adjacent mainland between Knobby Head (29° 39') and a point just north of Leeman (29° 55'), for the purpose of protection of marine flora and fauna, with accommodation made for the continuance of the rock lobster fishery."

Jurien (Map IV-6)

Working Group recommendations

Having considered the limited available information on the marine habitats and flora and fauna of the central West Coast, the Working Group concluded that a section about 26 km long encompassing Jurien Bay has excellent potential as a multiple-use marine reserve representing the regional environment, when taken together with the Beagle Islands sector. As indicated previously, the two areas represent about 16% of the Port Denison to Whitfords coastal type.

The Jurien sector has complex bathymetry with well developed reef systems, emergent rocks and islands, extensive sand banks with dense seagrass meadows, rocky shores with wide rock platforms, several deep semi-enclosed basins, and abundant and diverse marine flora and fauna. Consideration was given to a stretch of coast further south, adjacent to the Nambung National Park, but that area has less complex geomorphology and less diverse marine habitats.

The Working Group is aware that the rock lobster fishery makes extensive use of this area but believes that is compatible with reservation for multiple-use purposes under existing legislation (see Part 1).

Accordingly the Working Group recommends as follows:

> "Consideration should be given to reservation of the State Territorial waters between latitudes 30° 12' and 30° 26', encompassing Sandland Island, North Head, Jurien Bay, Island Point, Boullanger, Whitlock and Escape Islands and Booker Rocks, for the purposes of protection of marine flora and fauna and public recreation. The Jurien Boat Harbour should be excluded."

Shoalwater Islands Marine Park - Garden Island and Carnac Islands Extensions (Map IV-7)

Working Group recommendations

The Working Group notes the increasing recreational use of the waters off Carnac and Garden Islands and the importance of these areas for research and environmental education. Although no study of the Carnac Island area has been carried out as recommended by the EPA, the Working Group believes that sufficient is known of its marine communities and recreational activities in the area to justify reservation. However, there would be merit in extending the marine reserve southwards to link with the existing Shoalwater Islands Marine Park and providing added protection to the western shores of Garden Island. The Working Group also believes that the representativeness of the reserve would be greatly increased if its seaward boundary was located at the limit of the State Territorial Sea, thus incorporating a section of the submerged limestone ridge known as Five Fathom Bank.

Accordingly the Working Group recommends as follows.

> "Consideration should be given to the extension of the Shoalwater Islands Marine Park seaward to the limit of the State Territorial Sea, northward along the western shores of Garden Island and Carnac Island, and for 1 nautical mile east of Carnac Island, returning to Beacon Head on the north-eastern corner of Garden Island."

Peel-Harvey Inlet (Map IV-8)

Working Group recommendations

Notwithstanding the present polluted condition of the Peel-Harvey estuary, the Working Group believes that parts of this estuary have very high value as habitat for waterbirds, including migratory waders whose protection is subject to international treaties, and warrant reservation as an added protection measure. Changes to the estuarine ecosystem following the opening of the Dawesville Channel are likely to be, on the whole, beneficial although the effects on waterbird feeding, roosting and nesting habitats will need to be carefully monitored.

The recreational and fishing activities in the Peel-Harvey Estuary are at present adequately controlled under the authority of the Peel Inlet Management Authority and the Fisheries Department. Accordingly the Working Group:

> "1. Endorses the recommendations in the EPA System 6 report for the reservation of three areas within Peel-Harvey Inlet, namely:
>
> - the waters surrounding the Creery Islands at the entrance to Peel Inlet (C 50. 3);
> - the waters and intertidal lands in the eastern part of Peel Inlet and south of the Yunderup, adjacent to Nature Reserve No 4990 delta (C 50.5);
> - the waters of Harvey Estuary south of a line between Herron Point and Island Point (51.3)
>
> for the purpose of protection of flora and fauna, specifically for the protection of waterbirds and their habitats.
>
> "2. Suggests that the lower reaches of the Harvey River as far upstream as the southern boundary of Nature reserve No. 23756 should be included within the reserved area.

"3. Notes that, under present legislation subtidal waters reserved for this purpose must necessarily be declared marine nature reserve and vested in the National Parks and Nature Conservation Authority.

"4. Notes that the Peel-Harvey Estuary is a declared management area under the control of the Peel Inlet Management Authority and recommends that a review of legislation be undertaken to find the most effective management structure to ensure collaboration between the several Government agencies and Statutory Authorities which would have responsibility for management of areas of the inlet declared marine nature reserve under the CALM Act."

Leschenault Inlet and Estuary (Map IV-9)

Working Group recommendations

Although Leschenault Inlet and Leschenault Estuary have been considerably disturbed and modified by urban and industrial development, the Working Group believes that they retain important values for both public recreation and conservation.

The present arrangement whereby these waterways are managed by the Leschenault Inlet Management Authority under the authority of the Waterways Conservation Act is entirely satisfactory as a means to protect and manage those values and there would be nothing to be gained by reservation of the whole estuary and inlet as marine park.

Nevertheless, as an added protection there would be merit in reserving the most important areas for conservation of flora and fauna, notably the important waterbird areas and the mangrove areas, specifically for that purpose. These are correctly identified in the 1992 Leschenault Waterways Management Program.

Accordingly the Working Group recommends as follows:

"The following areas should be reserved for the protection of aquatic flora and fauna and waterbird habitat:

(i) Leschenault Inlet;

(ii) two areas of Leschenault Estuary:

  a) the northern estuary above Waterloo Head, and

  b) Vittoria Bay (Turkey Point to Pelican Point, including the Preston River mouth).

"The most appropriate reserve category is marine nature reserve with vesting in the National Parks and Nature Conservation Authority. Management should be carried out in collaboration with the Leschenault Inlet Management Authority."

Geographe Bay - Cape Leeuwin (Map IV-10)

Working Group recommendations

Although there has been no investigation of the Leeuwin-Naturaliste coast, the Working Group believes that there is already sufficient information to support a recommendation for declaration of a marine reserve. These are shores of two very distinctive coastal types with outstanding public recreational potential, a wide range of habitats and very high conservation values.

The Working Group agrees that the areas identified in the Leeuwin-Naturaliste Management Plan have high conservation value but considers that it would be unwise to select only these for reservation. Other areas are known to be of similar importance, for example the sheltered rocky shores of Flinders Bay and the leeward side of Cape Naturaliste, and the near-shore sublittoral area between Bunker Bay and Dunsborough where there is spectacular underwater scenery and prolific growth of tropical corals. Given the high public recreational use of the Leeuwin-Naturaliste National Park and its coast, as well as its high conservation value, there would be merit in declaring the whole sector a multiple-use marine park. Commercial fishing is also important and would be provided for by management programs under the control of the Fisheries Department.

The major distinctive coastal type represented by the sandy beaches, sheltered waters and vast seagrass meadows of Geographe Bay are also worthy of representation in the State's marine reserve system. The densest seagrass meadows, most prolific coral growth, best underwater scenery and most used areas for

recreation are located at the western end of the bay in the lee of Cape Naturaliste. As this area is contiguous with the distinctive rocky coast of the Leeuwin-Naturaliste Ridge there would be merit in extending the proposed marine park eastwards, perhaps as far as Vasse, to encompass a portion of the Geographe Bay distinctive coastal type.

The Working Group believes that a multiple-use marine park encompassing the shores of the Leeuwin-Naturaliste Ridge and the western end of Geographe Bay would become one of Australia's most significant recreation and conservation marine reserves. Accordingly the Working Group recommends as follows:

"1. Consideration should be given to the reservation of the State Territorial waters adjacent to the Leeuwin-Naturaliste National Park as a multiple-use reserve for protection of marine flora and fauna and public recreation, with provision made for the continuance of commercial fishing.

"2. That in the north the reserve should extend around into Geographe Bay as far as Vasse so encompassing the Dunn Bay sand bar, the best of the Bay's seagrass meadows, and the areas with most prolific coral growth.

"3. That in the south the reserve should extend around Cape Leeuwin to encompass Flinders Bay and the seal and sea lion colonies on the offshore rocks. (The reserve should also include the Hardy Inlet estuary - see Part V.)."

PART V: MARINE RESERVES ON THE SOUTH COAST

RECOMMENDATIONS FOR MARINE RESERVES ON THE SOUTH COAST

Hardy Inlet (Map V-1)

Working Group recommendations

The Working Group notes the high recreational values of Hardy Inlet and the upper parts of the Blackwood Estuary and the fact that increasing activity in the area places increasing stresses on its biological resources. The estuary is one of the two large estuaries on the South Coast which are permanently open to the sea and it supports a relatively large diversity of aquatic species of plants and animals. Although the basin is wide, the volume is relatively small and there will be an increasing need to manage human activities, especially fishing, so that the aesthetic and biological values of the estuary are maintained.

Accordingly the Working Group recommends that:

> "The estuary of the Blackwood River, including the Deadwater, Swan Lake, Hardy Inlet, Molloy Basin and the tidal parts of the Scott and Blackwood Rivers be considered for reservation as a marine reserve for dual recreation and conservation purposes.
>
> "The estuarine reserve should be continuous with the eastern portion of the proposed Leeuwin-Naturaliste marine reserve."

D'Entrecasteaux (Map V-1)

Working Group recommendations

Noting that the promontory is unique in its geology and landforms and that the shore above low water mark is within the D'Entrecasteaux National Park, the Working Group recommends that:

> "a survey of the marine habitats adjacent to Black Point be conducted and an assessment made of their value for conservation purposes, with a view to consideration being given to reservation of the area as a marine reserve for the conservation of marine flora and fauna."

The Working Group considered that there would be merit in extending the proposed reserve west or east to include a section of the wide beach characteristic of the southern shore of the Perth Basin. However, not all of the hinterland of those areas is presently included within the national park and it was concluded that a representative portion of that coastal type would be better selected further east (see section 3.2.2).

Warren Beach

Working Group recommendations
Although species diversity is unlikely to be high in this habitat, it is representative of a coastal type and ecosystem not otherwise represented or proposed in the South Coast marine reserve system. The Working Group recommends that:

> "State coastal waters adjacent to the D'Entrecasteaux National Park between the mouth of the Donnelly River and Black Head be considered for reservation for the conservation of marine flora and fauna and their habitats."

Broke Inlet

Working Group recommendation
Broke and Wilson Inlets are similar in many respects. Both are large, lagoonal estuaries which are seasonally open. However, while the catchment of Broke lies within a conservation reserve, that of Wilson Inlet lies largely in agricultural lands. Broke Inlet has every chance of remaining in virtually pristine condition without eutrophication while Wilson Inlet is already eutrophic. Although Wilson Inlet has a richer flora and fauna than Broke, its status as a biological environment is less secure. For catchment management reasons as well as management of the estuary, the Wilson Inlet bar is artificially opened every year. Access to Wilson Inlet is considerably greater than to Broke and it is more extensively used for recreation. Management of Wilson Inlet and recreational use of it is presently under the control of the Wilson Inlet Management Authority, empowered by the Waterways Commission Act.

The Working Group concluded that there would be little point in reserving Wilson Inlet for conservation purposes as it is now subject to such intensive human impact. As the inlet is already controlled by the Management Authority, neither would there be any advantage in reserving it for recreational purposes. For conservation purposes Broke Inlet is a better choice as an example of the large, lagoonal, seasonally-opened estuary because it is likely to remain in natural condition. Because of its isolation within the national park, Broke also offers the prospect of management to preserve its present peaceful character and use for passive recreation.

Accordingly the Working Group recommends that:

> "Broke Inlet and the tidal parts of the Shannon, Forth and Inlet Rivers be reserved for recreation and conservation and their management integrated with that of the D'Entrecasteaux National Park."

Donnelly and Gardner Inlets

Working Group recommendation
The Working Group considers that the inlets of the Donnelly and Gardner Rivers have considerable scientific and recreational value and should be managed as part of the surrounding D'Entrecasteaux National Park. It is unclear whether these areas are already included within the national park. Accordingly the Working Group recommends that:

> "Legal advice should be taken on the status of the tidal parts of the Donnelly and Gardner Rivers and if they are not already reserved within the D'Entrecasteaux National Park under the Land Act, consideration should be given to reserving them under the Conservation and Land Management Act for conservation and recreational purposes."

Walpole-Nornalup (Map V-1)

Working Group recommendations
The Working Group believes that the Walpole-Nornalup estuarine system has very high conservation and recreational values. Although in size it is similar to Broke and Wilson Inlets it is quite different in that it is naturally permanently open to the sea. It is the only permanently open lagoonal estuary on the South Coast and, apart from the partly estuarine Oyster Harbour, it has the most diverse estuarine flora and fauna of any estuary in the region. It also has outstanding scenic qualities and is largely surrounded by National Park.

The Working Group notes that in 1972 the Government included Walpole-Nornalup Inlets within the national park until it was discovered later that this was not possible under the Land Act. Accordingly the Working Group recommends that:

> "declaration of Walpole and Nornalup Inlets and the tidal parts of the Deep, Frankland and Walpole Rivers as marine park be
> "implemented as a matter of high priority, and its management integrated with that of the surrounding national park."

William Bay (Map V-2)

Working Group recommendation
Noting the high scenic and recreational values of the locality and its likely diverse marine flora and fauna representative of the South Coast rocky shore habitat, the Working Group recommends that:

> "the State waters adjacent to the William Bay National Park be surveyed and assessed for their conservation values, with a view to possible reservation as a marine reserve for dual conservation and recreation purposes."

West Cape Howe (Map V-2)

Working Group recommendations
Noting the high scenic values of the shore, the ready access to deep water and magnificent underwater scenery, and the variety of habitats and likely high diversity of marine flora and fauna, the Working Group recommends that:

> "consideration be given to reservation of the State waters adjacent to the West Cape Howe National Park as a marine reserve for the purposes of conservation of flora and fauna and recreation, with the possible inclusion of the western part of Torbay adjacent to the Shire reserve."

King George Sound - Princess Royal Harbour (Map V-2)

Working Group recommendations
The Working Group recognises that King George Sound, Princess Royal Harbour and Oyster Harbour are extensively used for port and recreational purposes and that the two inlets show evidence of environmental degradation. Nevertheless, these areas are of such biological importance that reservation of some parts of them for conservation purposes should be considered. There might also be merit in reservation of some parts to protect and promote recreational activities, especially diving.

Of particular importance are the seagrass beds on either side of Vancouver Peninsula and in Frenchman Bay. The sheltered deep basin in Frenchman Bay is also a rare feature on the South Coast. These areas are of special value for both conservation and recreation. The rocky sublittoral ridge and reefs in the vicinity of Michaelmas and Breaksea Islands have special attractions for recreational divers, including the commercial dive tour industry. Although similar underwater scenery and flora and fauna occurs further east around Cape Vancouver, the King George Sound sites are much more easily accessible to vessels from Albany.

Accordingly the Working Group recommends that:

> "1. the western shore of Vancouver Peninsula in Princess Royal Harbour, and the eastern shore of that Peninsula in King George Sound as far east as Flat Rock, and extending seaward as far as Seal Island to include the waters of Frenchman Bay, should be considered for reservation as a marine reserve for the purposes of conservation of flora and fauna and recreation;
>
> "2. a survey be conducted of the deep ridge and reefs in the vicinity of Michaelmas and Breaksea Islands, together with a survey of the waters around Cape Vancouver, to assess their relative underwater scenic

values and merits as dive sites, with a view to selecting areas to be reserved for conservation and recreation use."

Cape Vancouver to Bald Island (Map V-2)

Working Group recommendations
Noting the wide variety of coastal types and habitats that are represented, the relative remoteness and lack of access to the shore and the degree of protection that provides, and the value of the inshore waters for public recreation, especially fishing and diving, the Working Group recommends that:

"the State coastal waters between the western boundary of the Two Peoples Bay Nature Reserve and Lookout Point, including the tidal waters of Waychinicup Inlet and encompassing Bald Island, be considered for reservation as a marine reserve for conservation of flora and fauna and recreation."

Fitzgerald Biosphere Reserve (Map V- 3)

Working Group recommendations
While acknowledging the lack of information about the marine flora and fauna on the shores of the Fitzgerald River National Park, the Working Group believes that reservation of the coastal waters adjacent to the park would have merit for recreation and management reasons. With limited access to the shore, significant human impact on the marine flora and fauna is unlikely. Reservation would be consistent with the principal uses of the coastline, that is sight-seeing and recreational fishing, and a logical extension of the International Biosphere Reserve status of the coast.

The importance of Doubtful Island Bay as a nursery area for Southern Right Whales is in itself a reason for reservation. Assuming that care is taken to avoid interference with the whales, the existing commercial Australian Salmon fishery would be readily accommodated within marine park management programs.
The Working Group notes the greater public access to the coast on the north side of Point Hood and the presence there of housing but believes that there is a case for extending the proposed marine reserve to encompass the Doubtful Islands and Point Hood providing additional protection to the sea lion and fur-seal colonies and adding a significant area of rocky shore to the reserve.

The small inlets of the Fitzgerald River National Park, impoverished though they are in terms of aquatic flora and fauna, nevertheless represent a type of semi-permanently closed "estuary" peculiar to the eastern part of Western Australia's South Coast. They have considerable scenic merit and contribute significantly to the scenic and recreational values of the Fitzgerald River National Park and to the integrity of the status of the area as an International Biosphere Reserve. Culham Inlet is hardly claimable as an estuary at all and it is now highly modified by human activity and has less value as a potential reserve for either conservation or recreational purposes.

For the above reasons the Working Group recommends that:

"the area of State coastal waters between the mouth of Gordon Inlet and the mouth of Culham Inlet , that is the coast adjacent to the Fitzgerald River National Park, should be considered for reservation as a marine reserve for conservation of flora and fauna and recreation, and that it should be added to the Fitzgerald Biosphere Reserve;

"consideration also be given to reservation for the same purposes of the southern part of Doubtful Island Bay encompassing the Doubtful Islands and Point Hood;

"legal opinion be obtained on the status of Gordon, St Mary, Fitzgerald, Dempster and Hamersley Inlets and if they are judged to be 'tidal' and therefore excluded from the national park as declared under the Land Act, consideration should be given to reservation of them as marine reserves under the CALM Act and that their management be integrated with that of the national park."

Stokes Inlet (Map V-4)

Working Group recommendations

The repeated sequence of rocky headland-beach present on this section is representative of the South Coast except that the headlands are low and without high cliffs. The near-shore limestone reefs which are a common feature at the eastern ends of the bays east of Hopetoun are very well represented here. The deep channels between the reefs on the western side of Shoal Cape are a unique feature and undoubtedly provide habitat for a diverse marine flora and fauna. The coast has excellent potential for sightseeing, recreational fishing and diving which would add significantly to the recreational opportunities of the Stokes National Park.

Stokes and Torradup Inlets have high conservation values as representatives of the South Coast semi-permanently closed lagoonal and riverine estuaries. Stokes is the most easterly of the lagoonal inlets of any size. It has relatively deep water and does not dry out. Undoubtedly for that reason, it supports a more diverse aquatic flora and fauna than other estuaries of similar type further west. The inlet has high scenic value and is an important element of the scenic quality of the surrounding national park. It also has considerable value for its recreational fishing.

The Working Group recommends that:

> "State coastal waters adjacent to the Stokes National Park, encompassing Margaret Cove, Dunster Castle Bay and Fanny Cove, and including the tidal parts of Stokes Inlet and Torradup Inlet, be considered for reservation as a marine reserve for the purposes of conservation of flora and fauna and public recreation, and managed in conjunction with the national park."

Recherche Archipelago (Map V-4)

Working Group recommendations

While acknowledging the paucity of information about the marine flora and fauna of the Recherche Archipelago, the Working Group believes that reservation of these waters can be justified on the grounds that habitats are diverse and that added protection would be provided for the sea lion, fur-seal and seabird colonies. Protection of areas for the purposes of recreational diving and development of the commercial dive tour industry can also be justified.

However, with the limited information available, the Working Group was unable to identify parts of the Archipelago which are particularly worthy of reservation. It was concluded that selection of specific areas would be unwise and that reservation of the entire area as a multiple-use marine reserve is warranted. Subsequent surveys in the course of preparation of a management plan would identify areas of particular importance for conservation, recreation and commercial fishing and appropriate zoning would resolve potential conflicts between these activities.

Accordingly the Working Group recommends that:

> "the waters of the Recherche Archipelago between Butty Head in the west and Israelite Bay in the east , extending to the limit of the State Territorial Sea, including the areas of State waters surrounding the outer islands but excluding the Port of Esperance, should be considered for reservation as a marine reserve for multiple purposes including conservation of flora and fauna and public recreation."

Twilight Cove (Map V-5)

Working Group recommendations

This section of the coast is selected for consideration by the Working Group because it represents the two coastal types characteristic of the shores of the Eucla Basin and not because it has any known special conservation or recreation values. The Working Group recommends that:

> "a survey of the coast between about 50 km east and west of Twilight Cove should be conducted to assess the value of the area as a marine reserve for the protection of marine flora and fauna and coastal landforms."

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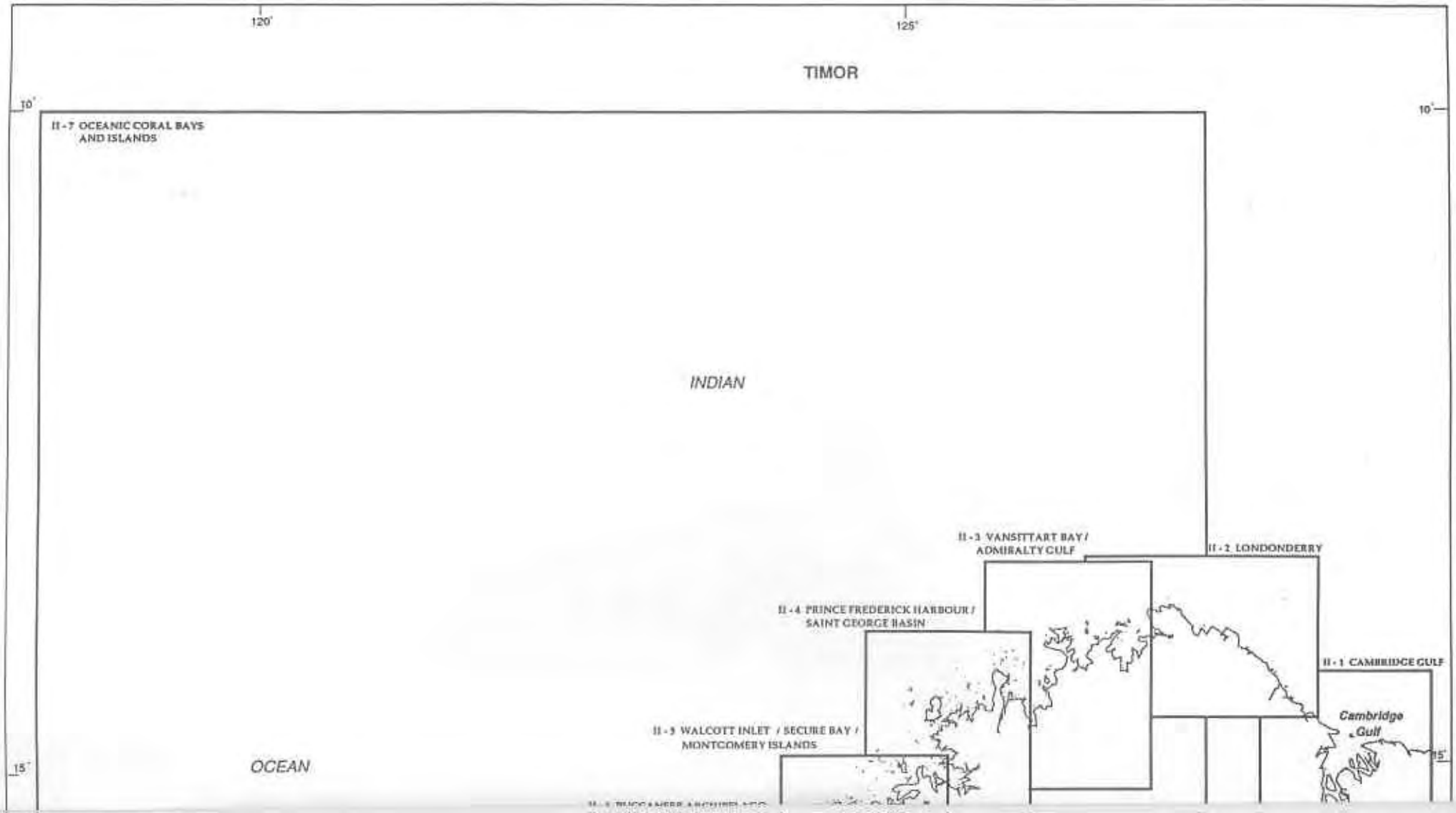
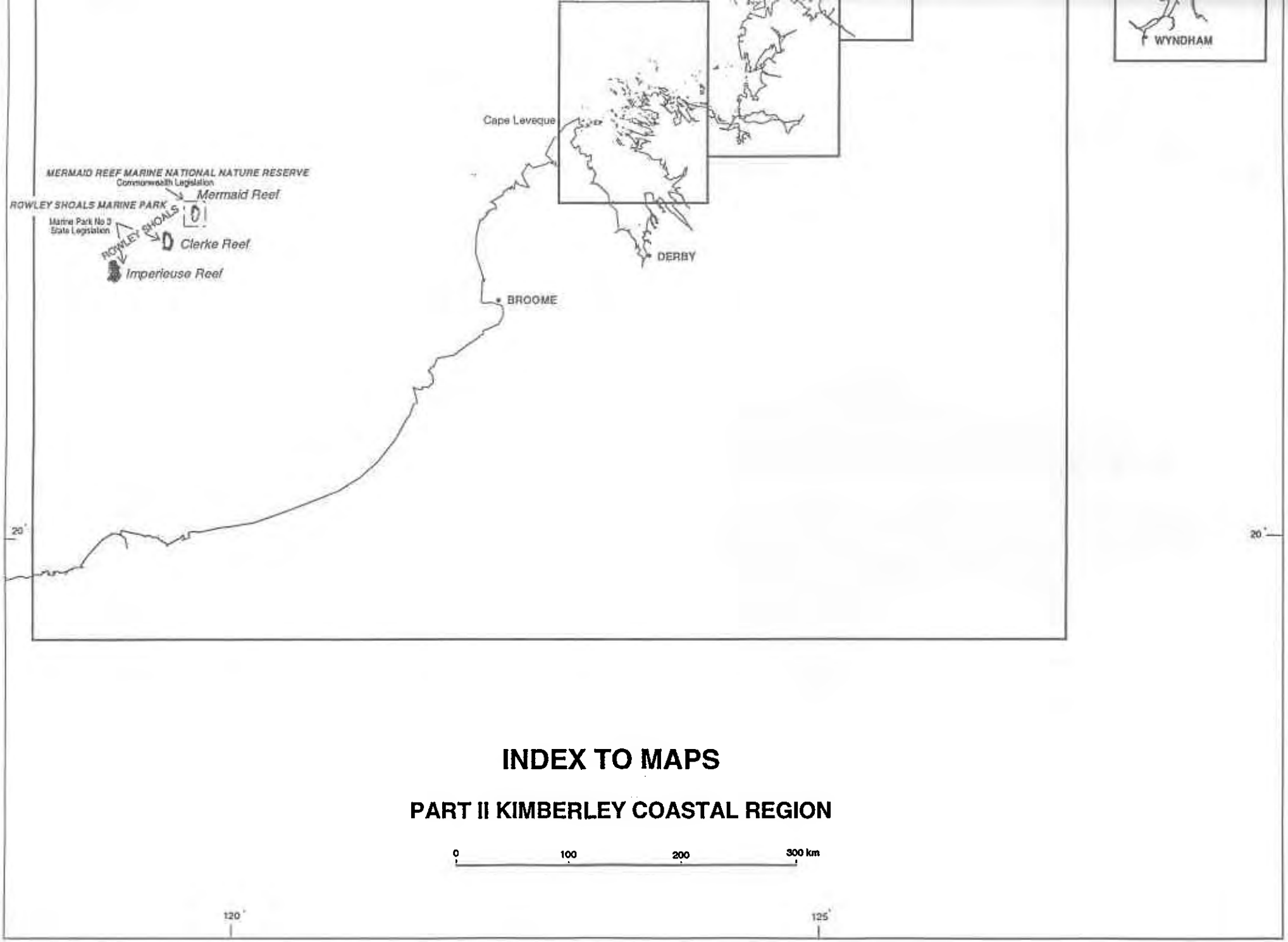
LIST OF MAPS


120°
125°
TIMOR
10°
10°
II - 7 OCEANIC CORAL BAYS AND ISLANDS
INDIAN
II - 3 VANSITTART BAY / ADMIRALTY GULF
II - 2 LONDONDERRY
II - 4 PRINCE FREDERICK HARBOUR / SAINT GEORGE BASIN
II - 1 CAMBRIDGE GULF
Cambridge Gulf
II - 5 WALCOTT INLET / SECURE BAY / MONTGOMERY ISLANDS
15°
OCEAN
15°



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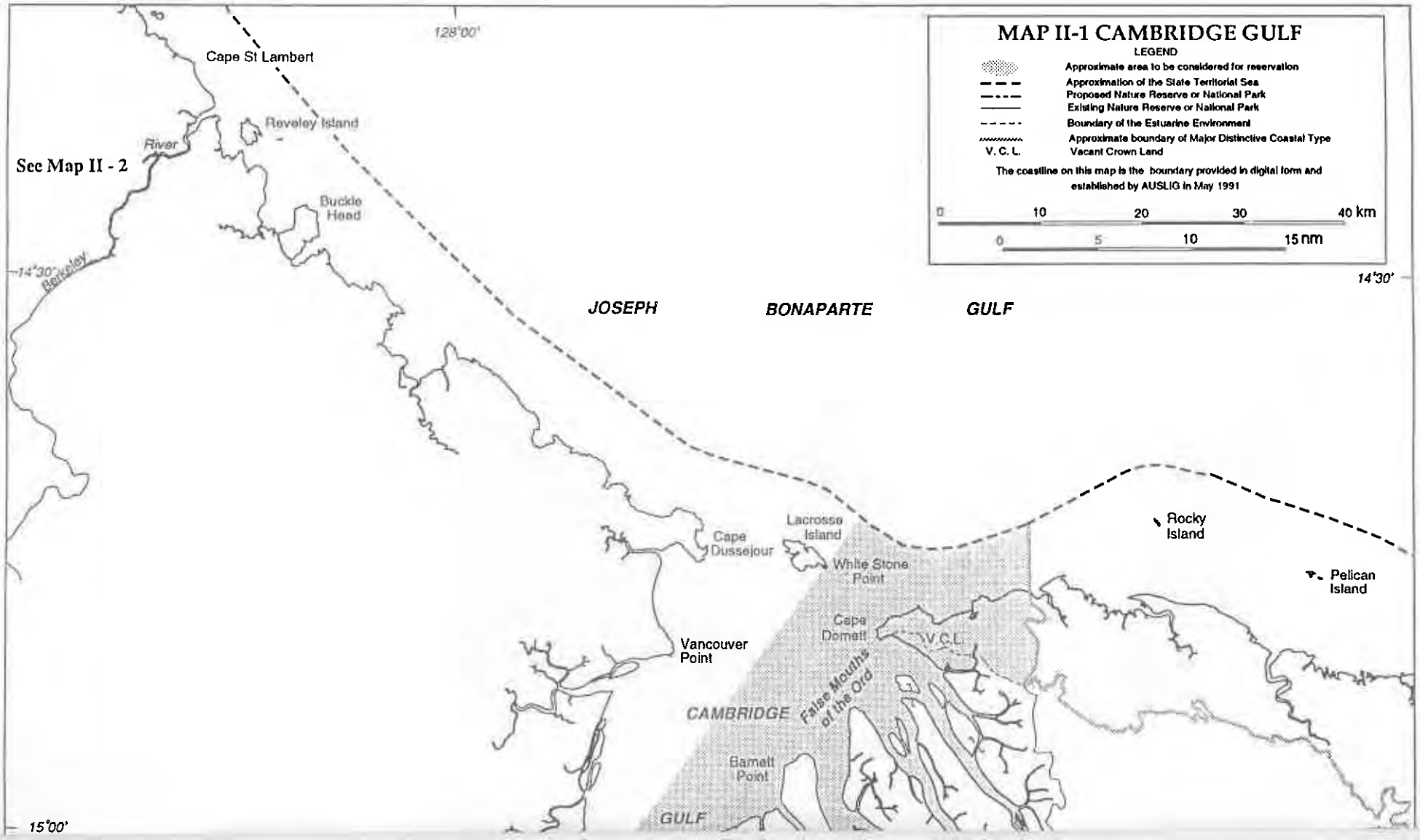
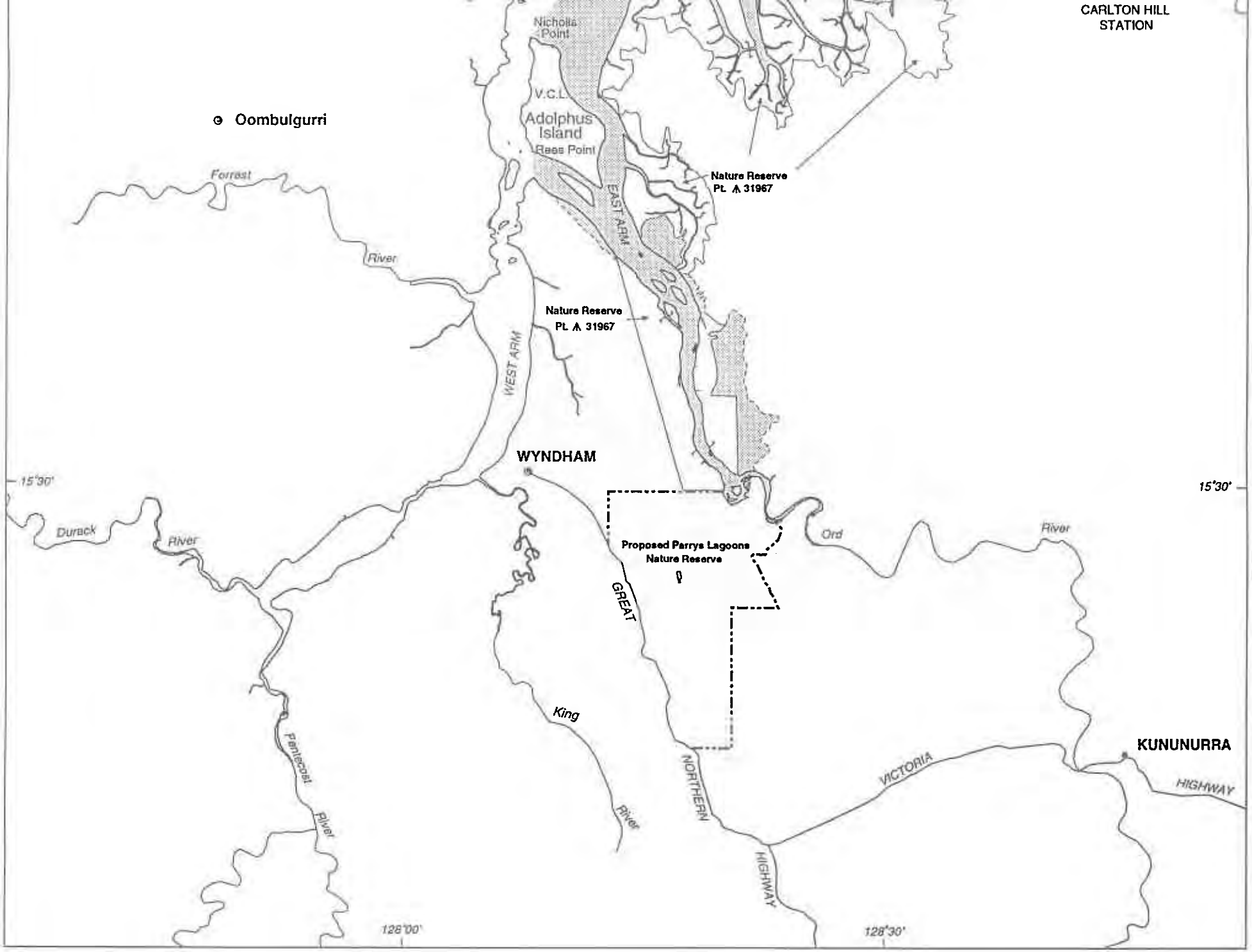
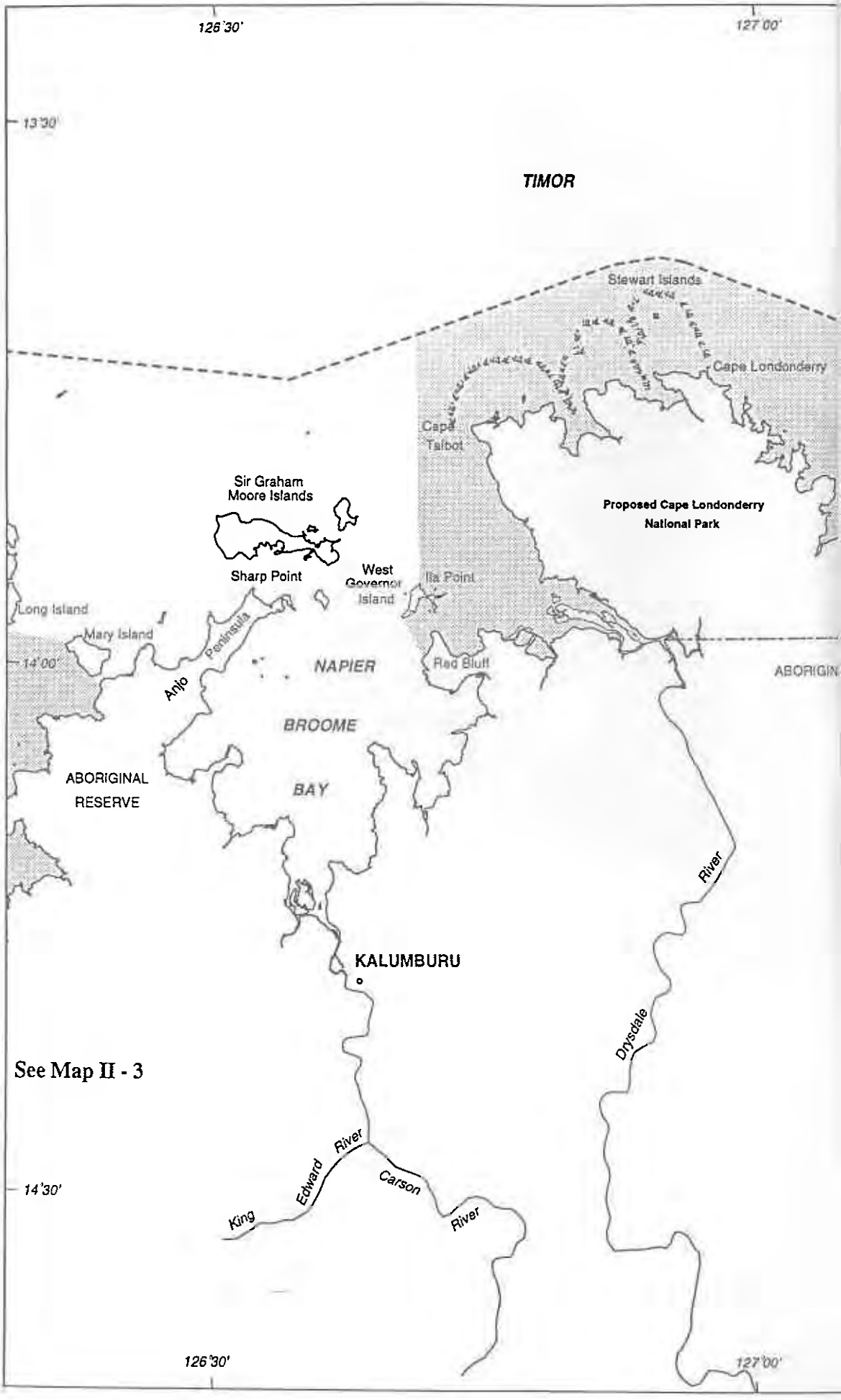
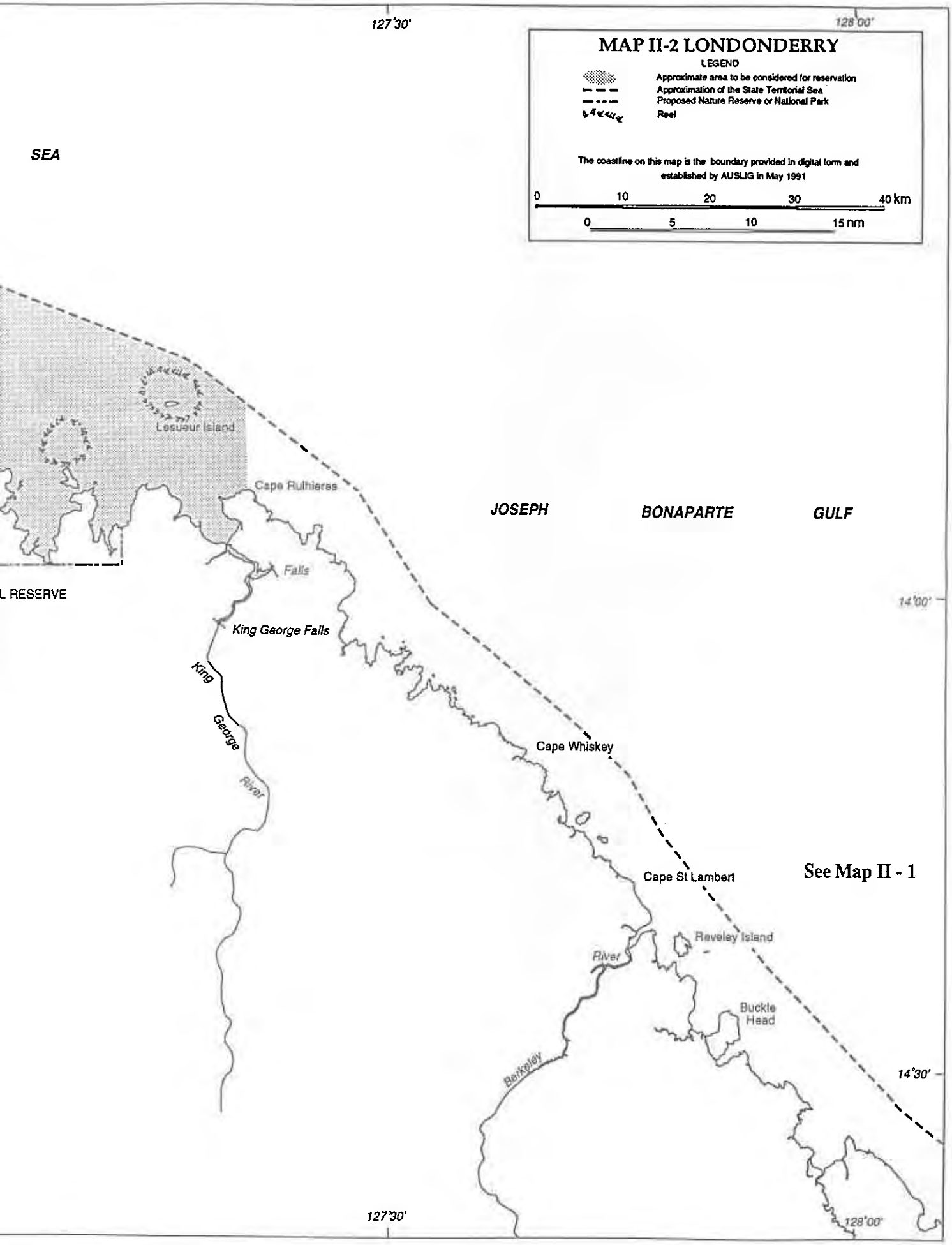
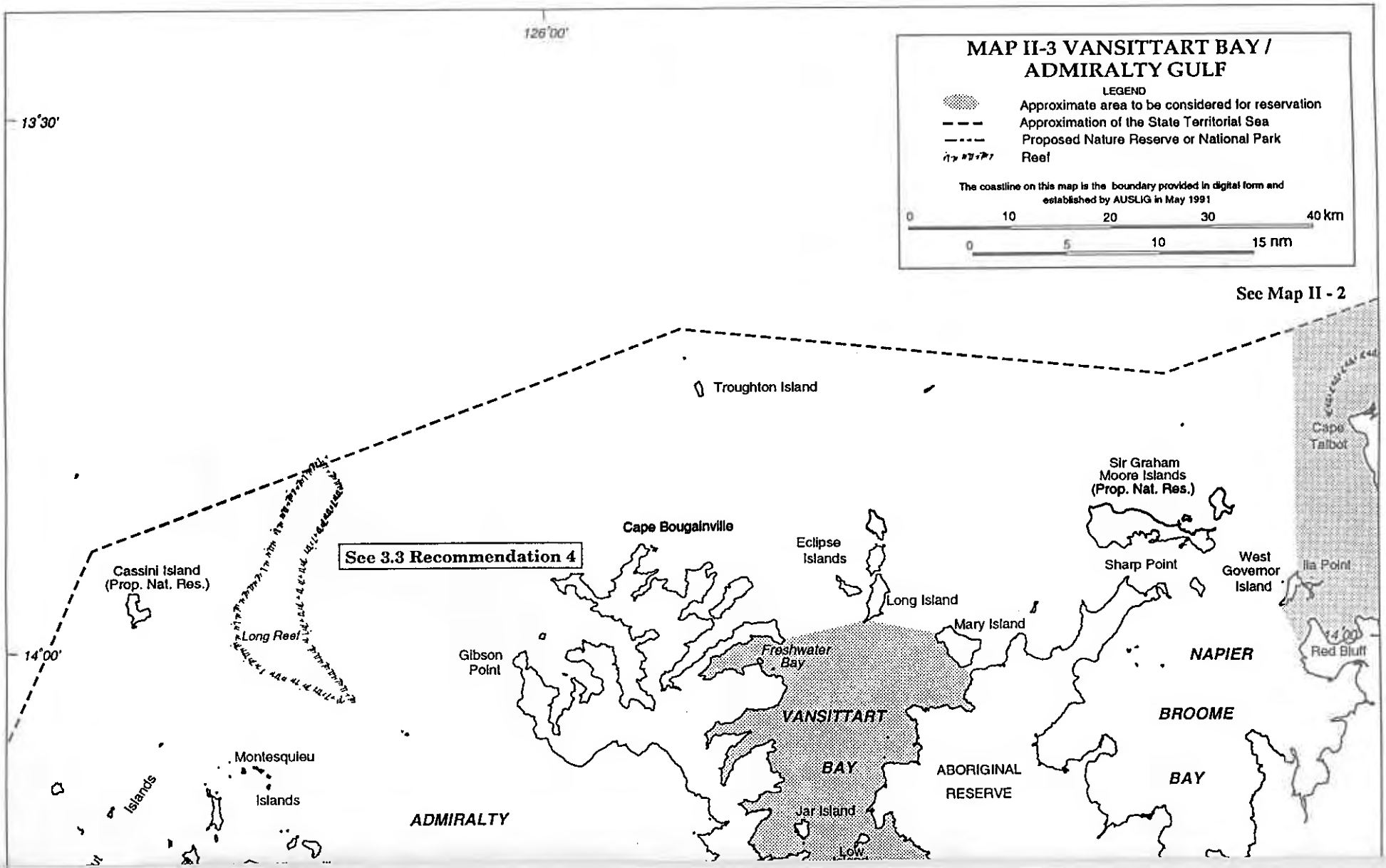
PART II KIMBERLEY COASTAL REGION


MAP II-1 CAMBRIDGE GULF
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
Proposed Nature Reserve or National Park
Existing Nature Reserve or National Park
Boundary of the Estuarine Environment
Approximate boundary of Major Distinctive Coastal Type
V. C. L. Vacant Crown Land
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40 km
0 5 10 15 nm
128°00'
14°30'
15°00'
See Map II - 2
Cape St Lambert
Reveley Island
River
Buckle Head
Berkley
JOSEPH BONAPARTE GULF
Cape Dussejour
Lacrosse Island
White Stone Point
Rocky Island
Pelican Island
Cape Domett
V.C.L.
Vancouver Point
False Mouths of the Ord
CAMBRIDGE GULF
Barnett Point

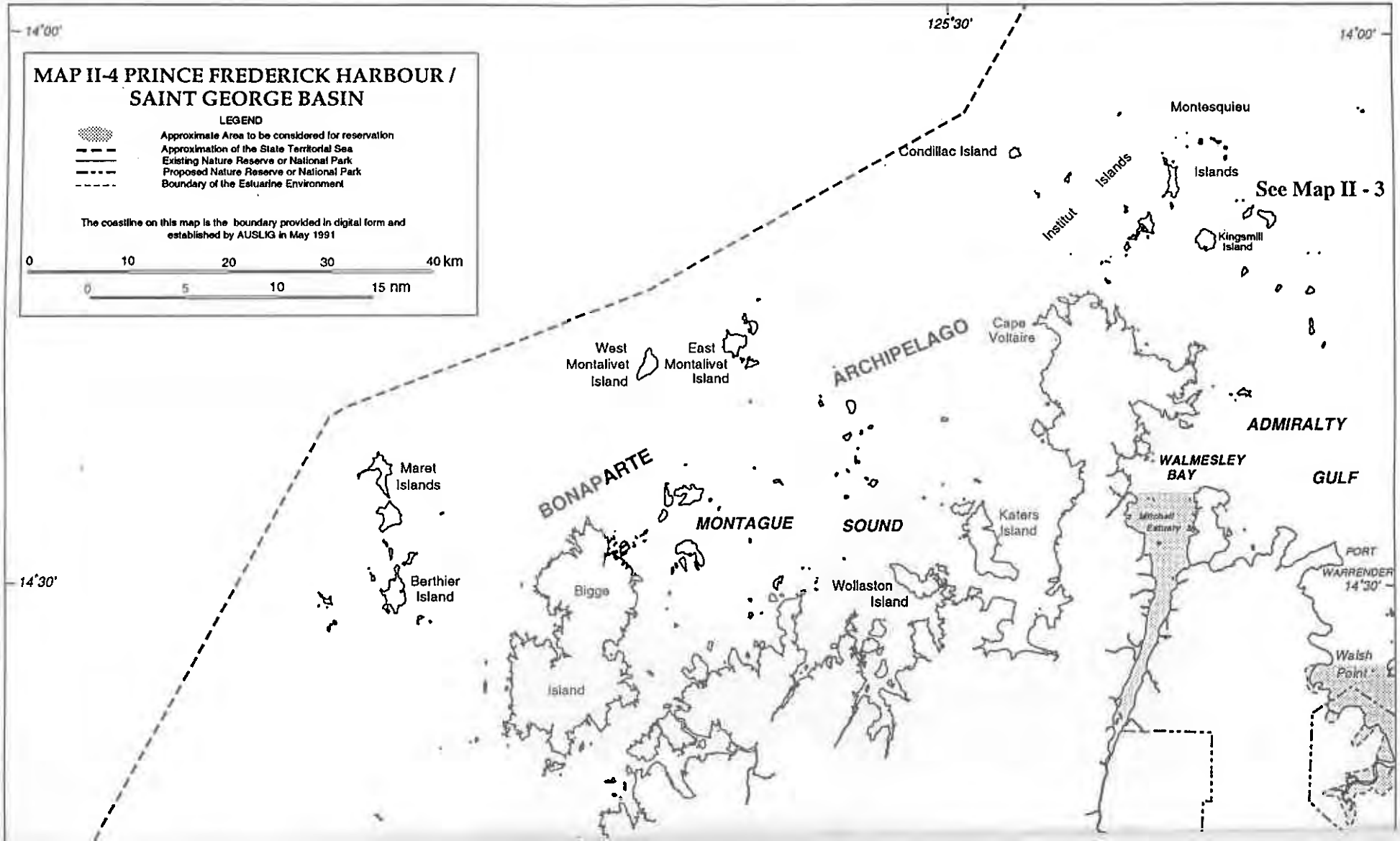

CARLTON HILL
STATION
Nicholls
Point
V.C.L.
Adolphus
Island
Rees Point
Oombulgurri
Forrest
River
EAST ARM
Nature Reserve
PL A 31967
Nature Reserve
PL A 31967
WEST ARM
WYNDHAM
15°30'
Durack
River
Proposed Parrys Lagoons
Nature Reserve
GREAT
Ord
River
King
River
Pentecost
River
NORTHERN
HIGHWAY
VICTORIA
HIGHWAY
KUNUNURRA
128°00'
128°30'

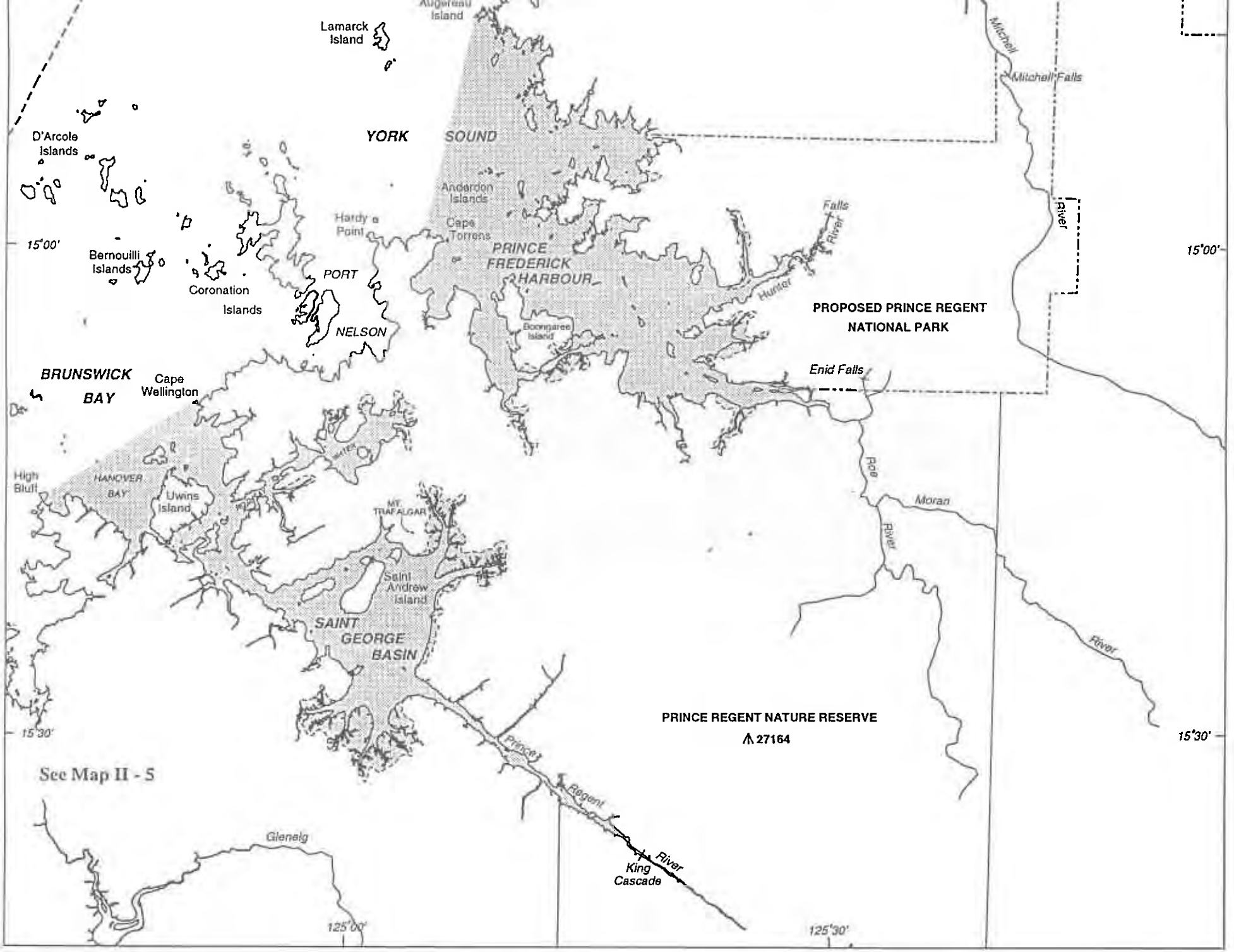

126°30'
127°00'
13°30'
TIMOR
Stewart Islands
Cape Londonderry
Cape Talbot
Sir Graham Moore Islands
Proposed Cape Londonderry National Park
Sharp Point
West Governor Island
Ila Point
Long Island
Mary Island
Peninsula
14°00'
NAPIER
Red Bluff
ABORIGIN
Anjo
BROOME
BAY
ABORIGINAL RESERVE
KALUMBURU
See Map II - 3
River
Drysdale
Edward River
Carson River
King
14°30'
126°30'
127°00'

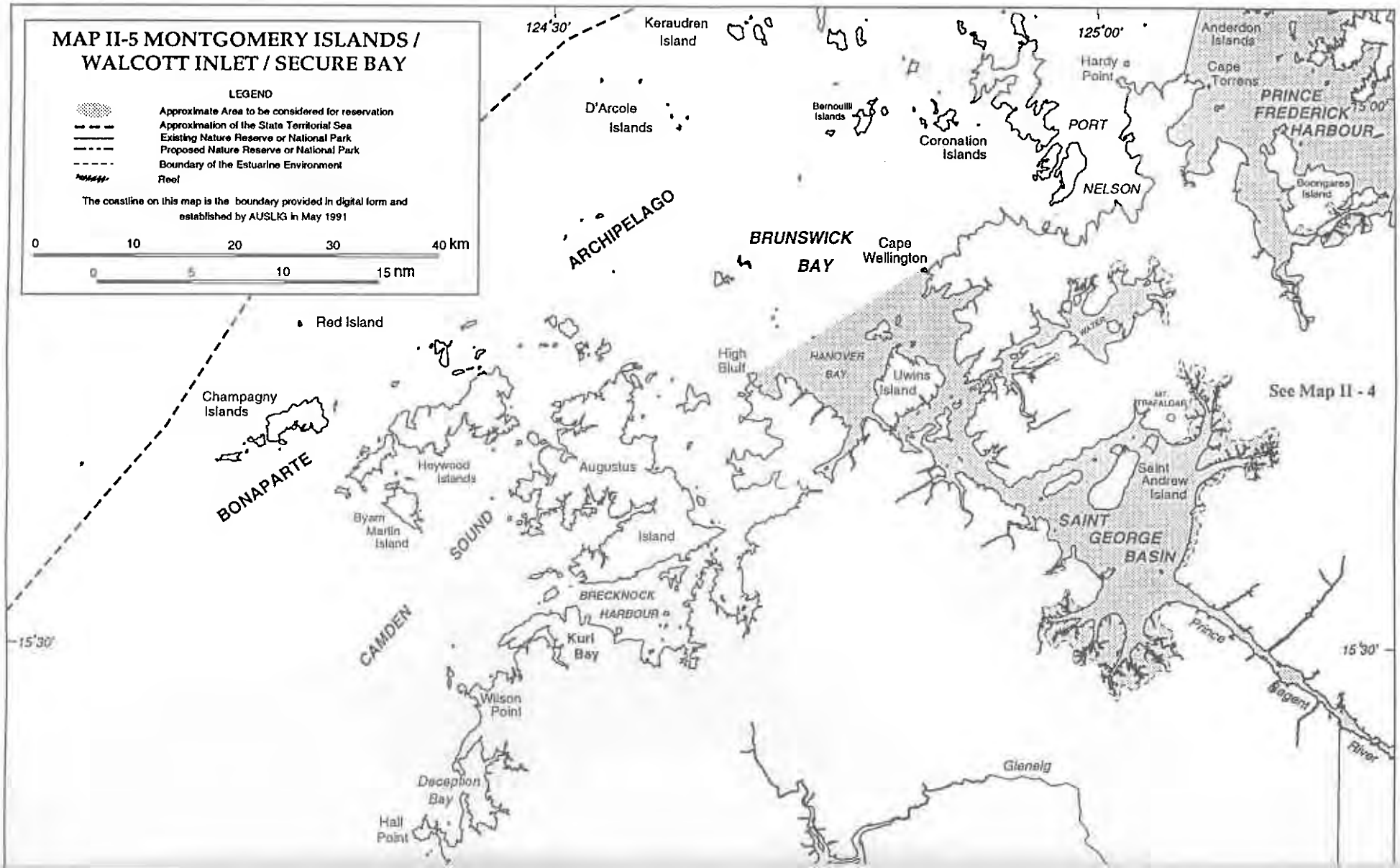

MAP II-2 LONDONDERRY
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
Proposed Nature Reserve or National Park
Reef
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40 km
0 5 10 15 nm
127°30'
128°00'
SEA
Lesueur Island
Cape Rulhieres
JOSEPH
BONAPARTE
GULF
L RESERVE
Falls
King George Falls
King George River
14°00'
Cape Whiskey
Cape St Lambert
See Map II - 1
Reveley Island
River
Buckle Head
Berkeley
14°30'
127°30'
128°00'

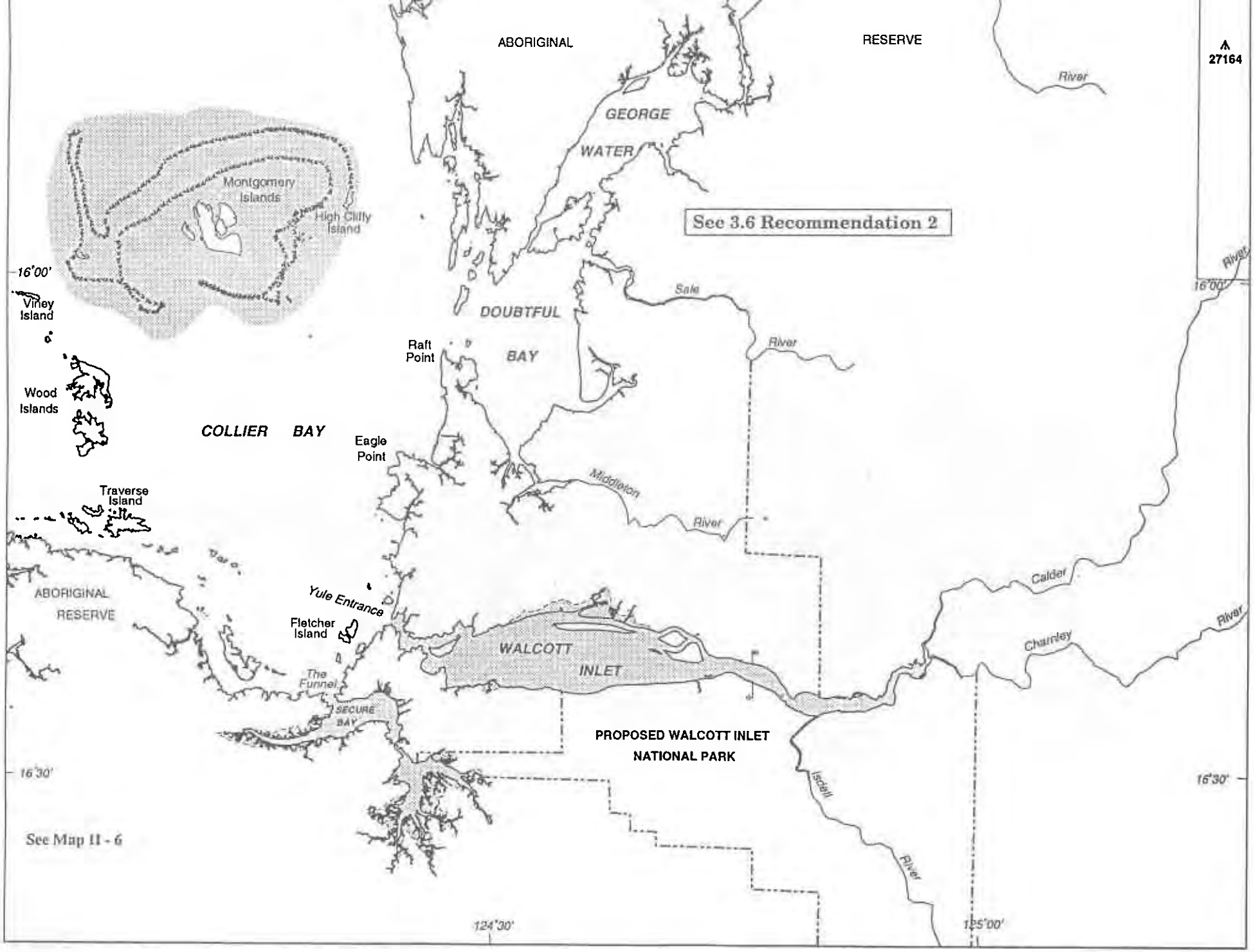

MAP II-3 VANSITTART BAY / ADMIRALTY GULF
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
Proposed Nature Reserve or National Park
Reef
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40 km
0 5 10 15 nm
See Map II - 2
126°00'
13°30'
14°00'
Troughton Island
Cape Talbot
Sir Graham Moore Islands (Prop. Nat. Res.)
Cape Bougainville
See 3.3 Recommendation 4
Eclipse Islands
Sharp Point
West Governor Island
Ila Point
Cassini Island (Prop. Nat. Res.)
Long Reef
Long Island
Mary Island
Gibson Point
Freshwater Bay
NAPIER
BROOME
VANSITTART
BAY
ABORIGINAL RESERVE
BAY
Red Bluff
Montesquieu Islands
Islands
ADMIRALTY
Jar Island
Low

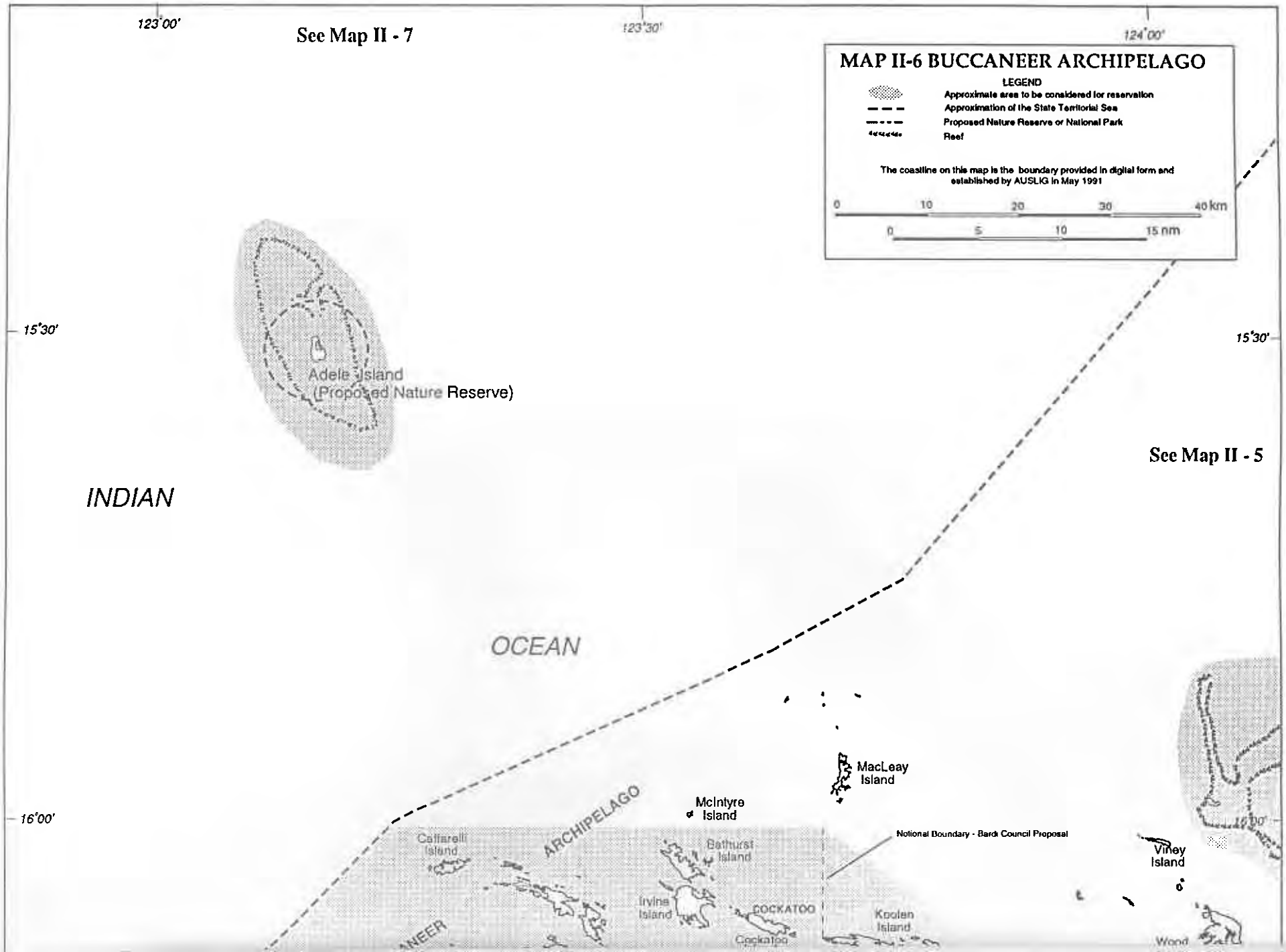

Island
GULF
Borda Island
Cape
Voltaire
Osborn Islands
(Prop. Nat. Res.)
Parry Island
KALUMBURU
Walmesley
Bay
Pickering
Point
Mitchell
Estuary
Katers
Island
14°30'
Crystal
Head
PORT WARRENDER
River
Carson
Edward
King
14°30'
River
Walsh
Point
Lawley
Estuary
ABORIGINAL
RESERVE
ABORIGINAL
RESERVE
MITCHELL
PLATEAU
Proposed
Mitchell
Proposed Lawley River
National Park
Lawley
River
Mitchell Falls
See Map II - 4
Prince Regent
River
15°00'
National Park
126°00'
126°30'
15°00'


MAP II-4 PRINCE FREDERICK HARBOUR / SAINT GEORGE BASIN
LEGEND
Approximate Area to be considered for reservation
Approximation of the State Territorial Sea
Existing Nature Reserve or National Park
Proposed Nature Reserve or National Park
Boundary of the Estuarine Environment
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40 km
0 5 10 15 nm
14°00'
125°30'
14°00'
14°30'
Montesquieu
Condillac Island
Islands
Islands
See Map II - 3
Institut
Kingsmill Island
West Montalivet Island
East Montalivet Island
ARCHIPELAGO
Cape Voltaire
ADMIRALTY
WALMESLEY BAY
GULF
Maret Islands
BONAPARTE
MONTAGUE
SOUND
Katers Island
Mitchell Estuary
FORT WARRENDER
Berthier Island
Bigge
Wollaston Island
Walsh Point
Island

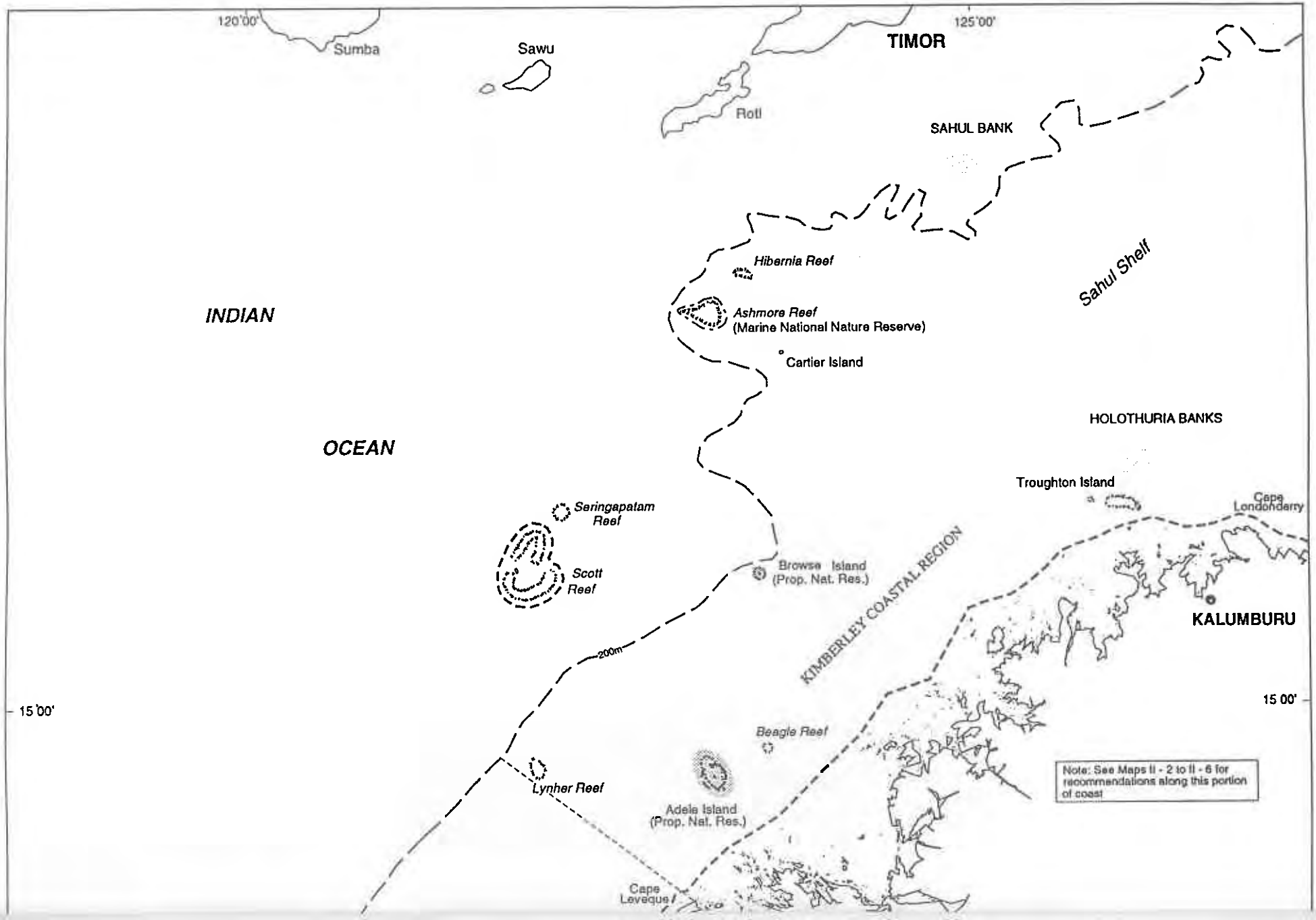

Augereau Island
Lamarck Island
D'Arcole Islands
YORK SOUND
Anderdon Islands
Hardy a Point
Cape Torrens
PRINCE FREDERICK HARBOUR
Falls River
Mitchell
Mitchell Falls
River
15°00'
Bernouilli Islands
PORT
Coronation Islands
NELSON
Hunter
Boongaree Island
PROPOSED PRINCE REGENT NATIONAL PARK
Enid Falls
BRUNSWICK BAY
Cape Wellington
High Bluff
HANOVER BAY
Uwins Island
MT. TRAFALGAR
Saint Andrew Island
SAINT GEORGE BASIN
Roe
Moran
River
PRINCE REGENT NATURE RESERVE
27164
15°30'
See Map II - 5
Prince
Regent
River
King Cascade
Glenelg
125°00'
125°30'

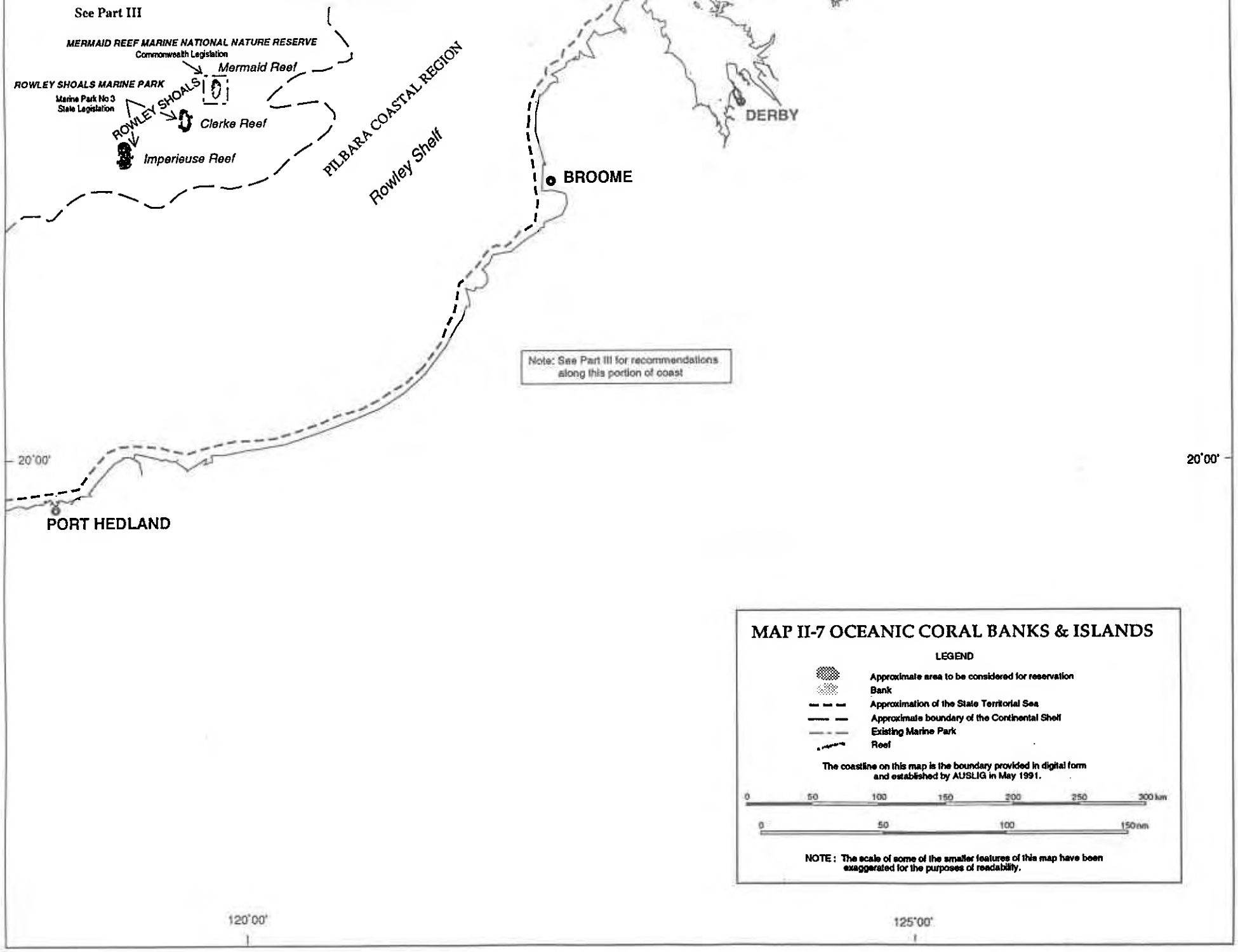

MAP II-5 MONTGOMERY ISLANDS / WALCOTT INLET / SECURE BAY
LEGEND
Approximate Area to be considered for reservation
Approximation of the State Territorial Sea
Existing Nature Reserve or National Park
Proposed Nature Reserve or National Park
Boundary of the Estuarine Environment
Reef
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40 km
0 5 10 15 nm
124°30'
125°00'
15°00'
15°30'
Keraudren Island
D'Arcole Islands
Bernoullii Islands
Coronation Islands
Hardy Point
Anderdon Islands
Cape Torrens
PRINCE FREDERICK HARBOUR
PORT NELSON
Boongaree Island
ARCHIPELAGO
BRUNSWICK BAY
Cape Wellington
Red Island
Champagny Islands
BONAPARTE
High Bluff
HANOVER BAY
Uwins Island
See Map II - 4
Haywood Islands
Augustus Island
Byam Martin Island
SOUND
CAMDEN
BRECKNOCK HARBOUR
Kurl Bay
Wilson Point
Deception Bay
Hall Point
SAINT GEORGE BASIN
Saint Andrew Island
Prince Regent River
Glenelg


ABORIGINAL
RESERVE
27164
River
GEORGE
WATER
Montgomery
Islands
High Cliffy
Island
See 3.6 Recommendation 2
16°00'
Viney
Island
DOUBTFUL
BAY
Sale
River
Raft
Point
Wood
Islands
COLLIER BAY
Eagle
Point
Middleton
River
Traverse
Island
ABORIGINAL
RESERVE
Yule Entrance
Fletcher
Island
WALCOTT
INLET
Calder
Chamley
River
The
Funnel
SECURE
BAY
PROPOSED WALCOTT INLET
NATIONAL PARK
16°30'
See Map II - 6
124°30'
125°00'


123°00'
See Map II - 7
123°30'
124°00'
MAP II-6 BUCCANEER ARCHIPELAGO
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
Proposed Nature Reserve or National Park
Reef
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40 km
0 5 10 15 nm
15°30'
Adele Island
(Proposed Nature Reserve)
See Map II - 5
INDIAN
OCEAN
MacLeay Island
McIntyre Island
16°00'
Cassarelli Island
ARCHIPELAGO
Bathurst Island
National Boundary - Bardi Council Proposal
Viney Island
Irvine Island
COCKATOO
Koolan Island
Cockatoo
Wood


Bedford Islands
Hidden Island
North West Twin Island
South East Twin Island
Swan Island
Cape Leveque
East Sunday Island
Sunday Island
One Arm Point
Shanlon Bluff
LOMBADINA
Skeleton Point
CYGNET BAY
Proposed Cygnet Bay Nature Reserve
Cunningham Point
Amalangoora Point
High Island
STRICKLAND BAY
Mermaid Island
CONE BAY
Long Island
CASCADE BAY
Point Usborne
ABORIGINAL RESERVE
TALBOT BAY
ABORIGINAL RESERVE
Traverse Island
Scaddan Island
Islands
Robinson River
KING SOUND
STOKES BAY
16°30'
17°00'
123°00'
123°30'
124°00'


120°00'
125°00'
Sumba
Sawu
Roti
TIMOR
SAHUL BANK
Hibernia Reef
Sahul Shelf
INDIAN
OCEAN
Ashmore Reef
(Marine National Nature Reserve)
Cartier Island
HOLOTHURIA BANKS
Troughton Island
Cape Londonderry
Seringapatam Reef
Scott Reef
Browse Island
(Prop. Nat. Res.)
KIMBERLEY COASTAL REGION
KALUMBURU
200m
15°00'
15 00'
Beagle Reef
Lynher Reef
Adele Island
(Prop. Nat. Res.)
Note: See Maps II - 2 to II - 6 for recommendations along this portion of coast
Cape Leveque



MAP II-7 OCEANIC CORAL BANKS & ISLANDS

LEGEND

- Approximate area to be considered for reservation
- Bank
- Approximation of the State Territorial Sea
- Approximate boundary of the Continental Shelf
- Existing Marine Park
- Reef

The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991.

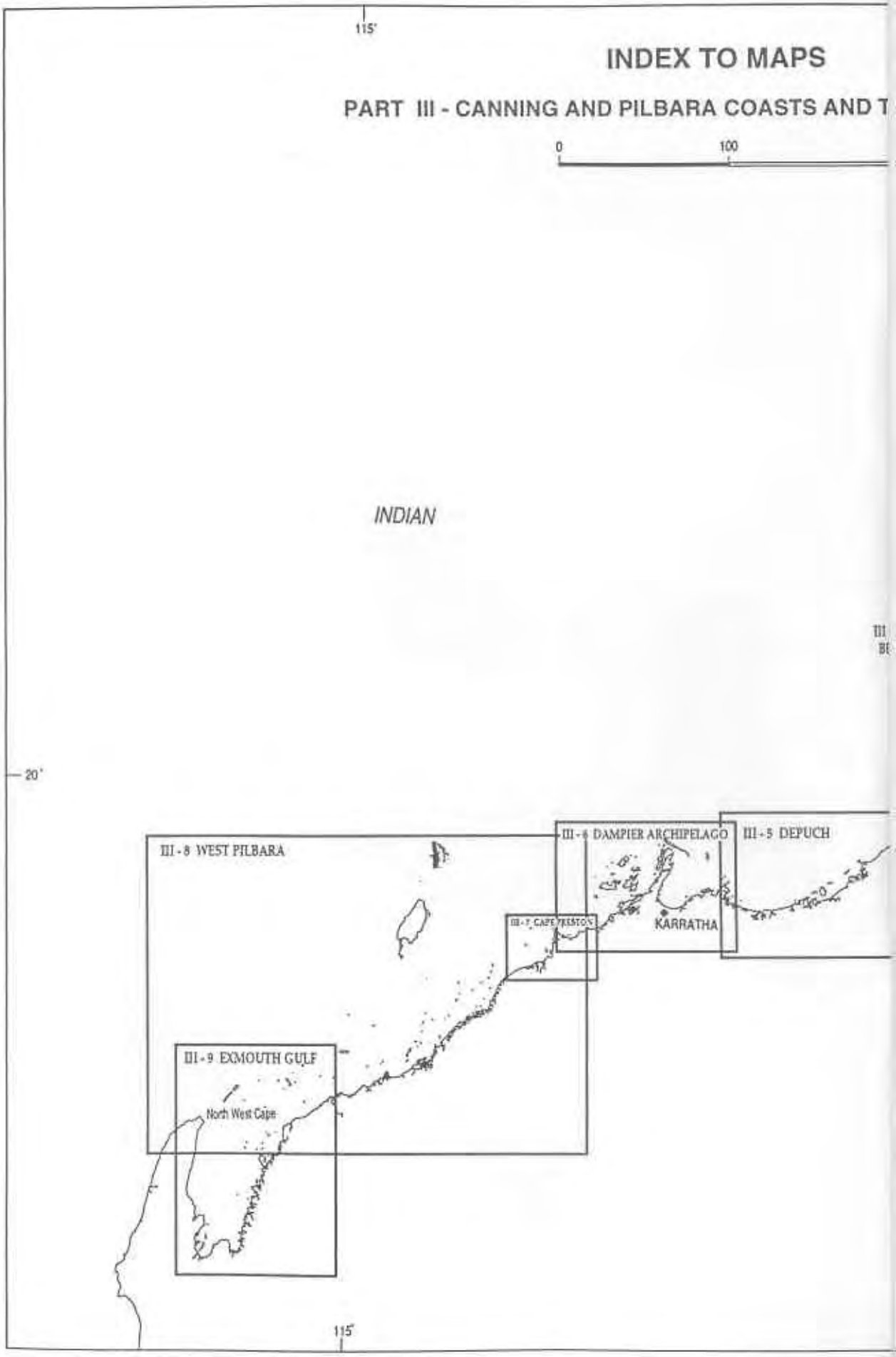
0 50 100 150 200 250 300 km

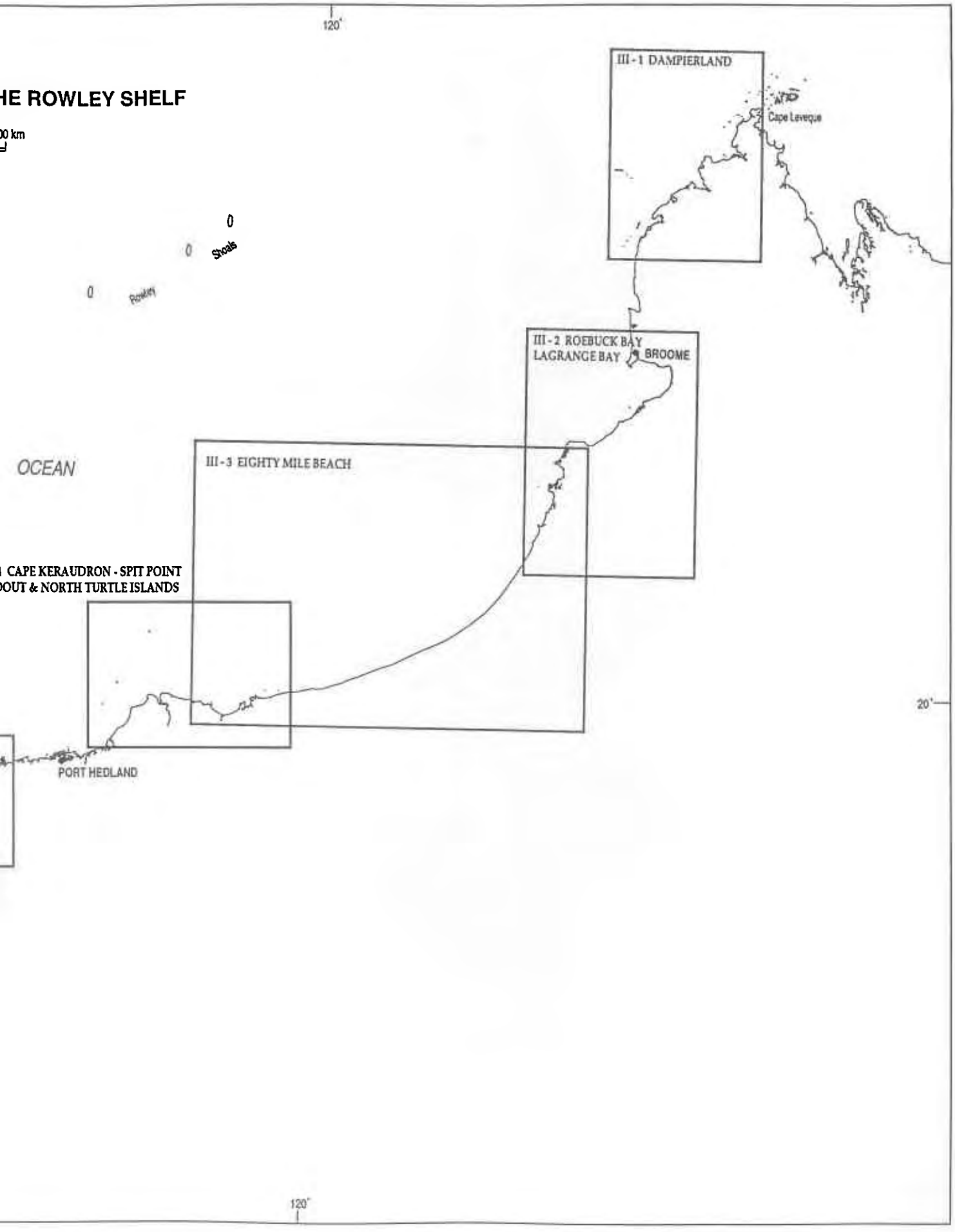
0 50 100 150nm

NOTE : The scale of some of the smaller features of this map have been exaggerated for the purposes of readability.

INDEX TO MAPS

PART III - CANNING AND PILBARA COASTS AND T




120°
HE ROWLEY SHELF
00 km
Shoals
Rowley
III - 1 DAMPIERLAND
Cape Leveque
III - 2 ROEBUCK BAY
LAGRANGE BAY
BROOME
OCEAN
III - 3 EIGHTY MILE BEACH
CAPE KERAUDRON - SPIT POINT
OUT & NORTH TURTLE ISLANDS
PORT HEDLAND
20°
120°

MAP III - 1 DAMPIERLAND

LEGEND

- Approximate area to be considered for reservation
- Approximate boundary of Major Distinctive Coastal Type
- Approximation of the State Territorial Sea
- Proposed Nature Reserve or National Park

The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991

0 10 20 30 km

0 5 10nm

122°00'

122°30'

16°30'

INDIAN

See 3.1 Recommendation 2

Leveque Island

Cape Leveque

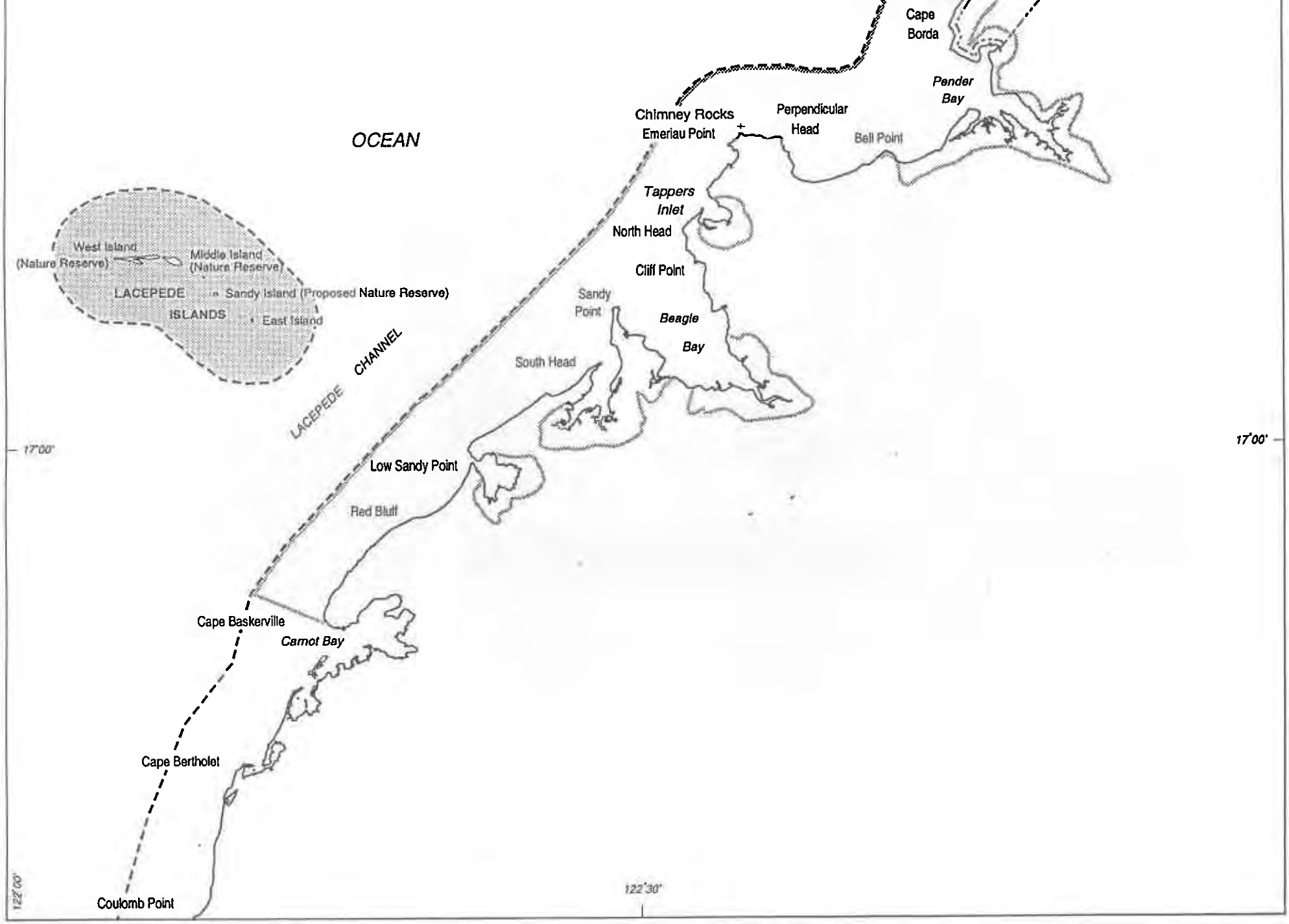
Thomas Bay

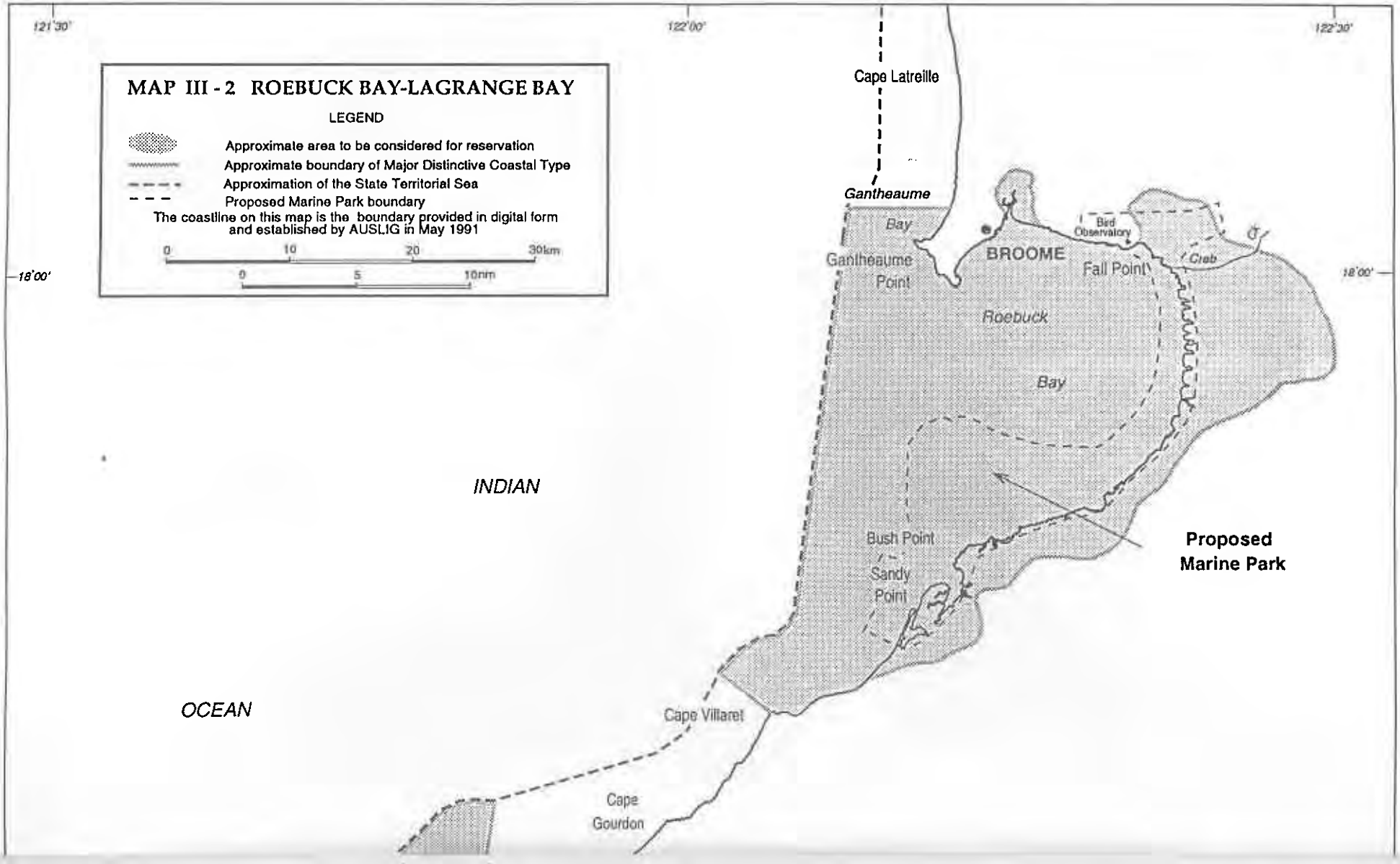
Chili Head

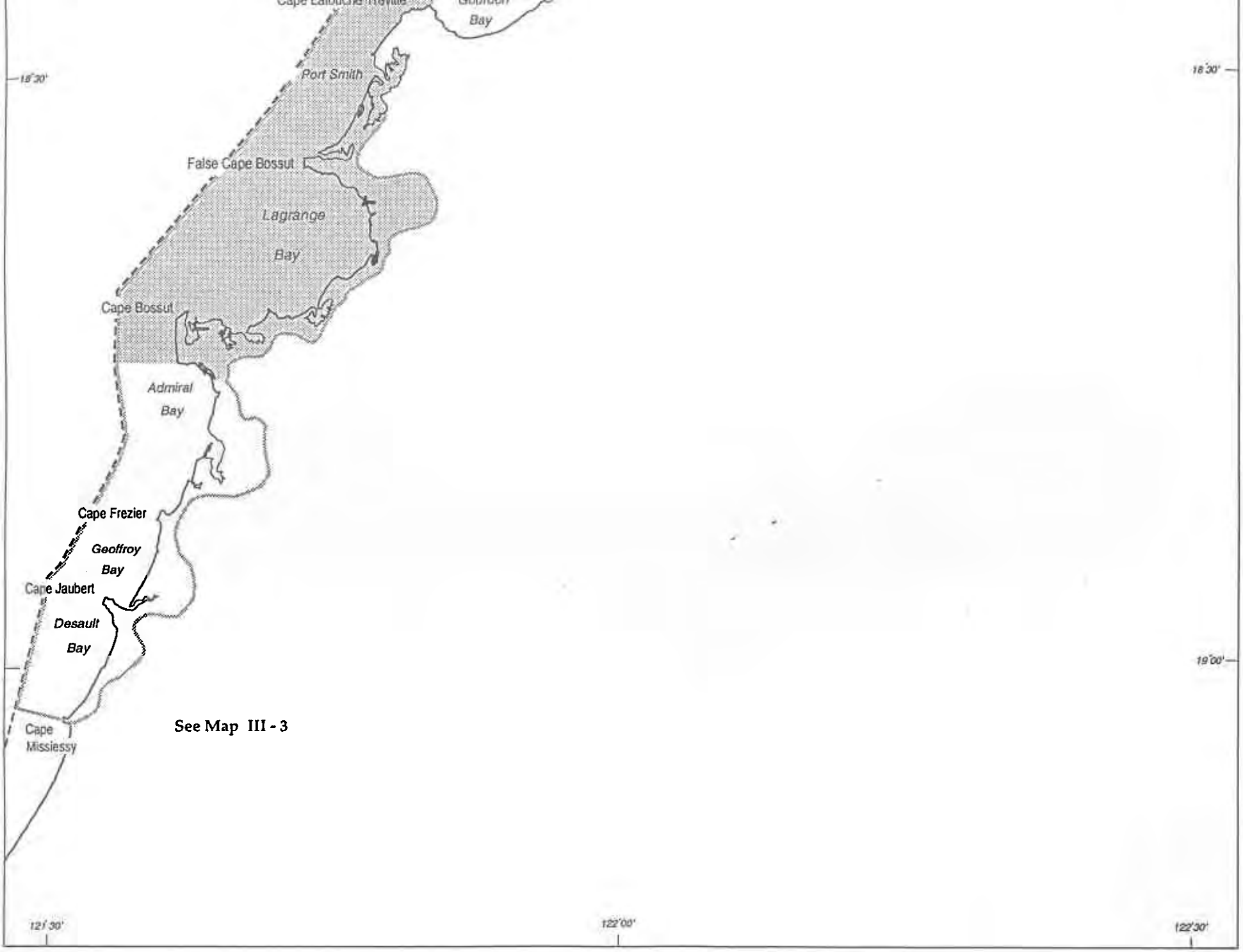
Lombadina Point

Cygnet Bay

Proposed Borda Nature Reserve


Cape
Borda
Pender
Bay
Chimney Rocks
Emeriau Point
Perpendicular
Head
Bell Point
OCEAN
Tappers
Inlet
North Head
West Island
(Nature Reserve)
Middle Island
(Nature Reserve)
LACEPEDE
ISLANDS
Sandy Island (Proposed Nature Reserve)
East Island
Cliff Point
Sandy
Point
Beagle
Bay
South Head
LACEPEDE CHANNEL
17°00'
17°00'
Low Sandy Point
Red Bluff
Cape Baskerville
Camot Bay
Cape Bertholet
Coulomb Point
122°00'
122°30'


MAP III - 2 ROEBUCK BAY-LAGRANGE BAY
LEGEND
Approximate area to be considered for reservation
Approximate boundary of Major Distinctive Coastal Type
Approximation of the State Territorial Sea
Proposed Marine Park boundary
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30km
0 5 10nm
121°30'
122°00'
122°30'
18°00'
Cape Latreille
Gantheaume Bay
Gantheaume Point
BROOME
Bird Observatory
Fall Point
Crab
Roebuck Bay
INDIAN OCEAN
Bush Point
Sandy Point
Proposed Marine Park
Cape Villaret
Cape Gourdon


Cape Latouche Treville
Gibbon Bay
18°30'
Port Smith
False Cape Bossut
Lagrange Bay
Cape Bossut
Admiral Bay
Cape Frezier
Geoffroy Bay
Cape Jaubert
Desault Bay
Cape Missiessy
See Map III - 3
19°00'
121°30'
122°00'
122°30'

MAP III - 3 EIGHTY MILE BEACH

LEGEND

Approximate area to be considered for reservation

Approximate boundary of Major Distinctive Coastal Type

Approximation of the State Territorial Sea

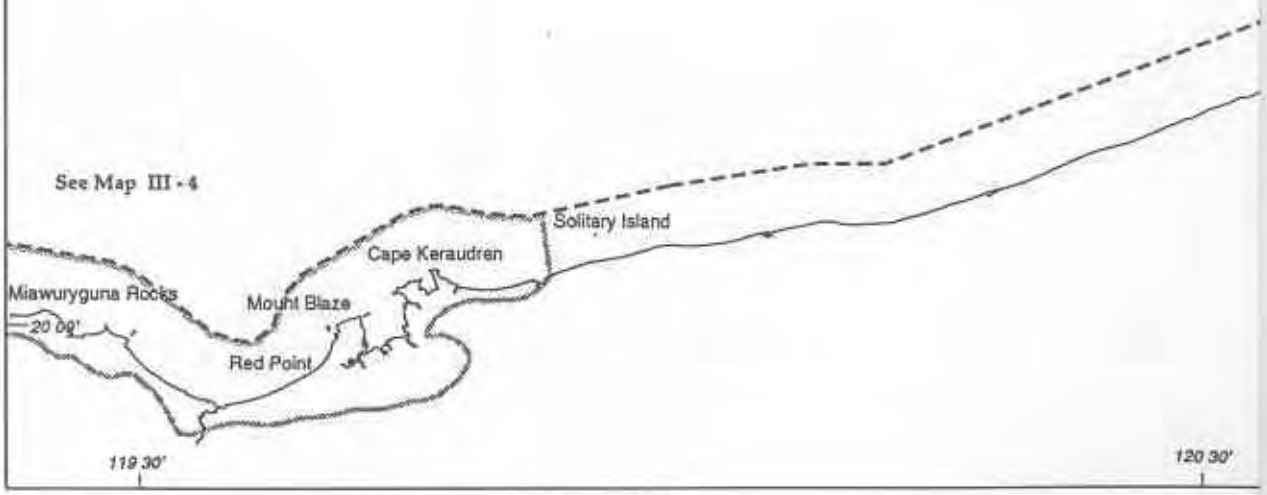
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991

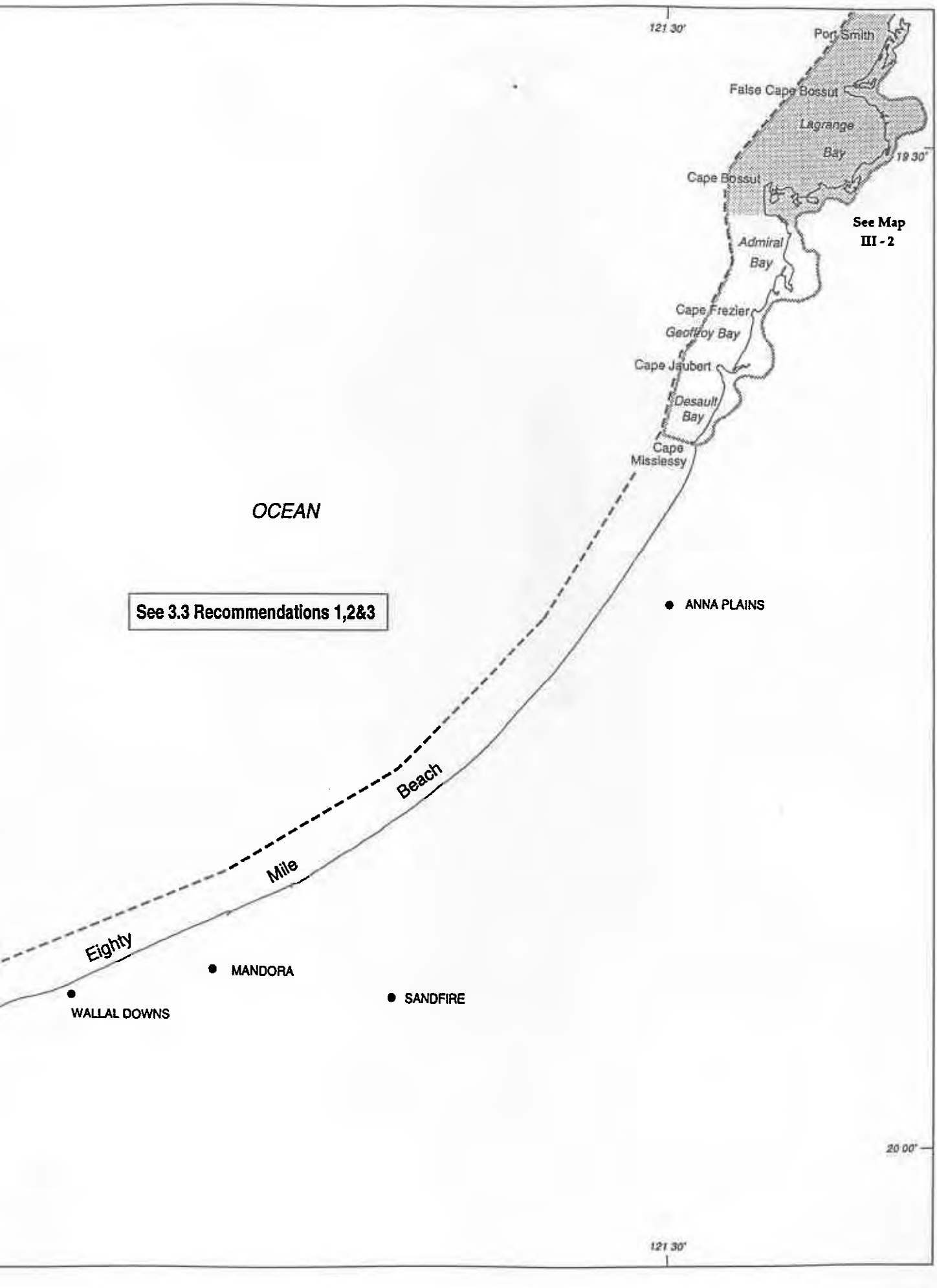
0 20 40 60 km

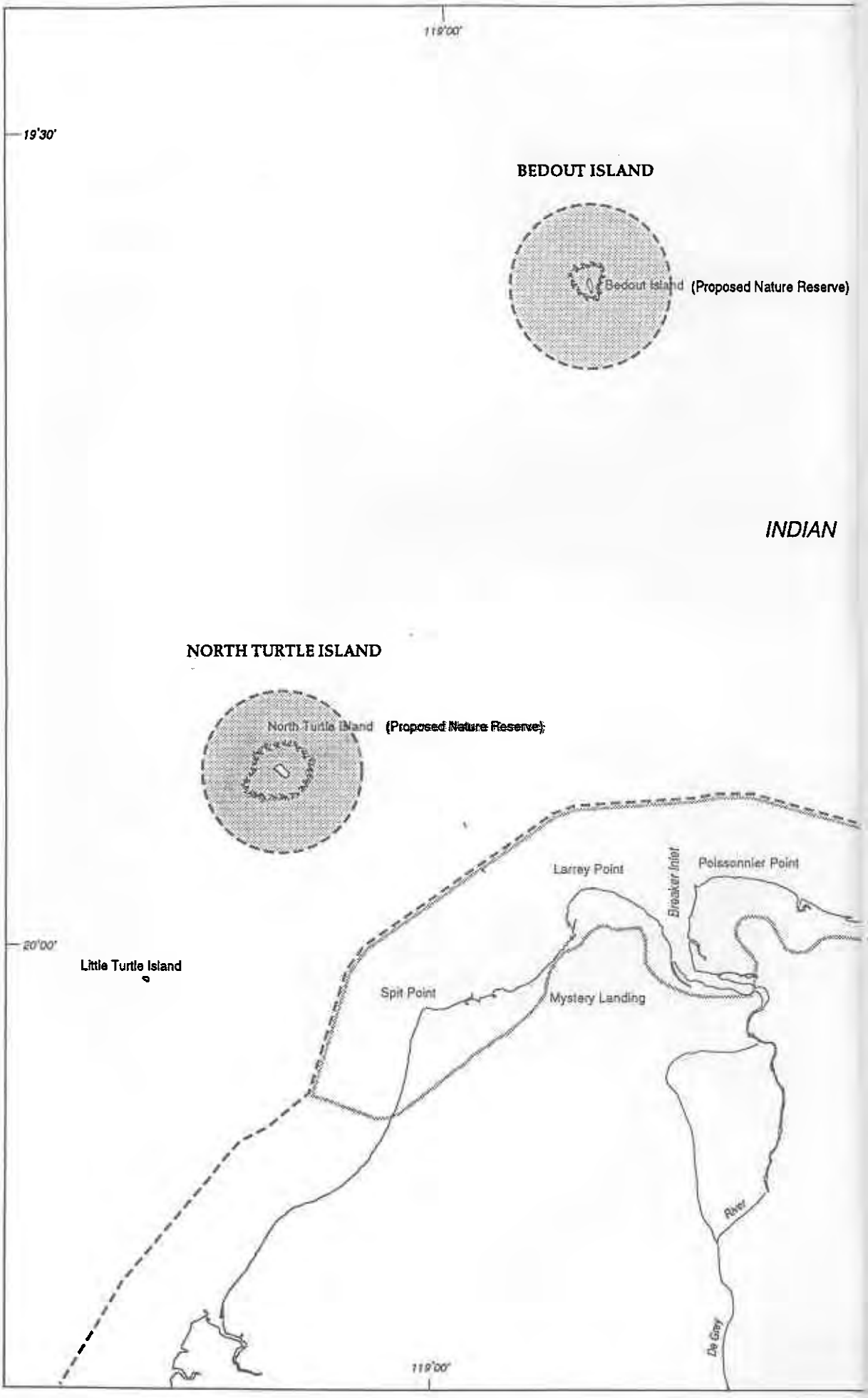
0 10 20 nm

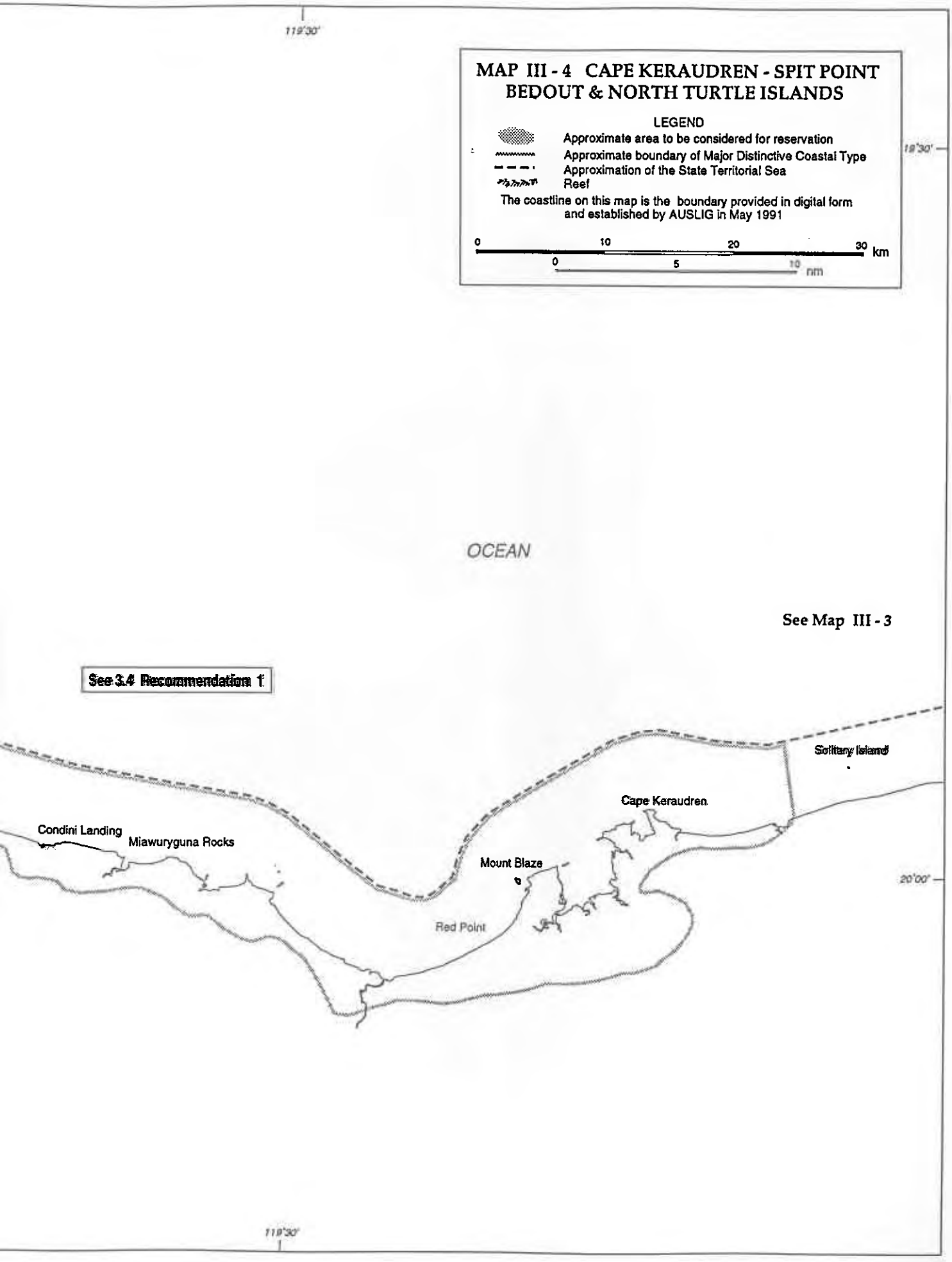
120 30'

INDIAN




121 30'
Port Smith
False Cape Bossut
Lagrange
Bay
19 30'
Cape Bossut
See Map
III - 2
Admiral
Bay
Cape Frezier
Geoffroy Bay
Cape Jaubert
Desault
Bay
Cape
Misslessy
OCEAN
See 3.3 Recommendations 1,2&3
ANNA PLAINS
Beach
Mile
Eighty
MANDORA
SANDFIRE
WALLAL DOWNS
20 00'
121 30'


119°00'
19°30'
BEDOUT ISLAND
Bedout Island (Proposed Nature Reserve)
INDIAN
NORTH TURTLE ISLAND
North Turtle Island (Proposed Nature Reserve)
Larrey Point
Breaker Inlet
Poissonnier Point
20°00'
Little Turtle Island
Spit Point
Mystery Landing
River
De Grey
119°00'


119°30'
MAP III - 4 CAPE KERAUDREN - SPIT POINT
BEDOUT & NORTH TURTLE ISLANDS
LEGEND
Approximate area to be considered for reservation
Approximate boundary of Major Distinctive Coastal Type
Approximation of the State Territorial Sea
Reef
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 km
0 5 10 nm
18°30'
OCEAN
See Map III - 3
See 3.4 Recommendation 1
Solitary Island
Cape Keraudren
Condini Landing
Miawuryguna Rocks
Mount Blaze
20°00'
Red Point
119°30'

MAP III - 5 DEPUCH

LEGEND

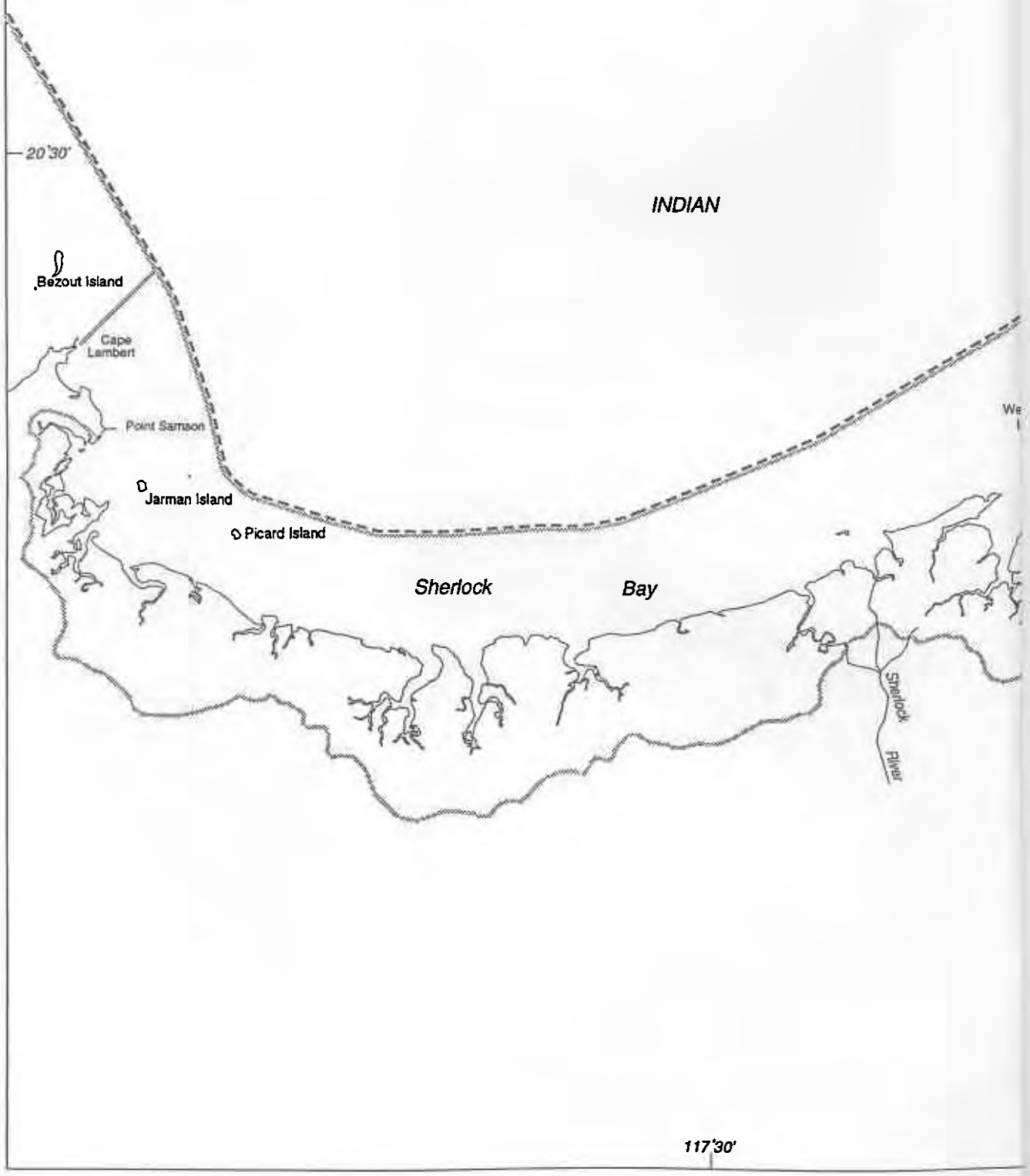
Approximate area to be considered for reservation
Area of Major Distinctive Coastal Type
Approximation of the State Territorial Sea

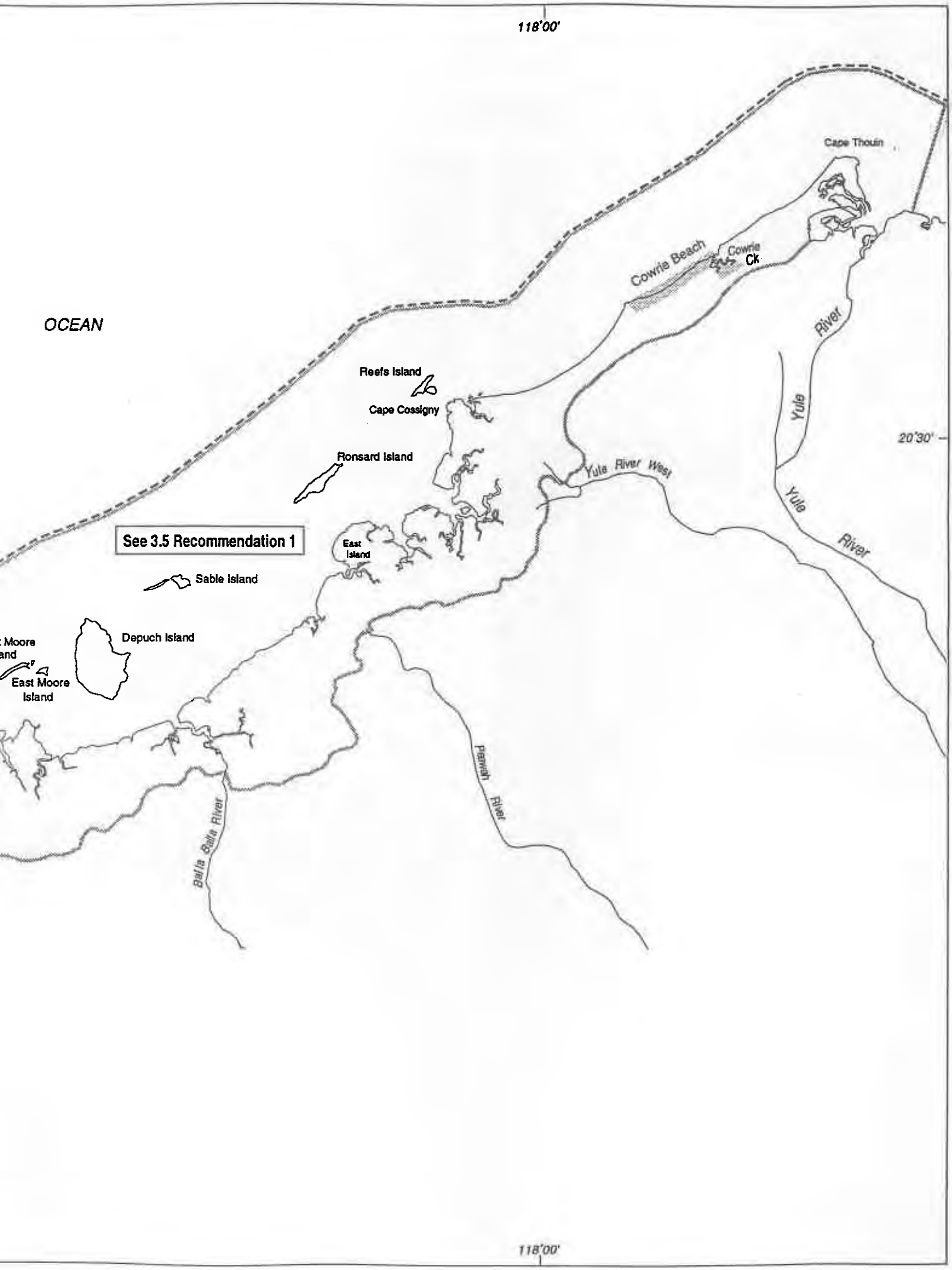
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991

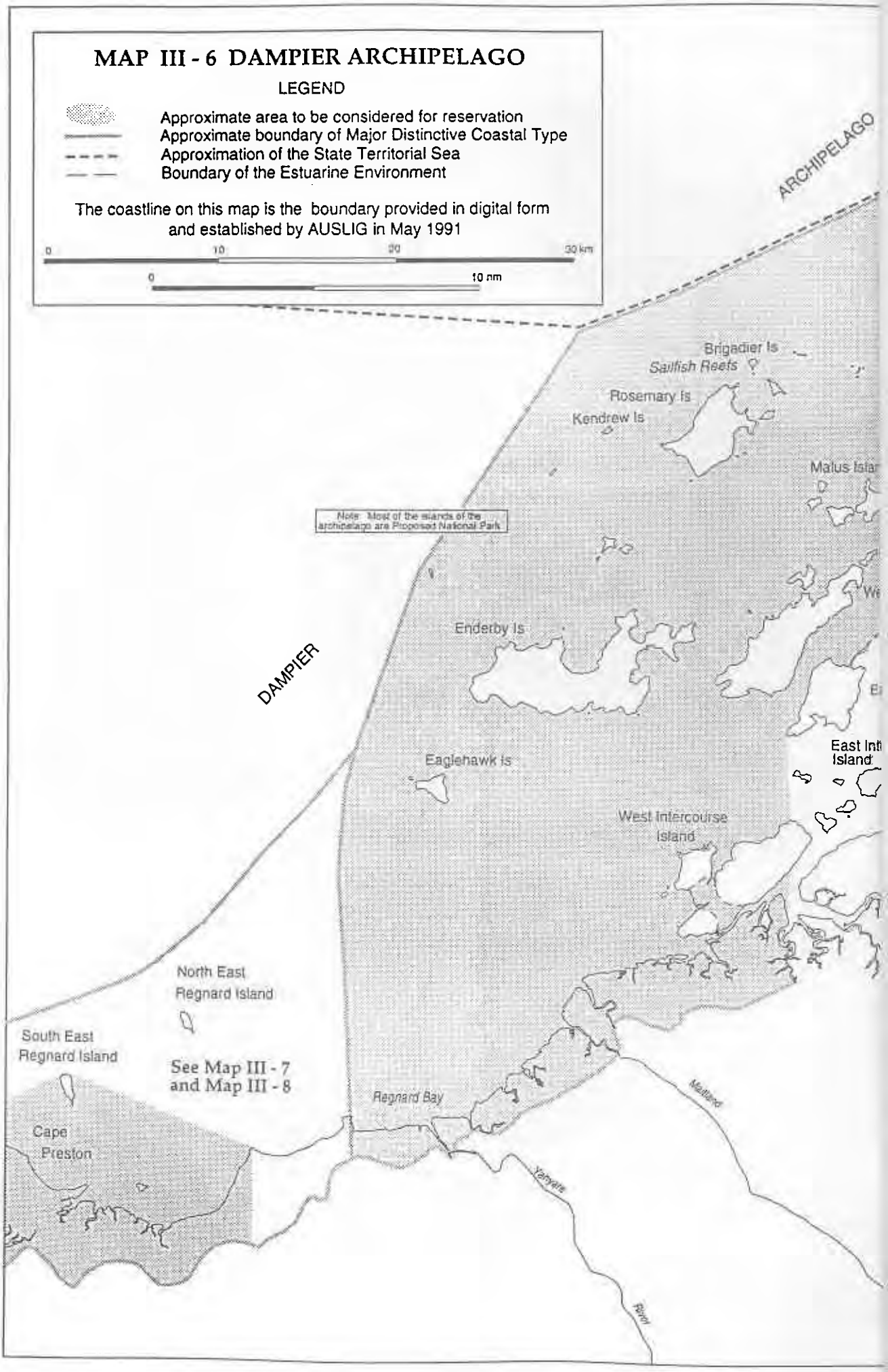
0 5 10 15 20 km

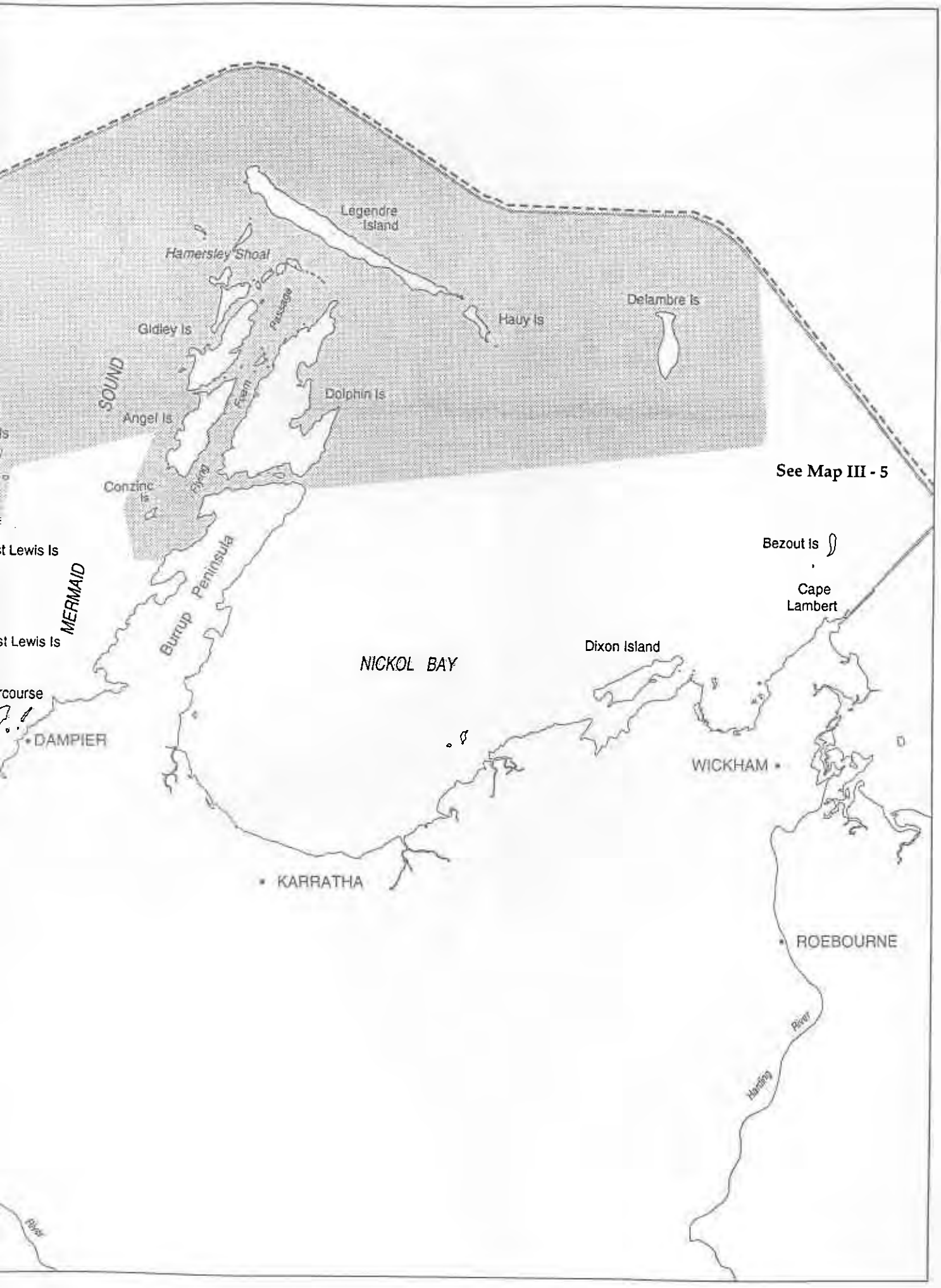
0 5 10 15 nm

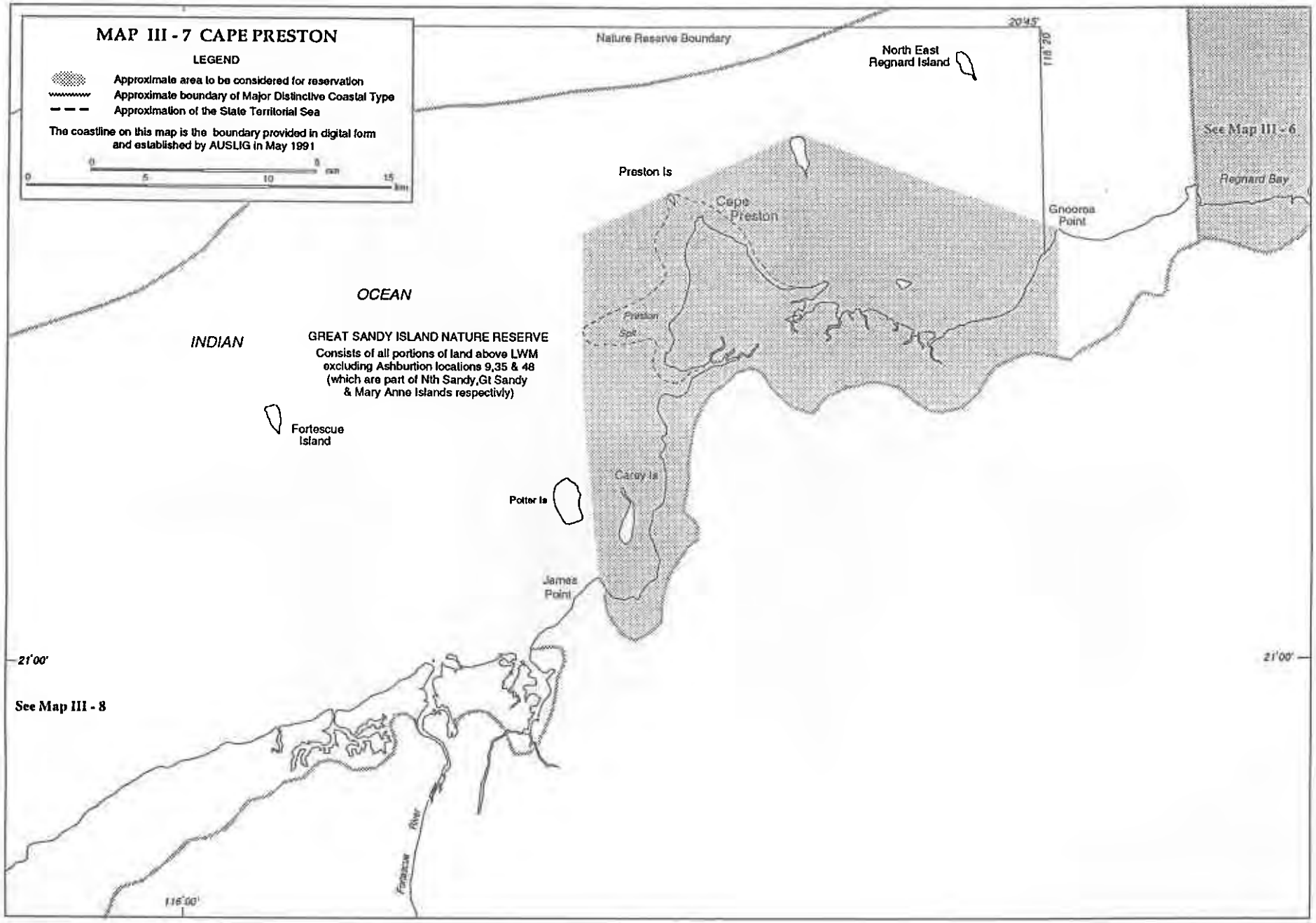
See Map III - 6




118°00'
Cape Thouin
Cowrie Beach
Cowrie Ck
OCEAN
Reefs Island
Cape Cossigny
Ronsard Island
Yule River
Yule River West
20°30'
See 3.5 Recommendation 1
East Island
Sable Island
Depuch Island
East Moore Island
Balla Balla River
Pilawah River
118°00'


MAP III - 6 DAMPIER ARCHIPELAGO
LEGEND
Approximate area to be considered for reservation
Approximate boundary of Major Distinctive Coastal Type
Approximation of the State Territorial Sea
Boundary of the Estuarine Environment
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 km
0 10 nm
ARCHIPELAGO
Brigadier Is
Sailfish Reefs
Rosemary Is
Kendrew Is
Malus Islar
Note: Most of the islands of the archipelago are Proposed National Park
Enderby Is
DAMPIER
Eaglehawk Is
East Int Island
West Intercourse Island
North East Regnard Island
South East Regnard Island
See Map III - 7 and Map III - 8
Regnard Bay
Cape Preston
Maitland
Yanyare
River


Legendre Island
Hamersley Shoal
Passage
Gidley Is
Hauy Is
Delambre Is
SOUND
Angel Is
Dolphin Is
Conzinc Is
See Map III - 5
Bezout Is
Cape Lambert
t Lewis Is
MERMAID
Burrup Peninsula
Dixon Island
NICKOL BAY
rcourse
DAMPIER
WICKHAM
KARRATHA
ROEBOURNE
River
Harding River


MAP III - 7 CAPE PRESTON
LEGEND
Approximate area to be considered for reservation
Approximate boundary of Major Distinctive Coastal Type
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 5 nm
0 5 10 15 km
Nature Reserve Boundary
20°45'
116°30'
North East Regnard Island
See Map III - 6
Regnard Bay
Preston Is
Cape Preston
Gnoorea Point
OCEAN
INDIAN
Preston Spit
GREAT SANDY ISLAND NATURE RESERVE
Consists of all portions of land above LWM excluding Ashburton locations 9,35 & 48 (which are part of Nth Sandy,Gt Sandy & Mary Anne Islands respectivly)
Fortescue Island
Carey Is
Potter Is
James Point
21°00'
See Map III - 8
Fortescue River
116°00'

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MAP III - 8 WEST PILBARA

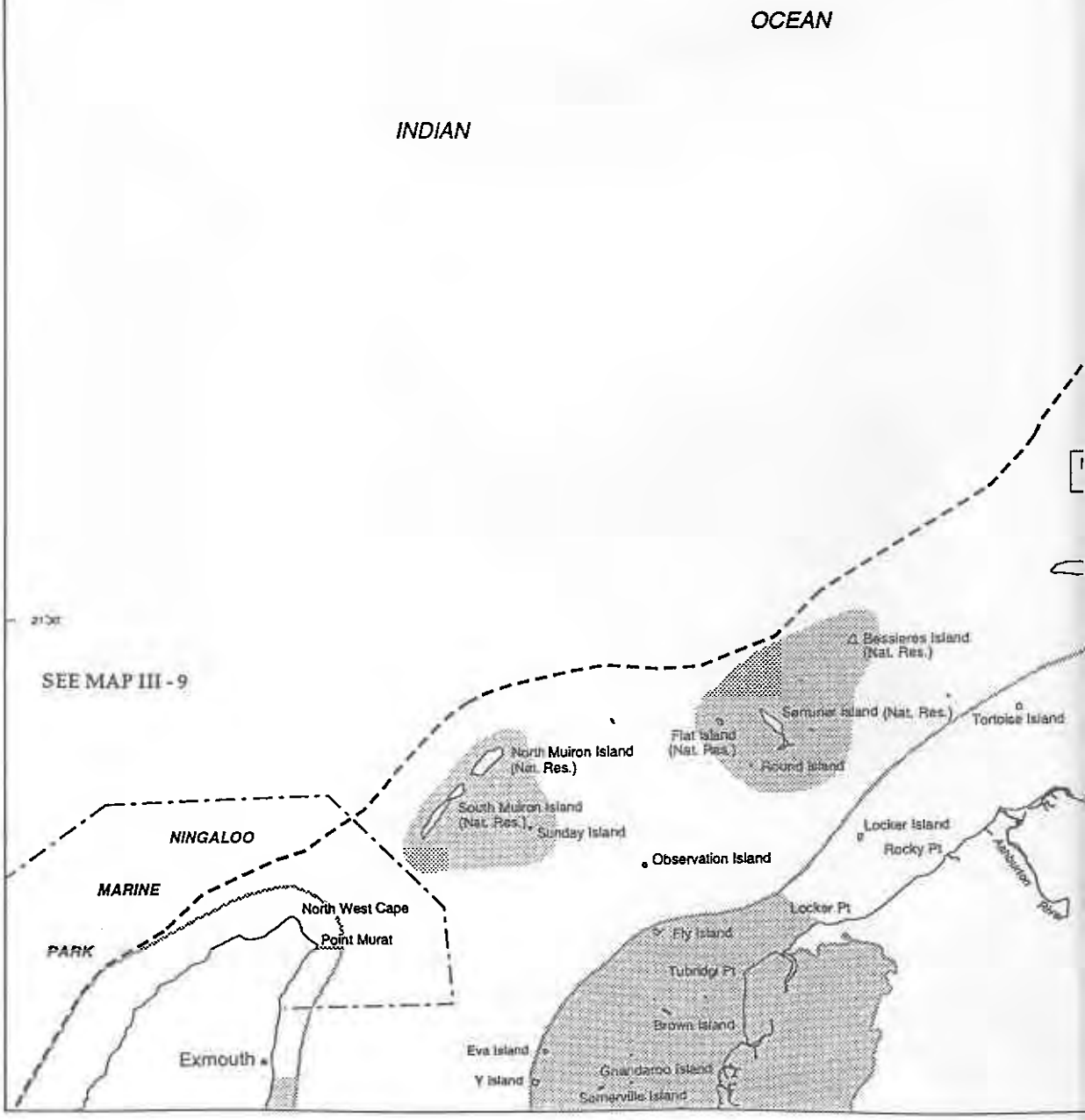
LEGEND

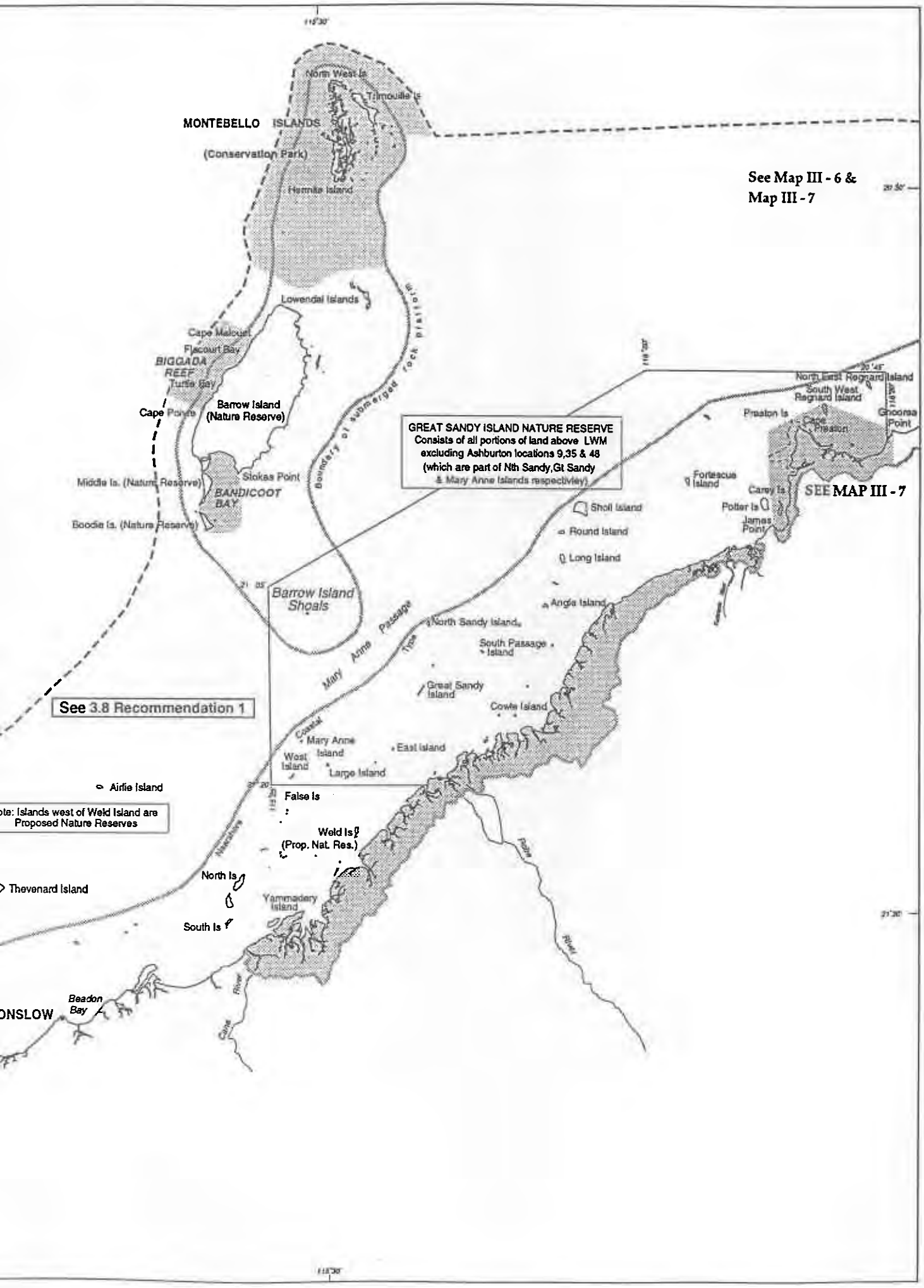
Approximate area to be considered for reservation
Approximate boundary of Major Distinctive Coastal Type
Approximation of the State Territorial Sea
Existing Marine Park Boundary

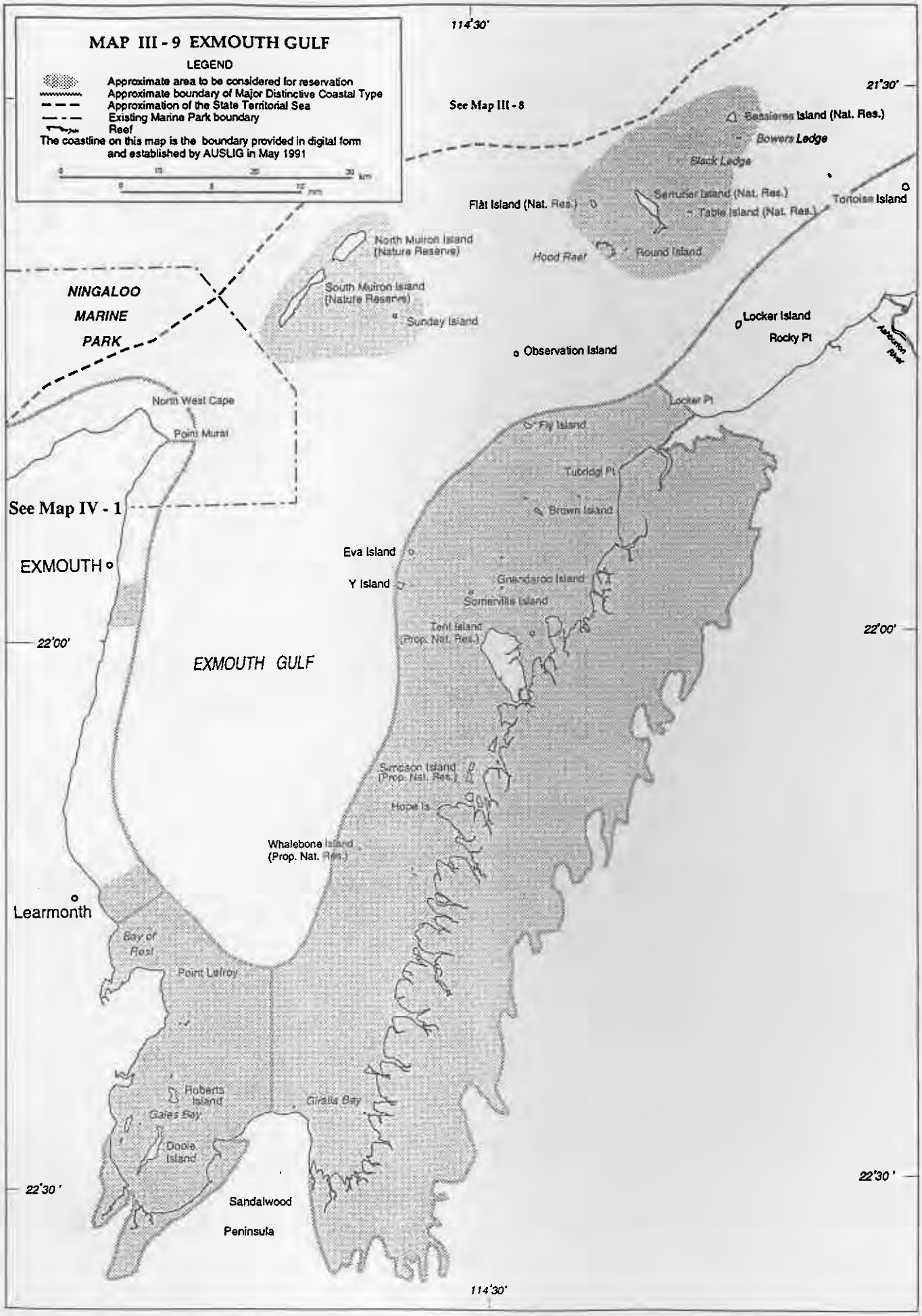
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991

0 20 40 60 km

0 10 20 nm




MONTEBELLO ISLANDS
(Conservation Park)
North West Is
Trimouille Is
Hermite Island
Lowendal Islands
Cape Malouet
Flacourt Bay
BIGGADA REEF
Turtle Bay
Cape Poivre
Barrow Island (Nature Reserve)
Middle Is. (Nature Reserve)
Stokes Point
BANDICOOT BAY
Boodie Is. (Nature Reserve)
Boundary of submerged rock platform
Barrow Island Shoals
Mary Anne Passage
Coastal
Mary Anne Island
West Island
Large Island
East Island
Airlie Island
Note: Islands west of Weld Island are Proposed Nature Reserves
False Is
Weld Is (Prop. Nat. Res.)
North Is
South Is
Yammadery Island
Thevenard Island
ONSLOW
Beadon Bay
Ashburton River
Cane River
Fortescue River
GREAT SANDY ISLAND NATURE RESERVE
Consists of all portions of land above LWM excluding Ashburton locations 9,35 & 48 (which are part of Nth Sandy, Gt Sandy & Mary Anne Islands respectivley)
Sholl Island
Round Island
Long Island
Angle Island
North Sandy Island
South Passage Island
Great Sandy Island
Cowle Island
North East Regnard Island
South West Regnard Island
Preston Is
Cape Preston
Groomsa Point
Forteacue Island
Carey Is
Potter Is
James Point
SEE MAP III - 7
See Map III - 6 & Map III - 7
See 3.8 Recommendation 1


MAP III - 9 EXMOUTH GULF
LEGEND
Approximate area to be considered for reservation
Approximate boundary of Major Distinctive Coastal Type
Approximation of the State Territorial Sea
Existing Marine Park boundary
Reef
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
114°30'
21°30'
See Map III - 8
Bessieres Island (Nat. Res.)
Bowers Ledge
Black Ledge
Flat Island (Nat. Res.)
Samuel Island (Nat. Res.)
Table Island (Nat. Res.)
Tortoise Island
North Muiron Island (Nature Reserve)
Hood Reef
Round Island
South Muiron Island (Nature Reserve)
Sunday Island
NINGALOO MARINE PARK
Observation Island
Locker Island
Rocky Pt
Ashburton River
North West Cape
Point Murat
Locker Pt
Fly Island
Tubbdgi Pt
Brown Island
See Map IV - 1
EXMOUTH
Eva Island
Y Island
Gnandaroo Island
Somerville Island
22°00'
Tent Island (Prop. Nat. Res.)
EXMOUTH GULF
Simpson Island (Prop. Nat. Res.)
Hope Is.
Whalebone Island (Prop. Nat. Res.)
Learmonth
Bay of Rest
Point Lefroy
Roberts Island
Gales Bay
Giralia Bay
Doole Island
22°30'
Sandalwood Peninsula
114°30'

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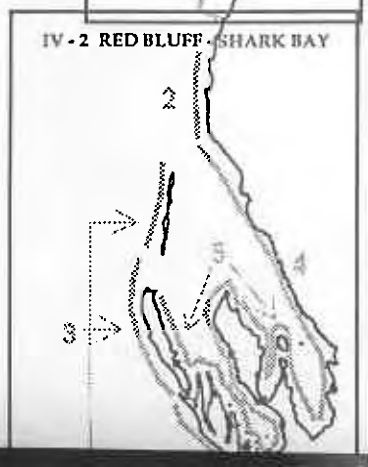
INDEX TO MAPS
PART IV - WEST COAST REGION

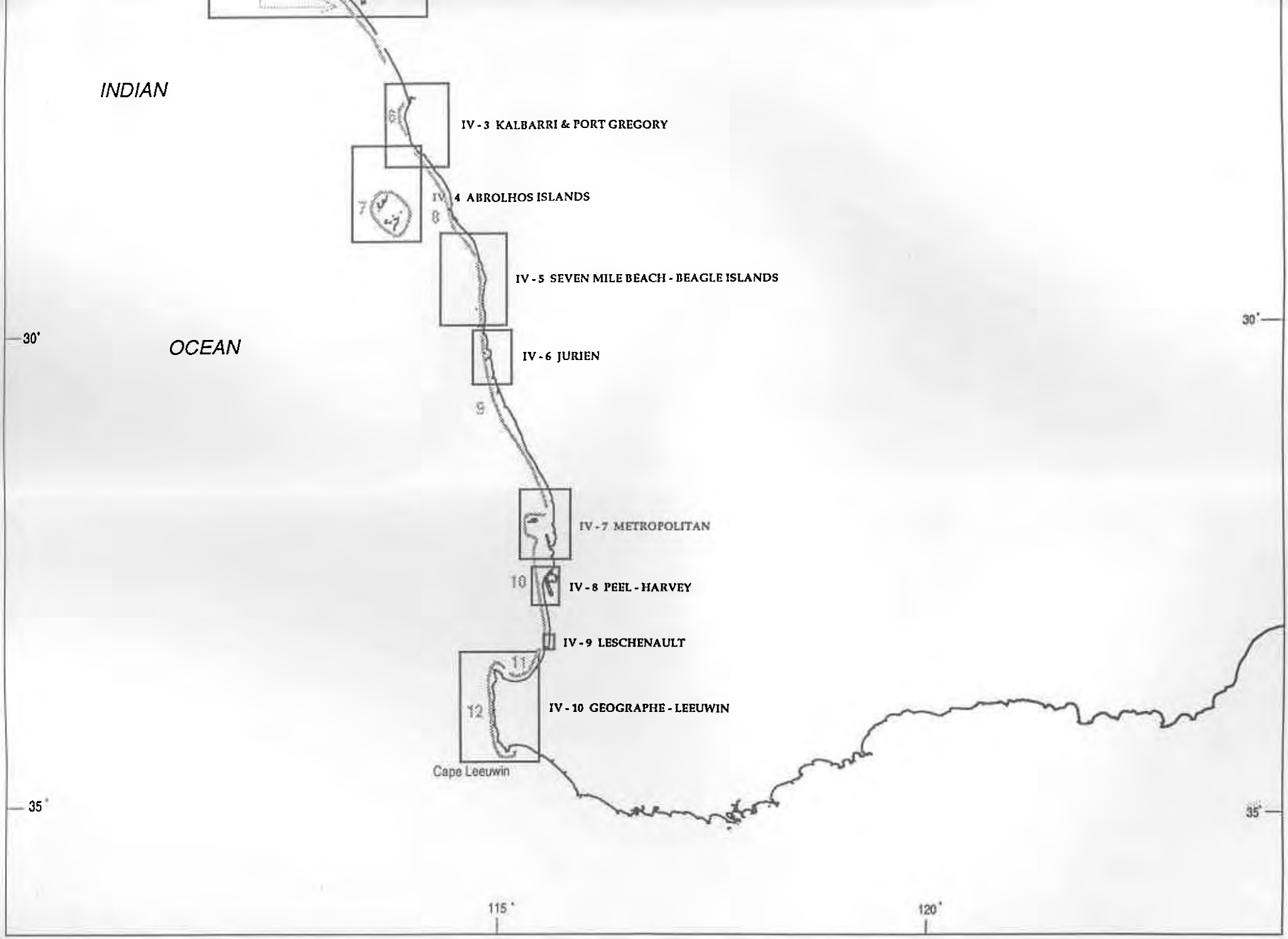
ALSO SHOWING
MAJOR DISTINCTIVE COASTAL TYPES

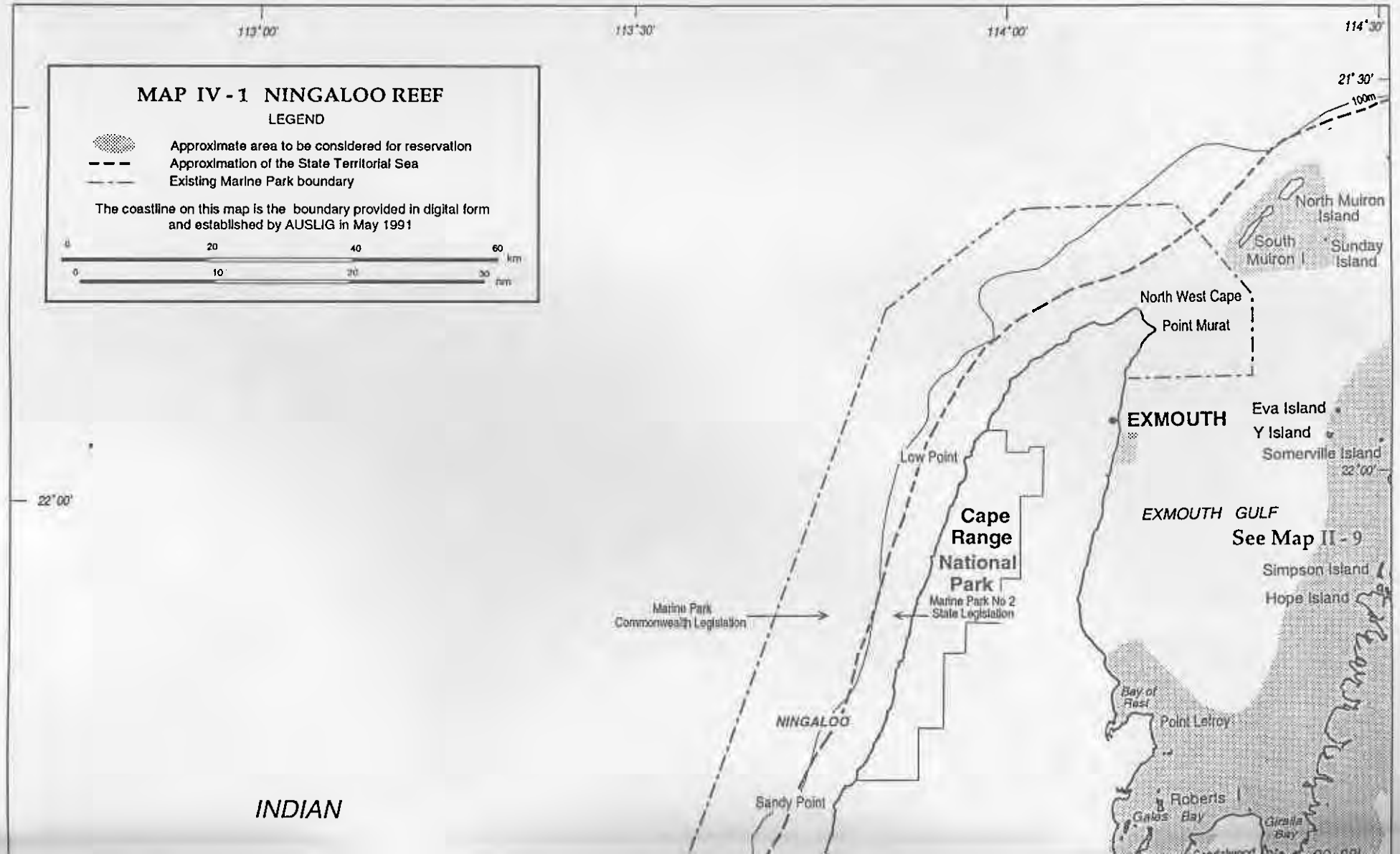
115°
120°
20°
25°
0 100 200 300 km

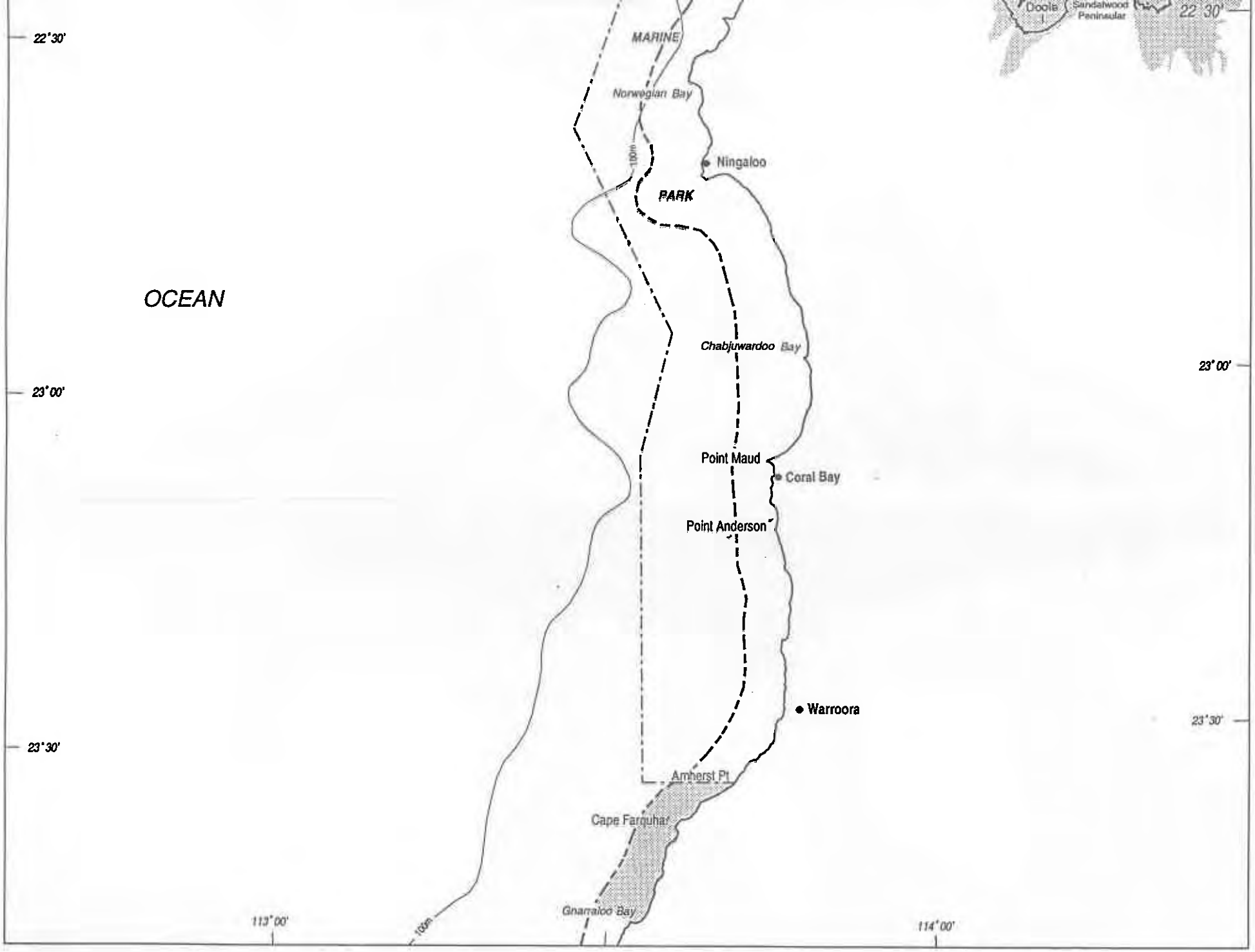


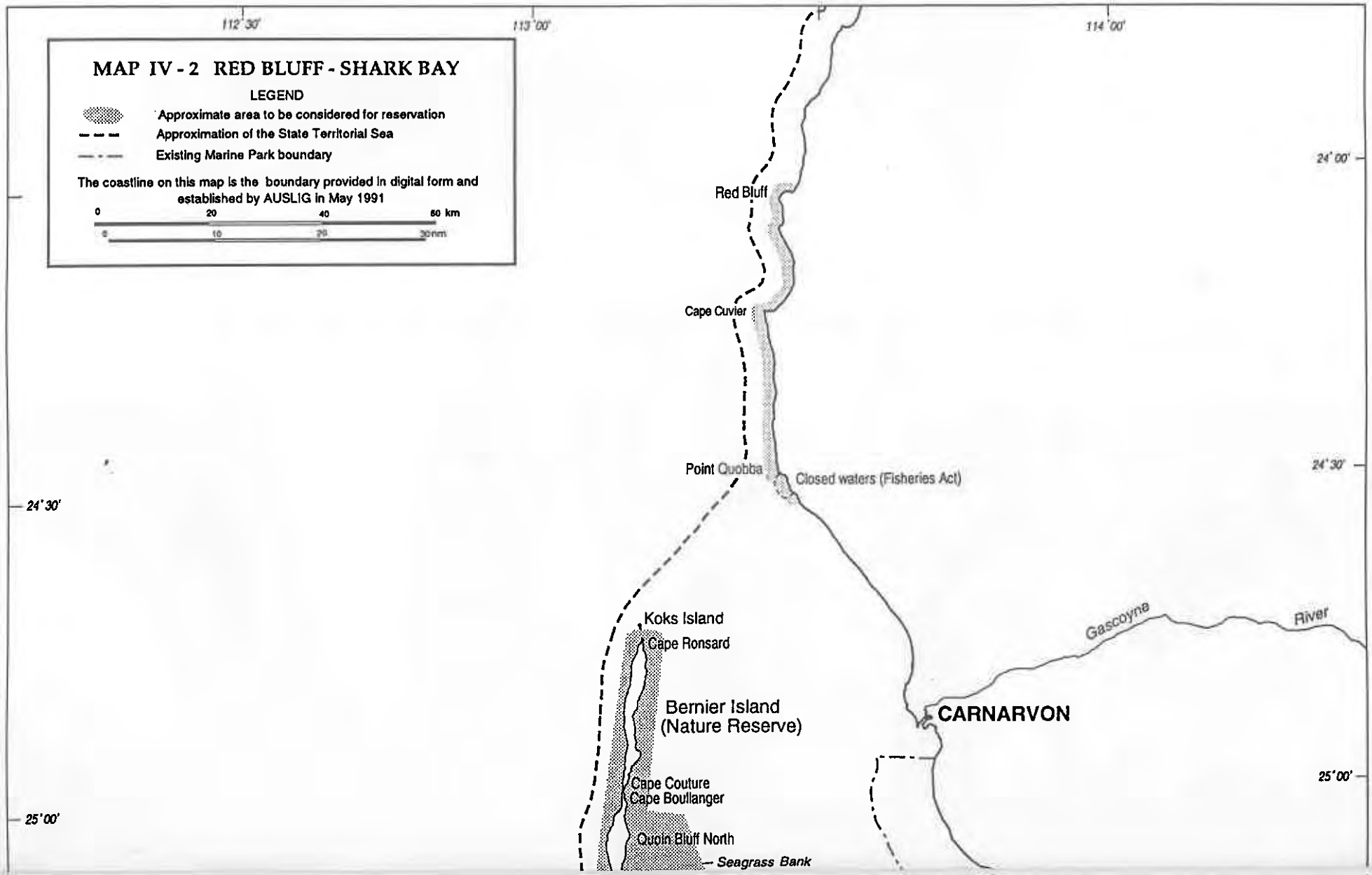
MAJOR DISTINCTIVE COASTAL TYPES

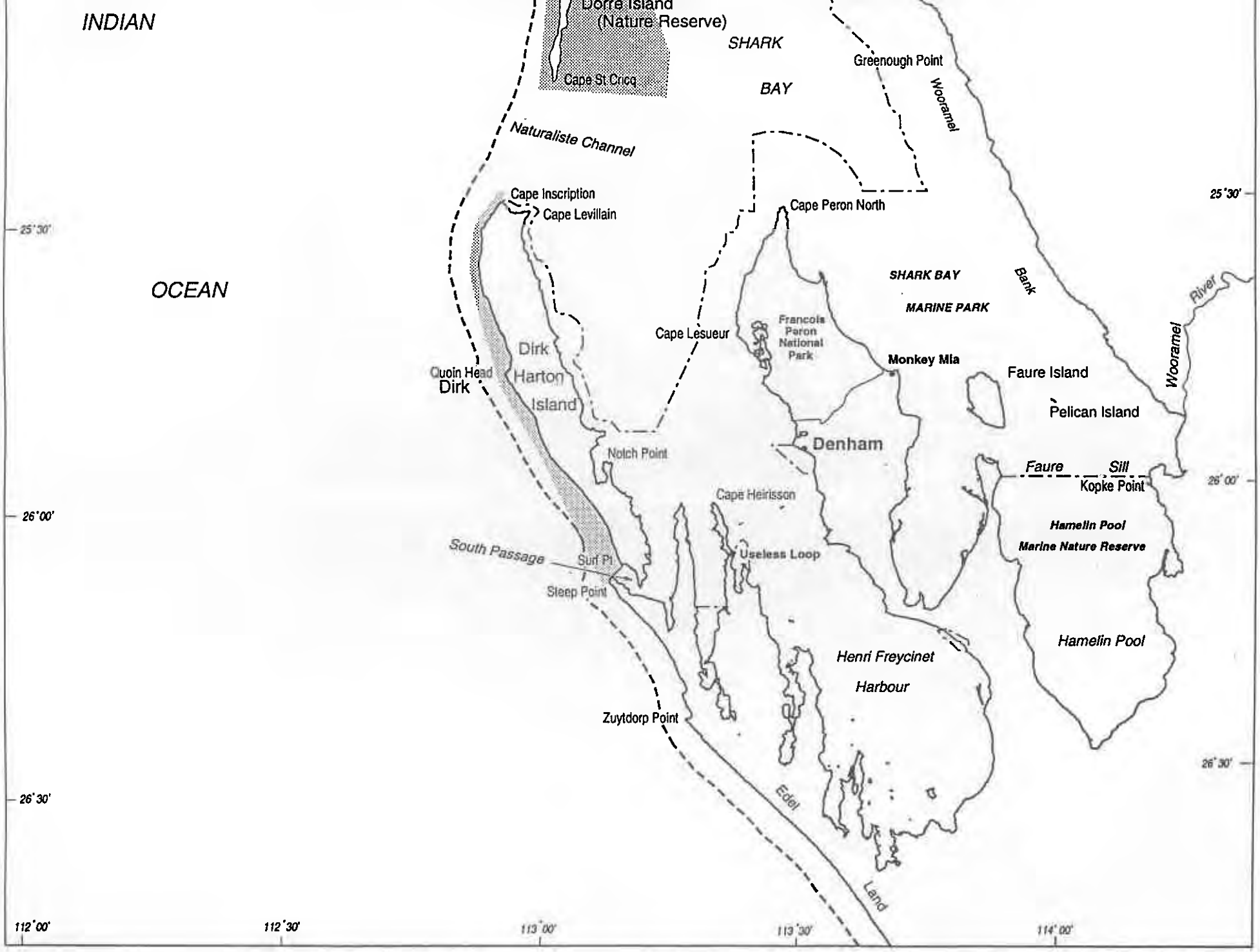
1 Ningaloo Reef
2 Red Bluff to Point Quobba
3 Western shores of the Shark Bay outer islands and Edel Land Peninsula (Zuytdorp Cliffs)
4 Eastern shores of Shark Bay - Hamelin Pool
5 Inner inlets &peninsulars of Shark Bay-Hamelin Pool
6 Kalbarri
7 Abrolhos
8 Kalbarri to Port Denison
9 Port Denison to Whitfords
10 Whitfords to Bunbury
11 Geographe Bay
12 The Naturaliste -Leeuwin Ridge

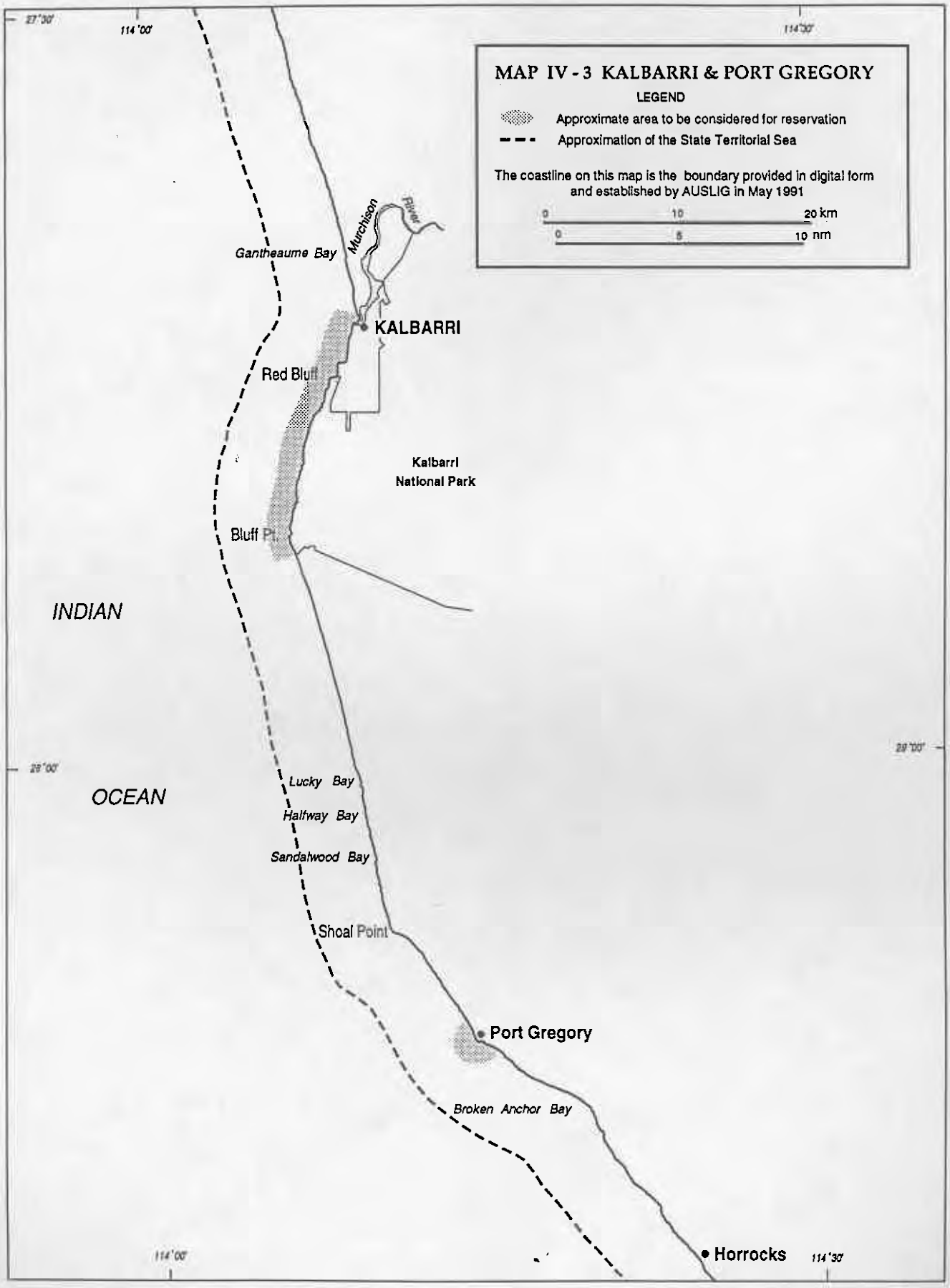

INDIAN
OCEAN
IV - 3 KALBARRI & PORT GREGORY
IV - 4 ABROLHOS ISLANDS
IV - 5 SEVEN MILE BEACH - BEAGLE ISLANDS
IV - 6 JURIEN
IV - 7 METROPOLITAN
IV - 8 PEEL - HARVEY
IV - 9 LESCHENAULT
IV - 10 GEOGRAPHE - LEEUWIN
Cape Leeuwin
30°
35°
115°
120°


MAP IV - 1 NINGALOO REEF
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
Existing Marine Park boundary
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 20 40 60 km
0 10 20 30 nm
113°00'
113°30'
114°00'
114°30'
21°30'
22°00'
100m
North Muiron Island
South Muiron I
Sunday Island
North West Cape
Point Murat
EXMOUTH
Eva Island
Y Island
Somerville Island
Low Point
Cape Range National Park
Marine Park No 2 State Legislation
Marine Park Commonwealth Legislation
EXMOUTH GULF
See Map II - 9
Simpson Island
Hope Island
NINGALOO
Bay of Rest
Point Lefroy
Sandy Point
Roberts
Gales Bay
Giralia Bay
INDIAN


Doole
Sandalwood Peninsular
22°30'
MARINE
Norwegian Bay
100m
Ningaloo
PARK
OCEAN
Chabluwardoo Bay
23°00'
Point Maud
Coral Bay
Point Anderson
Warroora
23°30'
Amherst Pt
Cape Farquhar
Gnaraloo Bay
113°00'
114°00'


MAP IV - 2 RED BLUFF - SHARK BAY
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
Existing Marine Park boundary
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 20 40 60 km
0 10 20 30nm
112°30'
113°00'
114°00'
24°00'
24°30'
25°00'
Red Bluff
Cape Cuvier
Point Quobba
Closed waters (Fisheries Act)
Koks Island
Cape Ronsard
Bernier Island
(Nature Reserve)
Cape Couture
Cape Boullanger
Quoin Bluff North
Seagrass Bank
Gascoyne River
CARNARVON


INDIAN
OCEAN
Dorre Island
(Nature Reserve)
Cape St Cricq
SHARK
BAY
Greenough Point
Wooramel
Naturaliste Channel
Cape Inscription
Cape Levillain
Cape Peron North
25°30'
SHARK BAY
MARINE PARK
Bank
River
Wooramel
Francois
Peron
National
Park
Cape Lesueur
Monkey Mia
Faure Island
Pelican Island
Dirk
Harton
Island
Quoin Head
Dirk
Denham
Notch Point
Faure
Sill
Kopke Point
26°00'
Cape Heirisson
Hamelin Pool
Marine Nature Reserve
South Passage
Surf Pt
Useless Loop
Steep Point
Hamelin Pool
Henri Freycinet
Harbour
Zuytdorp Point
Edel
Land
26°30'
112°00'
112°30'
113°00'
113°30'
114°00'


MAP IV - 3 KALBARRI & PORT GREGORY
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 km
0 5 10 nm
27°00'
114°00'
114°30'
Gantheaume Bay
Murchison River
KALBARRI
Red Bluff
Kalbarri National Park
Bluff Pt.
INDIAN
OCEAN
29°00'
Lucky Bay
Halfway Bay
Sandalwood Bay
Shoal Point
Port Gregory
Broken Anchor Bay
Horrocks
114°00'
114°30'

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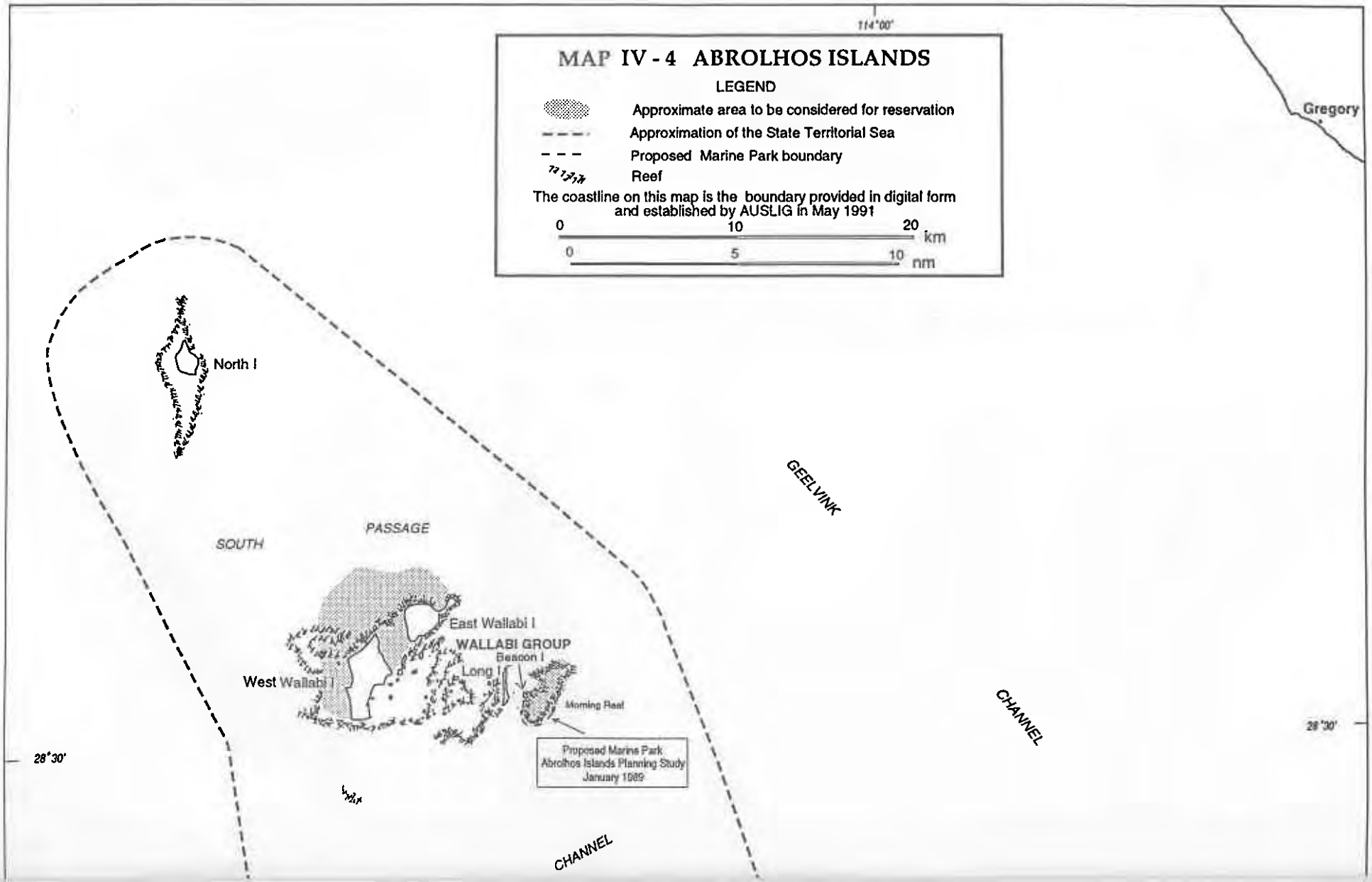
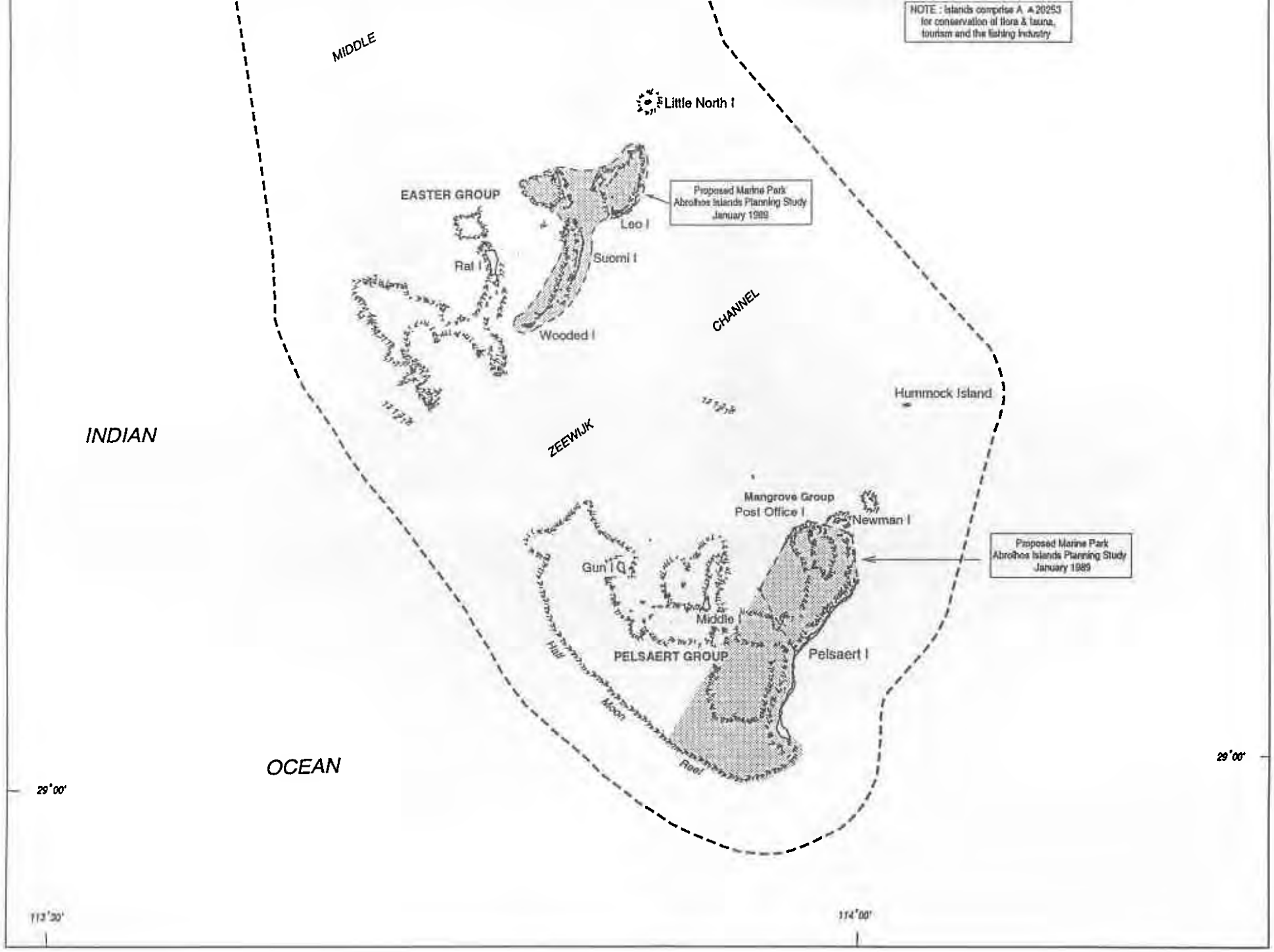
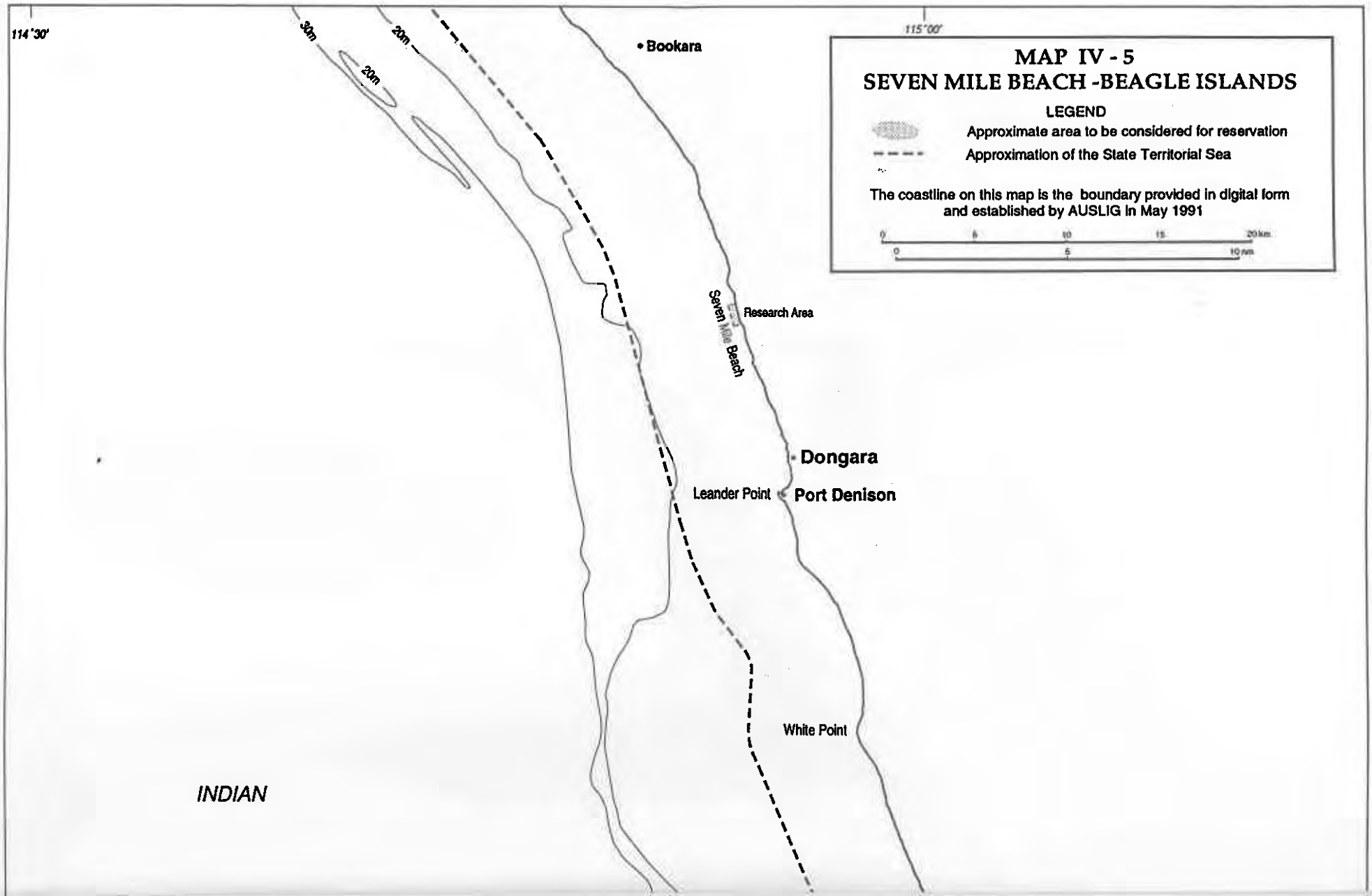
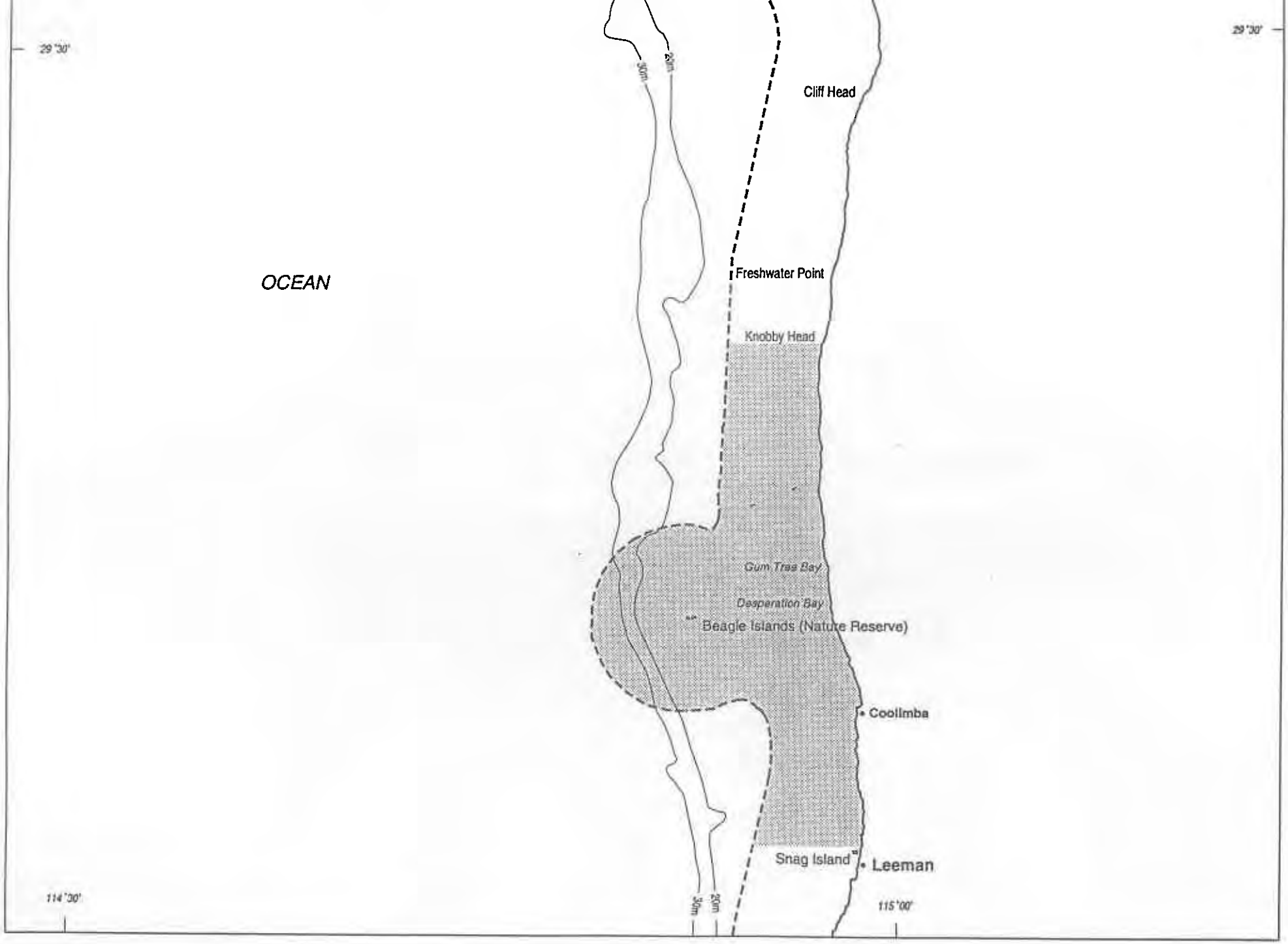
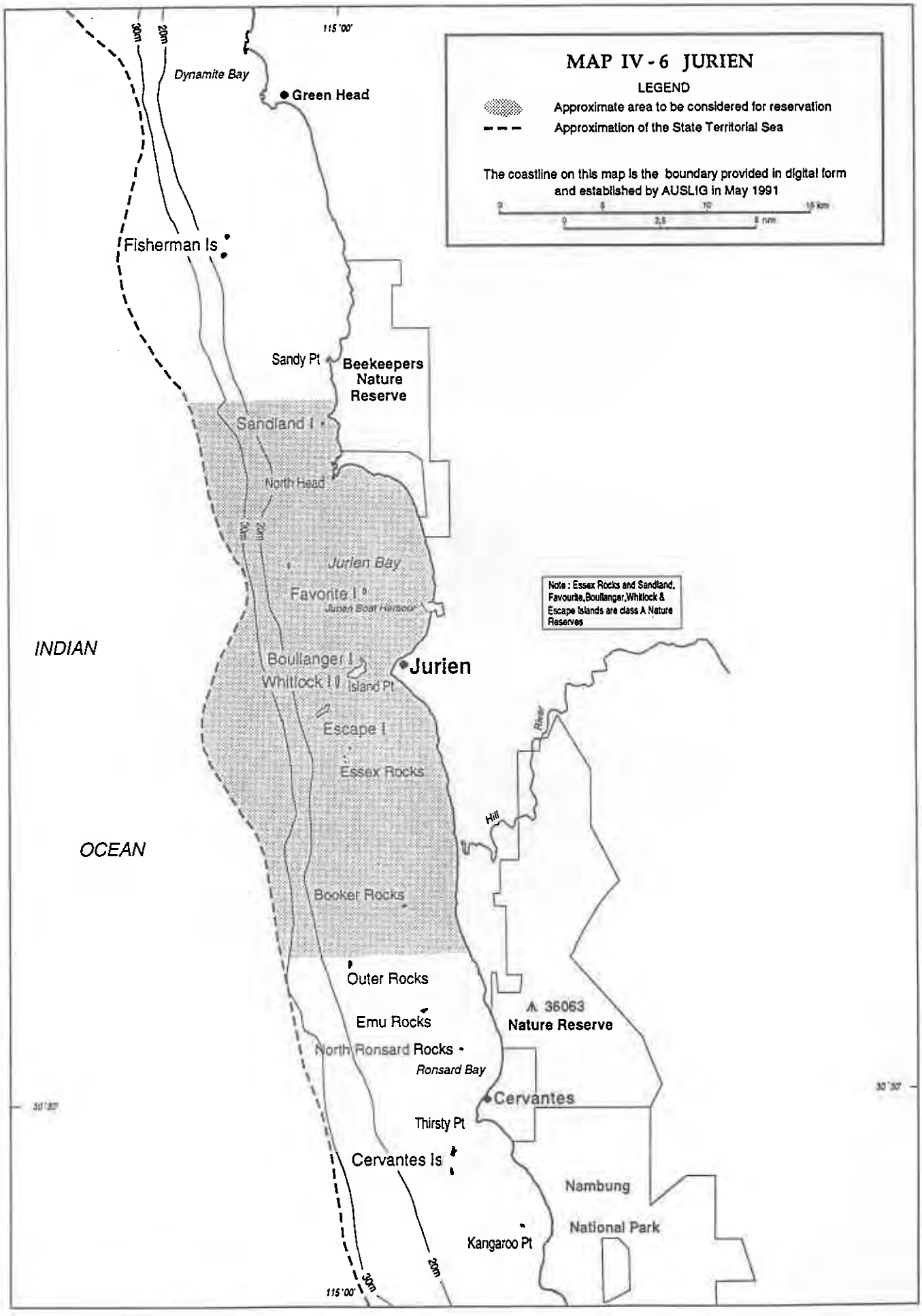

MAP IV - 4 ABROLHOS ISLANDS
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
Proposed Marine Park boundary
Reef
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 km
0 5 10 nm
114°00'
Gregory
North I
SOUTH PASSAGE
GEELVINK CHANNEL
East Wallabi I
WALLABI GROUP
Beacon I
Long I
West Wallabi I
Morning Reef
Proposed Marine Park
Abrolhos Islands Planning Study
January 1989
28°30'
28°30'
CHANNEL


NOTE : Islands comprise A. A20253 for conservation of flora & fauna, tourism and the fishing industry
MIDDLE
Little North I
EASTER GROUP
Proposed Marine Park Abrolhos Islands Planning Study January 1989
Leo I
Suomi I
Rat I
Wooded I
CHANNEL
Hummock Island
INDIAN
ZEEWIJK
Mangrove Group
Post Office I
Newman I
Gun I
Middle I
PELSAERT GROUP
Pelsaert I
Hill
Moon
Reef
OCEAN
29°00'
113°30'
114°00'


114°30'
115°00'
30m
20m
20m
Bookara
MAP IV - 5
SEVEN MILE BEACH -BEAGLE ISLANDS
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 5 10 15 20 km
0 5 10 nm
Research Area
Seven Mile Beach
Dongara
Leander Point
Port Denison
White Point
INDIAN


29°30'
30m
20m
Cliff Head
OCEAN
Freshwater Point
Knobby Head
Gum Tree Bay
Desperation Bay
Beagle Islands (Nature Reserve)
Coolimba
Snag Island
Leeman
114°30'
30m
20m
115°00'


MAP IV - 6 JURIEN
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
Note : Essex Rocks and Sandland, Favourite,Boullanger,Whitlock & Escape Islands are class A Nature Reserves
INDIAN
OCEAN
Dynamite Bay
Green Head
Fisherman Is
Sandy Pt
Beekeepers Nature Reserve
Sandland I
North Head
Jurien Bay
Favorite I
Jurien Boat Harbour
Boullanger I
Whitlock I
Island Pt
Jurien
Escape I
Essex Rocks
Booker Rocks
Outer Rocks
Emu Rocks
North Ronsard Rocks
Ronsard Bay
Cervantes
Thirsty Pt
Cervantes Is
Hill River
36063 Nature Reserve
Nambung National Park
Kangaroo Pt
115°00'
30°30'
30m
20m

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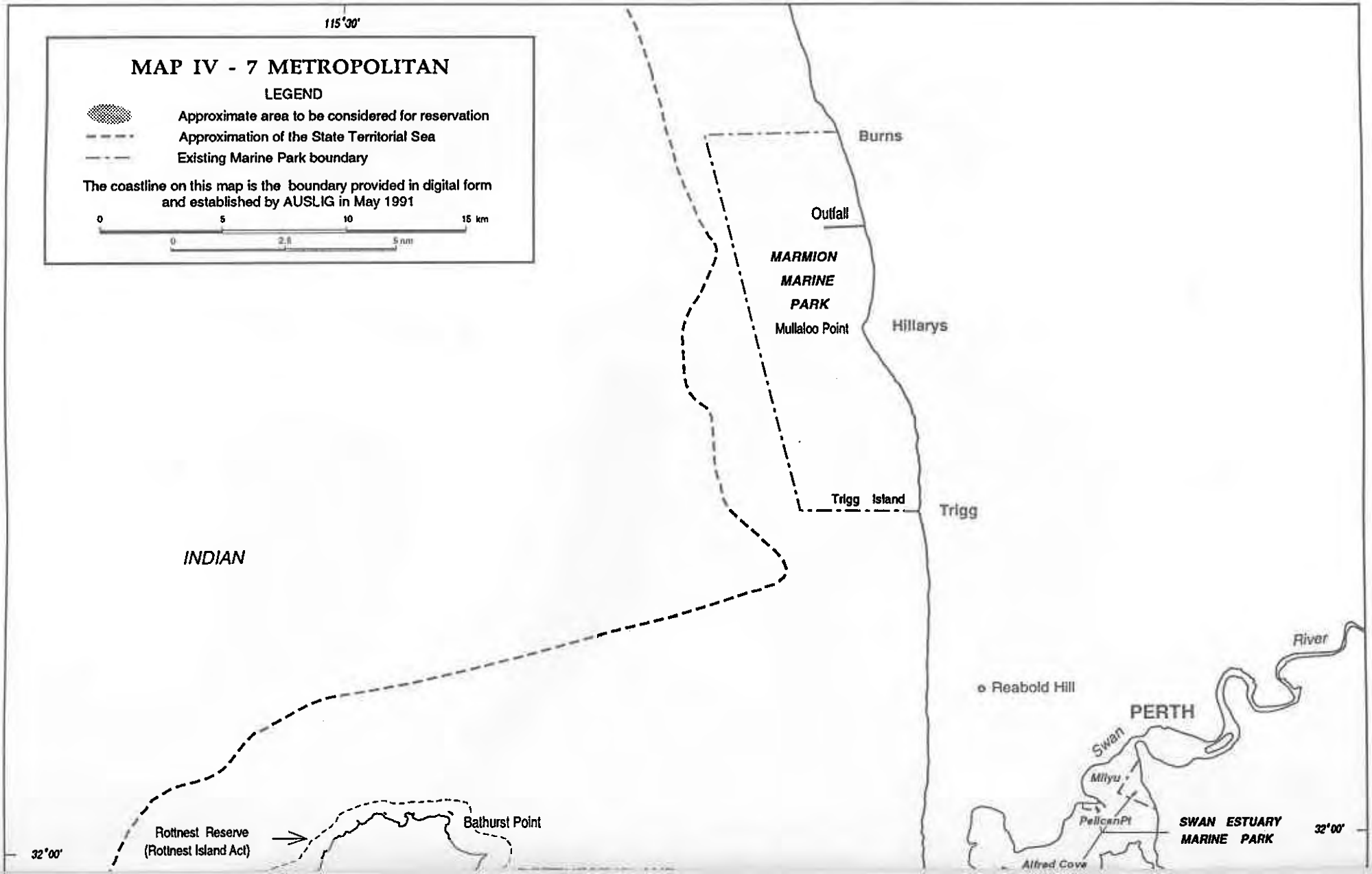
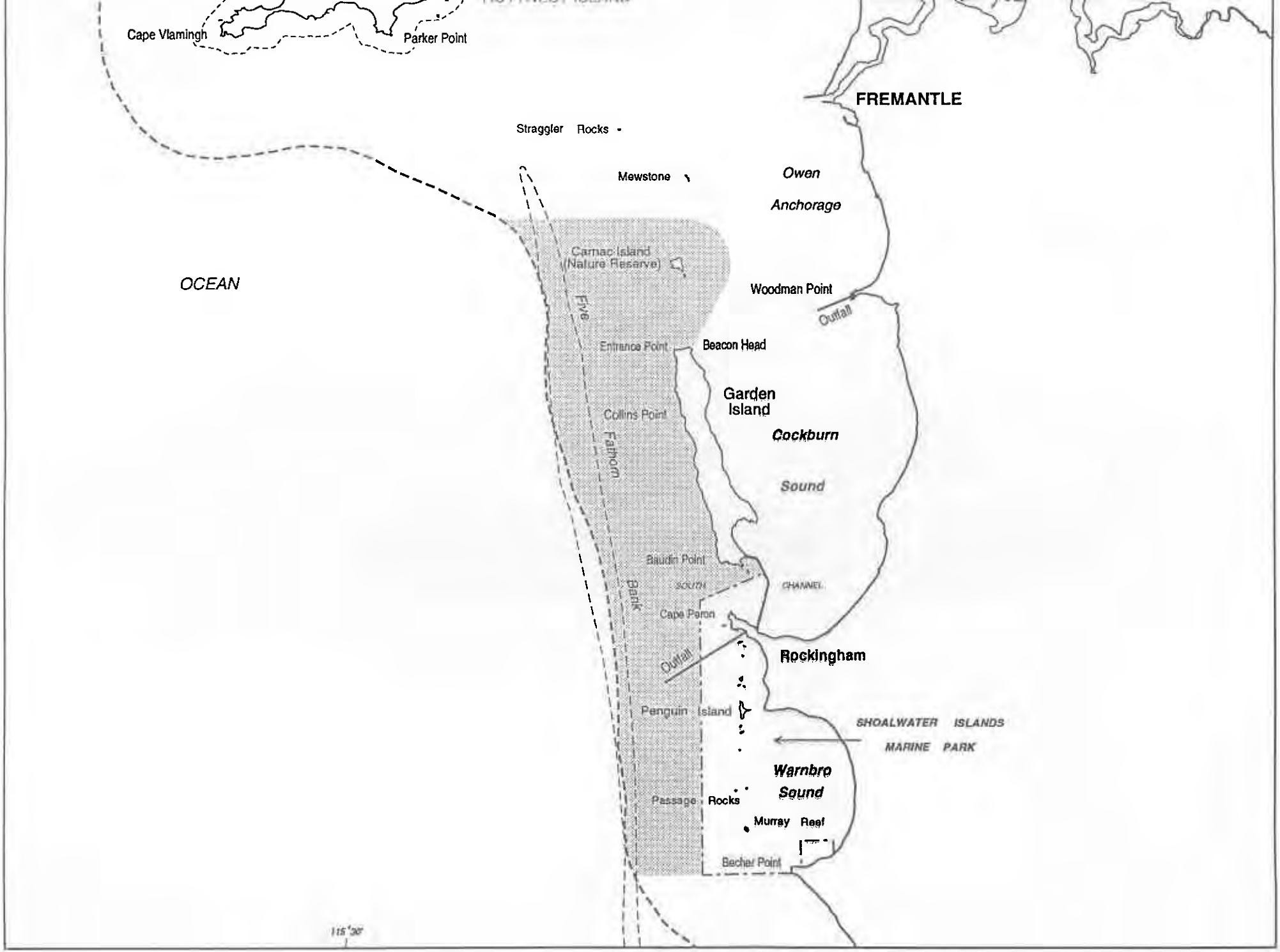
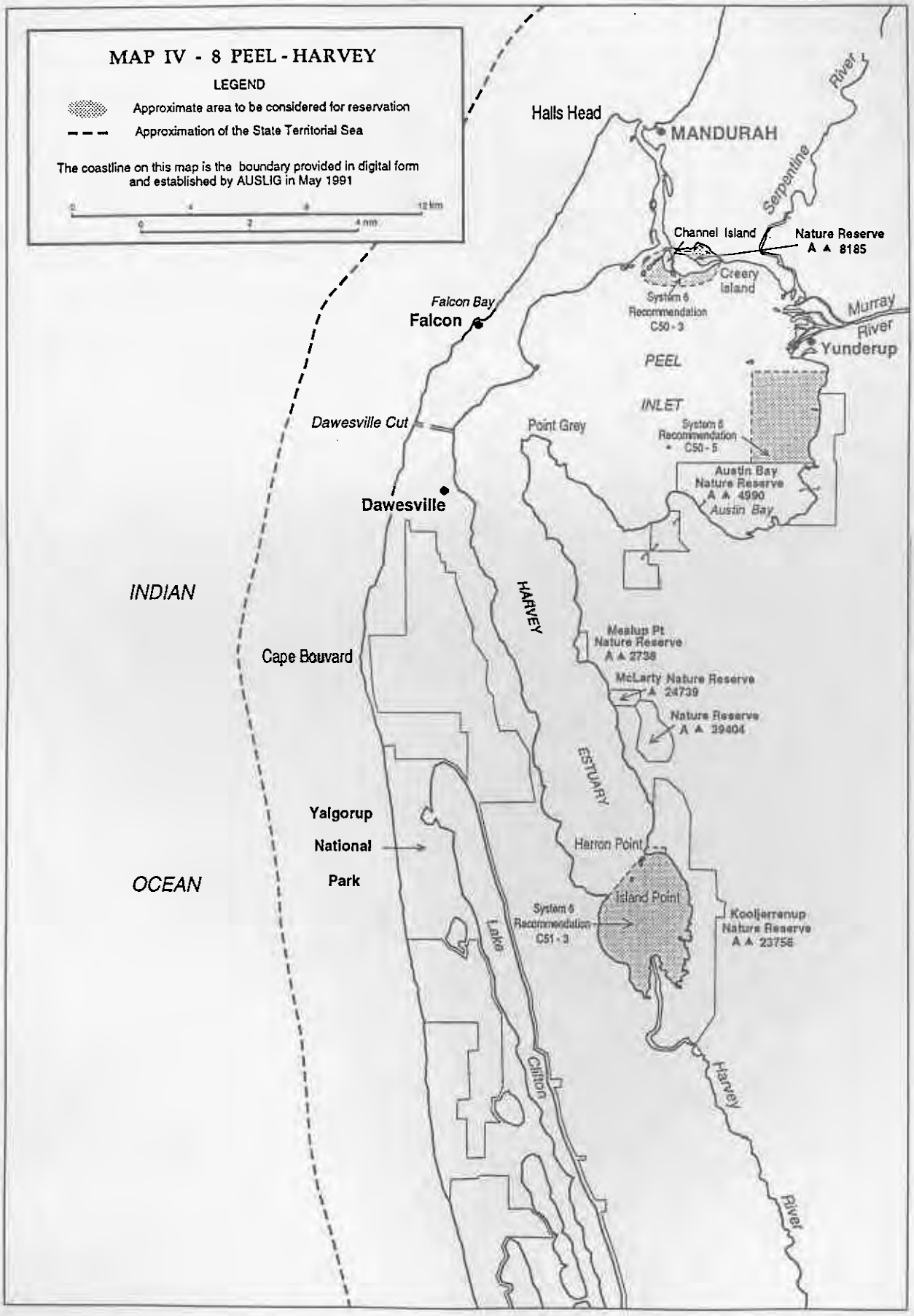
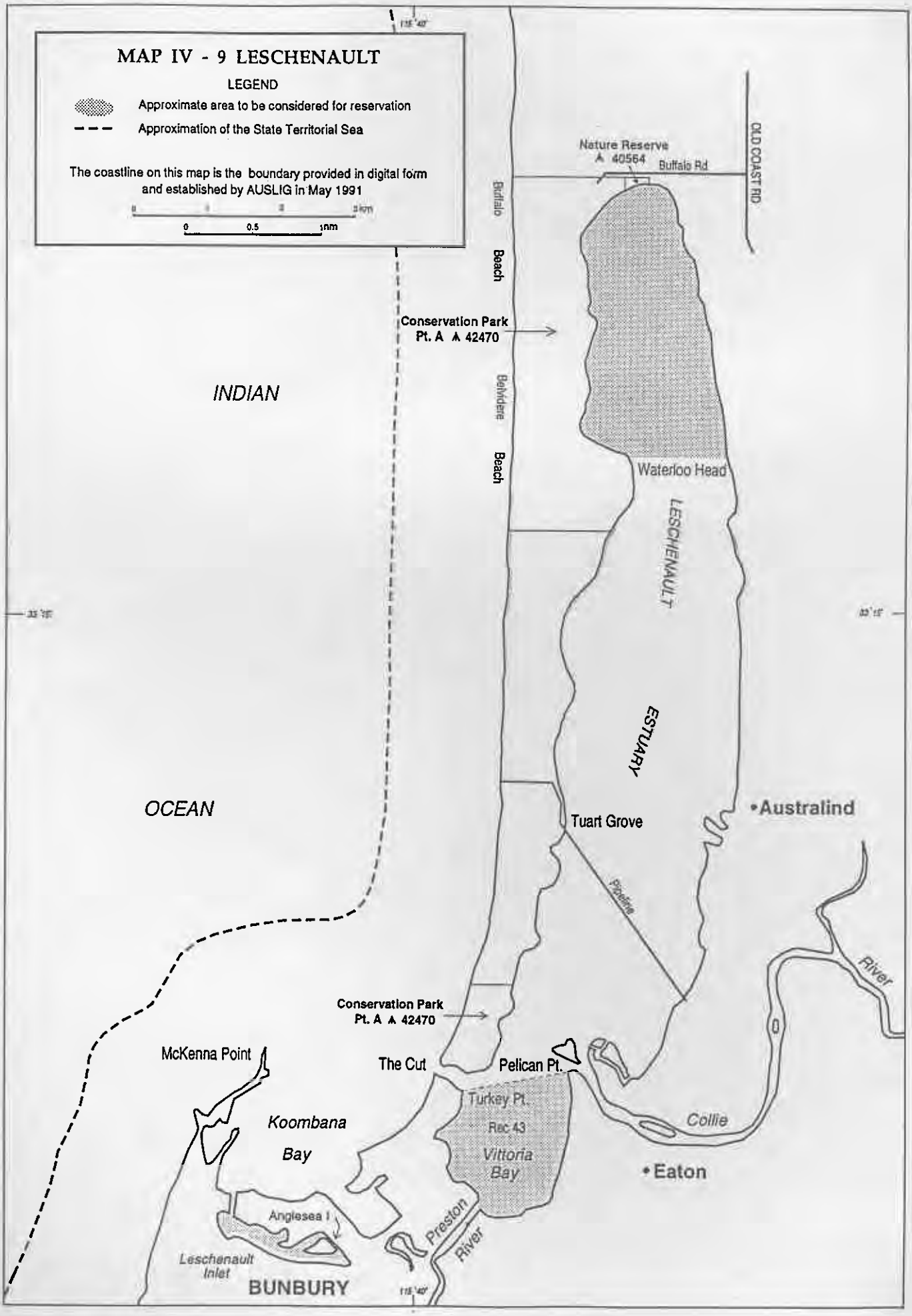
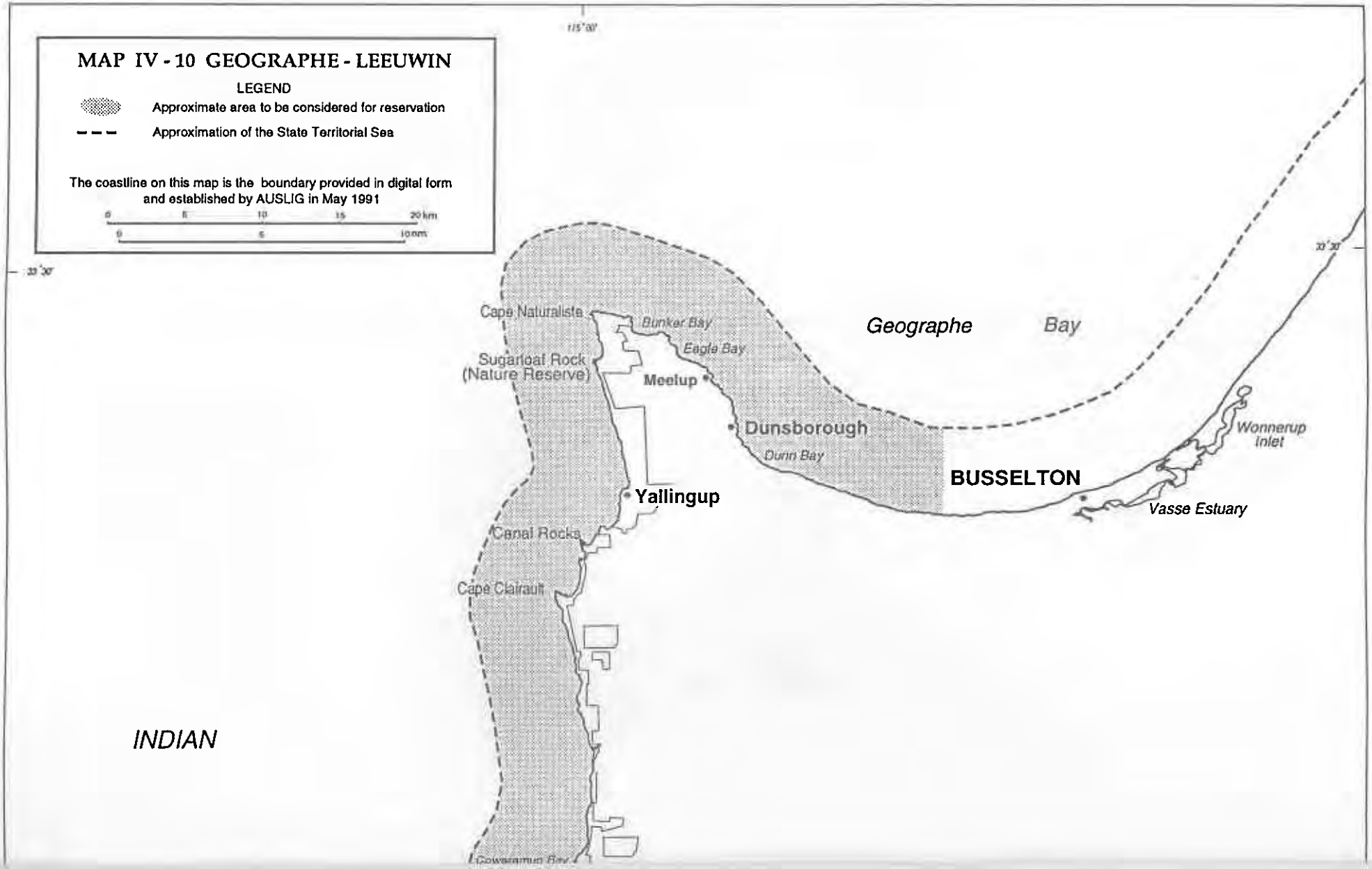
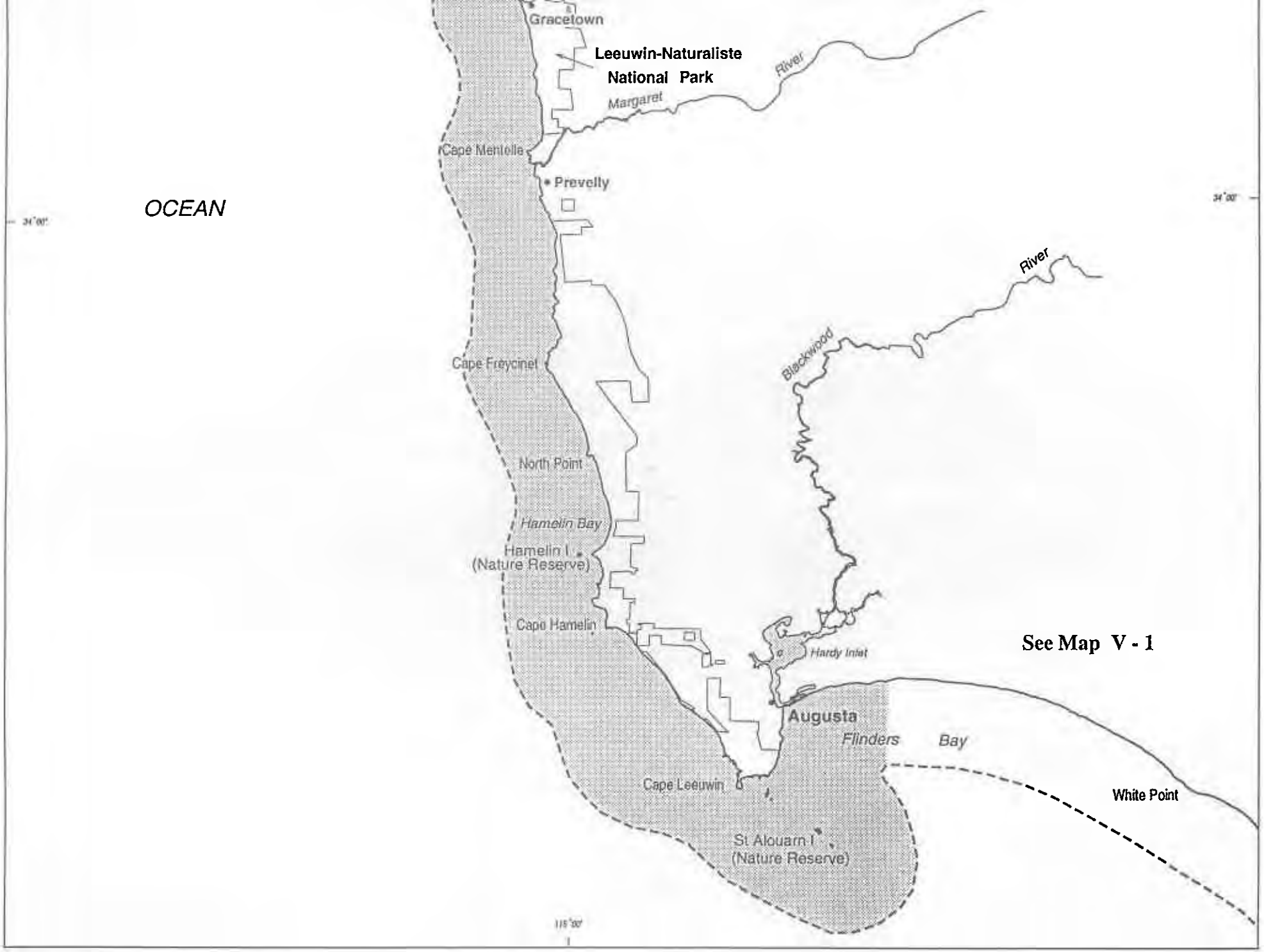

115°00'
MAP IV - 7 METROPOLITAN
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
Existing Marine Park boundary
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 5 10 15 km
0 2.5 5 nm
Burns
Outfall
MARMION MARINE PARK
Mullaloo Point
Hillarys
Trigg Island
Trigg
INDIAN
River
Reabold Hill
PERTH
Swan
Milyu
PelicanPt
SWAN ESTUARY MARINE PARK
Alfred Cove
Rottnest Reserve (Rottnest Island Act)
Bathurst Point
32°00'
32°00'

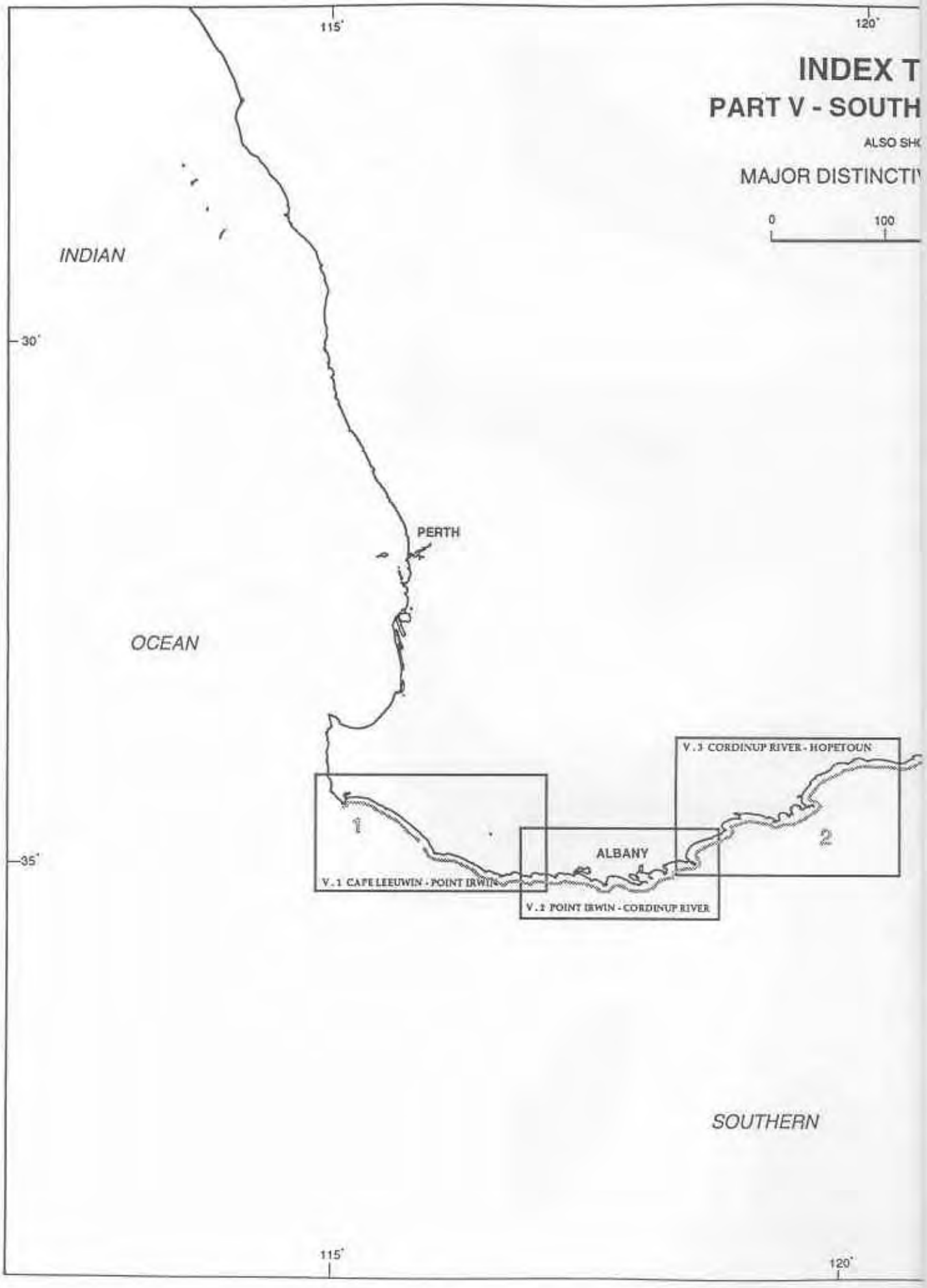

Cape Vlamingh
Parker Point
FREMANTLE
Straggler Rocks
Mewstone
Owen
Anchorage
Carnac Island
(Nature Reserve)
OCEAN
Five
Fathom
Bank
Woodman Point
Outfall
Entrance Point
Beacon Head
Garden
Island
Collins Point
Cockburn
Sound
Baudin Point
SOUTH
CHANNEL
Cape Peron
Outfall
Rockingham
Penguin Island
SHOALWATER ISLANDS
MARINE PARK
Warnbro
Sound
Passage Rocks
Murray Reef
Becher Point
115°30'


MAP IV - 8 PEEL - HARVEY
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
Halls Head
MANDURAH
Serpentine River
Channel Island
Nature Reserve A ▲ 8185
Creery Island
System 6 Recommendation C50 - 3
Falcon Bay
Falcon
Murray River
Yunderup
PEEL
INLET
Dawesville Cut
Point Grey
System 6 Recommendation C50 - 5
Austin Bay Nature Reserve A ▲ 4990
Austin Bay
Dawesville
INDIAN
OCEAN
HARVEY
Cape Bouvard
Mealup Pt Nature Reserve A ▲ 2738
McLarty Nature Reserve A 24739
Nature Reserve A ▲ 39404
ESTUARY
Yalgorup National Park
Herron Point
Island Point
System 6 Recommendation C51 - 3
Kooljerrenup Nature Reserve A ▲ 23756
Lake
Clifton
Harvey River


MAP IV - 9 LESCHENAULT
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 0.5 nm
Nature Reserve A 40564
Buffalo Rd
OLD COAST RD
Buffalo Beach
Conservation Park Pt. A A 42470
Belvidere Beach
INDIAN
OCEAN
Waterloo Head
LESCHENAULT
ESTUARY
Australind
Tuart Grove
Pipeline
River
Conservation Park Pt. A A 42470
McKenna Point
The Cut
Pelican Pt.
Turkey Pt.
Rec 43
Vittoria Bay
Collie
Eaton
Koombana Bay
Anglesea I
Preston River
Leschenault Inlet
BUNBURY


MAP IV - 10 GEOGRAPHE - LEEUWIN
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 5 10 15 20 km
0 5 10 nm
115°00'
33°30'
33°30'
Cape Naturaliste
Bunker Bay
Eagle Bay
Sugarloaf Rock (Nature Reserve)
Meelup
Geographe Bay
Dunsborough
Dunn Bay
BUSSELTON
Wonnerup Inlet
Vasse Estuary
Yallingup
Canal Rocks
Cape Clairault
INDIAN


Gracetown
Leeuwin-Naturaliste
National Park
Margaret
River
Cape Mentelle
Prevelly
OCEAN
River
Blackwood
Cape Freycinet
North Point
Hamelin Bay
Hamelin I
(Nature Reserve)
Cape Hamelin
Hardy Inlet
See Map V - 1
Augusta
Flinders
Bay
Cape Leeuwin
White Point
St Alouarn I
(Nature Reserve)

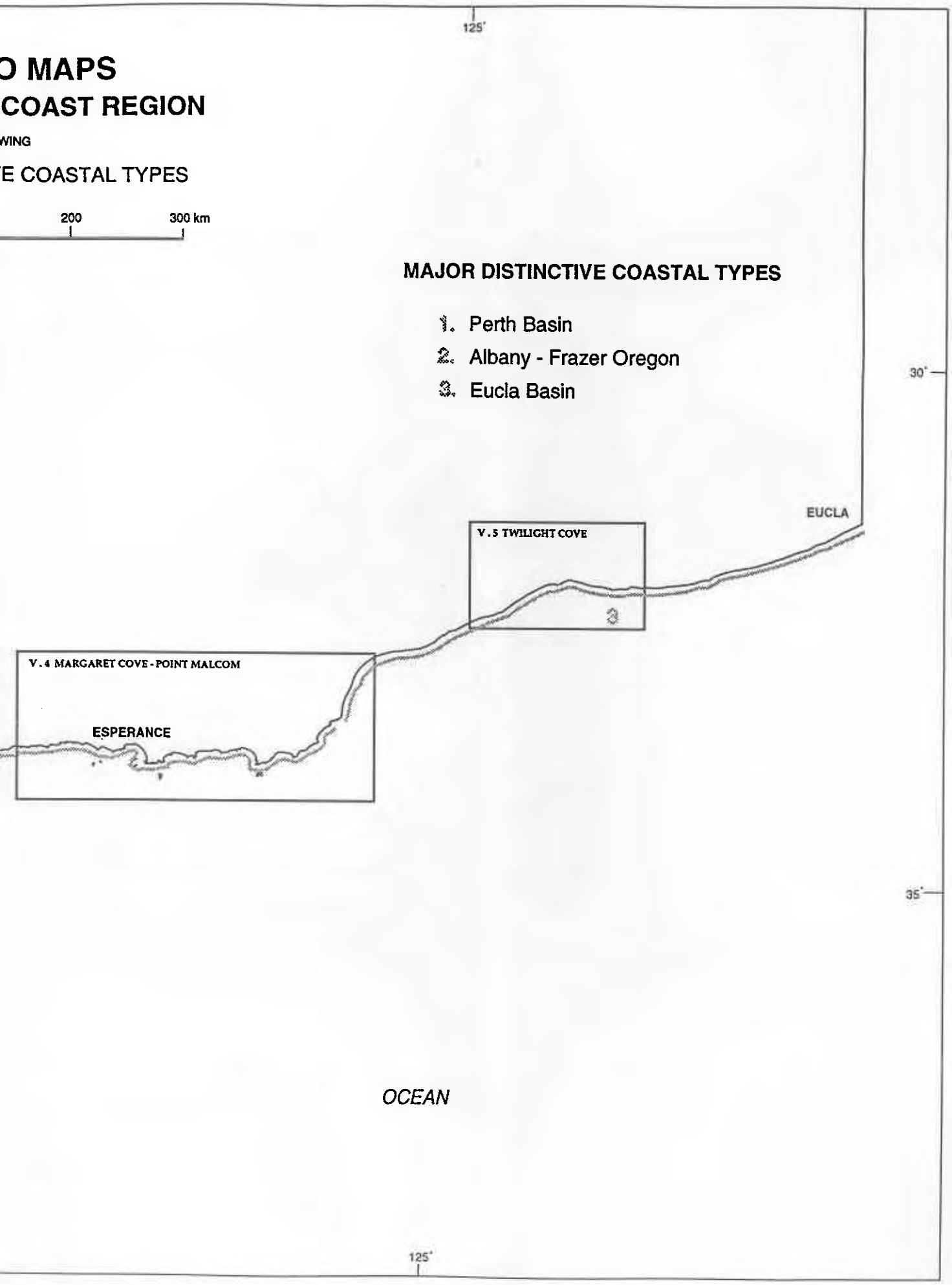

115°
120°
INDEX T
PART V - SOUTH
ALSO SH
MAJOR DISTINCTI
0
100
INDIAN
30°
PERTH
OCEAN
V.3 CORDINUP RIVER - HOPETOUN
1
2
ALBANY
35°
V.1 CAPE LEEUWIN - POINT IRWIN
V.2 POINT IRWIN - CORDINUP RIVER
SOUTHERN
115°
120°

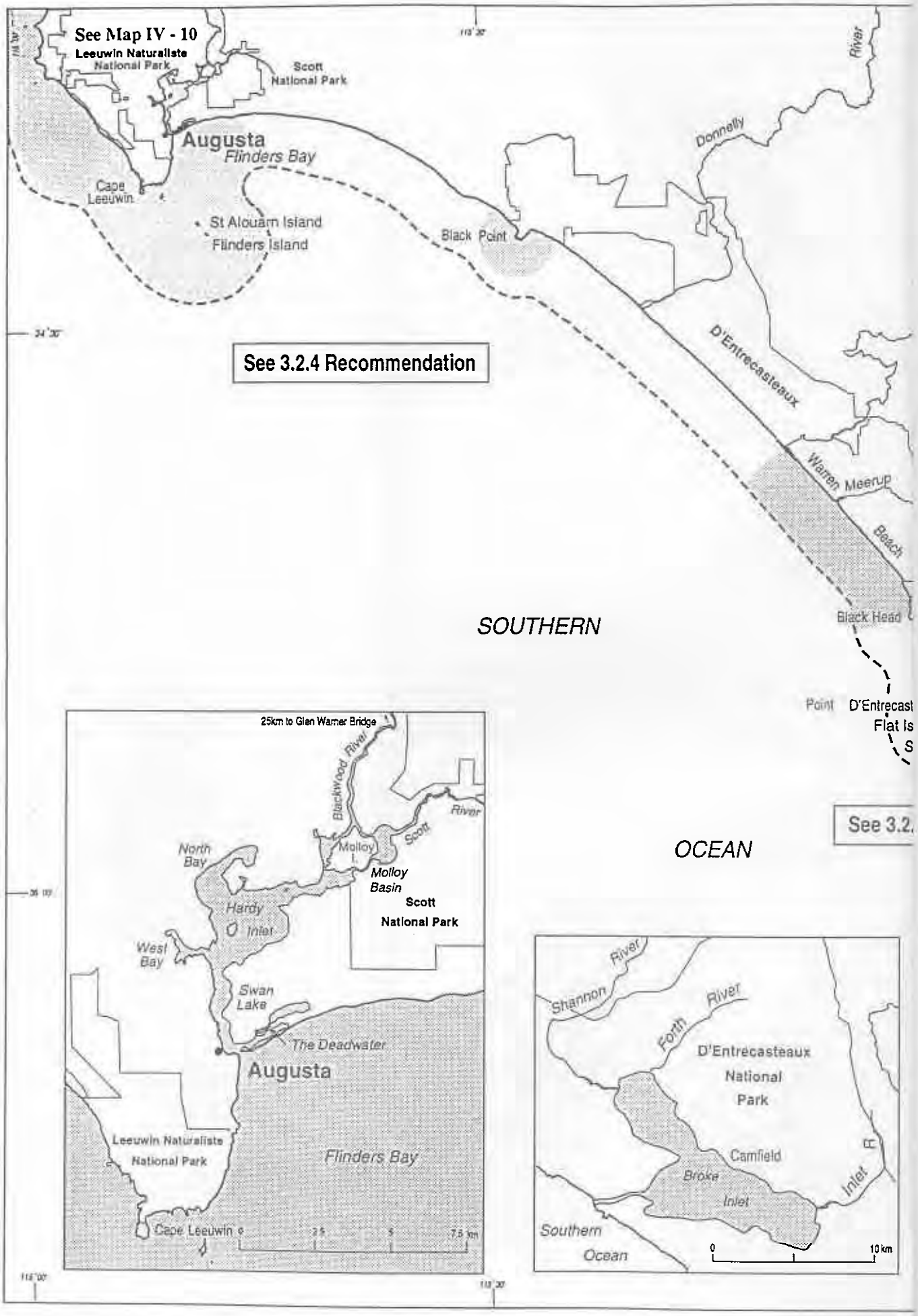
O MAPS
COAST REGION

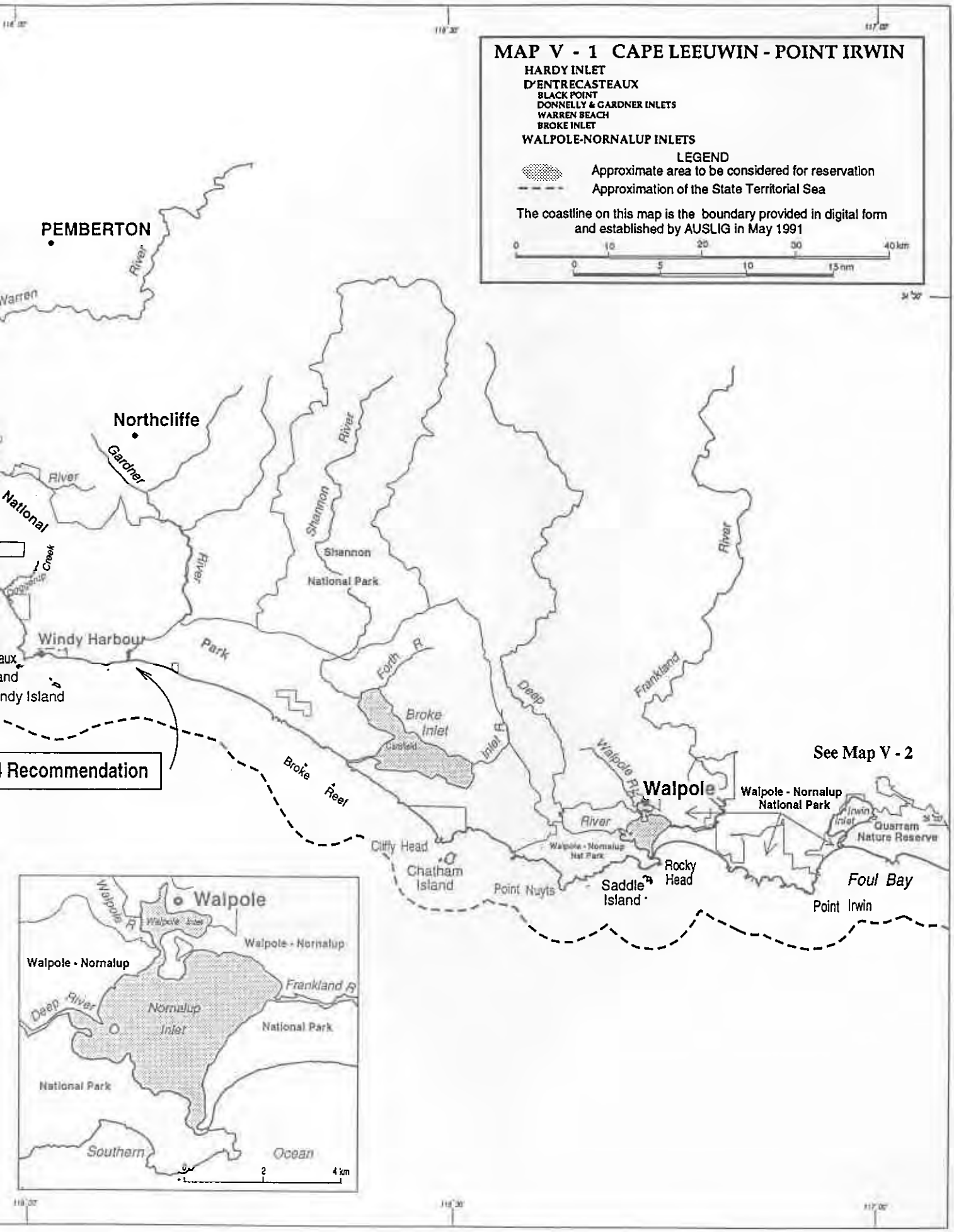
WING

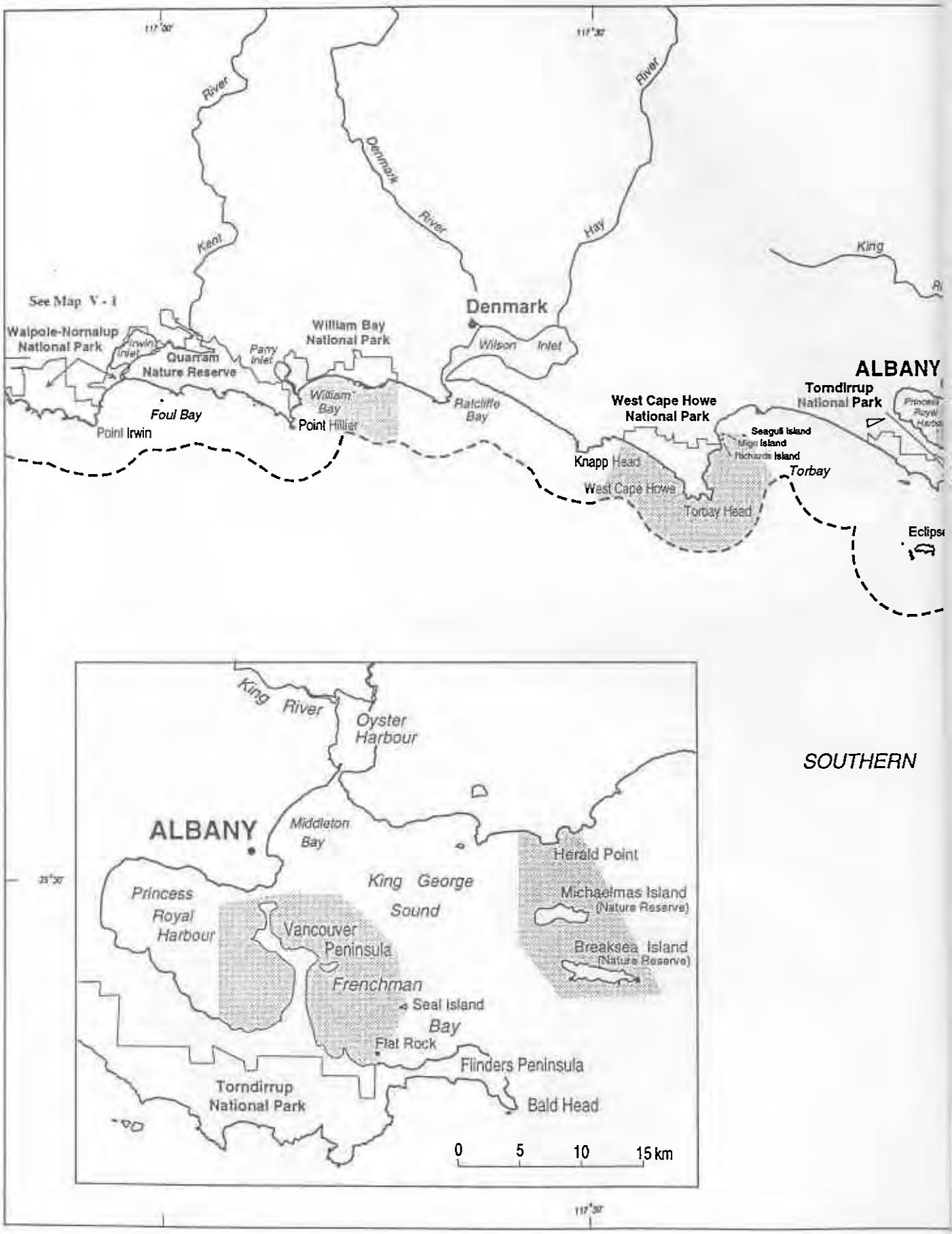
E COASTAL TYPES

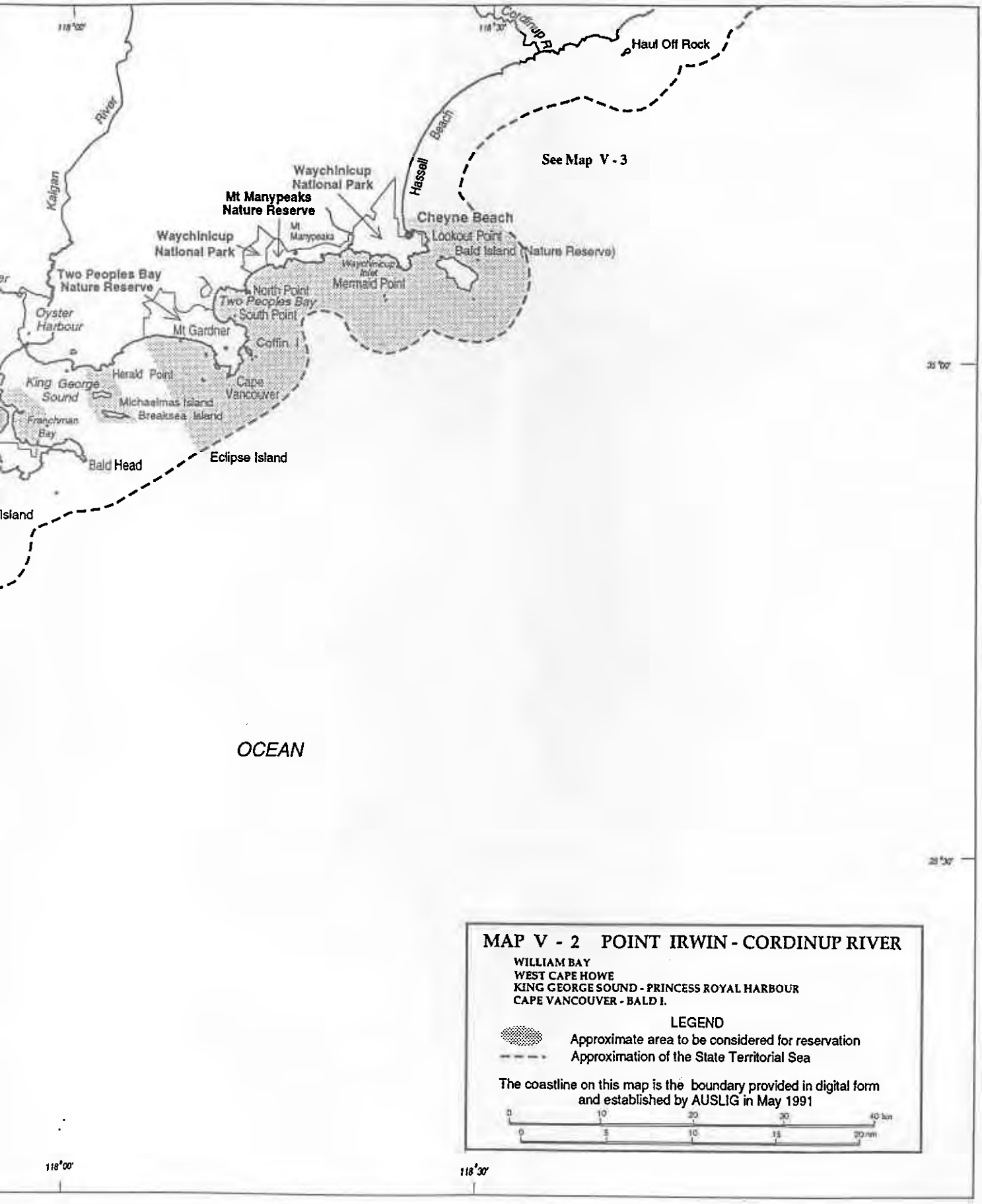
200 300 km




See Map IV - 10
Leeuwin Naturaliste
National Park
Scott
National Park
Augusta
Flinders Bay
Cape
Leeuwin
St Alouarn Island
Flinders Island
Black Point
Donnelly
River
D'Entrecasteaux
Warren
Meerup
Beach
Black Head
SOUTHERN
OCEAN
Point D'Entrecast
Flat Is
S
See 3.2.4 Recommendation
See 3.2.
25km to Glen Warner Bridge
Blackwood River
River
Scott
Molloy
I.
North
Bay
Molloy
Basin
Scott
National Park
Hardy
Inlet
West
Bay
Swan
Lake
The Deadwater
Augusta
Leeuwin Naturaliste
National Park
Flinders Bay
Cape Leeuwin
2.5
5
7.5 km
River
Shannon
River
Forth
D'Entrecasteaux
National
Park
Camfield
Broke
Inlet
Inlet
R
Southern
Ocean
0
10 km


MAP V - 1 CAPE LEEUWIN - POINT IRWIN
HARDY INLET
D'ENTRECASTEAUX
BLACK POINT
DONNELLY & GARDNER INLETS
WARREN BEACH
BROKE INLET
WALPOLE-NORNALUP INLETS
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40 km
0 5 10 15 nm
PEMBERTON
Warren
River
Northcliffe
Gardner
River
National
Shannon
River
Shannon
National Park
River
Windy Harbour
Park
Forth R
Deep
Frankland
River
Broke Inlet
Inlet R
Walpole R
Walpole
Walpole - Nornalup National Park
See Map V - 2
Recommendation
Broke
Reef
River
Irwin Inlet
Quarram Nature Reserve
Cliffy Head
Chatham Island
Walpole - Nornalup Nat Park
Point Nuyts
Saddle Island
Rocky Head
Foul Bay
Point Irwin
Walpole
Walpole R
Walpole Inlet
Walpole - Nornalup
Walpole - Nornalup
Frankland R
Deep River
Nornalup Inlet
National Park
National Park
Southern
Ocean
0 2 4 km


See Map V - 1
Walpole-Nornalup National Park
Irwin Inlet
Quarram Nature Reserve
Parry Inlet
William Bay National Park
William Bay
Point Hillier
Foul Bay
Point Irwin
Kent River
Denmark River
Hay River
Denmark
Wilson Inlet
Ratcliffe Bay
West Cape Howe National Park
Knapp Head
West Cape Howe
Torbay Head
Seagull Island
Magpie Island
Richards Island
Torbay
ALBANY
Torndirrup National Park
King River
Oyster Harbour
ALBANY
Middleton Bay
Princess Royal Harbour
King George Sound
Vancouver Peninsula
Frenchman Bay
Seal Island
Flat Rock
Herald Point
Michaelmas Island (Nature Reserve)
Breaksea Island (Nature Reserve)
Flinders Peninsula
Bald Head
Torndirrup National Park
0 5 10 15 km
SOUTHERN



MAP V - 2 POINT IRWIN - CORDINUP RIVER

WILLIAM BAY
WEST CAPE HOWE
KING GEORGE SOUND - PRINCESS ROYAL HARBOUR
CAPE VANCOUVER - BALD I.

LEGEND

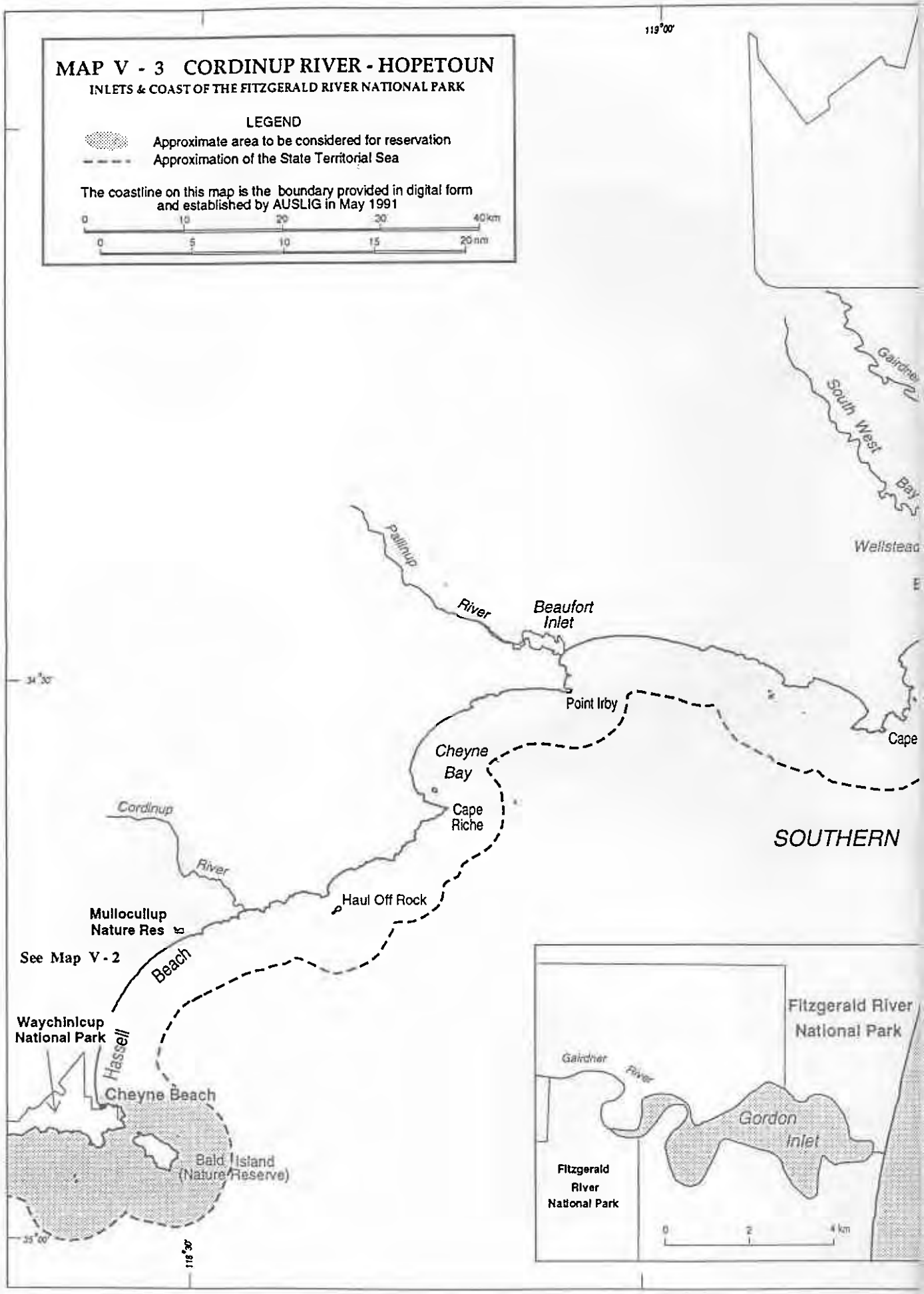
Approximate area to be considered for reservation

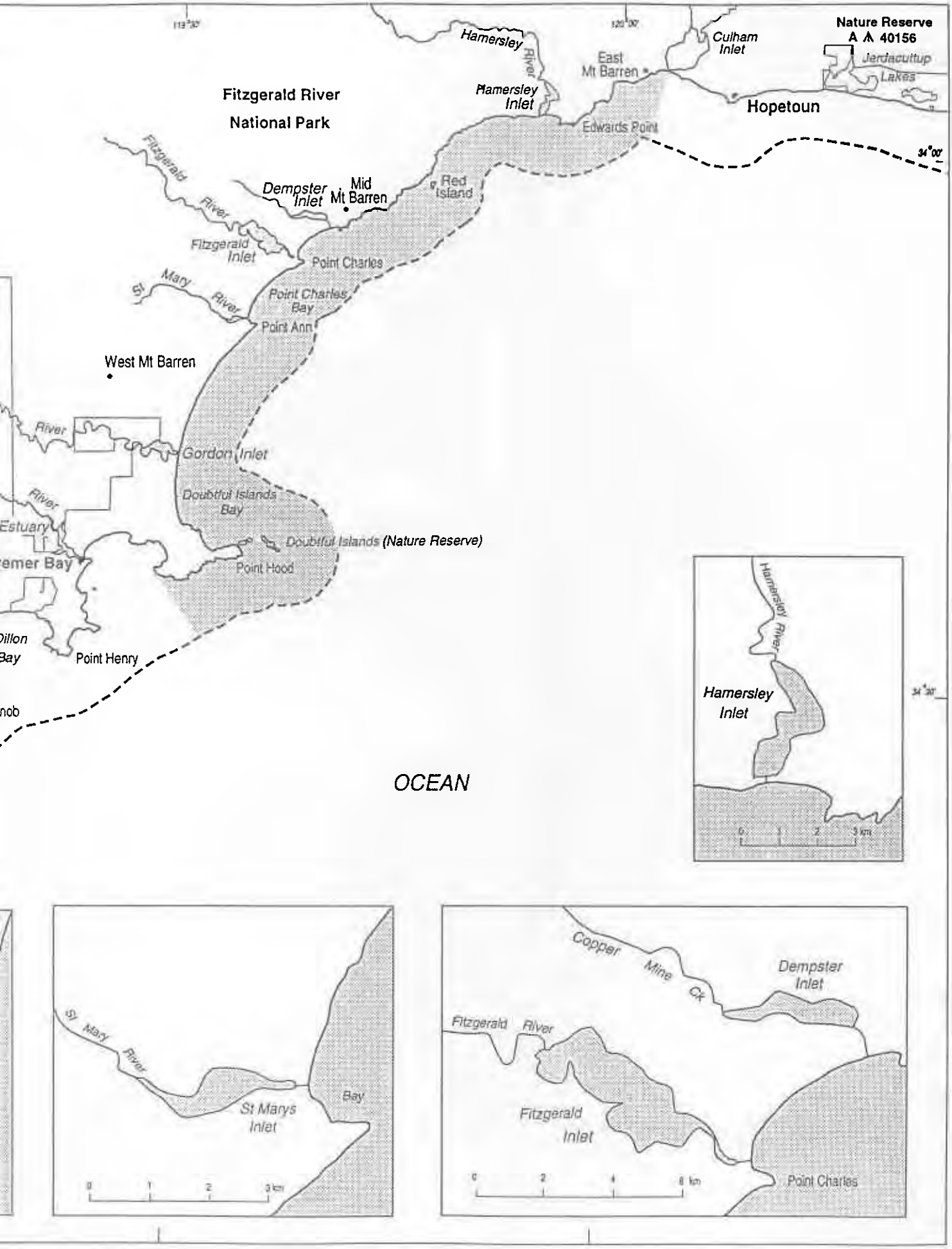
Approximation of the State Territorial Sea

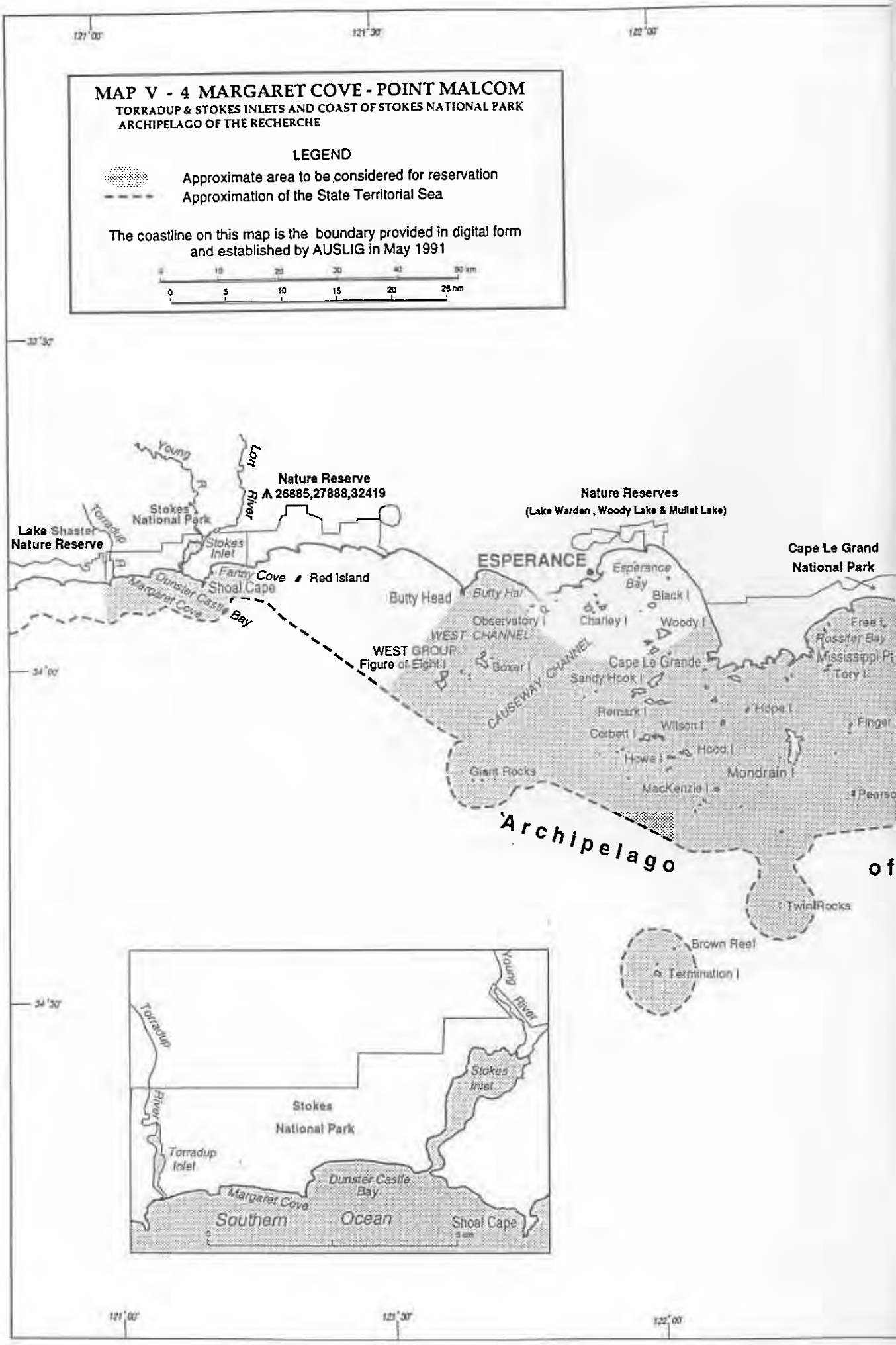
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991

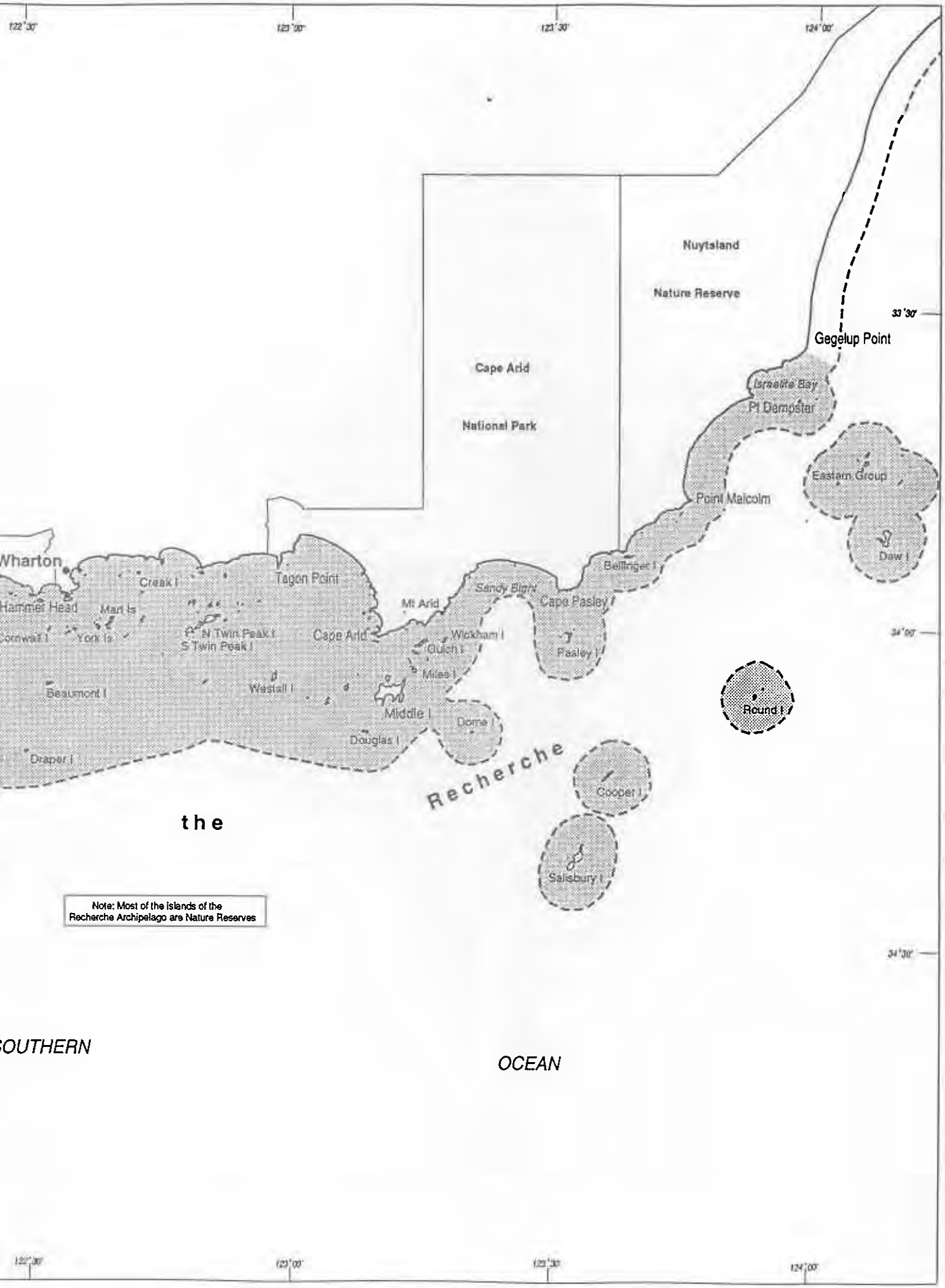
0 10 20 30 40 km

0 5 10 15 20 nm


MAP V - 3 CORDINUP RIVER - HOPETOUN
INLETS & COAST OF THE FITZGERALD RIVER NATIONAL PARK
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40km
0 5 10 15 20nm
119°00'
Gairdner
South West
Bay
Wellstead
Pallinup
River
Beaufort
Inlet
34°30'
Point Irby
Cape
Cheyne
Bay
Cape
Riche
SOUTHERN
Cordinup
River
Haul Off Rock
Mullocullup
Nature Res
See Map V - 2
Beach
Waychinicup
National Park
Hassell
Cheyne Beach
Bald Island
(Nature Reserve)
35°00'
118°30'
Fitzgerald River
National Park
Gairdner
River
Gordon
Inlet
Fitzgerald
River
National Park
0 2 4 km


Nature Reserve
A A 40156
Jerdacuttup
Lakes
Hopetoun
Culham
Inlet
East
Mt Barren
Hamersley
River
Hamersley
Inlet
Edwards Point
34°00'
Fitzgerald River
National Park
Fitzgerald
River
Dempster
Inlet
Mid
Mt Barren
Red
Island
Fitzgerald
Inlet
Point Charles
St Mary
River
Point Charles
Bay
Point Ann
West Mt Barren
River
Gordon Inlet
River
Doubtful Islands
Bay
Estuary
Doubtful Islands (Nature Reserve)
Point Hood
Point Henry
OCEAN
Hamersley
River
Hamersley
Inlet
0
1
2
3 km
St Mary
River
St Marys
Inlet
Bay
0
1
2
3 km
Copper
Mine
Ck
Dempster
Inlet
Fitzgerald
River
Fitzgerald
Inlet
Point Charles
0
2
4
6 km

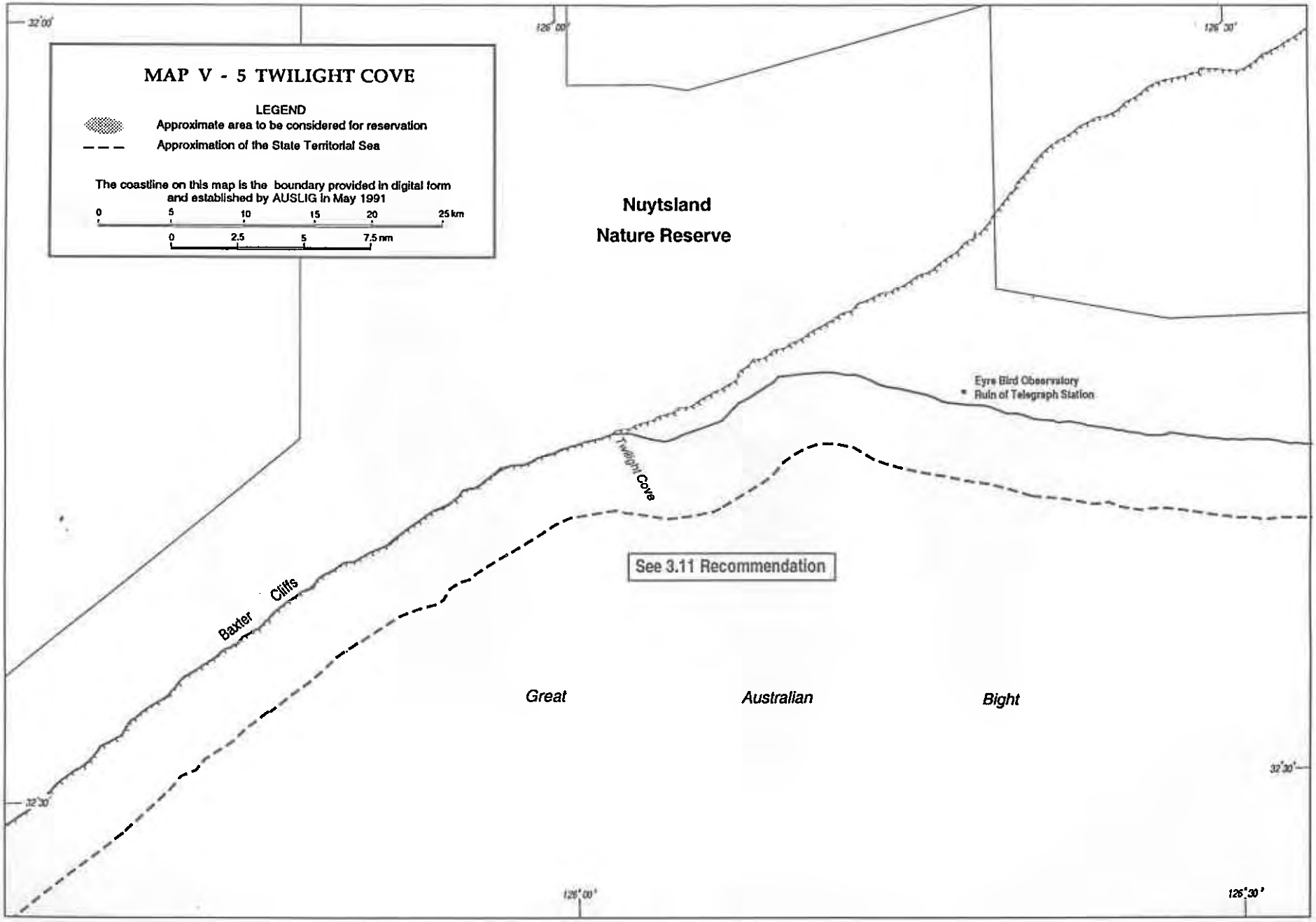

MAP V - 4 MARGARET COVE - POINT MALCOM
TORRADUP & STOKES INLETS AND COAST OF STOKES NATIONAL PARK
ARCHIPELAGO OF THE RECHERCHE
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 10 20 30 40 50 km
0 5 10 15 20 25 nm
121°00'
121°30'
122°00'
33°30'
34°00'
34°30'
Young River
Lort River
Torradup River
Stokes National Park
Stokes Inlet
Lake Shaster Nature Reserve
Nature Reserve
A 26885,27888,32419
Nature Reserves
(Lake Warden , Woody Lake & Mullet Lake)
Cape Le Grand National Park
ESPERANCE
Esperance Bay
Black I
Woody I
Charley I
Observatory I
WEST CHANNEL
Butty Head
Butty Hat
Fanny Cove
Shoal Cape
Red Island
Dunster Castle
Margaret Cove
Bay
WEST GROUP
Figure of Eight I
Boxer I
CAUSEWAY CHANNEL
Sandy Hook I
Cape Le Grande
Free I
Rossiter Bay
Mississippi Pt
Tory I
Remark I
Hope I
Finger
Wilson I
Corbett I
Hood I
Howe I
Giant Rocks
Mondrain I
MacKenzie I
Pearso
Archipelago
of
Twin Rocks
Brown Reef
Termination I
Young River
Torradup River
Stokes Inlet
Stokes National Park
Torradup Inlet
Dunster Castle Bay
Margaret Cove
Southern Ocean
Shoal Cape



the

SOUTHERN

OCEAN


MAP V - 5 TWILIGHT COVE
LEGEND
Approximate area to be considered for reservation
Approximation of the State Territorial Sea
The coastline on this map is the boundary provided in digital form and established by AUSLIG in May 1991
0 5 10 15 20 25 km
0 2.5 5 7.5 nm
32°00'
126°00'
126°30'
Nuytsland
Nature Reserve
Eyre Bird Observatory
Ruin of Telegraph Station
Twilight Cove
See 3.11 Recommendation
Baxter Cliffs
Great Australian Bight
32°30'
125°00'
125°30'