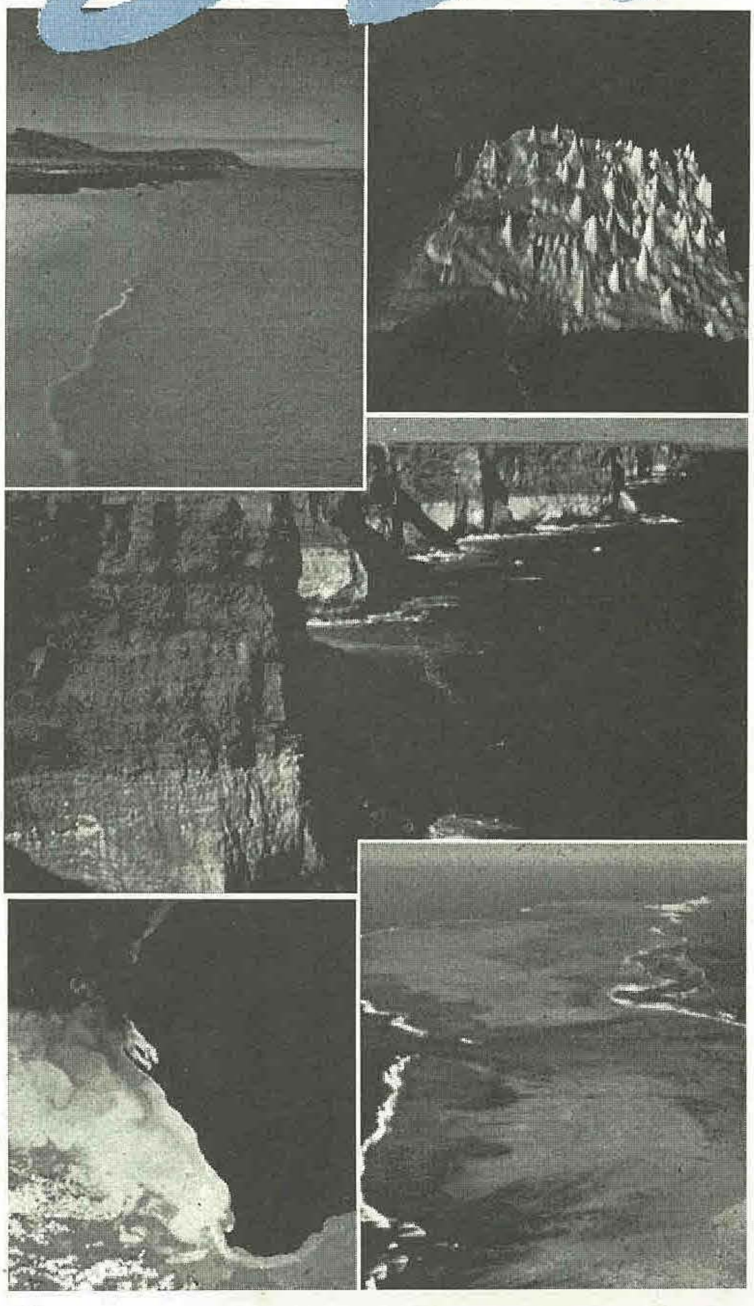
OCEAN RESCUE 2000 WORKSHOP SERIES

Towards a Marine Regionalisation for Australia



Publication Number

1

OCEAN RESCUE 2000 WORKSHOP SERIES

Towards a Marine Regionalisation for Australia

Proceedings of a Workshop held in Sydney, New South Wales
4-6 March 1994

Edited by Jim Muldoon

Great Barrier Reef Marine Park Authority

Ocean Rescue 2000

ISSN 1324-3799
ISBN 0 642 17439 3
Published by the Great Barrier Reef Marine Park Authority September 1995

The opinions expressed in this document are not necessarily those of the publisher, the Great Barrier Reef Marine Park Authority.

National Library of Australia Cataloguing-in-Publication data:

Towards a marine regionalisation for Australia : proceedings of a workshop held in Sydney, New South Wales 4-6 March 1994.

Bibliography.
ISBN 0 642 17439 3.

1. Marine resources - Australia. 2. Marine resources conservation - Australia. 3. Biogeography - Australia. I. Muldoon, Jim (James), 1950- . II. Great Barrier Reef Marine Park Authority (Australia). III. Ocean Rescue 2000. (Series : Ocean Rescue 2000 workshop series ; no. 1).

333.952

ACKNOWLEDGEMENTS

The success of the workshop was due to the efforts and contributions by many people from a number of organisations. In particular, the assistance is acknowledged of the New South Wales National Parks and Wildlife Service and New South Wales Fisheries who together coordinated the workshop arrangements; the staff from the North Head Quarantine Station for ensuring that the workshop venue lived up to expectations; and finally to Sharon Pretty and Allison Pearson from the Great Barrier Reef Marine Park Authority for administrative support and perseverance before, during and after the workshop.

TABLE OF CONTENTS

INTRODUCTORY ADDRESS

Ian Carruthers,
Chair, ANZECC National Advisory Committee on Marine Protected Areas 7

PAPERS

Session 1 - Background

Development of a Marine Protected Area System Planning Regional Framework in Canada. *(Dr Doug Yurick - Chief, New Park Proposals, South Parks Canada, Ottawa.* 13

The New Zealand Experience in Developing a Marine Biogeographic Regionalisation. *(Ms Kathy Walls - New Zealand Department of Conservation)* 33

Biogeography and Diversity of Australia's Marine Biota. *(Dr Gary Poore - Museum of Victoria)* 49

Uses and Misuses of Regionalisations: Experiences Gained from Terrestrial Environments. *(Mr Richard Thackway - Australian Nature Conservation Agency)* 65

Session 2 - Case Studies

The Application of Marine Biogeographic Techniques to the Oceanic Environment. *(Dr Neil Hamilton and Dr Doug Cocks - CSIRO, Division of Wildlife and Ecology)* 81

The Development of a Representative System of Marine and Estuarine Protected Areas for New South Wales. *(Mr E Ortiz and Mr D Pollard - NSW Fisheries)* 91

Queensland Marine Habitats - A Biophysical Classification at the Meso-scale for Conservation Planning. *(Mr Tim Stevens - Queensland Department of Environment and Heritage)* 95

The Western Australian Marine Regionalisation Project. *(Mr Hugh Chevis - Western Australian Department of Conservation and Land Management)* 113

The South Australian Marine Regionalisation Project. *(Dr Karen Edyvane and Ms Janine Baker - South Australian Research and Development Institute)* 121

Biophysical Classification of Victoria's Marine Waters.
(Mr Don Hough - Land Conservation Council, and Mr Garry Mahon - Victorian Department of Conservation and Natural Resources) 141

Development of a Terrestrial Biogeographic Regionalisation for Australia.
Mr Richard Thackway and Mr Ian Cresswell - Australian Nature Conservation Agency) 145

Completing a Network of Protected Areas in British Columbia.
(Ms Kris Kennett, BC Parks, Prince George, British Columbia) 161

Session 3 - Methodology

The Delphic Approach as Applied in Western Australia.
(Dr Barry Wilson - Murex Consultants Pty Ltd) 167

Multivariate Analysis and Biogeographic Regionalisation.
(Dr Brian McArdle - University of Auckland) 175

Session 4 - Data Options

Perspectives from the State of the Marine Environment Report (SOMER) on an Australian Marine Biogeographic Regionalisation.
(Dr Leon Zann - Great Barrier Reef Marine Park Authority)
Note. Oral Presentation Only - No Paper Provided

CAMRIS, NATMIS and AGSO Coastal and Marine Information Systems.
(Dr Neil Hamilton and Dr Doug Cocks - CSIRO, Division of Wildlife and Ecology, Dr John Busby - Environmental Resources Information Network, and Dr Bob Burne - Australian Geological Survey Organisation) 195

Information Available from the Bureau of Resource Sciences for the Development of an Australian Marine Biogeographic Regionalisation.
(Dr Russel Reichelt and Dr Julie Bowyer - Bureau of Resource Sciences) 209

WORKSHOP OVERVIEW

ANZECC's Marine Biogeographic Regionalisation Workshop.
(Mr Jim Muldoon - Great Barrier Reef Marine Park Authority, and Mr John Gillies - Department of the Environment, Sport and Territories) 219

APPENDIXES

a. Workshop Program 231

b. Worskhop Participants 235

INTRODUCTORY ADDRESS

Australia and New Zealand Environment and Conservation Council's (ANZECC) Marine Biogeographic Regionalisation Workshop

Ian Carruthers
ANZECC National Advisory Committee on Marine Protected Areas

Good morning ladies and gentlemen.

I would like to welcome you to ANZECC'S Marine Biogeographic Regionalisation Workshop.

The workshop has its origins in a recommendation of the ANZECC National Advisory Committee on Marine Protected Areas (NACMPA) and is being sponsored by Ocean Rescue 2000.

Ocean Rescue 2000 has as its prime objective the conservation and sustainable use of the marine environment of Australia and its territories.

The establishment of a national representative system of marine protected areas is seen as an important, but not the only means of achieving this objective.

It is pleasing to see that we have been joined by so many of our state and territory colleagues as well as a number of overseas visitors in what promises to be a very interesting and challenging few days.

I am particularly pleased to welcome:

- Doug Yurick from Parks Canada
- Kris Kennett from British Columbia Parks
- Kathy Walls from the NZ Department of Conservation
- Brian McArdle from the University of Auckland, and
- Arief Yuwono who is on the staff of the Indonesian Assistant Minister for the Environment.

I would also like to thank NSW National Parks and Wildlife Service for providing such an excellent facility to stimulate our thinking.

I would like to take a few moments to tell you why we are having this workshop, why you peolpe and what we want from you.

First, what is the workshop about?

At its inaugural meeting in June 1993, the National Advisory Committee on Marine Protected Areas identified as its highest priority the organisation of a workshop to assess and advise on approaches to developing an agreed marine biogeographic classification system which could form the basis of a national representative system of marine protected areas.

No doubt some of you may recall that in February 1985, a technical workshop, under the auspices of the former Council for Nature Conservation Ministers (CONCOM) recommended that a map of geographical divisions be adopted as the basis for the classification of Australian marine and estuarine environments.

The workshop recommendations were adopted by CONCOM and the map of biogeographic classifications was adopted by the Australian Biological Resources Survey (ABRS) and is still used in the Zoological Catalogue of Australia .

However, this classification has not received the support of the states, the Northern Territory or Commonwealth agencies or programs other than the ABRS and it is now of limited value given the progress made since then through development of various other approaches to biogeographic classification and the increased level of information now available through research and monitoring programs.

As you know a number of agencies are interested in, or are in the process of developing biogeographic classification frameworks.

The marine biogeographic regionalisation workshop is a step in the process of developing an agreed set of australian marine biogeographical regions, as a basis for the national representative system of marine protected areas.

It must be clearly recognised that over the next few days we will not be drawing lines on maps.

Instead, we will be attempting to develop an approach in which to progress the development of a national representative system of marine protected areas.

Why you people?

You are here because we believe that as a group you have the relevant technical knowledge, operational experience and policy skills to assist with the task at hand.

What do we want from you?

We want your ideas, views and thoughts on marine biogeographic regionalisation. We do not expect them to be unanimous nor do we expect a list of recommendations.

We would also ask you to speak your minds, be candid. The most useful outcome will be achieved through expression of options, a diversity of views, and exchange of views and experiences.

We want you to be guided by the workshop objectives which you have seen which are to:

A) Review existing biogeographic regionalisations

B) Review the various approaches to developing a biogeographic regionalisation

C) Identify and assess the utility of the data sources that could be used to assist the development of a marine biogeographic regionalisation, and

D) Provide advice on how a national biogeographic regionalisation could be developed so that it:

- Can be the basis of a national representative system of marine protected areas for australia
- Can be used by other elements of the Ocean Rescue 2000 program (and other programs if required)
- Can be developed largely using existing data sources
- Would be supported by all jurisdictions
- Identifies key steps and a timetable, and
- Is realistic and achievable in terms of time, money and expertise.

What will we do with your views and ideas?

We will take your views and ideas away and consider what you propose.

There will be two definite products and a range of possible outcomes from the workshop.

Firstly, the proceedings will be published, including your papers, subsequent questions and your considerations arising from the workshop group sessions.

Secondly, a workshop report will also be prepared and conveyed to the national advisory committee on marine protected areas for consideration.

I envisage that your endeavours will form the basis of policies and actions for all governments in implementing a national representative system of marine protected areas.

The outcomes from the workshop will certainly guide us in the direction of the Ocean Rescue 2000 program in relation to marine protected areas projects.

PAPERS PRESENTED

Session 1
BACKGROUND

Development of a Marine Protected Area System Planning Regional Framework in Canada

D.B. Yurick
Chief, New Park Proposals,
South Parks Canada, Ottawa.

Thank you for inviting me to this workshop on bioregionalisation for marine protected areas in Australia, and for providing an escape from the Canadian winter in doing so!

At the outset, two key distinctions should be noted between the Canadian and Australian situations. The first is that most Canadian seas are ice-covered for much of the year, a key consideration in Parks Canada's regional definition efforts. The second is that, unlike Australia, Canada's marine regions are delimited to some extent by her political geography. Australia's circumcontinental seas place her in a unique situation.

Before addressing marine regions specifically, it may be helpful to recall briefly the history of national parks in Canada. If the establishment of parks through the first 85 years of the park system did not proceed in a totally ad hoc manner, then certainly it was not with any system plan in place either. Scenic grandeur and ease of access along early road and rail corridors generally counted for more than concepts such as representation of natural regions, ecological integrity and protection of biodiversity - concepts important to many national park systems today. For example, the high concentration of national parks in the Rocky Mountains and a number of the smaller parks, primarily in eastern Canada, can be traced back to this period and these factors, among others.

Most of the more remote and larger parks in Canada have a much shorter history, dating from the 1970's and 80's. It is not by chance that the Canadian national parks system has evolved in this manner, for it was at the beginning of the 1970's, following the example set by the US National Park Service, that Parks Canada first developed a system plan - a science-based, deliberate approach to completion of a system of national parks that is to be truly representative of the natural diversity of the country.

To achieve completion of such a system plan, a defined five-stage park establishment process also came into play, a process that begins with a much more rigorous approach to identifying candidates for new parks, and selecting the best from among them. Such an approach requires a solid underpinning if it is to be explicable and credible. For Parks Canada, the answer was a physiography/vegetation-based system planning framework for national parks that remains in use today. Consequently, Parks Canada has been able since 1972 to work toward one fixed and finite target - a park system representing every one of the 39 natural regions of Canada. That has been to our advantage for a number of reasons, not the least of them being political acceptance. Obtainable, finite park establishment objectives are certainly more attractive to cash-strapped governments in the current fiscal framework than would be the case were there no fixed vision in place.

Within this terrestrial park planning framework there are 39 natural regions of Canada (Fig. 1). There are currently 36 national parks and national park reserves in Canada, but for the historical reasons noted above, only 23 (60%) of the natural regions are presently represented in the parks system. The Green Plan adopted by the Government of Canada in 1990 has set the objective of reaching agreements for new parks in the remaining 16 regions by the year 2000, and work is well underway toward meeting that goal.

So much for terrestrial parks. Coincidentally, in the late 1960's and early 1970's, coastal states were first being asked in international fora to consider extending their national park systems or other forms of protection to representative marine areas. Parks Canada's response to that challenge took two forms. First, virtually every coastal park established at around that time incorporated a marine component. (Note, however, that only the marine component of Pacific Rim National Park Reserve is large enough to be considered now as adequately representative of the marine region in which it is situated. Most of the others are very small, and not satisfactorily representative of the marine regions which in which they lie.)

The second initiative undertaken by Parks Canada in the early 1970's was to begin first tentative steps toward a marine park system. The effort began, but soon failed, in the Strait of Georgia, between Vancouver Island and the mainland of British Columbia. However, before it failed, one result was a first marine regions framework for Parks Canada, totalling nine regions (Fig. 2).

The criteria used in deriving this first framework had very little to do with biology. Oceanography and coastal physiography were the dominant considerations, perhaps because the effort was seen as an extension of the 39-regions terrestrial planning framework which depended so heavily on a physiographic underpinning. Indeed, the nine regions were often spoken of in the same breath - identified simply as being among "Canada's 48 natural regions", and not always differentiated from the 39 terrestrial regions.

Notwithstanding the limited progress toward establishing marine parks during the 1970's and early 1980's, area identification work (step 1 of the 5-step establishment process) continued in several of the original nine marine regions. Such studies pointed increasingly to the conclusion that the framework was badly flawed. Many regional boundaries, such as that splitting Lancaster Sound in the Canadian Arctic, were inconsistent with local biology. In most of the nine marine regions, there was little within-region homogeneity to point to - they were simply too large and heterogeneous, and the result was that it had proven difficult to identify candidate marine park areas that could be assessed as representative of their entire regions. In short, not only did many of the regional boundaries seem to be out of place, but another hierarchical level below the nine regions framework seemed necessary.

New impetus was gained in the early 1980's with the decision to prepare a marine parks policy - probably the first of its kind in the world - to help overcome the strong local opposition that was encountered routinely in trying to apply terrestrial preservation-oriented parks policy to coastal environments and socioeconomic patterns. A complete reassessment of the marine regions planning framework began in 1982, in parallel with the development of the marine parks policy. Some guidance was taken from the hierarchical approach to marine regions worldwide that Hayden (1982) had undertaken for IUCN. In his approach, Hayden had come up with an 11-province system based once again on physical criteria - world-scale oceanic realms - polar, subpolar and temperate in the case of Canada - coastline exposure - whether polar, east- or west-facing - and coastal configuration - ocean margin, marginal sea, or marginal archipelago. This was a useful beginning, but in the end all that was retained of it was something akin to a second-order subdivision of Canada's ocean environments into Pacific, Arctic and Atlantic.

Beyond this second-order starting point, the balance of Parks Canada's approach to the definition of marine regions was quite straightforward, although influenced by certain internal objectives. For example, it was a policy decision that the Great Lakes (Canada's "fourth coast") should be included within any new marine regions framework. The most significant decision was that physical themes and biological themes deserved equal consideration. It was desirable from the outset that miscues such as splitting Lancaster Sound should be avoided. Other criteria included the use of best existing information only, and arrival at a reasonable number of marine regions for park planning purposes at the end of the process; that is, splitting regions down to something akin to the ecodistricts level was not the intention.

It should be noted that "best use of existing data" does not mean that the entire array of available marine resource data in Canada was brought to the job. It was not a number-crunching exercise. As well, for the majority of Canada's coastal seas, including most of Labrador and the Arctic, it was acknowledged at the outset that distribution and abundance data are very limited for all but some commercial fish and the very visible marine mammals and birds. Among the invertebrates, only general littoral community structures were considered well enough known around all coasts to be of utility.

The process used can be illustrated by focussing on the Pacific coast. It was decidedly more qualitative (Delphic) than quantitative. Thematic mapping by regional marine specialists, facilitated by a consultant, led to two so-called base-case maps for each of the second-order divisions named above - one biological and the other physical. To arrive at each of these base cases, three or four thematic maps were constructed initially, by regional specialists, and this was followed by a workshop and then

further consultations as necessary, to arrive at a final result.
Three themes were selected as components of the physical base case: oceanography, coastal environments, and sea-bottom physiography. Thematic maps for the Pacific are as indicated in Figures 3, 4 and 5 and, if overlaid, indicate the need to devise some way to resolve discrepancies in order to arrive at a physical base-case map

Our solution was to apply some simple "rules" derived from bargaining theory, reproduced in Fig. 6. Most importantly, they enabled construction of a track record of consensus building, so that specialists from various marine science disciplines could come quickly to the realization that the boundaries arrived at had been well considered and represented best compromises amongst competing points of view. Application of these rules to the Pacific physical themes maps resulted in the physical base-case indicated in Fig. 7.

Similarly, a biological base-case was sought within each of the second-order divisions, based on marine mammal, marine bird, marine littoral community, and fish distribution theme maps. Upon overlaying the Pacific biological base-case of Fig. 8 and the physical base-case, there were clearly some remaining discrepancies to be overcome. Oceanographers and coastal physiographers against marine biologists. Once again, the rules were applied to arrive at a final Pacific coast framework totalling six marine regions (Fig. 9). They were subsequently reduced to five upon eliminating the coastal fjord region, a decision that had as much to do with applying similar rule-making to equal treatment for fjords along other coasts of Canada as it did to the marine science of the Pacific fjords.

Application of this delphic approach to all of Canada's coasts resulted in a marine park planning framework of 29 natural marine regions. Complete details are provided in Woodward- Clyde (1983). The current version of the Parks Canada marine regions framework is illustrated in Fig. 10.

It is reasonable to ask how well this approach to the definition of natural regions worked in practice. The answer is "Quite well". Having some accepted rules in place from the outset to resolve cross-discipline differences was crucial. By going straight to boundary issues that were based on specialist-drawn maps, there was respect for alternate points of view from the outset, and a willingness to find satisfactory tradeoffs.

Like all good results that are at least partially policy-driven, the Parks Canada marine regions framework is not without some limitations. A very significant bias was the stipulation, at the outset, that the marine regions in a Parks Canada planning framework would have to be terrestrially anchored, since it was anticipated that marine parks would normally require a land base for administrative reasons and because coastal physiography was to be one component in subsequent regional analyses to identify potential park sites. That, and the importance placed on coastal and intertidal environments as an interpretive theme, effectively ruled out possible regions that would have been wholly offshore on the basis of other themes. In Australia, similar policy-based questions may have to be considered, while bearing in mind that they may lead to regionalisation results that are not strictly science-based. An obvious constraint was the limited thematic information brought to the Parks Canada regionalisation effort, particularly on the biological side of the ledger. Marine mammals, marine birds and generalized littoral communities had prominence, but was it at the expense of adequately providing for the natural distribution of the other, majority living components of marine ecosystems? Were the themes utilized suitable surrogates or indicators for the larger marine ecosystems? We don't know, frankly, and indeed the natural distributions of many of our invertebrate species, especially in the Arctic, are so poorly known as to make such a question very difficult to answer for the foreseeable future.

That same issue - the very fragmented knowledge of marine biotic distributions in Canada, particularly in the Arctic - made a highly quantitative method of regions definition impractical in Parks Canada's view. Our method was very qualitative and consensus-driven. There is little in it to warm the hearts of statisticians.

An important consequence of constraints such as these is that marine region planning frameworks need not - and should not - be static. For example, within one year of concluding the initial 29-regions framework in 1983, some regional boundaries in the Arctic and around Newfoundland were redrawn upon incorporating new scientific information within the existing consensus-building approach, and there remains room for further boundary shifts as our knowledge increases.

Further revisions of a much more substantive nature are now being derived elsewhere. One of the early priorities of a new State of Environment Reporting (SOER) group within Environment Canada has been to review and update ecosystem mapping for all of terrestrial Canada, down to the ecodistricts level. With that work well underway, SOER turned its attention in 1992 to a first-ever national marine ecological classification system. One of the starting points was the Parks Canada marine natural regions, and the same private sector consultant who led that effort was engaged to coordinate the SOER project.

The SOER project has resulted in a new, draft marine classification which has undoubtedly benefited (from a science perspective) for having discarded two of the constraints that were imposed on the development of Parks Canada marine regions. First, there was no prerequisite land base for each defined ecological unit; and second, there was no prohibition on developing a hierarchy of subdivisions. The methods employed remained essentially the same, however: thematic and base-case maps, regional workshops, participation by selected marine scientists, physical and biological, from across the country.

A number of things stand out immediately upon examining the first-, second- and third-order results illustrated in Fig. 11. One is that the number of first-order subdivisions has increased from three in the Parks Canada classification (discounting the Great Lakes) to five since two separate ecozones (the SOER first order) are recognized in both the Arctic and Atlantic. A second is recognition of a number of ecological units that are entirely offshore, usually determined by some combination of bathymetry and water masses. For example, SOER third-order ecoregions 1 and 2 in the Pacific are distinct from ecoregion 3 primarily because of shelf-edge bathymetry, but the separation between regions 1 and 2 has more to do with water-mass characteristics. (Note, therefore, that physical criteria remain important in this classification; only certain of the decisional constraints have been removed.)

A third result that stands out is that while many of the SOER ecoregional boundaries bear resemblance to the Parks Canada planning region boundaries, others are quite different, even nearshore. This is more evident in Fig. 12, which also points out that the SOER classification incorporates hierarchical fourth-order (ecodistricts) subdivisions, something that the Parks Canada planning framework does not. Therefore, an important question for Parks Canada, should we contemplate adopting a classification of this nature for planning a system of protected areas, will be to what hierarchical level thematic representation should be achieved. Or, said another way, should area identification studies proceed at the level of ecoregion, ecodistrict, or ecoprovince? Frankly, the answers may be as much political and administrative as scientific - 18 protected areas at the ecoregions level would be much more saleable as a policy objective than would 48 at the ecodistricts level. As well, marine protected areas that were wholly offshore and not readily accessible would provide little in the way of direct socieconomic benefit or visitor opportunities, two important considerations within Parks Canada area selection policy.

Similar questions will have to be addressed in Australia if a hierarchical classification of marine regions is sought.

BRITISH COLUMBIA

Despite the fact that eight of Canada's ten provinces and both northern territories front on her coasts, which in total add up to being the longest national coastline in the world, only British Columbia has developed a system of marine parks. Jurisdiction over the seabed and certain resources varies from place to place in Canada - there is no uniform 3-mile jurisdictional boundary as in Australia. Even so, there are a number of provinces in eastern Canada with extensive seabed under provincial jurisdiction, but they have not ventured into marine parks. One likely reason is that irrespective of variations in jurisdiction over the seabed, administration of the water column and its resources resides with the federal government.

British Columbia's current system of marine parks is not based on a marine regions framework, and indeed most of its units might more properly be labelled as coastal parks since they extend only a short distance into the sea, if at all. The majority of them are situated in the Strait of Georgia and its adjacent passages, where one of their primary purposes has been to protect destinations for B.C.'s large recreational boating community. The province has also established a number of marine ecological reserves to protect particularly significant but relatively small areas.

All of that is changing. Within the last three years B.C. has developed a comprehensive new ecoregions-based Protected Areas Strategy for the province, aimed at achieving protection of 12% of British Columbia by the year 2000. (Workshop participants will recall the separate presentation on this subject by Kris Kennett of B.C. Parks.)

It is within this context that B.C. Parks is looking very closely at the new SOER marine regions framework as a possible planning base for a comprehensive system of marine protected areas, developed cooperatively with Parks Canada and Fisheries and Oceans Canada. Discussion of such a shared federal-provincial initiative is still at an early stage, including whether to adopt the SOER framework. If adoption of this new regional framework were to become reasonable for Parks Canada in the Pacific, then similar revision of our marine regions planning framework elsewhere would be a reasonable expectation.

UNITED STATES

Brief remarks are offered on marine regionalisation efforts in the United States. Although it remains relatively unknown in comparison to the U.S. national parks, which include sizeable marine components in places such as Everglades and Biscayne in Florida, and Glacier Bay in Alaska, the U.S. National Marine Sanctuaries Program has become the primary marine protected areas program in America.

The sanctuaries program has the appearance of being regionally based, in that regions are defined as noted in Fig. 13. However, there has been little attempt to do more than reflect the marine biogeographic provinces of Ekman and Briggs. The sanctuary regions also fairly closely follow a number of the marine fisheries management zones in the U.S. As with fisheries management, the sanctuaries program has had to deal frequently with political imperatives, and it is not by system design that most progress in achieving new marine sanctuaries has occurred off the Florida and California coasts. The large, recent Florida Keys and Monterey Bay sanctuaries both owe much to strong political intervention. Staff in the sanctuaries program are working hard to add sanctuaries in the less represented regions, and Stellwagen Bank off Massachusetts has been a singular success in this regard.

CONCLUDING REMARKS

The following points are offered as a consequence of marine regionalisation efforts in Canada and insights into the Australian setting gained during the Sydney workshop:

1. Be clear as to what your objectives are in establishing a marine regional classification system.

What criteria will be used to define it, and what criteria will be used later to select candidate marine protected areas from within regions?

The Australian objective appears to be somewhat distinct from that within Parks Canada. In Australia, the intent appears to be to define regions to a finer hierarchical level than was attempted in Canada, and to establish relatively smaller protected areas representative of the resultant smaller regions. State jurisdiction over coastal areas appears to be a key factor in this distinct approach. By contrast, the Parks Canada approach is to look for larger areas representative of larger marine regions during the first step of the five-step park establishment process. Both are valid approaches.

Will you strike a balance between physical and biological factors, as in Canada, or will you indeed attempt bioregions?

The workshop results indicate the former, with physical measures such as coastal morphology or bathymetry serving as a surrogate measure of biological regionalisation.

Will you focus on coastal marine regions, or give equal attention to the Australian offshore?

The workshop was inconclusive, and state interests are recognised as a key consideration. Ideally, the commonwealth and state interests can be merged to result in a regionalisation having broad application.

2. Qualitative or delphic methods have the benefit of being relatively easy to apply, and they are easily explained to the lay person (including political decision makers).

3. But are quantitative, statistical methods preferable from a scientific rigour perspective?

   Do the data allow them to be applied?

   Will the results justify the higher cost?

4. Accept that you may not get it entirely right the first time!

NOTE: The views offered throughout this paper are those of the author and do not necessarily reflect those of Parks Canada or any other agency cited herein.

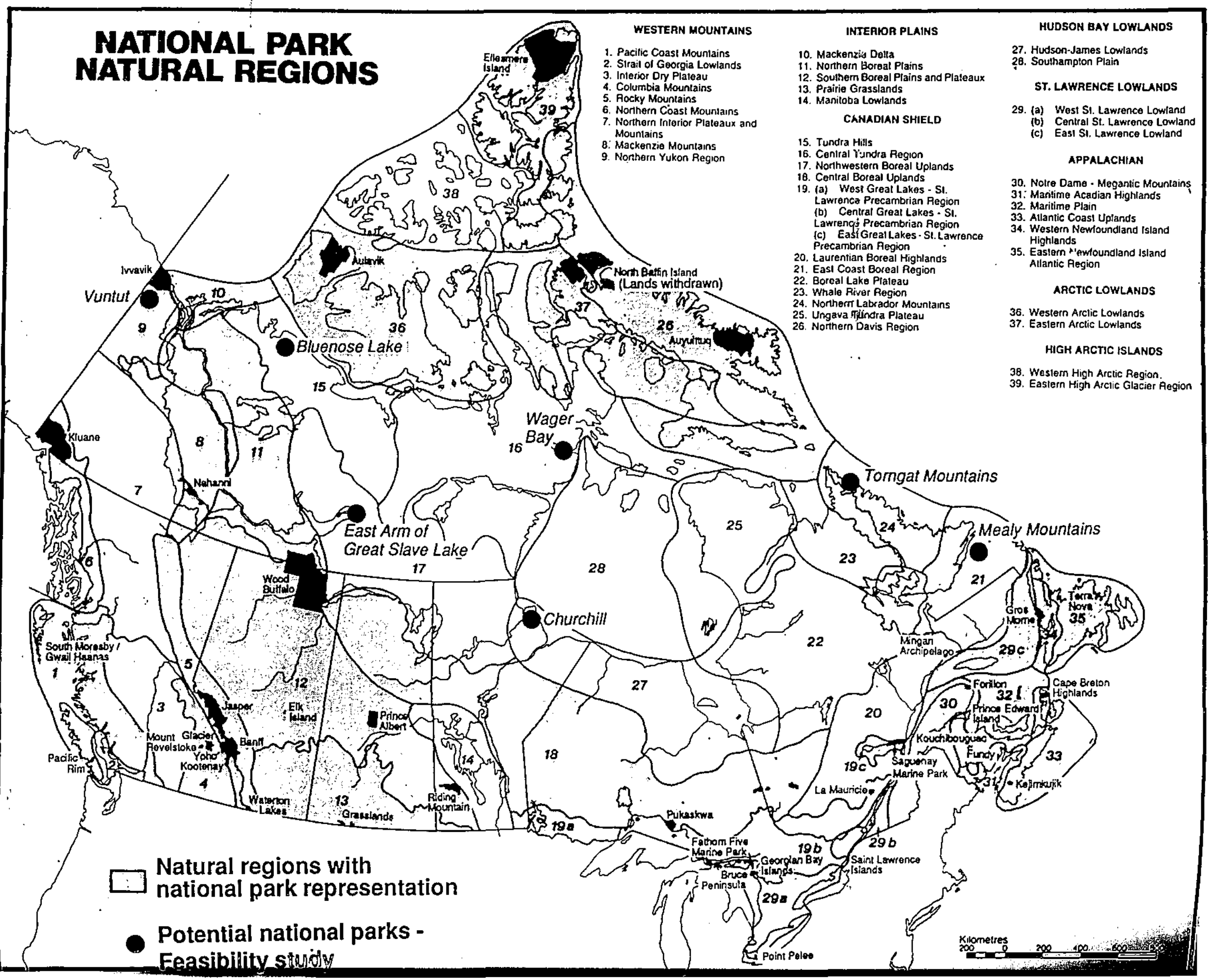

NATIONAL PARK NATURAL REGIONS
WESTERN MOUNTAINS
1. Pacific Coast Mountains
2. Strait of Georgia Lowlands
3. Interior Dry Plateau
4. Columbia Mountains
5. Rocky Mountains
6. Northern Coast Mountains
7. Northern Interior Plateaux and Mountains
8. Mackenzie Mountains
9. Northern Yukon Region
INTERIOR PLAINS
10. Mackenzie Delta
11. Northern Boreal Plains
12. Southern Boreal Plains and Plateaux
13. Prairie Grasslands
14. Manitoba Lowlands
CANADIAN SHIELD
15. Tundra Hills
16. Central Tundra Region
17. Northwestern Boreal Uplands
18. Central Boreal Uplands
19. (a) West Great Lakes - St. Lawrence Precambrian Region
(b) Central Great Lakes - St. Lawrence Precambrian Region
(c) East Great Lakes - St. Lawrence Precambrian Region
20. Laurentian Boreal Highlands
21. East Coast Boreal Region
22. Boreal Lake Plateau
23. Whale River Region
24. Northern Labrador Mountains
25. Ungava Tundra Plateau
26. Northern Davis Region
HUDSON BAY LOWLANDS
27. Hudson-James Lowlands
28. Southampton Plain
ST. LAWRENCE LOWLANDS
29. (a) West St. Lawrence Lowland
(b) Central St. Lawrence Lowland
(c) East St. Lawrence Lowland
APPALACHIAN
30. Notre Dame - Megantic Mountains
31. Maritime Acadian Highlands
32. Maritime Plain
33. Atlantic Coast Uplands
34. Western Newfoundland Island Highlands
35. Eastern Newfoundland Island Atlantic Region
ARCTIC LOWLANDS
36. Western Arctic Lowlands
37. Eastern Arctic Lowlands
HIGH ARCTIC ISLANDS
38. Western High Arctic Region
39. Eastern High Arctic Glacier Region
Ellesmere Island
North Baffin Island (Lands withdrawn)
Auyuittuq
Aulavik
Ivvavik
Vuntut
Bluenose Lake
Wager Bay
Kluane
Nahanni
Torngat Mountains
Mealy Mountains
East Arm of Great Slave Lake
Wood Buffalo
Churchill
Terra Nova
Gros Morne
Mingan Archipelago
South Moresby / Gwaii Haanas
Forillon
Cape Breton Highlands
Prince Edward Island
Kouchibouguac
Fundy
Kejimkujik
Saguenay Marine Park
La Mauricie
Jasper
Elk Island
Prince Albert
Mount Revelstoke
Glacier
Yoho
Kootenay
Banff
Pacific Rim
Waterton Lakes
Grasslands
Riding Mountain
Pukaskwa
Fathom Five Marine Park
Georgian Bay Islands
Bruce Peninsula
Saint Lawrence Islands
Point Pelee
Kilometres
Natural regions with national park representation
Potential national parks - Feasibility study

FIGURE. 1

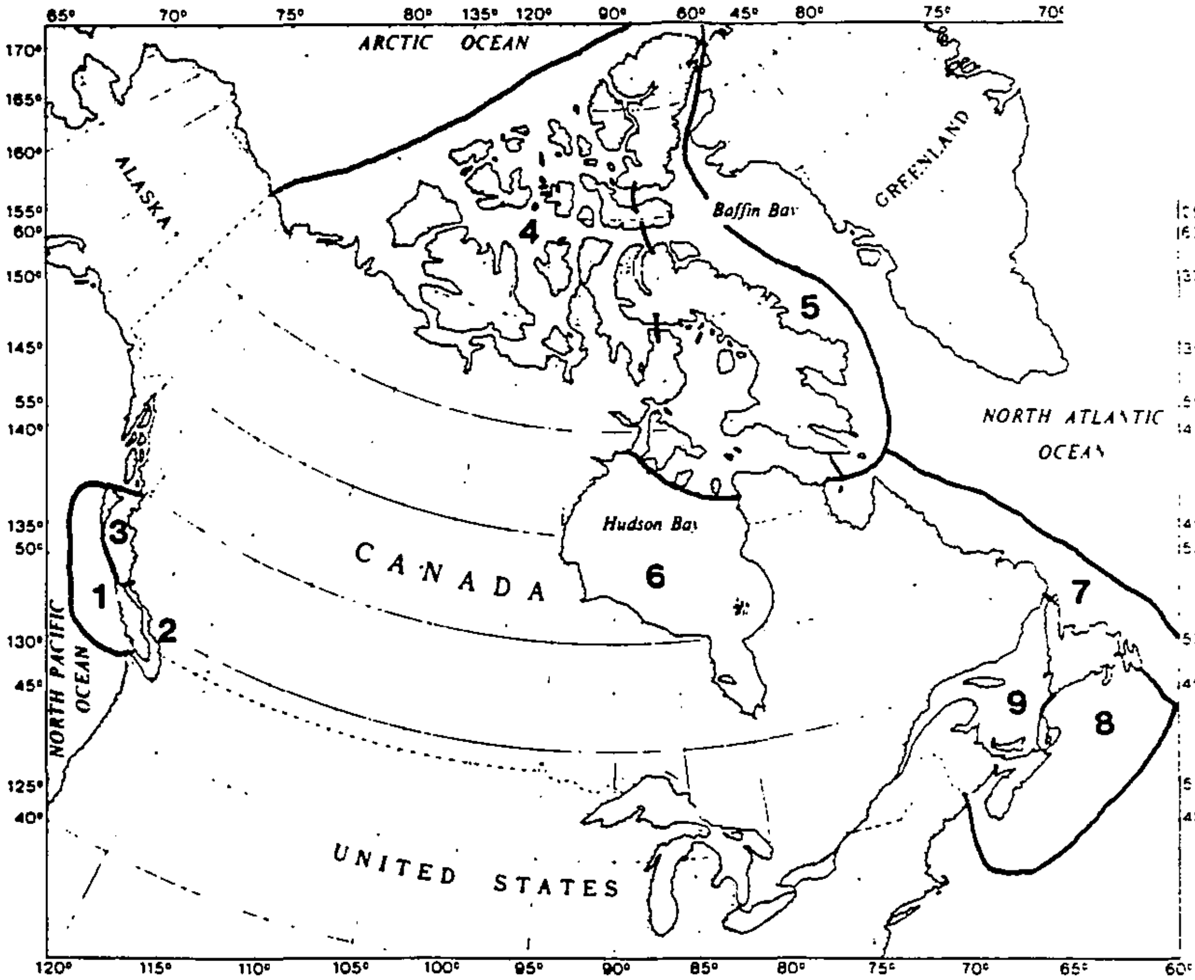


FIGURE 2. Previously defined Marine Regions of Paish (1970) from Woodward - Clyde (1983)

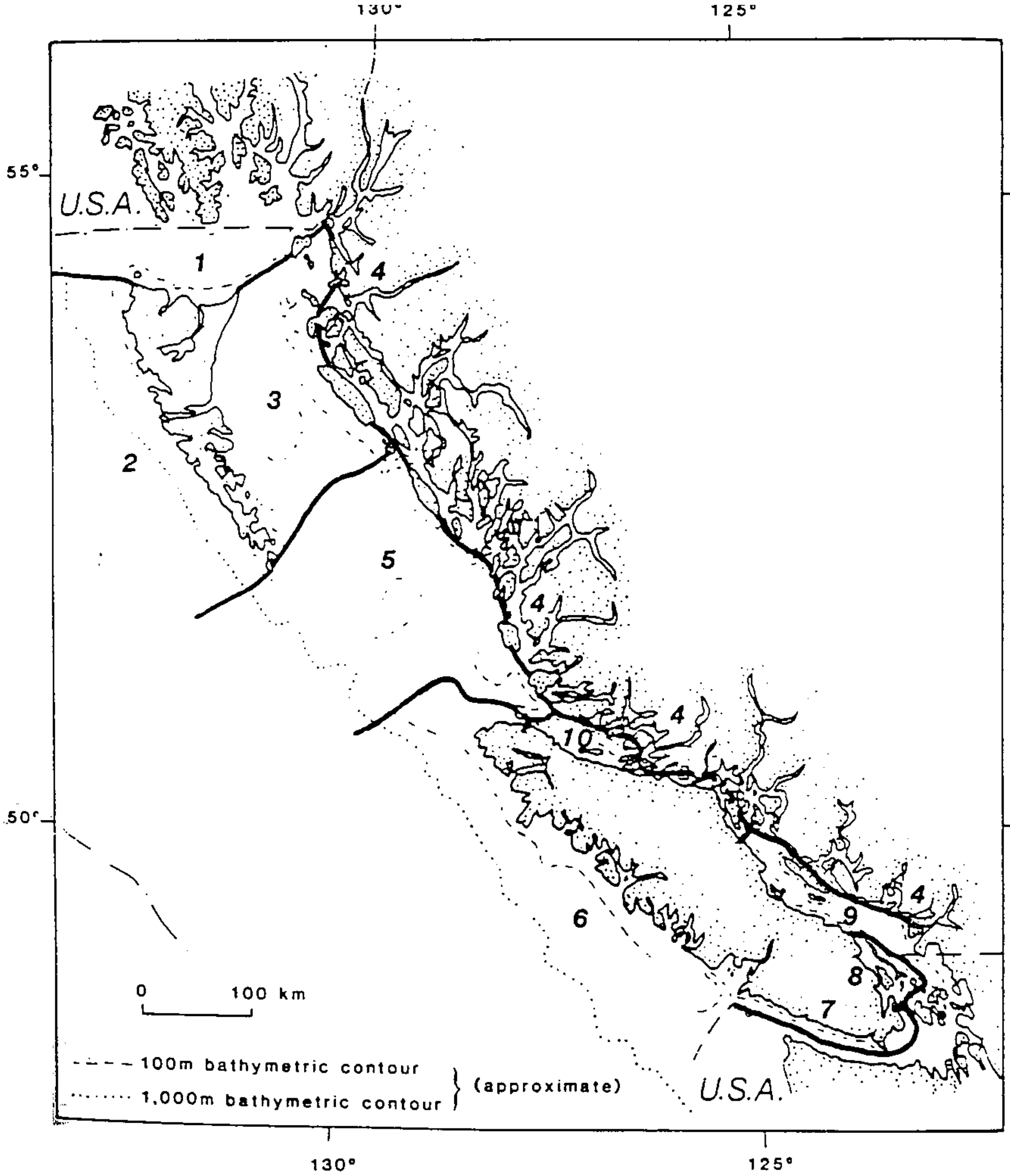


FIGURE 3. Pacific Oceanographic Regions

from Woodward - Clyde (1983)

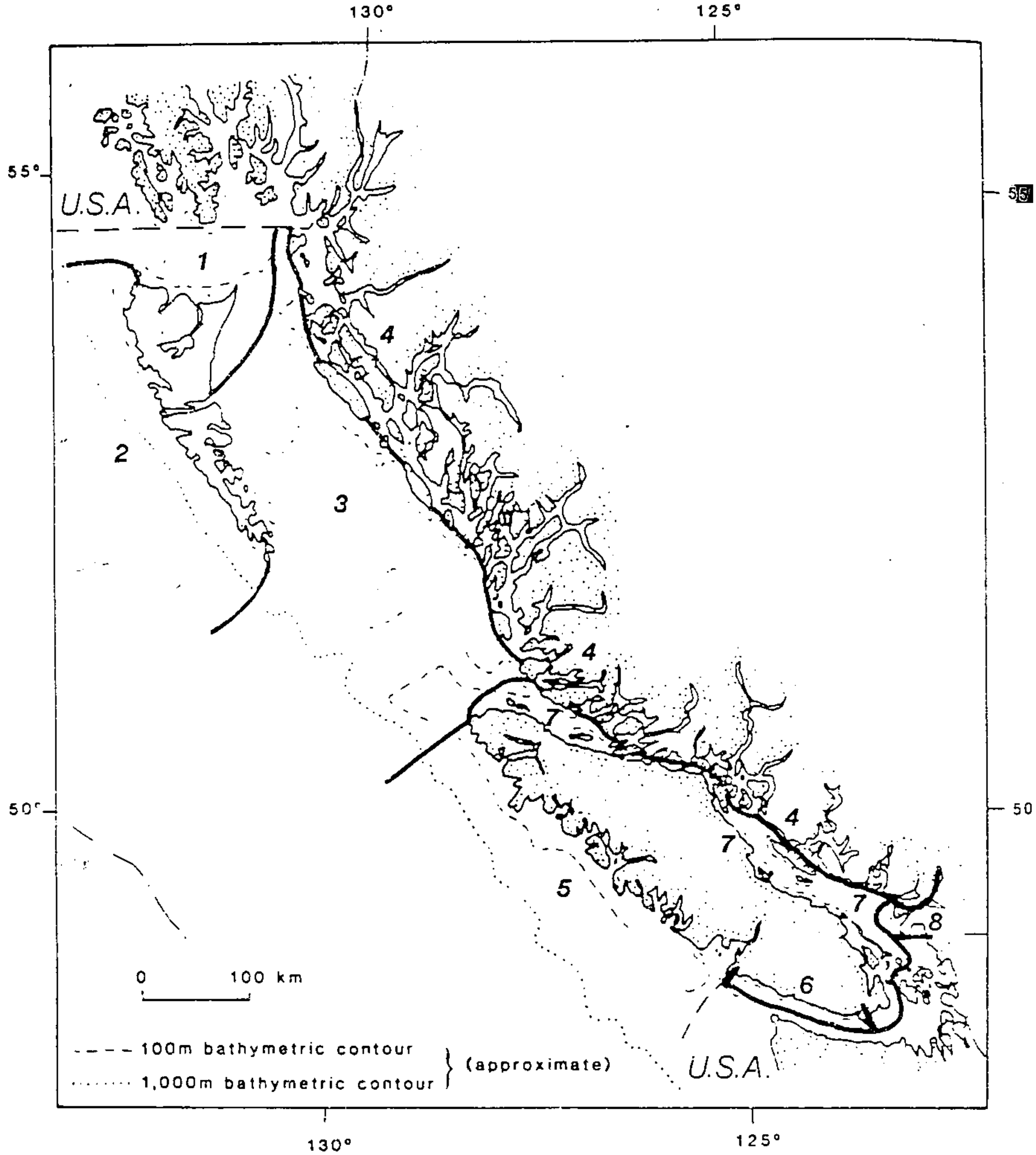


FIGURE 4. Pacific Coastal Environments (after Owens 1977) from Woodward - Clyde (1983)

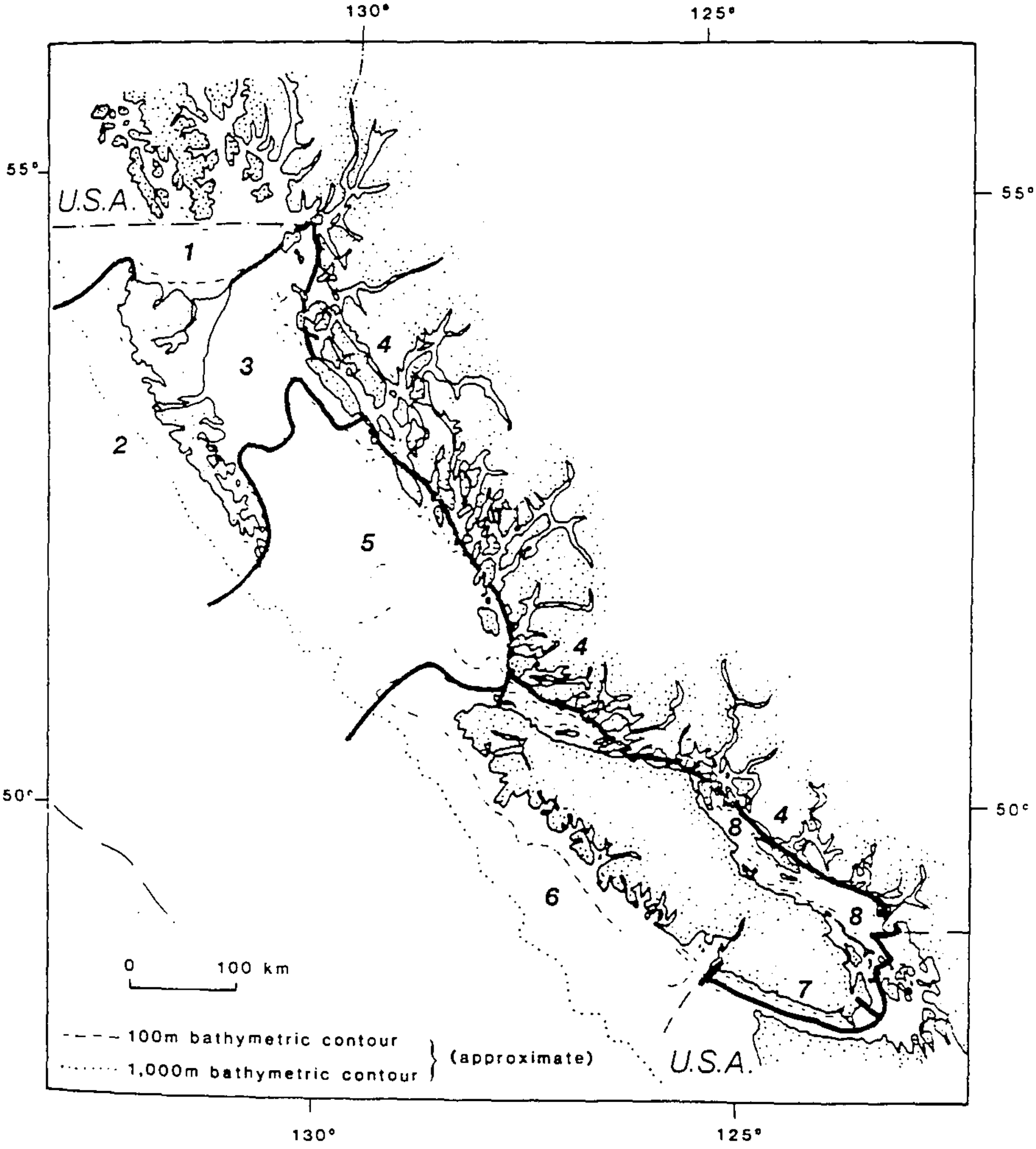


FIGURE 5. Pacific Marine Physiographic Regions

from Woodward - Clyde (1983)

1. Where two or more theme boundaries concide, adopt that as a base case boundary
2. Where two them boundaries are near each other and generally parallel, adopt a base case boundary half way between the two (the amount of contested area is independent of where the base case boundary is placed between the two; the contested area is balanced between the two themes).
3. Where a single theme boundary is very important, adopt it as a base case boundary. Where a boundary is not considered important, do not adopt it (minimizes total number of regions).
4. Where three theme boundaries are near each other and generally parallel, treat the two nearest each other with rule number 1 or 2, and treat the remaining boundary with rule number 3 (minimizes the contested area).

FIGURE 6. Development of Biological and Physical Base Cases - Rules
(Source: Marine Regions of Canada: Framework for Canada's System of National Marine Parks. Prepared for Parks Canada by Woodward-Clyde Consultants. pp3-3, 3-7)

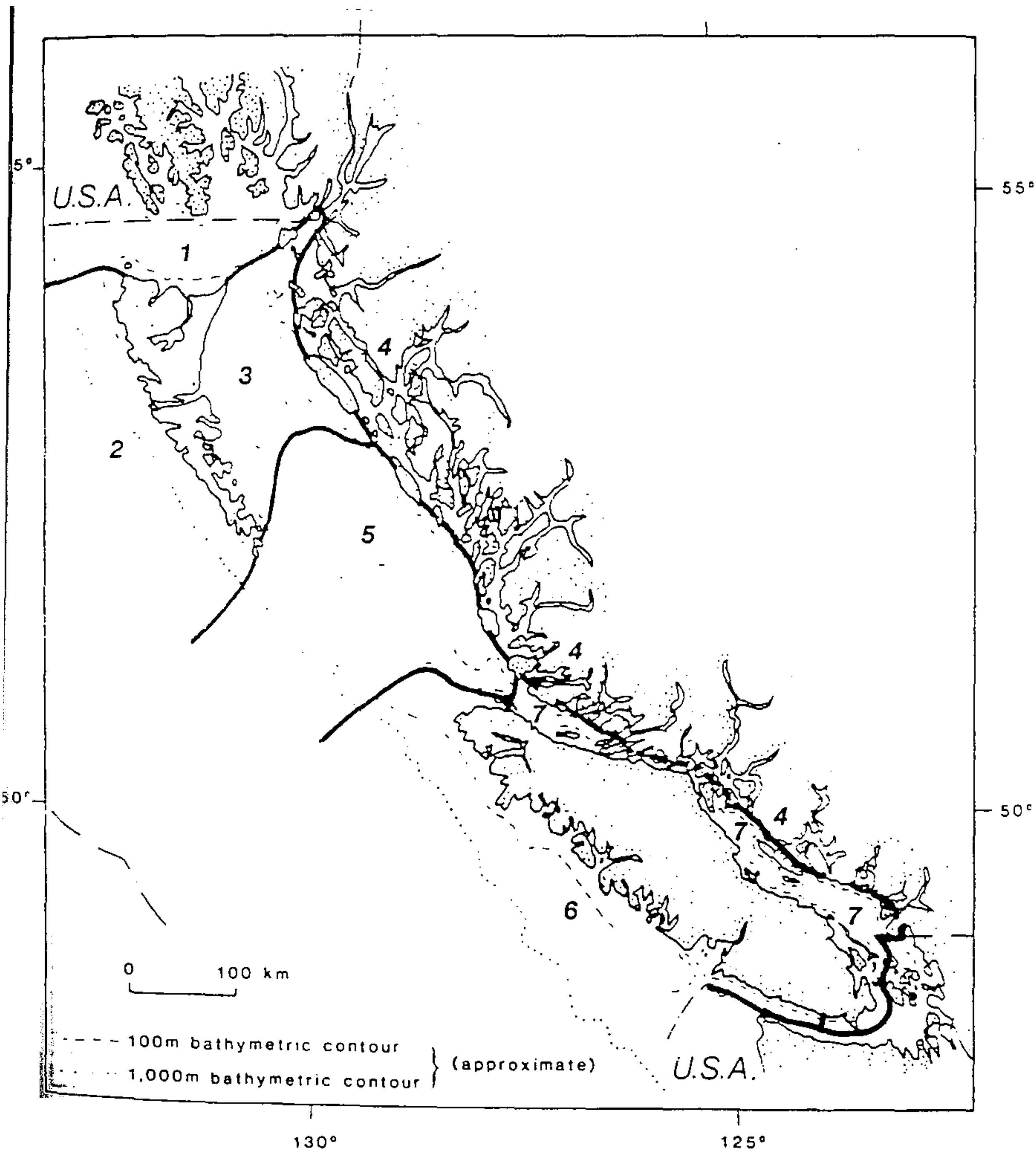


FIGURE 7. Pacific Physical Base Case

from Woodward - Clyde (1983)

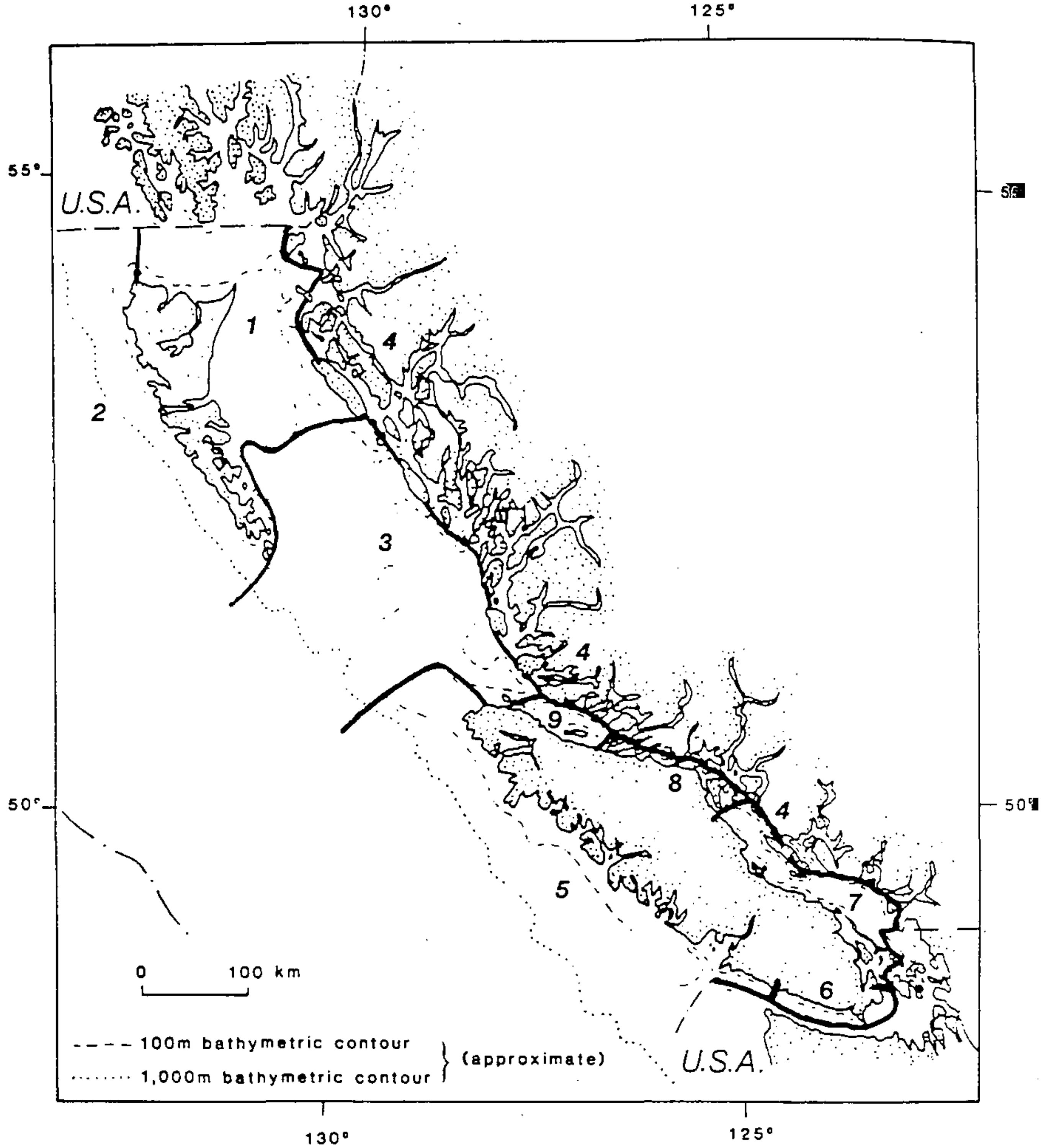


FIGURE 8. Pacific Biological Base Case from Woodward - Clyde (1983)

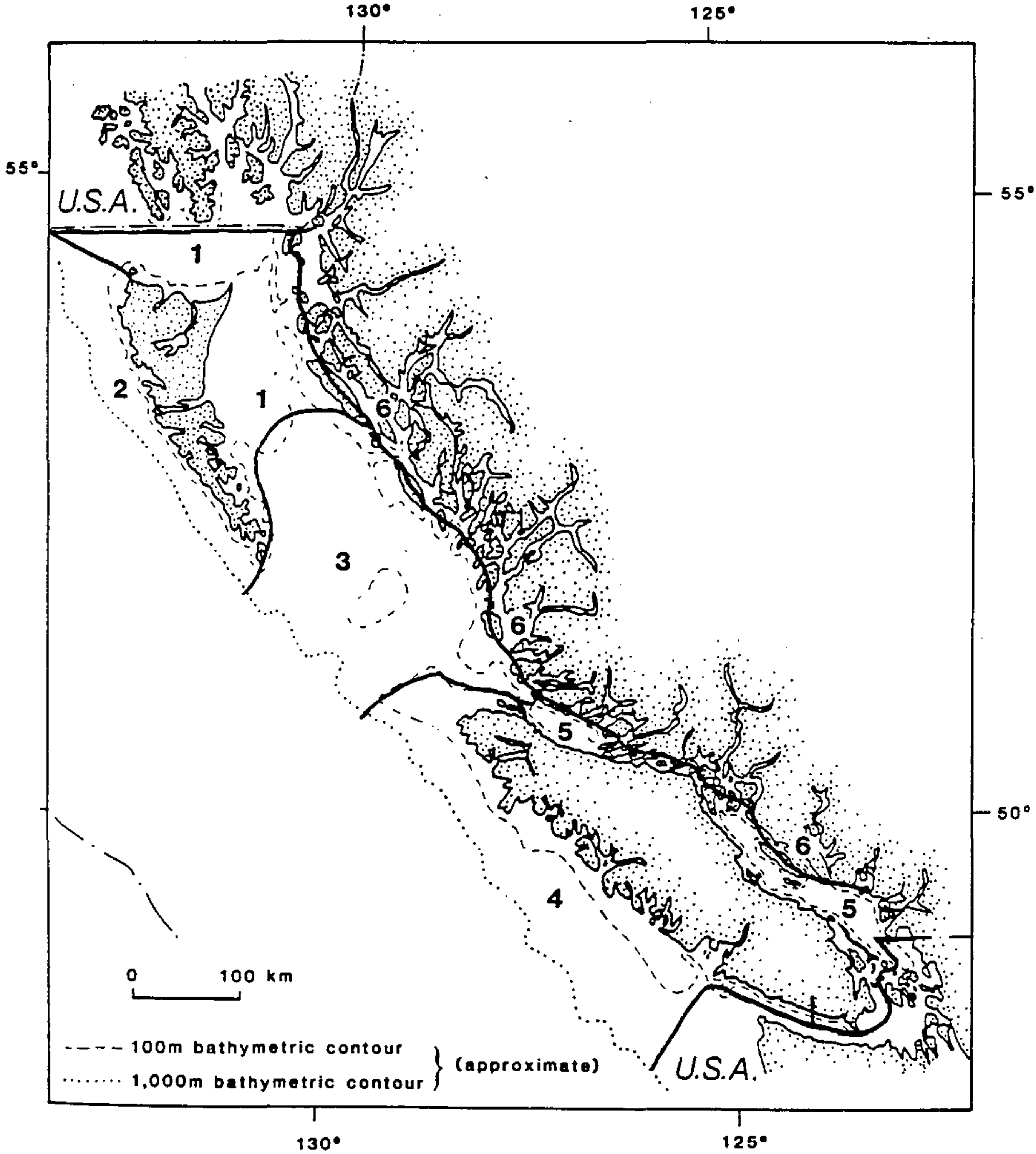


FIGURE 9. Marine Regions of the Pacific Coast from Woodward - Clyde (1983)

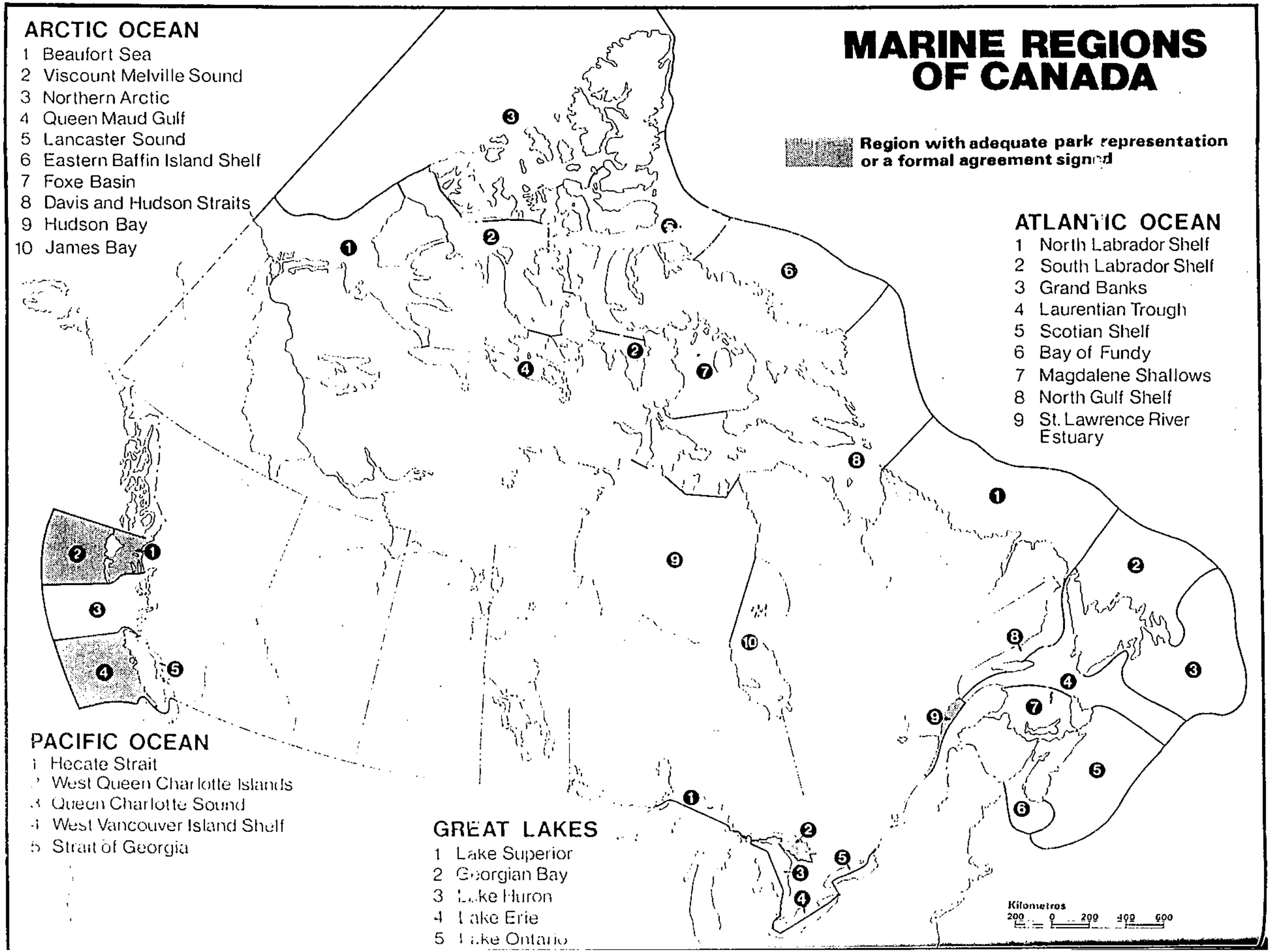
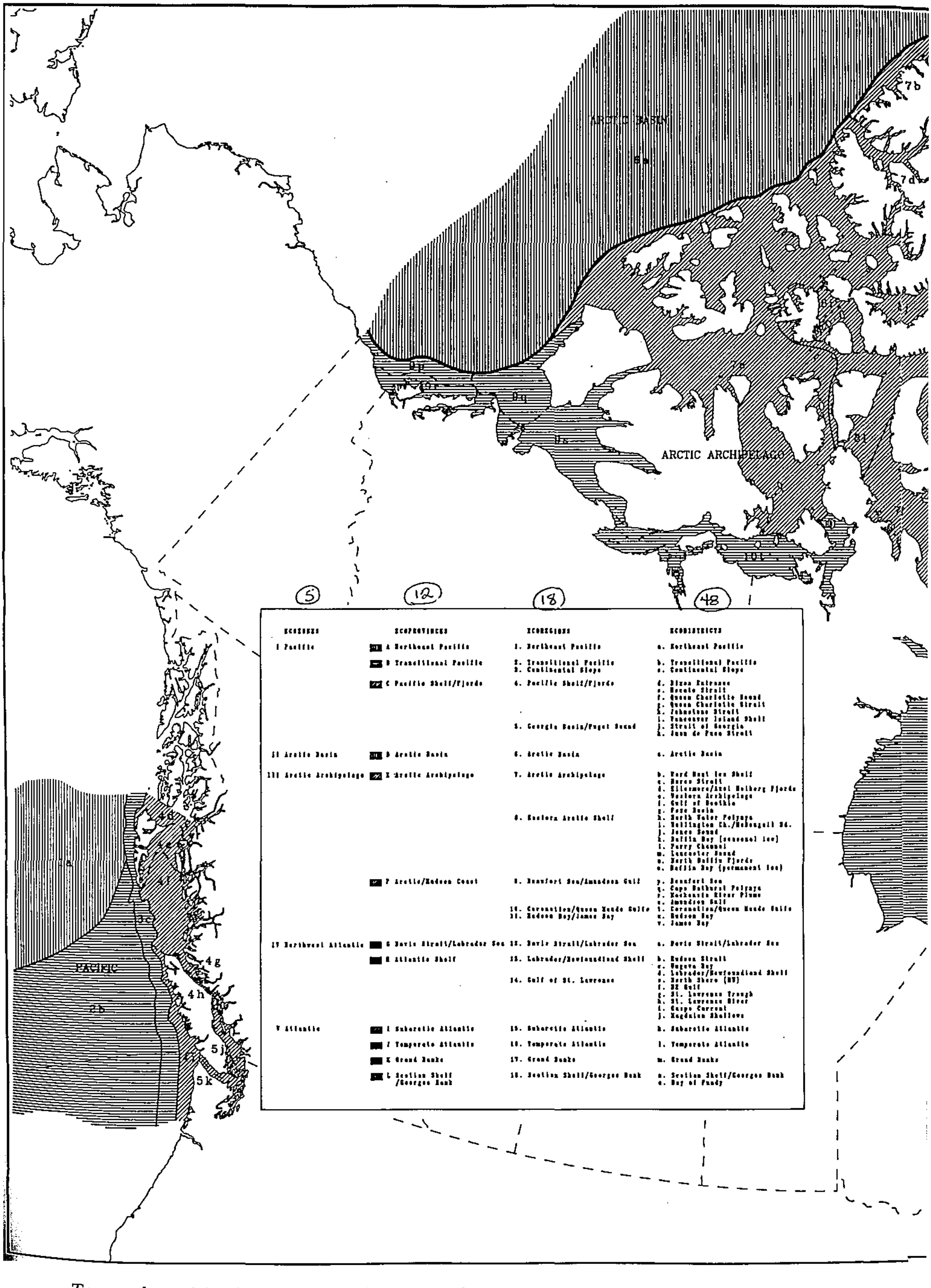


FIGURE 10. Marine Regions of Canada


ARCTIC BASIN
6a
7b
7d
9p
9q
9s
ARCTIC ARCHIPELAGO
10t
4d
4f
3c
4g
4h
5j
5k
PACIFIC
2b
5
12
18
48
ECOZONES
ECOPROVINCES
ECOREGIONS
ECODISTRICTS
I Pacific
A Northeast Pacific
1. Northeast Pacific
a. Northeast Pacific
B Transitional Pacific
2. Transitional Pacific
3. Continental Slope
b. Transitional Pacific
c. Continental Slope
C Pacific Shelf/Fjords
4. Pacific Shelf/Fjords
d. Dixon Entrance
e. Hecate Strait
f. Queen Charlotte Sound
g. Queen Charlotte Strait
h. Johnstone Strait
i. Vancouver Island Shelf
5. Georgia Basin/Puget Sound
j. Strait of Georgia
k. Juan de Fuca Strait
II Arctic Basin
D Arctic Basin
6. Arctic Basin
a. Arctic Basin
III Arctic Archipelago
E Arctic Archipelago
7. Arctic Archipelago
b. Ward Hunt Ice Shelf
c. Nares Strait
d. Ellesmere/Axel Heiberg Fjords
e. Western Archipelago
f. Gulf of Boothia
g. Foxe Basin
8. Eastern Arctic Shelf
h. North Water Polynya
i. Wellington Ch./McDougall Sd.
j. Jones Sound
k. Baffin Bay (seasonal ice)
l. Parry Channel
m. Lancaster Sound
n. North Baffin Fjords
o. Baffin Bay (permanent ice)
F Arctic/Hudson Coast
9. Beaufort Sea/Amundsen Gulf
p. Beaufort Sea
q. Cape Bathurst Polynya
r. Mackenzie River Plume
s. Amundsen Gulf
10. Coronation/Queen Maude Gulfs
11. Hudson Bay/James Bay
t. Coronation/Queen Maude Gulfs
u. Hudson Bay
v. James Bay
IV Northwest Atlantic
G Davis Strait/Labrador Sea
12. Davis Strait/Labrador Sea
a. Davis Strait/Labrador Sea
H Atlantic Shelf
13. Labrador/Newfoundland Shelf
b. Hudson Strait
c. Ungava Bay
d. Labrador/Newfoundland Shelf
14. Gulf of St. Lawrence
e. North Shore (NW)
f. NE Gulf
g. St. Lawrence Trough
h. St. Lawrence River
i. Gaspe Current
j. Magdalen Shallows
V Atlantic
I Subarctic Atlantic
15. Subarctic Atlantic
k. Subarctic Atlantic
J Temperate Atlantic
16. Temperate Atlantic
l. Temperate Atlantic
K Grand Banks
17. Grand Banks
m. Grand Banks
L Scotian Shelf /Georges Bank
18. Scotian Shelf/Georges Bank
n. Scotian Shelf/Georges Bank
o. Bay of Fundy

The New Zealand Experience in Developing a Marine Biogeographic Regionalisation

Kathy Walls
Department of Conservation - Te Papa Atawhai,
New Zealand

ABSTRACT

Although the New Zealand Marine Reserves Act was enacted in 1971, only two marine reserves had been established by the mid 1980's. With the formation of the Department of Conservation (DoC) in 1987 came a renewed commitment to establish marine reserves. DoC embarked upon a strategy to establish a network of marine reserves around the country. The first stage of a marine reserves network is development of a marine biogeographic regional framework. However, in 1987 there were no accepted regions for New Zealand. By December 1991 New Zealand had three marine reserves and 28 proposals at various stages of development, all chosen on a site by site basis.

In 1992 marine scientists and conservation managers from a variety of organisations met and agreed on the location of eight marine biogeographic regions for New Zealand. They used biotic, oceanographic and geological information.

This paper describes the processes involved in identifying the regions and candidate areas for protection as marine reserves.

INTRODUCTION

In New Zealand, our record of marine environment protection lags behind efforts on land where over 30% of the area is protected in some form of reserve. Yet, less than 1% of our 15,000km coastline is protected as marine reserves. The legislation used to protect areas of the marine environment is the Marine Reserves Act, 1971.

New Zealand's first marine reserve, Cape Rodney - Okakari Point Marine Reserve near Leigh, Northland, was gazetted in 1975, following over five years of requests by marine scientists to the Government.

New Zealand did not, however, take up the challenge of generating a system of marine reserves immediately. In fact, progress with marine reserve establishment was so slow, that a further six years elapsed before the country's second marine reserve - the Poor Knights Islands, was established. A number of agencies and bodies considered the marine reserves legislation inappropriate for creating marine reserves because of its scientific purpose and failure to provide for other reasons for protecting the marine environment.

As a result, other legislation was used. For example, three marine parks were established under the Fisheries Act 1983. These include Mimiwhangata and Tawharanui on the northeast coast of Northland; and the Sugar Loaf Islands off New Plymouth on the west coast of the North Island[1]. However, the fisheries legislation must specify the species to be protected, any method restrictions and bag limits to implement a marine park. This differs from the Marine Reserves Act which protects all marine life and their habitats within a particular area, unless specified otherwise.

Three government agencies have been involved in establishing marine reserves since the enactment of marine reserves legislation in 1971. Initially, the Marine Department administered the legislation. From 1972 to the mid 1980's, the Ministry of Agriculture and Fisheries held responsibility for the Marine Reserves Act, 1971; developed marine protected areas policy and identified potential marine protected area sites (MAF 1985, 1986 and 1987).

In 1987, the Department of Conservation (DoC) was formed and became the administering agency for the Marine Reserves Act. Since 1987, DoC has begun to develop a marine reserves network around New Zealand protecting representative and special areas of the coast. A network approach is probably the most systematic way of protecting areas of the coastal/marine environment and will assist with preserving biological diversity and protecting New Zealand's natural heritage.

Running in parallel with DoC's plans for marine protection in New Zealand, are varous recommendations by international organisations that all coastal nations establish marine protected area networks[2]. Kelleher and Kenchington (1992) stated:

> "The development by a nation of such a system [of marine protected areas] will be aided by ..... agreement on a marine and estuarine classification system, including identified biogeographic areas ....".

Later in 1992, the United Nations Conference on Environment and Development (UNCED) addressed, among a wide range of environmental matters, the state of the marine environment and its resources. Agenda 21, Chapter 17 requires nations to work towards protecting marine ecosystems within the EEZ by identifying those marine ecosystems which exhibit high levels of biodiversity and productivity and other critical habitat areas and provide necessary limitations on use in these areas,

---

1 The Sugar Loaf Islands were declared a marine protected area under a special Act of Parliament in 1991 to provide integrated protection for the islands, waters, marine life and seabed. The area is jointly administered by the Ministry of Agriculture and Fisheries and the Department of Conservation.

2 Marine protected areas - "Any area of intertidal or subtidal terrain, together with its overlying water and associated flora and fauna, historical and cultural features, which has been reserve by law or other effective means to protect part or all of the enclosed environment." (International Union for Conservation of Nature and Natural Resources (IUCN) definition).

through, among other things, the designation of protected areas (MERT/MfE 1992). New Zealand has ratified the Convention on Biological Diversity which came into force on 29 December 1993. It is therefore binding on New Zealand in international law. It covers all environments, specifically including marine:

> "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." (Convention on Biological Diversity, 5 June 1992).

This requires conservation of both diversity within species and ecosystems.

By the end of 1991, New Zealand had three marine reserves and 28 proposals at various stages of development. At that time, a marine reserves "network" around New Zealand was starting to develop through areas being identified on a case by case basis by both outside organisations and DoC. A rationale for a network of representative marine areas around the coast had yet to be developed[3].

Handford (1987) considered that an action plan for marine protected areas in New Zealand should include a generalised classification of marine areas into broad biogeographic zones and habitat/ecosystem types, which in turn would be represented within a system or network. Ballantine (1991) recommended using pragmatic and social criteria within a biogeographic framework to select the precise sites for marine reserves.

It is worth noting that a number of approaches have been used in the past to subdivide New Zealand's marine environment into biogeographic areas or zones. Although the approaches provided valuable information, the authors were largely unsuccessful in identifying distinct biogeographic regions that were acceptable to the scientific community at large. The literature, dating back to the 1920's (Finlay, 1926; Powell, 1961; Moore, 1949, 1961; Knox, 1963, 1975; and King et al, 1985) provides evidence to this effect. For example, Moore (1949, 1961) used conspicuous and ecologically important species in defining New Zealand marine algal provinces.

However, Dell (1962) questioned the methods used by some to arrive at biogeographic areas. He demonstrated that many distributional limits of molluscan species were overlapping, making the delineation of boundaries on the mainland unclear. He surmised that distributional data for all species should be gathered to avoid defining questionable provincial boundaries.

In his review of the marine biogeography of New Zealand's benthic and shallow water fauna, Knox (1975) identified six provinces. King et al (1985) subsequently determined that the Knox classification was too general to be of value when considering areas of the coastal\marine environment for protection purposes. They produced a finer scale classification using "districts", aggregating into successively larg-

3 By March 1994, the situation was: 10 marine reserves, 4 applications awaiting ministerial decisions before they can be gazetted (2 outside applicants, 2 DoC), 2 applications to Director-General of Conservation (outside applicant and DoC) and 18 proposed areas (outside applicants and DoC).

er "regions" and "territories". However, the way in which King et al (1985) used the information to develop smaller classification units has been questioned.

Although there has been much work done on the subject of New Zealand's marine biogeographic regions, it would appear that until recently, New Zealand was no nearer a generally accepted system for defining biogeographic areas than it was when the issue was considered in detail in the 1960's. Further, New Zealand was no satisfactorily addressing international obligations and recommendations.

A marine reserve network requires a systematic method for identifying appropriate areas for protection. DoC considered that a marine biogeographic regional framework would be the most appropriate first step towards identifying areas for reservation because the marine reserves legislation emphasises protection of marine areas for scientific study of marine life. However, if any scheme for selecting marine reserves was to meet with acceptance from outside DoC, the involvement and co-operation of marine scientists was required.

METHOD

The Second International Temperate Reefs Symposium was held in Auckland, New Zealand in early 1992. The Symposium was an appropriate venue to inform the scientists and conservation managers likely to be present, about the need for scientific input into developing DoC's strategy for a network of marine reserves around New Zealand. My colleague, G. McAlpine and I presented a paper to the Symposium entitled: "Developing a strategy for a network of marine reserves around New Zealand - a manager's perspective" (Walls & McAlpine, 1993).

In our paper, we outlined the need for a network of marine reserves around New Zealand and referred to the historical development of marine biogeographic regions;

> *"There are no accepted methods for subdividing the marine biogeographic areas of New Zealand and for establishing scientific selection criteria to identify suitable areas for marine reserves. The existing marine reserves have been chosen on an ad hoc basis. It is suggested that, in the interests of marine science and conservation in New Zealand, a working group of scientists is formed to assist with the third phase of the strategy".*

Over 170 people from Australia, South Africa, United States, Canada, Great Britain, Italy and New Zealand attended the Symposium. They included managers from local authorities and DoC, consultants, conservationists, research scientists and technicians. There was general acceptance for our recommendation.

Having gained a favourable response from the participants at the Symposium, DoC made preparations for a workshop later in the year. It was held in the same week as the annual Marine Sciences Society Conference. This conference provides an opportunity for New Zealand's marine scientists and science managers to present papers and share information. It also gave DoC an opportunity to tap into the wide variety of marine expertise likely to be attending. I also made a commitment to the Society's executive that I would present the results of the workshop to the conference. Marine scientists and managers from a wide range of disciplines were invited to the workshop (refer to Appendices I & II). The collective expertise included specialists in marine taxa, knowledge of the habitats of some coastal areas, specialists in marine geology, coastal geomorphology and oceanography and others with a background in marine reserves. They and others unable to attend, provided summary information on their particular areas of expertise before the workshop. Published material of relevance to New Zealand marine biogeography was also collated.

It was important to have an independent facilitator for the workshop. I felt that somebody from overseas would probably be most appropriate. Peter Bridgewater, Director of the former Australian National Parks and Wildlife Service (now Australian Nature Conservation Agency), facilitated.

A primarily biotic information base was used. Distribution patterns of fish, molluscs, echinoderms, bryozoans, sponges, ascidians, antipatharians, foraminifera, brachiopods and algae were identified. Factors used to differentiate distribution patterns included endemism, species diversity, as well as geological and oceanographic features.

The workshop was held over one very full day. After some general discussion and individual presentations, the participants divided into two project groups. Each group analysed the information in relation to the North Island, South Island, and offshore island coastal/marine environments. The groups later reported back and reached consensus for the marine biogeographic regions. A map of the regions and some subregions (ecological areas) was drawn up at the workshop.

RESULTS AND DISCUSSION

MARINE BIOGEOGRAPHIC REGIONS

In all, eight biogeographic regions (solid lines) and several subregions (broken lines) were identified by the workshop participants (Figure 1).

The outer limits of the regions, as shown in Figure 1, are arbitrary. It is not known with certainty how far offshore these region extend.

The regions and subregions are as follows :

1. Kermadec Islands

This area is characterised by the presence of subtropical faunal elements originating from warm temperate Australasia and tropical Indo Pacific, endemic elements (especially strong for the molluscs), and a unique and distinctive flora.

The Kermadec Islands group is a marine reserve with all marine life protected.

2. Three Kings Islands and North Cape

The Three Kings Islands and North Cape region (Cape Maria van Dieman to North Cape) covers a small area. The physical environment around the Three Kings

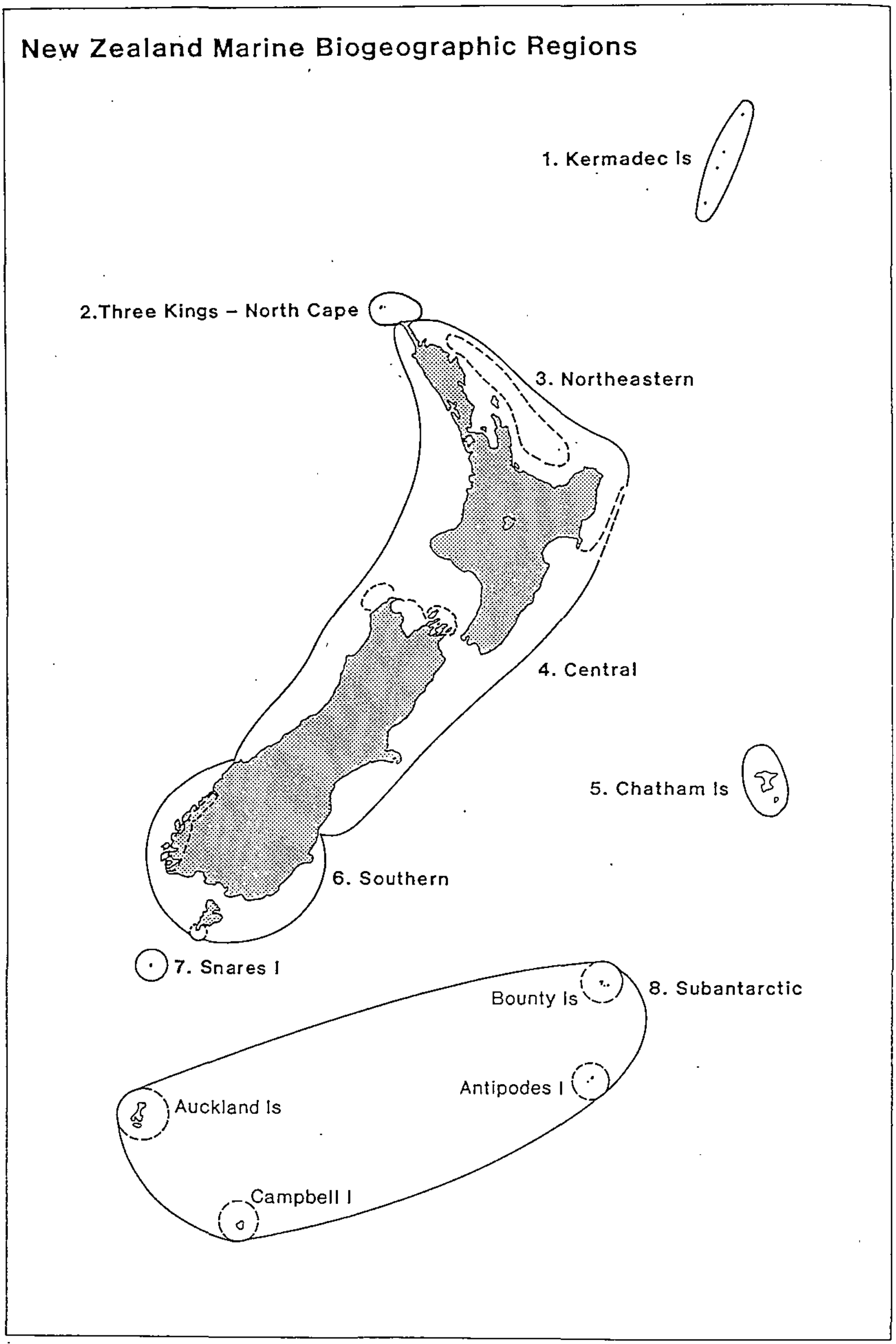

New Zealand Marine Biogeographic Regions
1. Kermadec Is
2.Three Kings – North Cape
3. Northeastern
4. Central
5. Chatham Is
6. Southern
7. Snares I
8. Subantarctic
Bounty Is
Antipodes I
Auckland Is
Campbell I

FIGURE 1

includes localised upwellings and is influenced by the Tasman Current. A high degree of endemism (molluscs, algae, fish and echinoderms) is evident. Some Australian and subtropical southwest Pacific taxa, not found elsewhere in New Zealand, are also evident. There are also species of New Zealand seaweeds occurring which are generally regarded as being of southern origins. Further, some genera and species which are common on the mainland are absent from the Three Kings.

There are overlaps in taxa between the Three Kings and North Cape regions, however, molluscan records indicate locally restricted endemics and the presence of a transitional fauna. This suggests the Three Kings - North Cape region warrants further investigation to determine whether subregions or two separate regions can be identified.

3. Northeastern

A northeastern region extends from North Cape to the East Cape. This region, especially the island groups, is influenced to varying degrees by the warm East Auckland Current. Therefore, the region is characterised by the presence of subtropical elements.

A subregion, strongly influenced by the East Auckland Current and comprising the Cavalli, Poor Knights, Mokohinau, Alderman, Mayor, and White island groups, was identified. A number of taxa - algae, molluscs, echinoids and antipatharians are endemic. Assemblages of sponges, ascidians, mollusca, fish, and echinoids are characteristic of this subregion.

Within the Northeastern region, rocky reef habitats interspersed with sand and gravel sediments are common.

The long established Cape Rodney - Okakari Point and recent Whanganui A Hei Marine Reserves, together with Mimiwhangata and Tawharanui Marine Parks, protect representative areas of the coast within this region.

Recognition of the region's special qualities has been acknowledged. The Poor Knights Islands were awarded marine reserve status some years ago. More recently, Mayor Island, in the Bay of Plenty, was established a marine reserve. Nearby, White Island is also under consideration for protection.

4. Central

An extensive central region was identified at the workshop. This extends along the east of the North and South Islands from East Cape to the Otago coast and in the west, North Cape south to Jackson Head, north of the fiords.

This middle New Zealand region is generally an area of mixed water masses with both subtropical and subantarctic influences. Most fish species, planktic foraminiferans, bryozoans, molluscs, sponges, and ascidian assemblages, are distributed widely over this region. The ascidian assemblages show temperate marine climate characteristics.

The molluscan fauna of this region is intermediate in composition between the Northeastern and Southern Regions with only a few endemic species. The Kaikoura area is an exception, there being more molluscan species in common with the Chatham Islands.

The Sugar Loaf Islands Marine Protected Area and the Kapiti Marine Reserve are the only marine protected areas on the North Island west coast.

Three subregions were identified at the top of the South Island. They show characteristic geology, oceanographic patterns, and biota. They are; the northwestern tip of the South Island including Farewell Spit, the Golden Bay area, and the Marlborough Sounds. The Long Island - Kokomohua Marine Reserve is representative of the mid-outer Marlborough Sounds and the Tonga Island Marine Reserve is representative of the rocky coastline of the Golden Bay area.

Several areas within this region should be investigated further. The area extending from East Cape to Mahia Peninsula is regarded as a transition zone between the Northeastern Region and the larger Central Region. The overlap of some taxa here indicates the influences of the warm East Auckland Current and the East Cape Current.

A paucity of information on some assemblages was evident, highlighting the need for further investigations. For example, there is insufficient information available to determine the degree of similarity or otherwise of the northern North Island west and east coasts flora.

Other areas within this large region warrant investigation also. In particular; Hawkes Bay/Cape Kidnappers, Castle Point/Matakaiona, Cape Turnagain, Cook Strait, Kaikoura, Canterbury Bight, and the west coast of both islands.

The biogeographic "boundaries" located on the Otago coast to the east and at Jackson Head in the west are characterised by the southern limits of long shingle beaches on both coasts and can be differentiated by the distribution of a number of taxonomic groups. On the Otago coast, Sertularian hydroids are represented by a greater number of species south of Oamaru. Crustacea become progressively more impoverished towards the south. These boundaries should be studied further to record the variety and extent of the changes in biota from the central to southern regions.

5. Chatham Islands

The fifth region identified surrounds the Chatham Islands. This region, situated in the Subtropical Convergence, is influenced by two major currents from the north and south. Biogeographically, the island group is interesting because of the notable absences of many taxa. This is likely to have resulted from the remoteness of the islands from mainland New Zealand, where much of the flora and fauna has been derived.

The fish fauna shows some affinities with the central region and endemic species are not evident. Algal assemblages are similar to those of both the North and South Islands. At present, seven endemic species of seaweeds are recognised from the Chathams and a number of species remain undescribed. On the other hand, a number of species common on the mainland in similar habitats at equivalent latitudes are absent from the islands. The molluscan fauna exhibits some endemic characteristics while some species show similarities with the Kaikoura area.

6. Southern

A Southern Region, extending south from the Otago coast around to Jackson Head in the west and including Stewart Island, was the sixth region to be identified. The flora and fish fauna show similarities with those found in the Central Region. Sponge, ascidian and bryozoan records exhibit some similarities with the central region, also. There are some subantarctic elements represented in the floral and sponge/ascidian assemblages. On the other hand, molluscan records suggest that a distinctive southern South Island fauna exists.

The Southern Region has a number of subregions comprising unique faunal assemblages. The extensive middle and inner fiords (Fiordland), notable for the sponges, ascidians, brachiopods, pennatulaceans, stylasterids and antipatharians which occur there, can be further categorised into northern and southern subregions. The inlets along Stewart Island's east coast are regarded, collectively, as a subregion. Distinctive brachiopod, antipatharian, and other faunal assemblages exist here.

There are two marine reserves in the northern Fiordland subregion.

7. Snares Islands

This island group is generally regarded as an overlap between the South/Stewart Islands and subantarctic island groups. The area is influenced and confined by the Subtropical Convergence which is located between the Snares and Auckland Islands. Molluscan and fish fauna show affinities with the Southern Region. However, the flora shows subantarctic elements, although 28% of algal species are not found on any of the subantarctic islands. This is due to several mainland species reaching their southern distributional limits at the Snares.

8. Subantarctic

The Subantarctic Region comprises the Auckland, Campbell, Antipodes and Bounty Island groups. These islands are influenced by the cold subantarctic waters and the West Wind Drift. They exhibit assemblages (fish, flora, ascidians and sponges) characteristic of both southern New Zealand and the subantarctic. Bryozoan records show a diverse range of endemic species. On the other hand, the molluscan fauna is limited in variety although each island group has a small number of endemic species. The fish fauna is poorly studied but appears to be low in diversity. Further investigations may determine whether each island group comprises a subregion within the region.

OTHER REGIONS

Continental shelf and slope

This regional type was not identified at the workshop but should be considered. There may be one or more separate regions extending beyond the shallower inshore regions.

Estuarine

This regional type was not identified at the workshop, either. However, a wide variety of estuaries are present throughout New Zealand. There may be several estuarine regions. Two of the most obvious regions are the mangrove areas of the northern half of the North Island and the remaining southern estuaries where other estuarine plant species occur. Recent work on foraminiferans recognised three estuarine biogeographic zones within mainland New Zealand - northern North Island, North Island and northern South Island/Stewart Island.

KEY POINTS ARISING FROM THE WORKSHOP

The workshop participants identified a number of key points in relation to the biogeographic exercise which are outlined below:

(i) The "general picture" developed at the workshop needs to be more specific. However, it was not decided "how specific should the picture be, to be of use in identifying areas worthy of preservation?"

(ii) There was support for considering the work of King et al (1975) and integrating it with the workshop information.

(iii) Scientific criteria should be used first when identifying areas for marine protection. Scientific criteria includes; degree of connectedness between marine reserves, size and shape, replication of similar areas.

(iv) There were numerous "information gaps", examples being the transition zone between East Cape and Hawkes Bay, and the West Coast of the South Island. Research should target these regions.

(v) Estuarine biogeographic patterns differ from the marine biogeographic patterns. These should be investigated in a further exercise.

(vi) Geomorphic systems may be the most useful as a basis for a classification system as more detailed information on the marine biota for all areas is required.

(vii) The offshore environments need to be considered, for example the Chatham Rise.

(viii) Adjacent terrestrial and marine ecosystems should be protected, where possible. This will ensure that the land use is complementary to the adjacent marine protected area.

(ix) Consideration should be given to the ecological relationship between marine reserves, to maximise the effectiveness of recruitment areas and of larval dispersal, as examples.

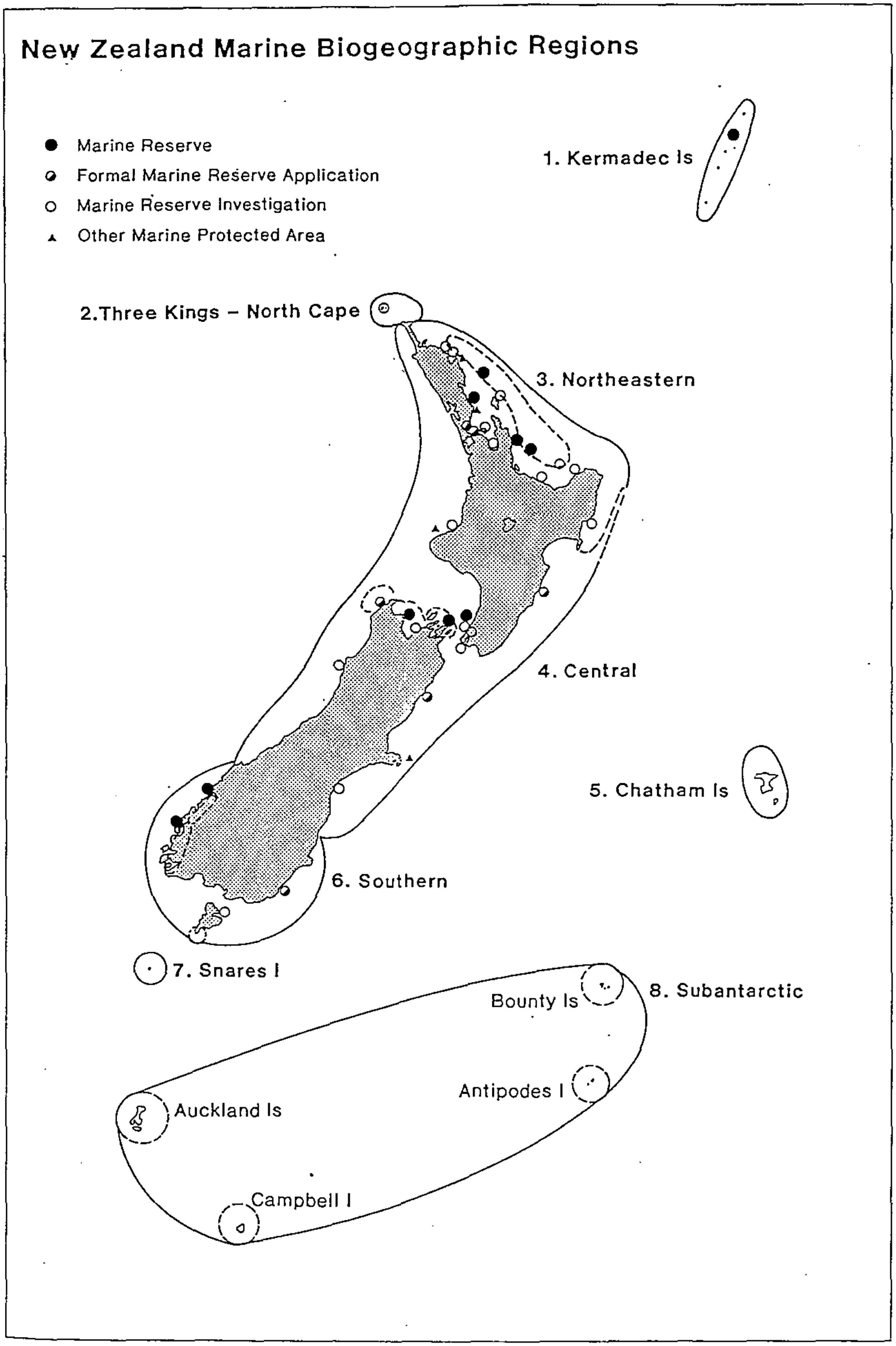

New Zealand Marine Biogeographic Regions
Marine Reserve
Formal Marine Reserve Application
Marine Reserve Investigation
Other Marine Protected Area
1. Kermadec Is
2.Three Kings – North Cape
3. Northeastern
4. Central
5. Chatham Is
6. Southern
7. Snares I
8. Subantarctic
Bounty Is
Antipodes I
Auckland Is
Campbell I

FIGURE 2

(x) There was merit in establishing both large marine reserves, comprising numerous habitats, and many small marine reserves which contain fewer habitats.

(xi) New Zealand's biodiversity is very rich with new taxonomic discoveries occurring frequently. However, there is poor resourcing for biosystematics. In addition, the information needs to be accessible. It is vital that voucher specimens be deposited with the appropriate institutions. The Museum of New Zealand and the New Zealand Oceanographic Institute (NIWA) are the nationally recognised institutions for collections.

MARINE SCIENCES SOCIETY CONFERENCE 1992

I presented the results of the workshop to the annual New Zealand Marine Sciences Society conference on in August 1992. Some 250 scientists, technicians and managers were present at the conference and this provided the opportunity to present the workshop results to a wide audience.

BIOGEOGRAPHIC REGIONS AND MARINE RESERVES ANALYSIS

I stated earlier that marine reserves are currently selected on a site by site basis without any reference to a biogeographic framework. Figure 2 and Table 1 show the location of existing marine reserves, applications and proposals/investigations in relation to the biogeographic regions.

A general comparison shows that marine reserves and proposals/investigations are not represented in regions 5 (Chatham Islands), 7 (Snares Island) and 8 (Subantarctic Group) and that region 4 (Central) is probably under-represented.

TABLE 1. **Marine Biogeographic Regional Analysis**

	Biogeographic Region	**No. of Marine Reserves, Applications, Proposals/Investigations**	
1.	Kermadec Islands	1	Marine Reserve
2.	Three Kings/North Cape	1	Proposal/Investigation
3.	Northeastern	4	Marine Reserves
		2	Applications
		8	Proposals/Investigations
4.	Central	3	Marine Reserves
		3	Applications
		8	Proposals/Investigations
5.	Chatham Islands	Nil	
6.	Southern	2	Marine Reserves
		1	Application
		1	Proposal/Investigation
7.	Snares Island	Nil	
8.	Subantarctic Islands	Nil	

The next part of the marine reserve network process will be to use the regions developed through the workshop as a framework within which habitats are classified and areas selected for protection as marine reserves. The workshop briefly considered classification systems and criteria but did not reach the stage of selecting any particular system for identifying marine reserves in New Zealand because of time constraints. It was agreed that DoC would investigate a number of systems used overseas and select one appropriate for New Zealand.

DoC has reviewed a number of classification systems and criteria used in the literature for identifying candidate areas for marine reservation. Essentially, classification systems aim to assist managers with identification of the full range of habitats, using relevant coastal/marine information. One or more criteria are then applied to the habitats which have been identified to select candidate areas for protection.

I anticipate that each of DoC's conservancies will work within the biogeographic regions which cover their particular conservancy.

When the classification and selection criteria have been finalised, I will work with the conservancies to assist with application of the classification and selection criteria to existing coastal/marine information bases. When the representative areas within each biogeographic region have been identified, subsequent steps include application of social, economic and pragmatic criteria to select particular sites for marine reserves and detailed public consultation for each site.

CONCLUSIONS

A systematic approach is required if DoC is to establish a network of marine reserves around New Zealand. A biogeographic regional approach has been chosen because the marine reserves legislation requires that areas be protected for scientific study of marine life. The agreement of the scientific community to the approach and the location of the regions has enabled DoC to begin work on selecting a suitable classification system and criteria to ultimately identify candidate areas for reservation.

REFERENCES

Ballantine, W.J. 1991. Marine reserves for New Zealand. *Leigh Laboratory Bulletin* 25. University of Auckland. 196 pp.

Convention on Biological Diversity, 5 June 1992. Rio de Janeiro, Brazil. Published by UNEP, 1992.

Dell, R.K. 1962. New Zealand marine provinces - do they exist? *Tuatara* 9: 1-23

Department of Conservation 1994. (in prep.) Status of New Zealand's marine flora and fauna. New Zealand Department of Conservation Report, Series ?. pp?

Finlay, H.J. 1925. Some modern conceptions applied to the study of the Cainozoic mollusca of New Zealand. In: Verbeek, Mem. Birthday Vol: 161-172

Handford, C. 1987. Towards an action plan for marine protected areas in New Zealand. pp62-74 in: Conserving the Natural Heritage of the Antarctic Realm, IUCN, Gland, Switzerland: *Proceedings of the 29th working session of the IUCN Commission on national parks and protected areas, Wairakei, New Zealand, August 1987*

Kelleher, G. and Kenchington, R. 1992. Guidelines for establishing marine protected areas. IUCN, Gland, Switzerland. *IVth World Congress on National Parks and Protected Areas, Caracas, Venezuela, 10-21 February 1992*

King, K.J., Bailey, K.N. and Clark, M.R. 1985. Coastal and marine ecological areas of New Zealand. A preliminary classification for conservation purposes. Information series 15/1985. Department of Lands and Survey, Wellington. 47pp

Knox, G.A. 1963. The biogeography and intertidal ecology of the Australasian coasts. *Oceanography and Marine Biology: Annual Review* 1: 341-404

Knox, G.A. 1975. The marine benthic ecology and biogeography. pp 353-403 in G.Kuschel (Ed), *Biogeography and Ecology in New Zealand.* Dr W. Junk b.v. publishers the Hague, Netherlands

MAF 1985. Auckland region marine reserves plan - a discussion paper. Fisheries Management Division, Ministry of Agriculture and Fisheries, MAF Discussion paper for public comment. 64pp.

MAF 1986. A discussion paper on marine protected areas - southern region. Fisheries Management Division, Ministry of Agriculture and Fisheries. MAF report pp33.

MAF 1987. Regional background discussion paper on areas to be investigated for proposed marine protected areas in the central fishery management area. Fisheries Management Division, Ministry of Agriculture and Fisheries. MAF report pp98.

MERT/MfE 1992. Protection of the Oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources. *Agenda 21, Chapter 17, United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, 3-14 June, 1992.* The outcomes of the conference. pp484.

Moore, L.B. 1949. The marine algal provinces of New Zealand (Report of the 6th Science Congress). *Transactions of the Royal Society of New Zealand* 77: 187-189

Moore, L.B. 1961. Distribution patterns in New Zealand Seaweeds. *Tuatara* 9: 18-23

Pawson, D.L. 1962. Distribution Patterns of New Zealand Echinoderms. *Tuatara* 10: 9-18

Powell, A.W.B. 1961. New Zealand biotic provinces. *Tuatara* 9:123

Salm, R.V. and Clark., J.R. 1989. *Marine and coastal protected areas: a guide for planners and managers.* IUCN, Gland, Switzerland. 302pp

Walls, K. and McAlpine, G. 1993. Developing a strategy for a network of marine reserves around New Zealand - a manager's perspective. In: Battershill C.N., Schiel D.R., Jones, G.P., Creese R.G. and MacDiarmid A.B. (Eds). In: *Proceedings of the Second International Temperate Reefs Symposium.* NIWA Marine, Wellington, New Zealand. pp? (In press).

APPENDIX I - LIST OF WORKSHOP PARTICIPANTS

1.	Peter Bridgewater	Australian National Parks and Wildlife Service (now Australian Nature Conservation Agency)
2.	Ken Grange	New Zealand Oceanographic Institute, NIWA
3.	Eduardo Villouta	Department of Conservation, Science and Research Division
4.	Bob Rowley	Department of Marine Services, University of Otago
5.	Andrew Jeffs	Department of Conservation, Marine Protected Areas Unit, Wellington
6.	Rob Forlong	Department of Conservation, Otago Conservancy
7.	Euan Harvey	University of Otago
8.	Bruce Hayward	Auckland Museum
9.	Dennis Gordon	New Zealand Oceanographic Institute, NIWA
10.	Karen Baird	Department of Conservation, Otago Conservancy
11.	Rob Davidson	Department of Conservation, Nelson/Marlborough Conservancy
12.	Jim Fyfe	Maruia Society, Dunedin
13.	Philip Mladenov	Department of Marine Sciences, University of Otago
14.	Clive Roberts	Museum of New Zealand, Wellington
15.	Chris Paulin	Museum of New Zealand, Wellington
16.	Glen Lauder	Department of Conservation, Southland Conservancy
17.	Kathy Walls	Department of Conservation, Marine Protected Areas Unit, Wellington

APPENDIX II - WORKSHOP CONTRIBUTIONS

LIST OF CONTRIBUTIONS

Bill Ballantine	University of Auckland Marine Laboratory, Leigh. *Marine Reserves for New Zealand.* Leigh Laboratory Bulletin 25. University of Auckland. 196pp.
Chris Battershill	New Zealand Oceanographic Institute, NIWA, Wellington. Sponge/ascidian biogeography.
George Branch	Zoology Department, University of Cape Town. Approaches to marine reserves through biogeographic regional divisions.
Fred Brook	Department of Conservation, Northland Conservancy. Biogeographic subdivision of shallow marine habitats in northern New Zealand.
Rob Davidson	Department of Conservation, Nelson /Marlborough Conservancy. Biogeographic subdivision in New Zealand Nelson/Marlborough area.
Clinton Duffy	Department of Conservation, Hawkes Bay Conservancy. Hawkes Bay Marine Environment.

Jim Fyfe	Maruia Society, Dunedin. Biological values of Otago. Coastal/marine area. Four Otago Marine Reserve Options - an overview of biological values. Jim Fyfe 1992. Report for Department of Conservation, Misc. Series No. 11.
Dennis Gordon	New Zealand Oceanographic Institute, NIWA, Wellington. Marine fauna and flora status list - Bryozoa.
Ken Grange	New Zealand Oceanographic Institute, NIWA, Wellington. Biogeographic range of the 4 species of black corals found in diving depths around New Zealand.
Bruce Hayward	Auckland Institute and Museum. A: NZ foraminiferal biogeography and ecological distribution. B: Ecological distribution of soft sediment macrobenthos of northern New Zealand. C: Earth science conservation initiatives.
Terry Hume	Ecosystems - Water Quality Centre, NIWA, Hamilton. A geomorphic classification of estuaries and its application to coastal resource management - a New Zealand example. Hume, T.M. & C.E. Herdenorf *Ocean and Shoreline Management* 11(1988) 149-274.
Glen Lauder	Department of Conservation, Southland Conservancy. Geomorphology of the New Zealand Coast - an overview with reference to marine protection.
Bruce Marshall	Museum of New Zealand, Wellington. Marine fauna and flora status list - Mollusca.
Sue Miller	World Wildlife Fund New Zealand, Wellington. Marine algae.
Chris Paulin and Clive Roberts	Museum of New Zealand, Wellington. A: New Zealand icthyofauna B: The Biogeography of New Zealand Rockpool fishes. Paulin C.P. & C.D. Roberts. In: Battershill, C.N., Schiel D.R., Jones, G.P., Creese R.G. and McDiarmid A.B. (Eds). *Proceedings of the Second I I International Temperate Reefs Symposium.* NIWA Marine, Wellington, NZ. pp? *(in press).*
Bob Rowely	Department of Marine Science, University of Otago. An assessment of the impacts of marine reserves on fisheries.
Dick Singleton	New Zealand Oceanographic Institute, NIWA, Wellington. Brachiopod distributions.
Kathy Walls	Walls, K. and McAlpine, G. 1993. Developing a strategy for a network of marine reserves around New Zealand - a manager's perspective. In: Battershill C.N., Schiel D.R., Jones, G.P., Creese R.G. and MacDiarmid A.B. (Eds). *Proceedings of the Second I International Temperate Reefs Symposium.* NIWA Marine, Wellington, New Zealand. pp? (In press).

Biogeography and Diversity of Australia's Marine Biota

Gary C. B. Poore
Department of Crustacea,
Museum of Victoria

INTRODUCTION

The Australian continent's shallow-water marine biota is notable for its high level of endemicity and for groups of animals and plants shared only with other Southern Hemisphere continents. The reasons for this are now emerging after nearly two centuries of taxonomic and biogeographic research.

We should start with a little biogeographic theory before applying it to the coasts of Australia.

Ball (1976) recognised biogeography as passing through three phases: "the descriptive or empirical phase, a narrative phase, and an analytical phase ... ". The same phases are seen in systematics and biogeography. Comparison of progress in the two disciplines leads to an understanding of how biogeographic hypotheses are developed.

The descriptive phase of systematics is alpha taxonomy (description of species and grouping into higher taxa). Descriptive biogeography is similar in that it attempts only to describe ecosystems as they are. Some might call this ecology. A species' ecological requirements (temperature, food, habitat etc.) enable ecological biogeographers to explain its geographical limits and why it does not occur in a neighbouring region where its requirements are not met. But similar habitats with the same ecological constraints are often found in remote seas and are inhabited by quite different species. Compare, for example, the rocky shores of southern Australia on which the dominant species are kelps of the genus *Durvillaea* while similar shores in Europe and in the northeast Pacific support forests of different kelps. Ecological biogeography does not explain these differences.

The narrative phase of systematics is characterised by construction of Darwinian trees of relationships by intuitive methods. Similarly, narrative explanations in biogeography are invented stories designed to match particular requirements. Ekman's explanation of modern marine distribution patterns using dispersal in an ancient Tethyan Sea is an example.

Analytical taxonomy (usually called phylogenetics) and analytical biogeography are linked by the use of cladistics, wherein relationships between taxa or geographical areas are expressed as branching trees. The trees are hypotheses which are testable after the acquisition of new data.
The cladistic approach to biogeography begins in systematics by attempting to find the phylogenetic interrelationships of the species concerned. Each phylogenetic tree is an expression of sequences of speciation events which may be compared with data on distribution and with similar treatments for other taxa. Since taxa in the same environment and with similar ecological requirements had common responses to geological and environmental events in the past, their phylogenies should be congruent. That is, the congruence provides the test of the hypothesis.

Analytical systematics assumes that vicariance resulting from tectonic and other processes has played a major role in driving allopatric speciation. This mechanism requires the formation of geographical barriers isolating sections of populations.

Barriers in marine environments, required for allopatric speciation, take two principal forms. The first is geographic, a land bridge separating two oceans or shores, or an open sea separating biotas on opposing shores or shelves. The second is environmental, for example, a steep temperature gradient which may arise to divide a longitudinally-aligned shore. Barriers come and go and affect different taxa differently.

If we are to make use of biogeographic theory in a regionalisation of Australia's marine biota we must first understand the geological history of the coast.

GEOLOGICAL HISTORY

Although the present biota of Australia's coast and shelf can be explained in part with reference to modern conditions it is also the result of a long history in a changing environment. Since the mid-1960s theories of continental drift and plate tectonics have been applied to our interpretation of the Australian marine biota, in particular, its position on the globe; its size, especially of its shelf; its connections to other land masses; the currents surrounding it; and the temperature of the sea surrounding it.

200 Mya Gondwana to the south and Laurasia to the north were connected in the west but separated in the east by a major incursion from the surrounding Tethys Sea. Australia was almost at right angles to its present orientation, and still connected to Antarctica (Fig. 1).

The breakup of Gondwana commenced with the separation of Africa (c. 125 Mya) and India (c. 118 Mya) from Australia—Antarctica. Later (82 Mya), the Tasman Sea opened to separate Australia and New Zealand and later still rifting between Australia and Antarctica began by intrusion from what is now the west. The colonising biotas of the Australian southern coast were therefore of tropical Tethyan origin. The biota of what is now the eastern coast of Australia was part of a Weddellian Province which extended across Australia and northwards up the coast of Chile.

By 60 Mya Australia had begun to rotate anticlockwise towards its present orientation and to move northwards. Although Australia was by then a separate continent with an isolated marine biota two other tectonic events are relevant. The first is the opening of the Drake Passage between West Antarctica and South America allowing the Circum-Antarctic Current to form. Global cooling resulted in polar ice caps and permanent cold water near the poles. The Antarctic Convergence (a steep temperature gradient) formed 22 Mya (Fig. 2) thus producing an important biogeographical boundary. This convergence and the Subtropical Convergence further north have persisted from these times but their latitudinal movements have had a profound effect on biogeographic regions of southern continents.

The second tectonic event of significance to Australia's biogeography was its collision with South-East Asia about 20 Mya when the New Guinea margin of the Australian block came in contact with eastern Indonesia. The two blocks continued to overlap and with the evolution of island arcs the Tethys Sea was no longer a barrier to marine shelf and coastal biota.

Over the last 2 My the arrangement of land and sea in the south-west Pacific has been essentially as it is today except that the size and shape of the Australian coastline and shelf continued to change due to sea levels fluctuating over 200 m (Fig. 2) and Torres Strait and Bass Strait opened and closed repeatedly. The changing shelf size, coastline and latitudes of the passages between the east coast of the Australian mainland and the remainder must have affected the continuity of their biotas.

In summary, the most important tectonic events affecting the biota of Australia's coasts and shelf are: its separation from other Gondwanan continents; its separation from Eastern Antarctica which allowed mixing of Tethyan and Austral biotas on the South Tasman Rise; and the collision of Australia with South-East Asia which provided pathways for the invasion of Laurasian Tethyan biota into northern Australia.

DISTRIBUTION PATTERNS

Present-day distribution patterns contribute to understanding the biogeography of Australia.

Wilson and Allen (1987) compared the number of species and species composition of fishes, molluscs, echinoderms and corals throughout the continent. These groups were chosen because their taxonomy is relatively well-known. They probably demonstrate general principles applicable to other groups. One example will do.

Of 3 300 species of Australian marine fishes some are pelagic or oceanic and are wide-ranging in the tropics or temperate seas. About three-quarters, 2 600, occur on the shelf and nearshore. More than half are tropical and most of these are shared with the Indo-West Pacific (Table 1). Although most species have pelagic eggs and larvae a moderate level of endemicity, 13%, is maintained with the help of southerly flowing currents on both the east and west Australian coasts.

TABLE 1. **Summary of Australian fish fauna** (Wilson and Allen, 1987: Table 3.1).

Major category	Estimated number of species
Tropical, inshore, marine	2 000
Midwater, pelagic, deepsea	700
Temperate, inshore, marine	600
Freshwater	180
Awaiting description (museum collections	120
Total	3 600

The fish fauna of southern temperate Australia comprises about 600 species of which 85% is endemic and 11% is shared with New Zealand.

Shallow-water reef fishes provide one of the best studies in zonation along the southern coast. Four ecological barriers appear to inhibit dispersal: a sharp temperature gradient around Albany near the end of the Leeuwin Current; and absence of nearshore rocky reefs in the centre of the Great Australian Bight, at the mouth of the Murray River, and in eastern Victoria. These barriers may act today to maintain allopatric eastern and western species pairs in 12 families, 18 pairs in all. East-west species pairs such as occur in the fishes occur in other groups, brachyuran crabs, molluscs and asteroids whose distributions overlap or are contiguous in Bass Strait (Fig. 3). This region is or has been a barrier stimulating speciation.

PRESENT AUSTRALIAN BIOGEOGRAPHIC PROVINCES

In his classification of the world's marine environments the biogeographer, S. Ekman (1953), was able to place tropical and subtropical Australia within his Indo-West Pacific region. He recognised that southern Australia was separate and placed it within the warm-temperate fauna of the Southern Hemisphere.

Several marine provinces within Australia have been proposed and reviewed many times (Knox 1963). Suggestions of as many as three tropical provinces and three or four temperate provinces no longer have currency partly because their boundaries are doubtful and not defined quantitatively (for example, Fig. 3 from Whitley 1932; Fig. 4 from Bennett and Pope 1953). Their definitions are intuitive; narrative biogeography.

Nevertheless, division into tropical and temperate regions has never been seriously disputed. Wilson and Gillett (1971) and Wilson and Allen (1987) simplified the picture by recognising northern and southern Australian regions (Fig. 5) with two transition zones, one on the east coast and one on the west, between. The distribution patterns seen today are the result of contributions from two different biotas:

(1) the pan-Pacific Tethyan biota and its derivatives have dominated the northern coasts of Australia since the beginning of the Tertiary and also

contribute to temperate biotas. To the north, barriers to interchange of shelf and coastal biotas with South-East Asia are only slight. There are therefore many widespread tropical elements in the northern Australian biota and a low percentage of endemicity. At its southern limit the Tethyan element is limited by the latitudinal temperature gradient.

(2) the temperate Palaeoaustral biota has dominated south-eastern Australian coasts also from the early Tertiary and is now the major element of the biota of the entire southern coast. Its high level of endemicity results from isolation by ocean basins from other southern continents and from a latitudinal temperature gradient (18—20∞C winter minimum surface temperature) to the north.

This gross picture of Australia divided into a northern region with low endemicity and a southern region of high endemicity is superimposed on other patterns. Most obvious of these is separation of the Great Barrier Reef ecosystem from that of the adjacent coast but it might be argued that this is an ecological division rather than a biogeographic one.

George (1969) divided tropical coasts on the basis of water turbidity: Queensland, Northern Territory and northern Western Australia where high monsoonal summer rain and dry winters result in grey mud sediments inshore and well developed mangrove creeks; and north-western Western Australia where rainfall is low and irregular, with occasional cyclonic disturbances and flash flooding resulting in brown sediments. The two tropical regions contrast with the southern half of the continent where rainfall is more reliable, uniform throughout the year in the east and falling in the winter in the west (Fig. 6). This division reflects modern ecological regimes rather than more ancient biogeographic events.

We must digress to consider the significance of ecological classifications in regionalisation. The marine environment is a mosaic of communities and ecosystems between which barriers can be drawn on many scales from thousands of kilometres to metres. On the largest scale there is a clear taxonomic difference between the biota of the Great Barrier Reef and that of the adjacent Queensland coast although both are elements of the broader Indo-West Pacific biota. These "regions" are probably of interest in our context because of the gross ecological differences between them.

On a smaller scale much of the intertidal coast of Victoria comprises alternating sandy beaches and rocky headlands with mutually exclusive biotas on the scale of tens or hundreds of metres. Are these ecological differences of interest? Probably not but we must decide at what scale ecological barriers play a part in the regionalisation debate.

DIVERSITY

Earlier, the number of species of fishes in Australia was discussed. Also of interest is the number of species of all taxa in a circumscribed habitat, so-called diversity, because this may vary in an informative way, with latitude for example.

The few quantitative attempts in Australia to obtain such figures are rarely comparable. The result depends on the habitat chosen, its size, methods, and on the effort and skills of the taxonomists involved. The poor state of knowledge of the biota may be seen as a problem but need not be for competent taxonomists.

Birtles and Arnold (1988) found 103 species of echinoderms and 196 species of molluscs at four sites on the Great Barrier Reef lagoon, and Ward and Rainer (1988) reported 308 species of decapod crustaceans from the North-West Shelf. Poore et al. (1993) discriminated 359 species of isopod crustaceans on the southeastern Australian slope, more than found in similar studies in the Northern Hemisphere. All studies are taxonomically limited.

In Port Phillip Bay 713 macrobenthic species were taken from 43 m^2 of sandy and muddy benthos. More recently we have discovered about 800 species in 10 m^2 of Bass Strait.

Less information has been published from macrobenthic communities in other parts of Australia and where data exists they are unlikely to be comparable. This points to the need for some basic protocols for quantification of "biodiversity" before regions can be compared and latitudinal gradients measured.

CONCLUSIONS: IMPLICATIONS OF BIOGEOGRAPHY FOR MANAGEMENT

Biogeographic regions

What does "biogeographic region" contribute to the regionalisation debate. The division of Australia into a northern tropical region and the southern temperate region with broad transition zones would seem inadequate for drawing lines on maps.

However, I would argue that finer division of the coast (and shelf and slope) has not yet been achieved satisfactorily. The divisions of the early biogeographers were entirely intuitive and therefore hotly debated. Most were based on a single taxonomic group or habitat: molluscs, echinoderms, algae, fishes, ascidiaceans or intertidal habitats. But in reality steep environmental gradients which might explain some of the provinciality do not exist and affect taxa and habitats unequally. The absence of reefs which have been said to be barriers to the distribution of reef fishes along the southern coast are not likely to be important for infaunal benthos.

IUCN Australian Committee (1986) adopted in its policy for protection of marine and estuarine areas a classification of the Australian habitats and coastline prepared by the Australian Bureau of Flora and Fauna (Fig. 7). Fourteen coastal (<200 m) geographic zones plus 18 oceanic zones and external territories are mapped. I am not aware of any empirical data to support these divisions and there is no evidence that they suit the environmental managers' purpose.

Considerable extractable information exists, mostly in museum collections, on the distribution of numerous species around the coast. Coverage of the coast and of taxa is uneven. These could be collated and analysed with multivariate techniques to determine where, if anywhere, biogeographic boundaries can be recognised but success will be slight since the data were not collected for this purpose. Much better would be to gather new strategic quantitative data.

Ideally, the discovery of biogeographic boundaries, past and present, depends on the revelation of phylogenetic relationships within numerous taxa (families and genera). The congruence of their distribution patterns will indicate barriers as are hinted at in the study of species pairs on the southern coast and around Bass Strait.

The costs of obtaining data and performing the required analyses will be high but until it is done biogeographic considerations can play little part in environmental management.

Endemism

The concept of endemism is an important criterion in the selection of areas for management. Such a criterion will shift emphasis from the north of Australia (low endemicity) to the south (high endemicity). It is in the south that Australia's "native" marine biota resides. Further, it is the southern temperate ecosystems which are the most threatened by the largest population centres.

Diversity

Management of marine environments must be geared to the management of communities of species rather than towards individual species. There are rare exceptions where a large and obvious species may warrant special attention.

Coral reefs in particular are said to be of special interest because of their high "biodiversity" but this has not been quantified and the relative importance of different reefs from the point of view of diversity is unknown. By and large the species inhabiting tropical reefs are widespread through the Indo-West Pacific but this may not be true for microinvertebrates. Concentration of research effort and management on Australian coral reefs at the expense of more southern ecosystems with a much more endemic biota can only be justified largely on the grounds of international responsibility.

In fact, many temperate marine environments are also inhabited by communities rich in species, no species especially more abundant than others. Investigations in Bass Strait and the southeastern slope have revealed diverse soft-bottom benthic communities but their geographic extent is unknown. It is certain that the relative taxonomic composition of communities does vary with latitude but does diversity change? Communities of such complexity are worthy of attention and I argue that diversity should be one of the criteria on which areas are selected for management. Selection should not be on the basis of high diversity; communities with natural low diversity such as estuaries are equally valuable.

The greatest obstacle to making real progress in this field is the paucity of taxonomists. Without a taxonomic input biogeography in Australia will not get beyond the narrative phase.

REFERENCES

Bennett, I., and Pope, E.C., 1953. Intertidal zonation of the exposed rocky shores of Victoria, together with a rearrangement of the biogeographic provinces of temperate Australian shores.*Australian Journal of Marine and Freshwater Research* 4: 105-59

Ball, I.R., 1976. Nature and formulation of biogeographical hypotheses. *Systematic Zoology*24: 407-30

Ekman, S., 1953. *Zoogeography of the Sea.* 417 pp. Sidgwick and Jackson: London

Dartnall, A.J., 1974. Littoral biogeography. Pp. 171-194 in *Biogeography and Ecology in Tasmania* (Ed. W.D. Williams.) Junk: The Hague

George R.W., 1969. Natural distribution and speciation of marine animals. *Journal of the Royal Society of Western Australia* 52: 33-40

IUCN Australian Committee, 1986. Australia's marine and estuarine areas - a policy for protection. *Australian Committee for the International Union for the Conservation of Nature and Natural Resources, Occasional Paper* no. 1

Knox, G.A., 1963. The biogeography and intertidal ecology of the Australasian coasts. *Oceanography and Marine Biology, Annual Review* 1: 341-404

Whitley, G. 1932, Marine biogeographic regions of Australia. *Australian Naturalist* 8: 166-167

Wilson, B.R. and Allen, G.R., 1987. Major components and distribution of marine fauna. Pp. 43-68 in *Fauna of Australia. Vol. 1A. General Articles* (Ed. G.W. Dyne.) Australian Government Publishing Service: Canberra

Wilson, B.R. and Gillett, K., 1971. *Australian Shells* . 168 pp. Reed: Sydney

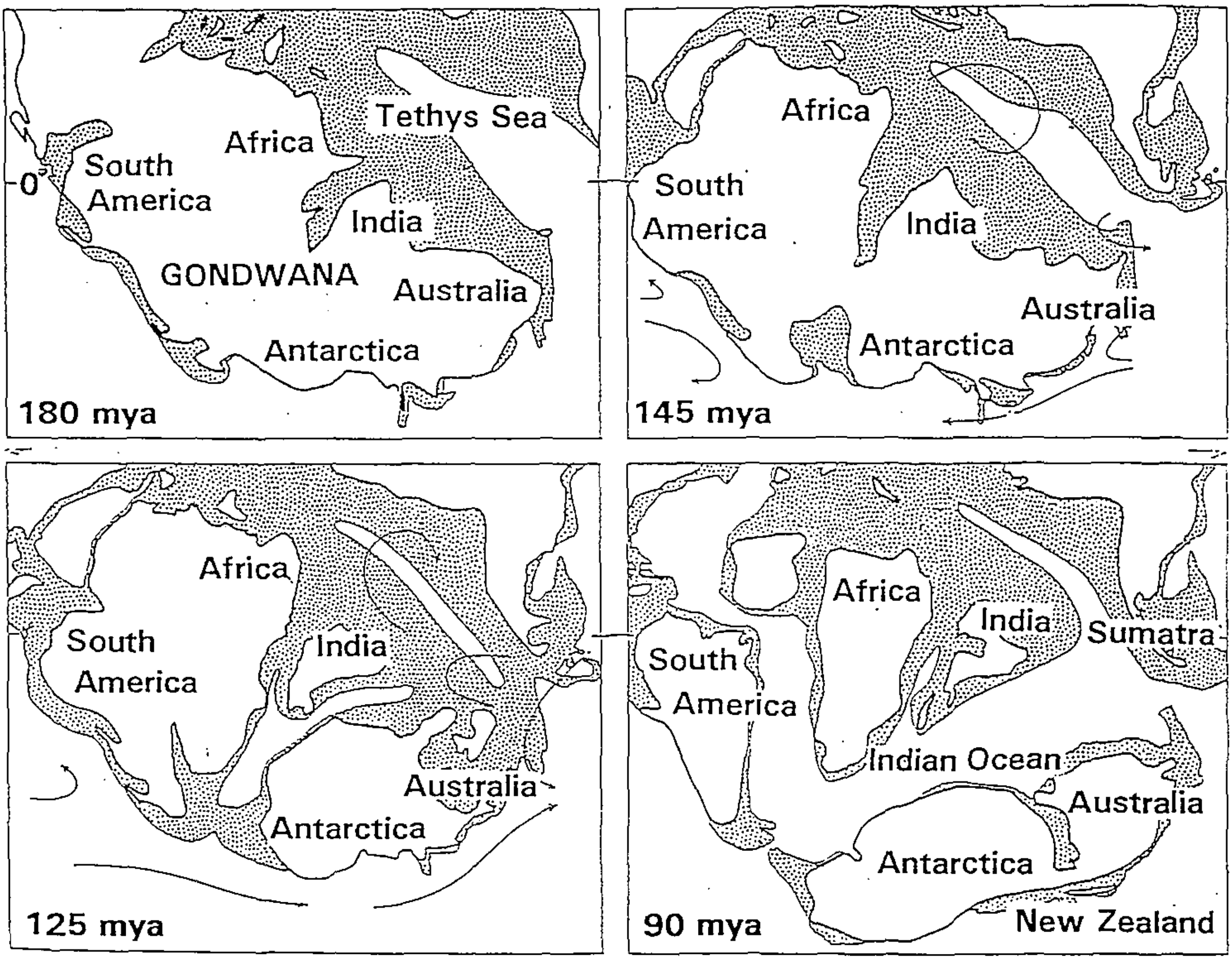


FIGURE 1. The relative position of Australian coasts and shelves among the southern *continents (Gondwana) during the Mesozoic: Early Jurassic (180 Mya) - the* Tethys Sea with its broad shelves separates Laurasia to the north from the fused continents of Gondwana; Late Jurassic (145 Mya) - Africa and Antarctica begin to rift apart; Early Cretaceous (125 Mya) - an ocean basin separates Africa and India from Antarctica and continental Australia is largely submerged by waters of the Tethys; Late Cretaceous (90 Mya) - New Zealand has separated and Australia and Antarctica begin to rift from the north-west. The bold line indicates coastlines and shading shelf waters.

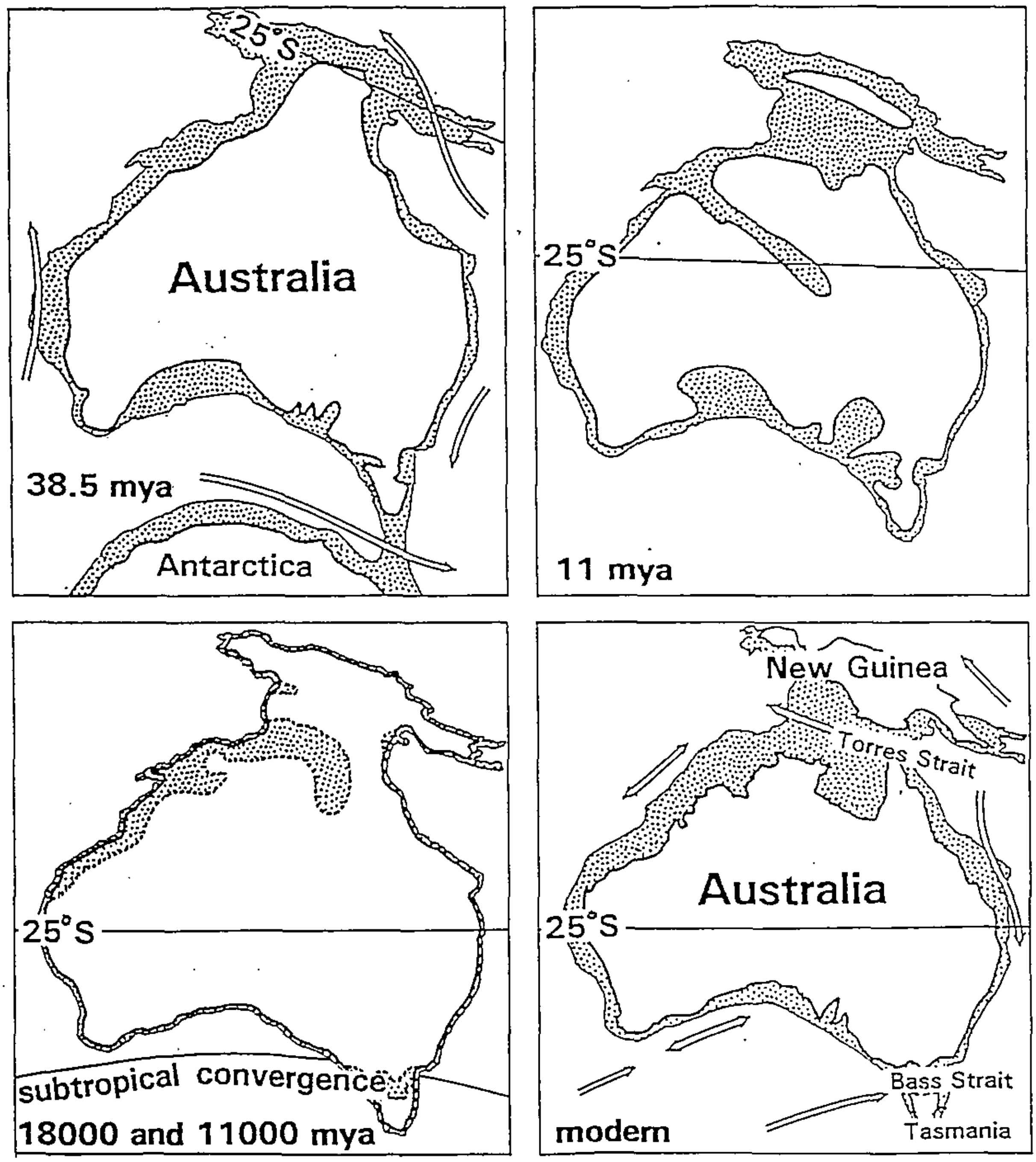


FIGURE 2. The changing shoreline and shelf of Australia during the Cainozoic: Late Eocene (38.5 Mya) - Australia and New Guinea still connected to Antarctica by the South Tasman Rise; Middle Miocene (11 Mya) - extensive marine transgressions in the south and north; Pleistocene (18 000 ya, solid line, and 10 000 ya, dotted line) - a period of minimum shelf area with the 10¿$\¿C-minimum Subtropical Convergence appearing across southeastern Australia; Modern - both New Guinea and Tasmania separate.

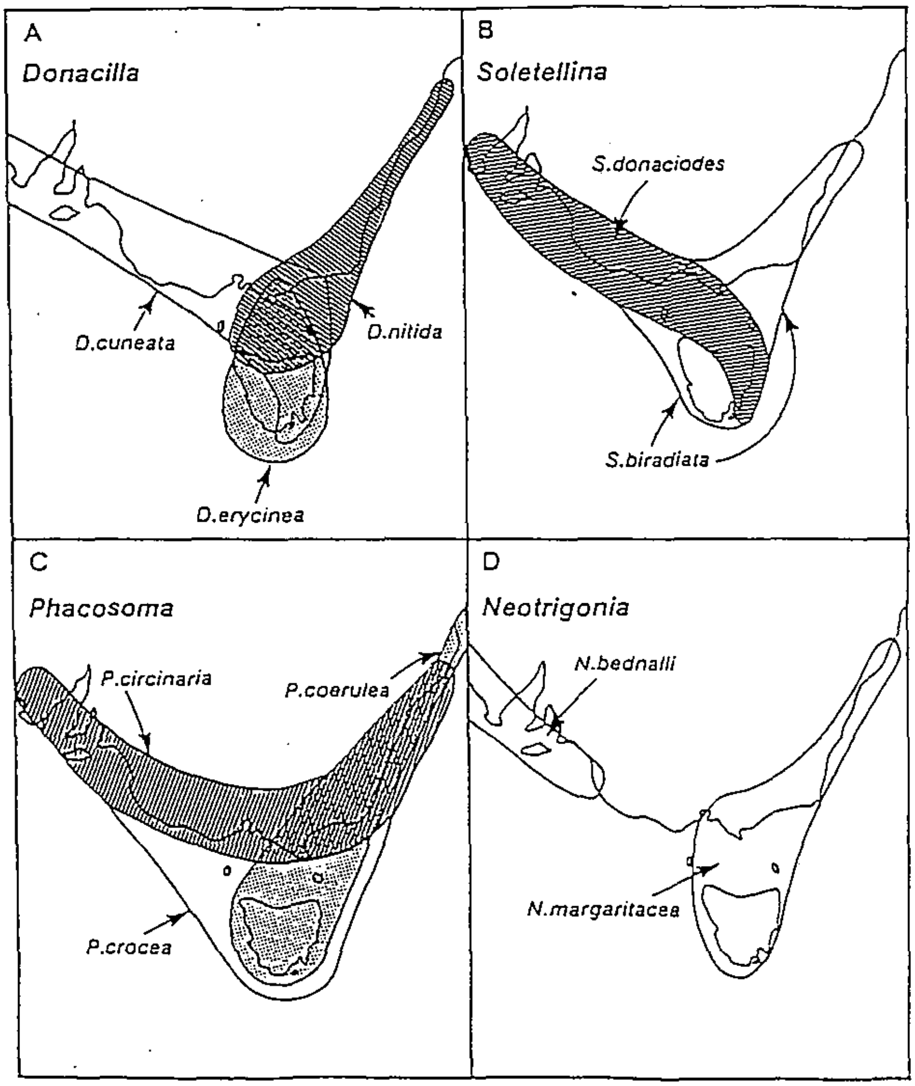


FIGURE 3. Distribution patterns of nine species of bivalve molluscs in southeastern Australia (after Dartnall 1974, reproduced from Wilson and Allen 1987).

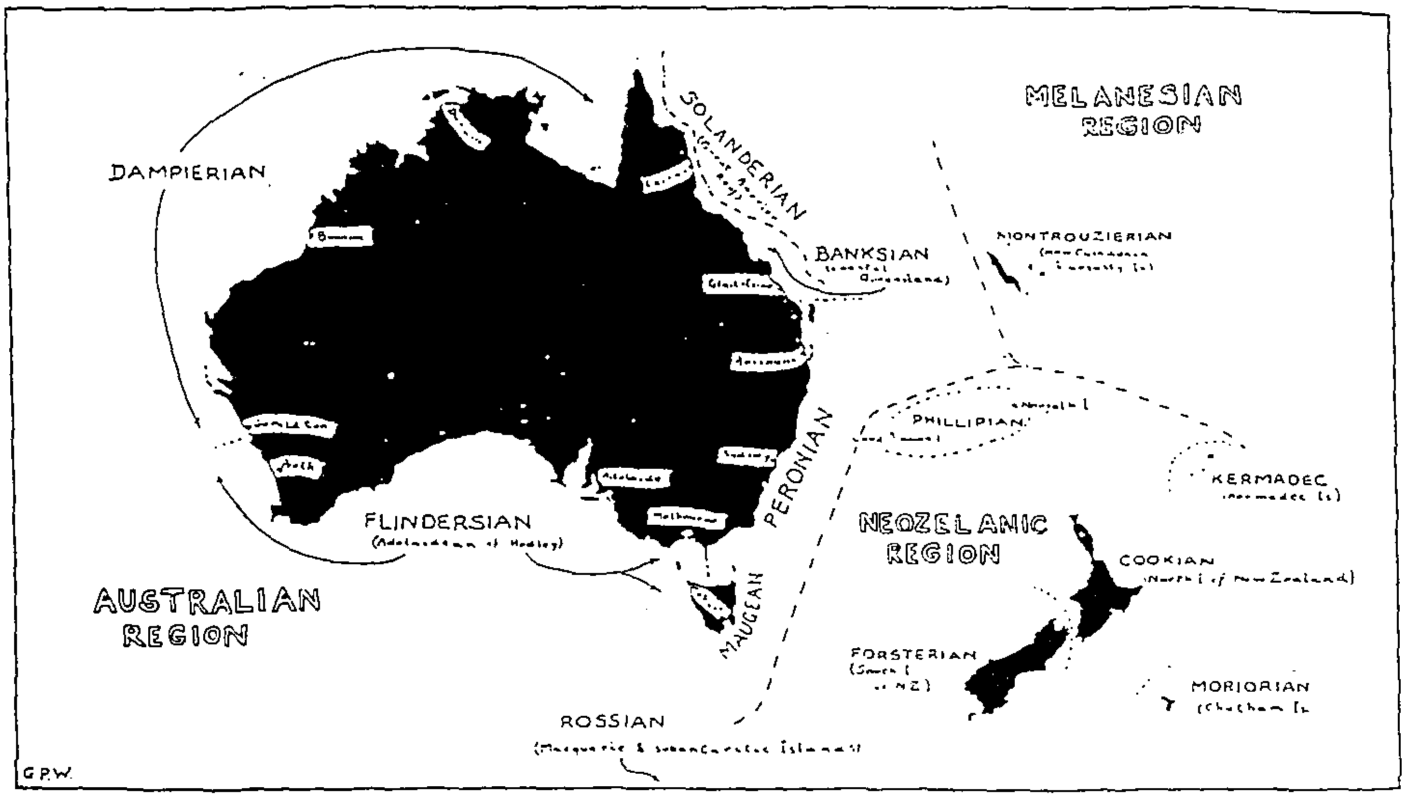


FIGURE 4. Zoogeographic regions of Australia proposed by Whitley (1932).

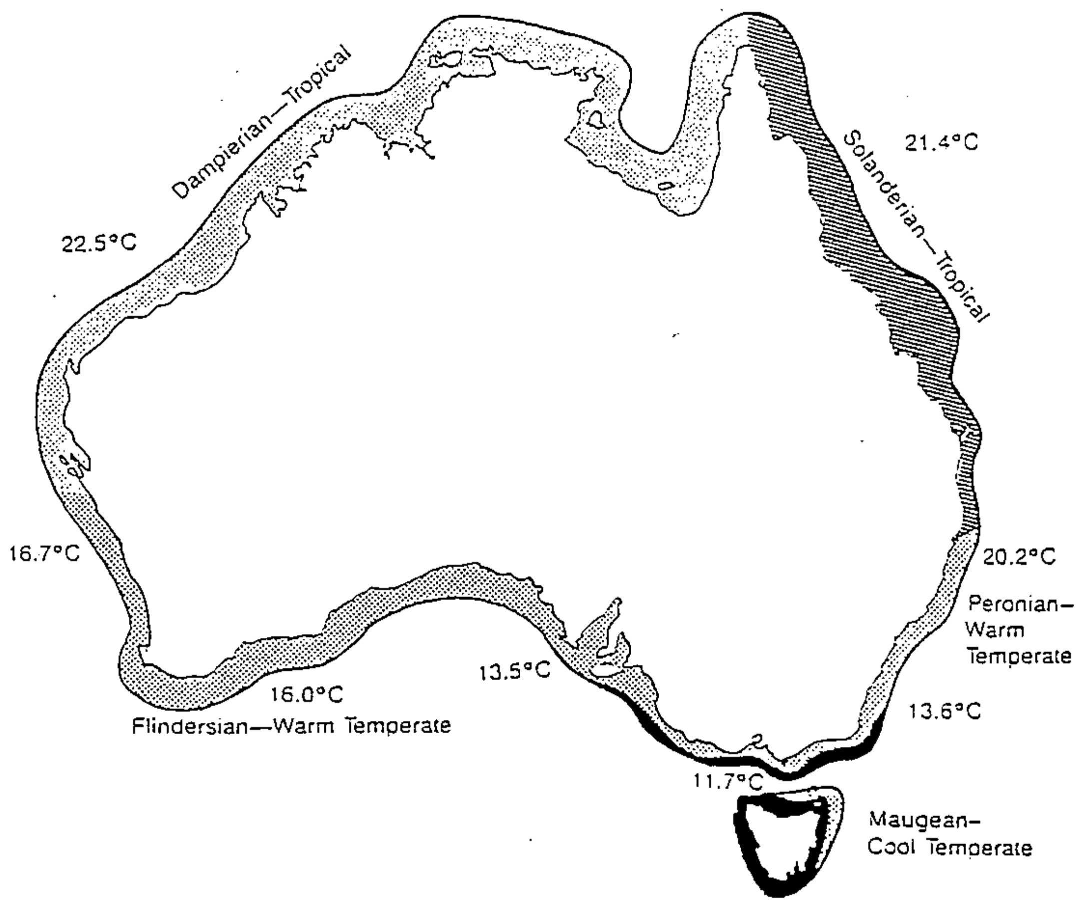


FIGURE 5. Biogeographic provinces of the Australian exposed intertidal coasts (after Bennett and Pope 1953, reproduced from Wilson and Allen 1987).

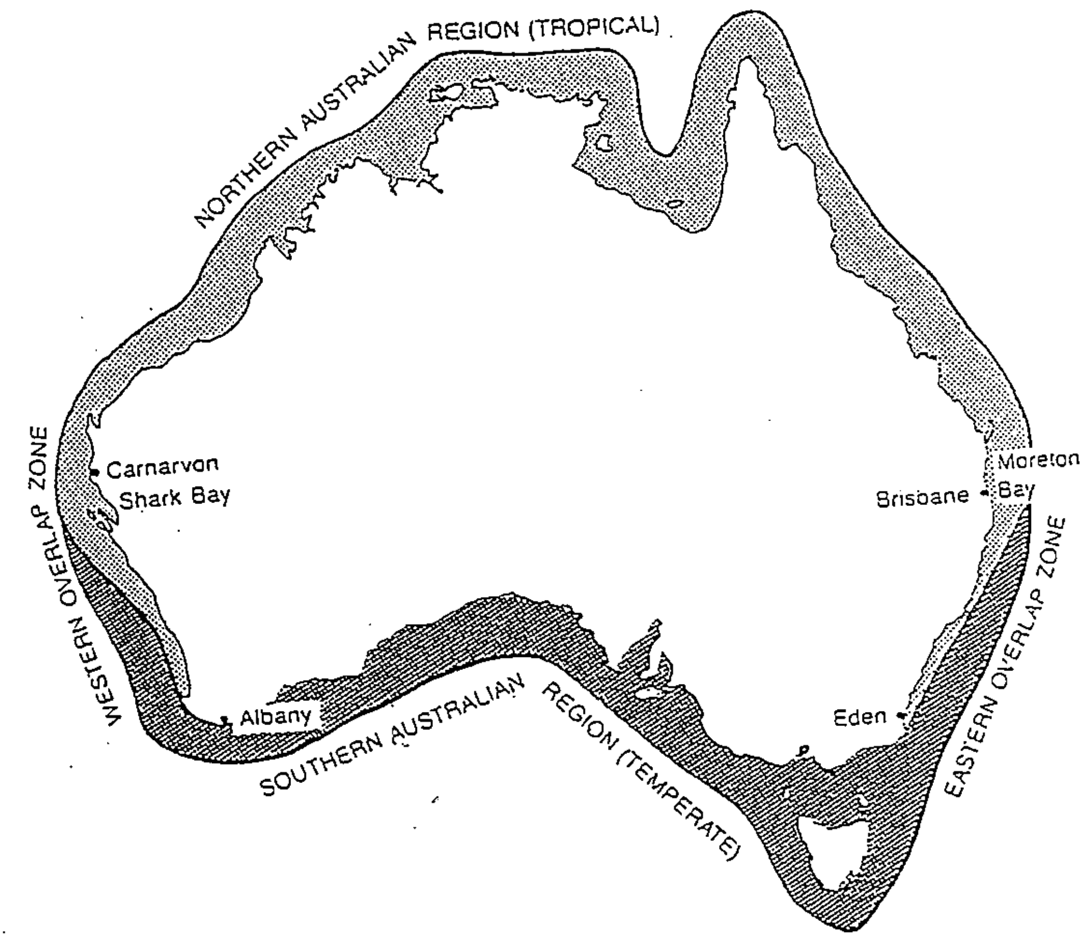


FIGURE 6. Major regions of the Australian coast (after Wilson and Gillett 1971).

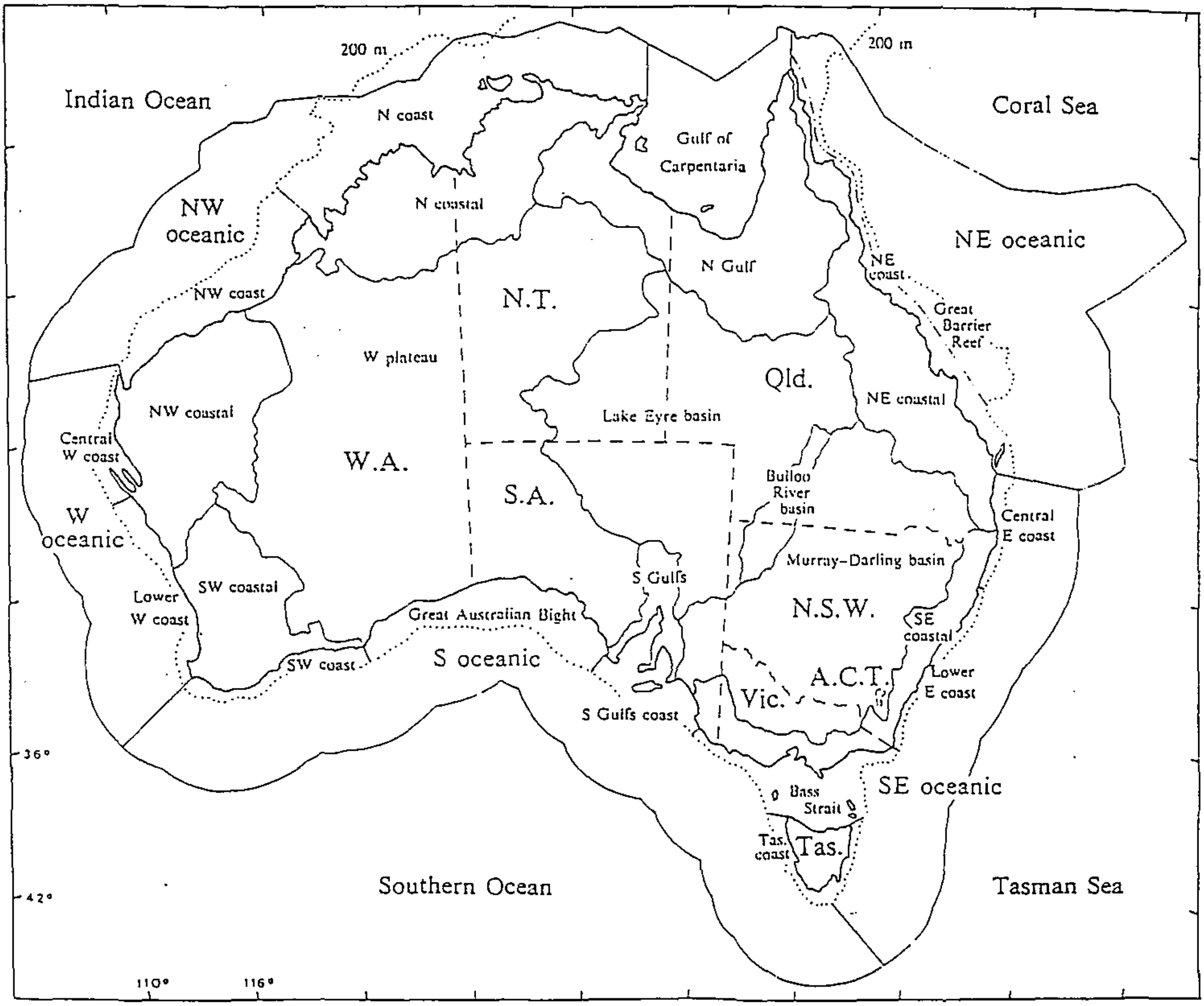


FIGURE 7. Coastal zones within the 200 m bathymetric contour and the 200 nautical mile EEZ adopted by the IUCN Australian Committee (1986).

Uses and Misuses of Regionalisations: Experiences Gained from Terrestrial Environments

R. Thackway
Australian Nature Conservation Agency,
Canberra

ABSTRACT

A review of approaches to classification and regionalisation in terrestrial environments in Australia Approaches to developing regionalisations are summarised into four paradigms. Regionalisations provide frameworks for decision support purposes. The features of these regionalisation paradigms make them more or less 'fit' for specific uses. Regionalisations are misused when these features are ignored and are inappropriately applied to applications other than those for which they were 'built'. A number of issues are discussed regarding how to determine whether an 'off the shelf' regionalisation is appropriate for an application and what issues need to be addressed if a new regionalisation is to be developed. The paper concludes with a discussion of ways for minimising the misuse of regionalisations.

1. Introduction

1.1. The needs for environmental regionalisations

The environment of terrestrial Australia is a diverse mosaic of various kinds of ecosystems. Given the plethora of issues facing decision makers involved in conservation assessment and planning, it is hardly reasonable to expect that a single regionalisation of ecosystems would suffice for all land use planning and management applications. Rather, what is needed is the development of repeatable methods and flexible approaches for classifying environmental data into integrated regions, depending on the requirements of decision makers. Basic to these requirements is that such approaches must be understandable, explainable and defendable.

Typically regionalisations have been developed to provide a simplified representation or picture of the landscape, biogeography or the environment. A wide range of uses has been found for regionalisations, the most obvious of these include assessing and planning networks of protected areas and for planning the allocation of sites in biological surveys.

Regionalisations are derived by classifying spatial patterns or attributes or a combination of both. As a general rule regionalisations do not seek to account for the inherent fine scale spatial and temporal dynamics of habitat, flora and fauna. Regionalisations therefore need to be viewed as approximations of the heterogeneity of nature, and exist only as abstractions of, or surrogates for, a true understanding of the complexity of the environment.

Ecosystem classification is complex, involving multi spatial and multi temporal attributes developed from a number of disciplines. Ecosystems have been distinguished on the basis of geomorphology, climate, vegetation, topography or biota, or a combination of any of these attributes. This disparity of definition has led to inconsistency in the methods of survey and interpretation of the results, as well as the application of regionalisations, as frameworks, to meet different conservation needs.

The influences of scale and the relationships between environmental attributes and the impact of human usage upon these attributes also needs to be recognised and taken into account. At the scale of the continent the distribution of natural ecosystems is shaped largely by the prevailing terrain and climate (Forman and Godron 1986). At regional and local scales, micro relief, regolith, microclimate, hydrology and wildfire have a greater influence on the patterning and distribution of natural ecosystems.

While Commonwealth and State and Territory Governments have developed regionalisations at varying scales for different purposes, there are major problems in compiling consistent data sets from these regionalisations at national scales and between different regions and States. The fact that there has been little agreement on the most appropriate number and size of regions, the essential data sets needed, or the methods used to generate regionalisations, bears testimony that no single regionalisation is sufficient or adequate for all applications. Historically, attempts to impose general purpose regionalisations have repeatedly failed. Rather than coercion, or hoping all users will adopt a single general purpose regionalisation to meet all conservation planning, assessment and management needs, what is required is a strategic approach which establishes the necessary infrastructure in terms of requisite data and classification methods.

This paper aims to present a review of environmental classification and regionalisation and their application to meet the multiple purposes associated with nature conservation planning and management in Australia. The concept of fitness for appropriate uses is explored using three case studies of the uses of regionalisations.

1.2. Definitions

1.2.1. What is environmental classification and regionalisation

Environmental classification is defined as a procedure for grouping spatial units or objects into groups (i.e. types) based on the association of environmental attributes recorded for these objects, that is objects that have similar environmental attributes are classed together. The output from the classification is a regionalisation, which comprises a mosaic of regions usually presented as a map, with a key to the types of ecosystems present.

Most regionalisations can provide only a generalised picture of the environment and do not account for the inherent fine scale spatial and temporal dynamics of habitat, flora and fauna. Recognising these limitations, all regionalisations need to be viewed as approximations of the heterogeneity of nature and exist only as surrogates for a true understanding of the complexity of the environment. Therefore, no single regionalisation should be regarded as sufficient to answer all questions regarding conservation assessment and planning.

Assuming patterns in the landscape reflect combinations of similar environmental attributes, the scale and dimension of which can be determined by the measurement of defined attributes, then it should be possible to find combinations of key attributes which define environments.

1.2.2. Defining what are appropriate uses and misuses of regionalisations

The term use is defined by the Macquarie Concise Dictionary (1988) as "to employ for some purpose"; or "to put into service" or a "way of using or treating an object". The term misuse is similarly defined as "wrong or improper use; or misapplication".

These definitions clearly indicate the importance of the purpose for which something is to be used, treated or employed. In the context of this paper, some applications of regionalisations are presented as appropriate uses, while there are other applications which are inappropriate or misuses of regionalisations. A misuse of a regionalisation occurs when it is applied to activities which exceed the limitations and assumptions underlying the construction of the regionalisation.

1.3. Four regionalisation paradigms

Thackway (1992) defined four classification paradigms which transcend the three jurisdictions of government (Commonwealth, State and local), as well as non-government activities related to regionalisations (Table 1).

TABLE 1. **Approaches to data management in developing regionalisations**

		Approaches to data *Pre-classified data*	**management** *Primary data*
Approaches to Regionalisations	*Thematic*	Paradigm 1	Paradigm 2
	Integrated	Paradigm 3	Paradigm 4

Definition of terms

Thematic regionalisations use a single thematic attribute (e.g. vegetation, geology, soils or climate).

Integrated regionalisations integrate several environmental themes to form regions based on a number of interacting attributes.

Pre-classified Data - This involves a top-down procedure which views the "whole picture" as a complex of interconnected objects and attributes which may be subdivided into progressively smaller and smaller units. Typically these units are not mapped, however they may be described as complexes, as in the case of vegetation and land unit mapping.

Primary Data - This involves a bottom-up procedure and involves building-up the "bigger" picture by synthesising its component parts (i.e. key environmental attributes or themes). One of the aims of the Primary Data approach to data management is to measure point based data and produce the most meaningful result with the least loss of variability in the data as one moves from the complex to the simple. This approach relies on the skill and experience of technical experts to establish a database of relevant environmental attributes, to then apply an appropriate numerical classification or pattern analysis algorithm, and finally to interpret the results.

While these four paradigms are convenient for discussion, there are obviously some studies which use combinations of the four.

1.3.1. Paradigm 1 - The pre-classified thematic approach

This involves delineation of regions into patterns observed within aerial photographs or satellite images. Typically, data sets and maps are prepared using a range of survey methods, including site surveys, transects and grid surveys. Analytical methods are mainly cartographic and the final output is generally presented as a cartographic product at scales which range between 1 :50 000 and 1 :2 000 000. An example of this classification method is broad scale mapping of vegetation formations on the Australian continent (Australian Surveying and Land Information Group 1990).

1.3.2. Paradigm 2 - The primary data thematic approach

This involves deriving spatial patterns or regions from single theme data sets (e.g. temperature, vegetation types) based on the variability observed within the data. Analytical methods typically include geographic information systems, statistical, modelling and pattern analysis software. An example of this classification method is floristic mapping of vegetation (Forbes et al. 1982).

1.3.3. Paradigm 3 - The pre-classified integrated approach

This approach usually involves delineation of regions based primarily on integrated patterns observed within aerial photographs or satellite images. The land-system approach (Christian and Stewart 1968) is the best known method in Australia of this approach and relies on the technical skill and experience of a multi disciplinary team to delineate integrated patterns of geology, topography, soil and vegetation. Typically, land system data sets and maps are prepared using a range of survey methods, including site surveys and transects, in combination with aerial photography and satellite imagery. Analytical methods include cartographic and geographic information systems, statistical and pattern analysis. The final output is generally presented as a cartographic product at scales which range between 1 :50 000 and 1 :2 000 000. This approach establishes an environmental data base at the completion of the classification.

1.3.4. Paradigm 4 - The primary data integrated approach

This approach usually involves deriving patterns or regions from data sets based on the variability observed within multiple layers of thematic data. An example of the integrated agglomerative approach would be classifying a set of thematic environmental attributes recorded at a site or within a sample unit (e.g. a grid cell, transect or irregular polygon) into uniform types based on similarity of the attributes. Analytical methods typically include the use of geographic information system, statistical, pattern analysis and modelling software. An example of this classification method is Mackey et al. (1988).

1.3.5. The preclassified data paradigms (Paradigms 1 and 3)

Of these ecosystem classification paradigms the most widely utilised and accepted is Paradigm 1, which has been to classify and regionalise terrestrial vegetation, soil, geology or climate. Thematic regionalisations are typically undertaken by specialised disciplines and involve single layer environmental themes, e.g. soil and vegetation.

Disciplines which produce environmental themes and which are relevant to environmental applications include pedology, botany, geology, hydrology and climatology. Examples of thematic preclassified vegetation mapping include Specht et al. (1974), Carnahan (1976), Australian Surveying and Land Information Group (1991) and Beard (1980).

The argument proffered for continuing to map vegetation as a surrogate for ecosystems is that vegetation integrates other complex interacting environmental attributes (such as climate, soils, terrain and biota). While vegetation does provide a reasonable approximation of the structure of ecosystems, such classifications are inadequate for addressing questions regarding relationships between a species and its physical environment, for understanding environmental processes and gradients or for understanding environmental heterogeneity.

Another widely applied ecosystem classification paradigm is Paradigm 3, which seeks to map ecosystems in terms of land system and units. Examples include Christian and Stewart (1968), Laut et al. (1977), Stanton and Morgan (1977) and Morgan and Terrey (1990a). This approach is similar to thematic mapping of vegetation in that it seeks to map and describe natural patterns' in terms of broad biological and environmental attributes. Recognition of spatial units is by manual interpretation of patterns in thematic maps and aerial photographs.

One of the obvious differences between this classification paradigm and that of Paradigm 1, thematic mapping into predefined classes such as vegetation, is that Paradigm 3 seeks to describe ecosystems as a function of integrated patterns between geology, soils, topography, climate and vegetation.

Most State, Territory and Commonwealth land management and nature conservation agencies continue to uphold classification paradigms (Paradigms 1 & 3) which do not require the data to be collected in its primary or non-aggregated form.

There are advantages in adopting ecosystem classification paradigms 1 or 3. It is cheaper and easier to collect and pre-classify data at the point of collection. But serious limitations are introduced by pre-classifying data in that it reduces the functionality of these data for different applications, particularly if the concepts underpinning the classes change.

1.3.6. The primary data paradigms (Paradigms 2 and 4)

Paradigms 2 and 4 collect and store non-aggregated or primary data, which is then used to derive regionalisations.

Regionalisations derived by classifying primary attributes (Paradigm 2) include Forbes et al. (1982), Specht et al. (1974) and Austin et al. (1983).

Regionalisations derived by classifying integrated primary attributes (Paradigm 4) include Laut et al. (1975), Laut et al. (1980), Mackey et al. (1988), Nix et al. (1988), Richards et al. (1990), Nix et al. (1992), and Cresswell et al. (in press).

Underpinning classification Paradigms 2 and 4 is the systematic collection and storage of primary data according to agreed standards, with easy access to these primary data. As primary data can be reused unlimited times without affecting the quality of the original data, it is essential to consider the acquisition of primary data as development of infrastructure. While substantial primary biological and environmental data have been developed across Australia, the scientific community has been slow to develop and use national standards for collecting and transferring biological and environmental attribute data. Until such standards are in place and widely used, the selection of attributes for use in regionalisations at continental and sub-continental scales must be restricted to the lowest common denominator with regards to the quality and quantity of primary data.

Several initiatives are currently in train which have the potential to radically alter the collection of data across Australia, which will greatly enhance the present situation and hence the potential of this regionalisation approach. Such initiatives include the Australian Collaborative Land Evaluation Program (McKenzie and Barson 1992) and ERIN's work on standards (e.g. Bolton 1992).

1.4. Features of regionalisation paradigms

The following characteristics of regionalisations apply to all four regionalisation paradigms.

1. Most ecologically based regionalisations provide only a generalised picture and do not attempt to account for the inherent fine scale spatial and temporal dynamics of habitats, flora and fauna.
2. All regionalisations are approximations of the heterogeneity of nature and exist only as surrogates for a true understanding of the complexity of the environment.
3. No single regionalisation should be regarded as sufficient to answer all questions regarding conservation assessment and planning.
4. A regionalisation is only one input into decision making process. Other factors need to be taken into account such as thematic attributes, resource constraints, known gaps in the input data and/or differences in analytical methods etc.

2 Discussion of the uses and misuses regionalisations

2.1. What are the uses of environmental regionalisations

Regionalisations provide convenient frameworks for a wide array of activities in nature conservation planning and management, some of these include:

- focussing attention and awareness of government and community
- summarising patterns between jurisdictions funds allocated to electorates
- monitoring trends between regions through time aggregating information from fine scale samples
- allocating resources equitably to each region
- allocating priorities; e.g. in 1997 chenopod shrublands will be a national issue
- representative sampling the range of variation present in a regionalisation
- defining and communicating context; e.g. local, regional and national significance

Conservation assessment and planning and the need for regionalisations which are ecologically sensible and scientifically credible, are inextricably linked. Some specific applications of regionalisations in conservation assessment and planning include:

- identifying areas to be added to the existing protected areas network (Fenner (1975), Bolton and Specht (1983), Margules et al (in press), Pressey and Nicholls (1988 and 1989), Australian National Parks and Wildlife Service (1987 and 1988) HORSCERA (1993);
- identifying land suitable for agricultural and forestry development (Christian and Stewart (1968) and Nix et al. (1992);
- mapping the habitats of priority species in need of management (e.g. vulnerable and endangered species and pest species) (Southwell and Fletcher (1989));
- locating regions suffering degradation of water and soil values; (Anon 1985);
- implementing ameliorative programs for the long-term maintenance of resources and environmental values (National Soil Conservation Program, The Save the Bush and One Billion Trees Programs, HORSCERA (1992a);
- developing and providing summary statistics on a range of environmental health indicators, land use activities and socio-economic indicators (Castles 1992); and
- planning the equitable distribution of long-term ecological monitoring sites (Walton et al. 1992 and HORSCERA 1992a).

2.2. What are the misuses of environmental regionalisations

Regionalisation products are misused when they are applied to activities which exceed the manufacturer specifications for example; careless attention to the products scale; levels of resolution of the input data; ignoring assumptions and limitations underlying attributes and methods; and lack of quality control and validation of the results.

Some of the reasons why regionalisations are misused include; ignorance on behalf of the practitioner, too busy to follow-up specifications and assumptions and limitations, and presuming that near enough is good enough.

2.3. Determining what regionalisation/s is required for particular uses?

The following criteria are suggested as a guide for determining if a regionalisation is required, and if so which classification paradigm is most appropriate to meet a user's needs for a regionalisation/s:

- what is the issue to be addressed is a regionalisation adequate or are primary data are essential?
- what scale and or resolution is necessary and / or sufficient?
- what data types and precision are required?
- where a regionalisation is required:
  - how many regions may be required?
  - how will the regions to be used?

2.3.1. Three key uses of environmental regionalisations

2.3.1.1. Designing a representative system of conservation reserves

Regionalisations provide a convenient framework for conservation assessment and planning applications, these include: determining the degree of representation of environmental regions in protected areas (Working Group on Australia's Biodiversity 1992), developing a systematic procedure for the identification of reserves to conserve representative environmental regions (Margules et al., in press) and establishing a framework for developing a national system of representative protected areas (HORSCERA 1992b, 1993, Brunckhorst 1994).

2.3.1.2. Identification of sites for regional biological surveys and long-term monitoring

Regionalisations provide a convenient sampling framework for planning the allocation of a representative field sites for biological surveys and long-term monitoring sites. A user-oriented approach integrated with a geographic information system (GIS) facility enables the analyst to examine patterns of multi-variate attributes, a, as well as, consider patterns of uni-variate data. In GIS environment the task of allocation of representative samples can be iteratively optimised to maximise sampling effort in relation to patterns of multi-variate or uni-variate attributes or a combination of both.

2.3.1.3. A framework for bio-regional planning and management

In order to plan and manage the complex task of protecting natural resources, the economic base, environmental integrity and the scenic values of the Australian landscape, it will be necessary to develop an integrated approach to landscape planning and management. Thus, for effective sustainable management to become a reality, it will be essential to adopt a bio-regional framework for land-sea planning and management.

The bio-regional framework emphasises the importance of ecological patterns and processes over and above those of current, and ephemeral, political and administrative boundaries. Management of the environment solely within political and administrative regions is unlikely to prove the most effective approach to, for example, conservation of biological diversity.

The concept of bio-regional framework seeks to assist land and sea managers to develop plans to protect representative samples of biodiversity and, In particular, to maximise the chances of survival of endangered, threatened, vulnerable and rare species.

3 Issues to considered when selecting and using regionalisations

3.1. Selecting existing regionalisations for particular uses

Care needs to be exercised when selecting existing regionalisations as they may have a number of deficiencies when applied to purposes other than for the reason they were prepared. These are summarised as follows:

1. problems with attempting to use a single, scale-dependent, static regionalisation for a variety of conservation assessment and planning applications at different scales;

2. unreasonable delays and costs involved in revising and refining those regionalisations which are distributed as a cartographic product;
3. problems in recovering primary data and sampling units where the data are aggregated within regions; and
4. analytical methods and/or detailed results are not often open to review and assessment.

Other issues to be considered include:

- what expertise needed to use it?
- is it readily understandable and by what audience?
- is it defendable in a legal forum?
- what reliability both in space and time are known about the attributes?
- is the scale and level of detail adequate for my needs?
- have any standards been used regarding the data, methods and nomenclature?
- what caveats are available on appropriate and inappropriate uses?
- who has given the regionalisation/s endorsement?

3.2. Developing a new regionalisation/s

- who are the stakeholders?
- what are the objective/s for developing the regionalisation/s?
- what resolution of the input data are required?
- what is the scale for the output and what level of detail is required?
- does the client need a flexible method or will a rigid one be adequate?
- does the client need an explicit method or will an intuitive method be adequate?
- is a multi-variate approach necessary or will an intuitive approach be adequate?
- is a hierarchical classification required or will a non-hierarchical approach be adequate?
- what resources - i.e. budget, time frame, and expertise are available?
- are standards on data, methods and output required?
- what limitations and reliability are required?
- who will provide custodianship and maintenance of the regionalisation?
- who will validate the regionalisation and how should this be done?

3.3. Minimising potential abuses of regionalisations

Regionalisations, in general, provide a useful framework for focussing attention, summarising patterns, aggregating information, and for allocating resources and priorities Environmental regionalisations are developed to assist decision makers to make informed decisions in resource assessment and planning. The characteristics of regionalisations will determine whether they are appropriate for particular applications. In order to minimise potential abuses of regionalisations in inappropriate applications, it is desirable to explicitly state what limitations and caveats relate specifically the regionalisation/s eg what are acceptable scales for its application and presentation, limitations on the input data (ie the reliability of these data in space and time and the sources of the attributes), limitations of the analytical procedure used to derive the regionalisation (any particular biases in the methodology).

4. CONCLUSIONS

Environmental regionalisations should not be seen to provide the sole or only solution to a problem. They should be used cautiously, preferably with other data and information either at the same scale of representation as the regionalisation or at finer scales.

No matter how environmental regionalisations are developed and used, there is a need to validate whether the outputs are valid and indeed appropriate for the purpose(s). This may involve comparing the regionalisations with independently collected data sets or through a systematic field checking program.

In order to minimise potential abuses of regionalisations in inappropriate applications, it is desirable to explicitly state what limitations and caveats relate specifically the regionalisation/s eg what are acceptable scales for its application and presentation, limitations on the input data (ie the reliability of these data in space and time and the sources of the attributes), limitations of the analytical procedure used to derive the regionalisation (any particular biases in the methodology).

The ideal data and information underlying regionalisations are combinations of similar environmental attributes, the scale and dimensions of which can be measured, as can the relationships between key environmental attributes. However, no single regionalisation should be regarded as sufficient to answer all questions regarding conservation assessment and planning. This philosophy is analogous to using a shopping list in a supermarket to select specific items for different occasions, rather than accepting the same set of items to suit all occasions.

The application of technological solutions to conservation issues is increasingly practical as access to decision support tools is improved. One technological advancement has been the recent to releases of more user-friendly interfaces, such that it is now possible for decision makers and stakeholders to analyse and view data and to compare options and priorities in relation to competing land uses. The progressive incorporation of modelling and analytical tools will, increasingly, support assessment of alternative scenarios and prediction of likely future consequences of management decisions. In this way users are able to define options which best suit their requirements.

Acknowledgements

I wish to thank Dr David Brunckhorst and Ian Cresswell for their comments on the draft of this manuscript.

REFERENCES

Austin, M.P., Cunningham, R.B. and Good, R.B. (1983). Altitudinal distribution of several Eucalypt species in relation to other environmental factors in southern New South Wales. Aust.J.Ecol. 8:169-180.

Australian National Parks and Wildlife Service (1987). Representation of ecosystems within reserves; Appendix 7.2 337-343 to Chapter 7, "Parks and Reserves". In: Murray-Darling Basin Environmental Resources Study. p426. State Pollution Control Commission, Sydney for the Murray-Darling Basin Ministerial Council, Canberra.

Australian National Parks and Wildlife Service (1988). National Index of Ecosystems of Australia and their representativeness in protected areas, pp.23-24. In: Australian National Parks and Wildlife Service Annual Report 1987-88. AGPS, Canberra.

Australian Surveying and Land Information Group. (1990). Vegetation. Atlas of Australian Resources AUSMAP, Department of Administrative Services, Canberra.

Australian Surveying and Land Information Group. (1991). Digital database on Present Vegetation of Australia, compiled at 1:5 000 000. Canberra.

Beard, J.S. (1980). A new Phytogeographic map of Western Australia. Western Australian Herbarium Research Notes 3: 37-58

Bolton, M.P. (ed.).(1992). Core Attributes for Terrestrial Biological Survey Data in Australia - Version 3.0, Environmental Resources Information Network, Australian National Parks and Wildlife Service, Canberra.

Bolton, M.P and Specht, R.L. (1983). A method for selecting nature conservation reserves. Oct. Paper.No.8, Australian National Parks and Wildlife Service, Canberra, Australia.

Brunckhorst, D.J. (1994). Developing a nationwide system of marine protected areas: a proposed framework and strategic approach. Biodiversity, Continuing the Debate 2:

Carnahan, J.A (1976). Natural vegetation. (Scale 1:6,000,000). Atlas of Australian Resources, 3rd Series. Division of National Mapping, Canberra.

Castles, I. (1992). Australia's environment: Issues and Facts. Australian Bureau of Statistics. ABS Catalogue No. 4140.0.

Christian, C.S. and Stewart, G.A. 1968. Methodology of integrated surveys. In: Aerial Surveys and Integrated Studies, 233-280. UNESCO Paris.

Cresswell, I.D., Kaye, P.E., Noble, S. and Thackway, R. (1992). Conservation Assessment of the Australian Coastal Zone. Environmental Resources Information Network. Australian National Parks and Wildlife Service, Canberra.

Anon (1985). National Soil Conservation program, Department of Primary Industry: progress report 1983/85. AGPS, Canberra.

Fenner F (1975). A representative system of ecological reserves in Australia: Proceedings of a symposium held in Canberra, 31 October 1974, under the auspices of the Australian Academy of Sciences, through its International Biological Programme, Sect C.T. Conservation of Terrestrial Communities. Canberra.

Forbes, S.J., Walsh, N.G. and Gullan, P.K.(1982). Vegetation of East Gippsland. Muelleria, 5(1): 53-112.

Forman,R.T.T. and Godron, M. (1986). Landscape Ecology. John Wiley & Sons, New York. 617pp.

HoRSCERA (1992a). *Biodiversity: The Contribution of Community-Based Programs.*

House of Representatives Standing Committee on Environment, Recreation and the Arts. Parliament of the Commonwealth of Australia. AGPS, Canberra. 98 pp.

HoRSCERA (1993a). Inquiry into the Role of Protected Areas in the Maintenance of Biodiversity - Workshop Discussion Paper. Workshop hosted by the House of Representatives Standing Committee on Environment, Recreation and the Arts, Parliament of the Commonwealth of Australia, held at parliament House Canberra, October 1992. (Brunckhorst, D.J., Ed.).63pp.

HoRSCERA (1993). *Biodiversity: The Role of Protected Areas*. House of Representatives Standing Committee on Environment, Recreation and the Arts. Parliament of the Commonwealth of Australia. AGPS, Canberra. 98 pp.

Laut, P., Margules, C.R. and Nix, H.A. (1975). Australian biophysical regions: a preliminary regionalisation. Department of Urban and Regional Development, AGPS, Canberra.

Laut P., Heyligers, P.C., Keig, G., Loffler, E.,Margules, C., and Scott, R.M. (1977). Environments of South Australia: Province Reports and Handbook (CSIRO: Melbourne).

Laut, P., Firth, D. and Paine, T.A. (1980). Provisional environmental regions of Australia. A working document towards a framework for Australian environmental statistics. Volume 1 The Regions, Volume 2 Attributes of local government areas. CSIRO Australia in collaboration with the department of Science and the Environment. Canberra. (CSIRO: Melbourne).

Mackey, B.G., Nix, H.A., Hutchinson, M.F., McMahan, J.P. and Fleming, P.M. (1988). Assessing representativeness of places for conservation reservation and heritage listing. Env. Manage. 12(4): 501-514.

Margules, C.R., Cresswell, I.D. and Nicholls, A.O. (in press). A scientific basis for establishing networks of protected areas. Systematics and Conservation Evaluation. Eds. Forey, P., Humphries, C.J. and Vane-Wright, R.I. Oxford University Press.

McKenzie, N.J. and Barson, M. (1992). Australian Collaborative Land Evaluation Program Newsletter. Vol 1, No. 1. ACLEP CSIRO Div. Soils, Canberra.

Morgan, G. and Terrey, J. (1990a). Natural regions of western NSW and their use for environmental management. Proceedings Ecological Society Australia. 1 (6): 467-473.

Nix, H.A, Cork, S.E., Day, K.L., Hutchinson, M.F. and Mackey, B.G. (1988). Representativeness of nature conservation reserves: an assessment of northern Australia using AEGIS technology. Unpublished consultancy report to the Australian National Parks and Wildlife Service, Research and Survey Program by the CSIRO Div. Water and Land Research, Canberra. 36pp.

Nix, H.A., Stein, J.A. and Stein, J.L. (1992). Developing an environmental geographic information system for Tasmania: an application to assessing the potential for hardwood plantation forestry. A consultancy report to the Land Resources

Division and the Bureau of Rural Resources, Department of Primary Industries and Energy, prepared by the Centre for Resources and Environmental Studies, Australian National University.

Pressey, R.L. and Nicholls, A.O. (1988). Reserve selection in the Western Division of New South Wales: development of a new procedure based on land system mapping. In: Proceedings of a workshop on cost-effective survey methods for nature conservation. CSIRO/NSW National Parks and Wildlife Service.

Pressey, R.L., and Nicholls, A.O. (1989). Application of a numerical algorithm to the selection of reserves in semi-arid New South Wales. Biol. Conserv. 50, 263-278.

Richards, B.N., Bridges, B.G., Curtin, R.A., Nix, H.A., Shepherd, K.R. and Turner, J. (1990). Biological conservation of the south-east forests. Report of the Joint Scientific Committee to the Minister for Resources, Commonwealth of Australia and the Minister for Natural Resources, State of New South Wales. Department of Primary Industry and Energy, Canberra.

Specht, G.L., Roe, E.M. and Boughton, V.H. (1974). Conservation of major plant communities in Australia and Papua New Guinea. Aust.J.Bot. Suppl.No.7.

Stanton, J.P. and Morgan, G. (1977). The Rapid Selection of Key and Endangered Sites. Rept to Dept of Housing and Community Development. Armidale: University of New England.

Southwell, C. and Fletcher, M. (1989). Whiptail wallaby survey in south-east Queensland. I. Abundance and harvesting of Whiptail wallabies. Internal report prepared by the National Kangaroo Monitoring Unit, ANCA for Queensland National Parks and Wildlife Service, Canberra.

Thackway, R. (1992). Establishing a systematic basis for national and regional conservation assessment and planning. In: Environmental Regionalisation - Establishing a Systematic Basis for National and Regional Conservation Assessment and Planning. R Thackway (1992) Ed. An Australian workshop held in Canberra, 11 - 12 May 1992. Environmental Resources Information Network Australian National Parks and Wildlife Service, Canberra, 102.

The Macquarie Concise Dictionary (1988) General editors A Delbridge and J.R.L. Bernard. The Macquarie Library Pty Ltd, Macquarie University, NSW, Australia.

Walton, D.W., Forbes, M.A., and Thackway, R (1992). Biological diversity, environmental monitoring and the nature conservation estate in Australia; relationship to ecologically sustainable development. 24-40. In: Biodiversity, Broadening the debate. A trilogy of discussion papers. Australian National Parks and Wildlife Service, Canberra.

Working Group on Australia's Biodiversity. (1992). Scientific aspects of major environmental issues: biodiversity. A paper prepared for 6th meeting of Prime Minister's Science Council. Office of the Chief Scientist, Department of the Prime Minister and Cabinet. AGPS, Canberra

PAPERS PRESENTED

Session 2
CASE STUDIES

The Application of Marine Biogeographic Techniques to the Oceanic Environment

Neil T. M. Hamilton and K. D. Cocks
CSIRO Division of Wildlife and Ecology,
CAMRIS Project

He had brought a large map representing the sea,
Without the least vestige of land;
And the crew were much pleased when they found it to be
a map they could all understand.

Lewis Carroll
from "The Hunting of the Snark"

INTRODUCTION

Marine regionalisation has become one of the foci of international geopolitics and international natural resource administration since the Convention on the Law of the Sea (United Nations, 1983) became the new paradigm for marine management. A variety of reasons exist for the creation of marine regions under this paradigm, both within the articles of the Convention and to satisfy the strategic needs of individual countries. Australia, with a maritime estate of about 10 million square kilometres and a small population, is a prime candidate for the useful application of regionalisation of marine areas for natural resource management. CAMRIS, the Coastal and Marine Resources Information System, has been constructed by the CSIRO Coastal Zone Program as a demonstration of the possible utility of marine and coastal regionalisation techniques.

Candidate research areas for the CAMRIS project developed from a set of issues identified for the ESD Working Group on Coastal Issues (Cocks and Crossland, 1991). High on this list of issues was the necessity for protection and utilisation of major coastal and marine ecosystems, and in particular the requirement to examine methodologies for the selection of possible sites or districts to enhance the conservation of biological resources. Progress towards this target is described in this paper.

The role of regionalisation as a tool for solving spatial problems has been addressed by academic geographers over a period of many years (Griggs, 1967; Haggett, 1965).

In doing so, a number of models of "the region" as an entity have evolved. Each has some value and some limitations which must be recognised by all those involved in the regionalisation process. As a contribution to the discussion on the use of marine regions as management units, a portion of the paper is devoted to the description of some of the recent developments in regionalisation, and an attempt is made to identify some significant problems in the implementation of a regional approach. Finally, we present some thoughts on possible ways and conceptual frameworks to extract maximum value from marine and coastal data sets in the search for biophysical regions.

CAMRIS MARINE REGIONALISATION EXERCISE

Background

The need to protect coastal and marine biodiversity has been adequately described by Beatley (1991) and will not be further developed here. However, the methods by which such protection is achieved, and by which areas needing protection are identified, are poorly understood. A wide range of factors have been suggested (e.g. Kelleher and Kenchington, 1991) for consideration when nominating sites as marine biological reserves. For the purposes of this exercise, it is assumed that in such reserves, exploitative and other uses are conducted in such a way as to minimize the impact on the sustenance and diversity of resident biological systems. These include attributes of the biota such as naturalness, economic importance, representativeness, taxonomic distinctness and diversity, plus site feasibility considerations such as threat of disturbance, tenure status, and accessibility. Unfortunately, knowledge of marine life and its distribution is inadequate, and probably not sufficient in a logical sense, to pursue a purely biota based approach to reserve selection in Australia. As a minimum, one would need a medium scale "ecosystem map" of the marine realm, a task which has not even been completed for the better known terrestrial environment. Comprehensive species and sub-species distribution data for groups such as fish, molluscs, crustaceans, mammals, corals, macro-algae and plants would be additionally desirable.

Ray and McCormick-Ray (1992) recognised this data gap and suggested a "landscape - seascape" approach to reserve selection. This approach is based on the assumption that areas which differ with respect to key environmental parameters would differ with respect to the biotic assemblages they support. Therefore, it is argued, if marine and estuarine protected areas are selected to represent the range of landscape - seascapes, they will also represent the range of marine ecosystems. The logic is similar to the "environmental domains" approaches developed by terrestrial ecologists (Belbin, 1993). The increased feasibility of the landscape - seascape or environmental regions approach is seen to lie in the greater availability of physio-chemical information compared to biological; there is, however, little testing of the assumptions behind this approach in the marine environment. The role of biological data at present is therefore only to refine and verify the results of a landscape - seascape classification.

A variation of the landscape - seascape / environmental domains approach is the "marine regions" approach used by Parks Canada to guide the development of a system of marine national parks representative of the full range of biological and oceanographic variation found around the coast of Canada (Mondor, 1991). Each marine region is relatively homogenous in terms of climate, seabed geology, ocean currents, water mass characteristics, sea ice distribution, coastal landforms, marine plants, sea birds, marine mammals, or contain recurring patterns of these characteristics. The Canadian approach is directly analogous to the terrestrial "land systems" philosophy developed by CSIRO in Australia (Christian et al., 1960). It could be implemented in Australia by supplementing existing data sets with "expert judgement" maps (such as water mass, breeding areas, etc.) produced by a panel of specialists.

A first Australian effort in the "sea systems" direction was the set of marine geographic zones and classification scheme for marine habitats proposed at a Council of Nature Conservation Ministers workshop (CONCOM, 1985). The Australian marine realm was divided into 21 geographic zones (13 coastal, 4 oceanic, 4 extra-territorial), each zone being further divisible on the basis of substrate type, and biotic association. Given the present state of biogeographic knowledge, it would be a major achievement to even map the Australian maritime realm according to these categories.

At this stage, no final decision has been made about the approach to be used for marine biological reserve selection in the CAMRIS exercise. Investigation of the potential of "sea systems" (marine regions) as a tool for understanding large marine areas is in progress, and will be followed with a similar exercise in the onshore coastal areas. Marine biological data is required to test the value of this research, as suitable spatial prediction models such as SIMPLE (Walker and Moore, 1988), HABITAT (Walker and Cocks, 1991), Diversity (CSIRO Wildlife and Ecology unpublished), and others based on Bayes' theorem (Aspinall, 1992; Bonham Carter et al., 1988), already exist.

Methodology

We have decided initially to build on the Canadian experience of "sea systems" as the fundamental unit to manage, recognising the inherent value in holistic consideration of the marine environment. Each marine region defined in such an exercise should be relatively homogeneous with respect to, or contain recurring patterns of, such variables as sea bed morphology and type, ocean climate, nutrient distribution, etc., and be meaningful in an ecological sense. It is as yet unclear whether the Canadian hierarchical model of first, second and third order regions, each defined by a unique set of predetermined exogenous constraints, is appropriate. The area selected for analysis around Australia is intentionally large, both to deal with the fairly coarse nature of some of the data sets used, and to examine the truly regional nature of the seas surrounding Australia: it extends from the equator to 550 South, and from 1000 east to 1700 East.

Briefly, the methodology used is as follows. We have taken a set of selected attributes (3 water mass characteristics, several derived bathymetric measures, broad substrate zones, and nutrient status, all described below), examined each data set for obvious pattern and variability, and classified each to encompass that pattern. The resulting maps are then overlaid to form an index (unique conditions) overlay map and accompanying table, with a unique set of data values for each attribute in each polygon. After data transformation from nominal to ratio (presence/absence) type, the data matrix is grouped through the use of a non hierarchical allocation algorithm, ALOC (Belbin, 1987). Allocated class or affinity to class centroid is then mapped back into the unique conditions polygons to produce a map which encompasses the multivariate pattern.

Added information is extracted from the resulting data matrix by subjecting it to analysis in a computer induction software package, KnowledgeSeeker (FirstMark Technologies, 1990). Incorporating statistical decision trees (Breiman et al., 1984) and machine learning concepts, KnowledgeSeeker is used in this exercise to derive the rules by which the allocation into specific groups is made. For example, it is possible to say that Group X created in the ALOC analysis occurs between sea surface (0m depth) temperatures A and B, 50m sea temperatures of C and D, at depths of between (E and F) or (G and H), and on substrate types J and K and in nutrient concentrations between L and M. Evaluation of the rules and maps for a range of solutions with different numbers of groups permits selection of the most significant result.

The methodology adopted in this study contrasts in concept with that proposed by O'Neill et al. (1989) based on hierarchy theory. Briefly, they hypothesize that all biological systems are limited by the behavior of their components, and by environmental constraints imposed by higher levels. Crucial to the latter assumption is the concept of an environmental (or constraint) envelope, "the set of conditions within which the ecological system can operate" (O'Neill et al., 1989, p.196). Whilst the environmental envelope is undoubtedly a very useful concept for understanding ecological processes, we feel that at the small scale (large area) of operation of CAMRIS its use is limited by the sheer number of groups of organisms involved and the problems of stochasticity. It may be an important factor for the delineation of areas at the mesoscale (5 - 50 km).

Data Sets

Four quite distinct types of data have been selected for inclusion in this marine regionalisation project: water mass characteristics, bathymetry, substrate type, and ocean nutrients. Each is described below.

Three measures of water mass identity were selected from the U.S. National Oceanographic Data Centre digital "Climatological Atlas of the World Ocean" (Levitus, 1982): ocean temperature, ocean salinity, and ocean dissolved oxygen saturation. The data represents a synthesis of most (several million) oceanographic station, mechanical bathythermograph, and expendable bathythermograph records in the NODC database. Records have been filtered and analysed by NODC prior to the construction of a gridded summary data set. Each attribute was available as a mean annual value for each of up to 33 standard depths between the sea surface and the bottom, on a one degree by one degree grid. Seasonal (three monthly) salinity and temperature data sets were also analysed. Monthly temperature data is available but was not included. The gridded data set was chosen over raw depth vs attribute profiles available on CD-ROM from NODC, CSIRO, or the RAN because of the consistent data density, objective record selection, and the long term data collection used in production of the Levitus atlas. It is hypothesised that a one degree grid is sufficient for the region covered in this analysis. Detailed work on the Australian continental shelf will require collation of further data from the acquisition agencies, with the inherent problems of patchy coverage and temporal variability. Time series analysis of remotely sensed variables (E. Ortiz, N.S.W. Fisheries, pers. comm.) may provide an alternative methodology.

The raw bathymetry data set has been constructed from three different sources. The first, and numerically largest data set is extracted from the U.S. NOAA "ETOPO5" global 5 minute (about 9km at the equator) digital elevation model. This data is the best available Australian regional deep water bathymetric summary, and provides a good filtered and gridded base from which to work. Attempts were made to include all research cruise bathymetric soundings, but poor data quality control (some cruises recorded a depth of 0m over wide areas of the ocean!) led to this approach being dropped. Approximately 650,000 data points in the ETOPO5 data set lie in the area south of 10 degrees South latitude. Shallow water bathymetry was obtained from the RAN Hydrographer who, through the AGSO Cartography Unit under contract to CSIRO Wildlife and Ecology, digitised all the 1 : 250,000 scale bathymetric charts around the coast. This provided continuous 20m, 50m, 100m, 150m, 200m, 250m, and 300m bathymetric contours around the country, with the exception of a couple of small areas in the Great Barrier Reef and Gulf of Carpentaria. To include this data with the ETOPO5 information the vectors were translated into points, producing approximately 100,000 extra data points largely on the continental shelf. The final data source was corrected sounding data loaned from the RAN Hydrographer for the areas in which 1 : 250,000 map coverage was not available.

Processing of the point information took the form of a simple linear interpolation contouring algorithm after the creation of a triangular irregular network (TIN) constrained to pass through the points. This process, while far from ideal in local areas with abundant data, had the advantage of consistency, determinancy (interpolated values will be bounded by the minimum and maximum elevations of the triangle corners), and relatively rapid calculation time.

The bathymetric data set resulting from this compilation exercise is probably sufficient for operations down to a scale of about 1 : 250,000 near the coast, which is more detailed than the present exercise. The main drawback is the lack of detailed information in shallow water: we lack the crucial 10m contour intervals necessary to properly characterise the depths less than 100m. This can be supplemented in areas where charts exist, should the requirement arise. A minor criticism of our approach is the inability to maintain variance across the region, with areas of rapidly varying topography being less well represented by the final surface than smooth areas. Incorporation of the research cruise bathymetry, once screened and filtered, would probably reduce this problem because of the concentration of data in areas of rugged undersea terrain.

Substrate type was digitised from a set of maps produced by the Ocean Sciences Institute of the University of Sydney under contract to the RAN (Schneider, 1985, 1987; Schneider et al., 1988). The nomenclature follows that used for deep sea sediments in the Deep Sea Drilling Project. The scale of these maps and the data density is only appropriate for use at the regional scale, and usually includes the continental shelf as a single unit (distinguishing only between siliclastic and carbonate sediment types). There is however, little other information in deeper areas available for reasonable cost. Shallower sediment samples have been digitised from the numerous BMR (now AGSO) bulletins (e.g. Jones, 1973) in co-operation with AGSO Coastal Geoscience but are not yet included in the sediment type database. Summary information for major sections of the shelf is available in Harris et al. (1991).

Very shallow water (less than 50m) substrate and habitat maps are being produced for large areas of the coast by CSIRO Fisheries under contract to CAMRIS. This is being done through a combination of enhancement of remotely sensed images, aerial photo interpretation, and extensive ground truthing, and is a highly skilled and expensive undertaking. At present, data is available for the southern half of Western Australia, most of South Australia, Victoria, and parts of Tasmania. Funding is being sought from each state and the Commonwealth at the planning stage for each coastal section.

Nutrient data from the CSIRO Marine Labs hydrographic database, including all records acquired on Australian and international collaborative cruises in Australian waters since the early 1900s, is the best data source of its type available at the continental scale. It includes a number of measures of nitrogen and phosphorus concentration at many depths, as well as silicate values. A summary of some of the earlier records may be found in Rochford (1979). We have to date only undertaken exploratory data analysis of the information, but have determined that it may be very useful in a regional sense, particularly in deep water. Detailed nutrient information close to the coast is available from other sources but is very patchy in time and space, and has not yet been collected by the CAMRIS team.

Progress

Substantial methodological progress has been made in this CAMRIS exercise. Selection of datasets and preliminary analysis is complete. A number of techniques have been developed to map the results of multivariate analysis, including a pseudo "fuzzy mapping" method which may be particularly appropriate in the marine environment. Further, the use of computer induction to derive rules for classifying data sets provides one method of determining, albeit somewhat subjectively, the relative merit of two or more allocation exercises. Ultimately, the value of any classification lies in the understanding it provides to the scientist or manager involved, so it appears appropriate at this point to start including some management objectives in the scientific process. Tools are already available to assess the relative value in environmental or biodiversity terms of one area against another, or to determine the likelihood of occurrence of certain species in an area. Application of these may assist in the achievement of management goals.

THE ACT OF REGIONALISATION: CONCEPTS AND PROBLEMS

If the world were an ideal place, and almost unlimited data and understanding were available to us, we could perhaps quickly generate models of ecosystem function and interrelationships between different spatial and temporal scales. This is, however, not the case, and we even have difficulty cataloging the range of organisms at a given site. One way used to help us understand the enormous complexity of reality is to abstract or generalise to a level we can appreciate; in other words, we regionalise. The relevance of this to the definition of marine regions is the scale to which we generalise: can we hope to define ecologically bounded objects for Australia's entire marine estate and understand the interactions in time and space, or are we simply trying to define a series of management units which approximate some level of ecological organization? There is a school of thought which recognises the existence of real or natural regions in the marine environment (for example Morgan, 1989; Steele, 1991; Sherman and Alexander, 1986), and has demonstrated that these regions are admirably suitable as management units. There has however, been failure in most attempts to link these regions with ecological process theory or to show where they lie in ecological hierarchies (Cousins, 1993).

The most obvious drawback to the use of the concept of the "marine region" is the problem of defining exactly what that region is, and where its boundaries lie. In the marine environment the problem is acute: " all biogeographical zones change geographically with time, marine zones more rapidly than zones on land, because faunal response to changes in current patterns and temperatures is immediate, and in the case of planktonic forms the environment carries the biota with it, their boundaries may well shift considerably over periods of a few years" (Dunbar, 1972, in Mondor, 1991). The CAMRIS team has attempted to overcome this problem using the group centroid affinity measure, but we still have no theoretical basis for placing a boundary at a particular point. Ultimately this must be a management decision.

A secondary problem in the use of multivariate classification methods is the inability to determine the relative value of any given solution. An obvious criticism of existing numerically derived regionalisations, such as that of Cresswell et al. (1992), is that no one can say which of a given number of solutions is "better". The problem comes down to the fundamental question which arises each time such an exercise is performed: what is the purpose of the regionalisation? Without this crucial answer even the most detailed analysis of each data layer is wasted. The use of the KnowledgeSeeker approach described earlier to help explain the results of a classification certainly improves our ability to discriminate between meaningless and meaningful regions, but does not eliminate the problem.

A further problem unique to the definition of "protected" or managed areas in the marine environment is that of the utility of a management unit in deep water. The concept of regionalising to define marine management units falls over if we have no knowledge of what we are managing, no criteria by which to manage, or no methods to implement the management strategy. Regionalisation techniques applied jointly to deep and shallow regions, but based on concepts of management of coastal areas, may therefore be inappropriate.

CONCLUSION: FUTURE RESEARCH DIRECTIONS FOR MARINE REGIONALISATION

The CAMRIS team does believe in the total reliance on a set of marine regions as a tool for the management of Australia's maritime estate. As an initial step, it would certainly be useful to construct a set of physical and biological domains at the continental level. This will require a concerted effort to gather and collate the enormous amount of biological data lying in archives around the country. We believe this task is a possible and necessary prelude to more detailed work. The real value of such an approach lies in the use of issue-based regionalisations to explore policy scenarios and therefore to enhance management, as discussed in Cocks (1992).

A few conceptual questions must be addressed before we have progressed too much further: the shallow / deep problem already mentioned, the need to decide exactly what data should be included in any regionalisation, and the scale at which further work should be pursued. Additionally, some process must be developed for assessing the validity of any set of regions produced. Prior to any of these questions being asked, however, we must still answer the most fundamental question of all: what are we trying to achieve by regionalising? We do not accept that the production of a set of biogeographic regions around the country will necessarily lead to the selection of an optimum set of marine management areas, unless the issues which are to be managed are included as part of the regionalisation process.

One scenario for further work which may help address some of these problems by identifying controls on different types of environments is to perform eight separate regionalisations based on the environmental and biological domains paradigm in four broad spaces: onshore coastal environments, estuaries, shallow marine environments, and deep marine areas. Each could use a specifically selected set of attributes chosen as important in that environment, and each could, by judicious selection of scales and methodologies, use the others to constrain solutions. There is little doubt that expert judgement will be required to assist in the assessment and combination of these solutions.

REFERENCES

Aspinall, R., 1992 An inductive modelling procedure based on Bayes' theorem for analysis of pattern in spatial data. International Journal of Geographical Information Systems, 6, 2, 105-121.

Beatley, T., 1991 Protecting biodiversity in coastal environments: introduction and overview. Coastal Management, 19, 1-19.

Belbin, L., 1987 The use of non hierarchical allocation methods for clustering large sets of data. Australian Computer Journal, 19, 1, 32-41.

Belbin, L., 1993 Environmental representativeness; regional partitioning and reserve selection. Biological Conservation, 66, 223-230.

Bonham-Carter, G. F., Agterberg, F. P., and Wright, D. F., 1988 Integration of geological data sets for gold exploration in Nova Scotia. Photogrammetry and

Remote Sensing, 54, 11, 1585-1592.

Breiman, L., Friedman, J., Olshen R., and Stone, C., 1984 Classification and Regression Trees. Wadsworth.

Christian, C. S., Stewart, G. A., and Perry, R.A., 1960 Land research in northern Australia. Australian Geographer, 7, 6, 217-231.

Cocks, K. D., 1992 Use with care: managing Australia's natural resources in the 21st century. University of New South Wales Press.

Cocks, K. D., and Crossland, C., 1991 The Australian coastal zone: a discussion paper. Resource Allocation Program Working Document 91/4. CSIRO Division of Wildlife and Ecology, Canberra.

CONCOM, 1985 Summary report of the second technical workshop on selection and management of marine and estuarine protected areas, Jervis Bay. Council of Nature Conservation Ministers, Canberra.

Cousins, S. H., 1993 Hierarchy in ecology: its relevance to landscape ecology and geographic information systems. In Haines-Young, R., Green, D., Cousins, S. (Eds.), Landscape ecology and geographic information systems, Taylor and Francis, London, 75-86.

Cresswell, I., Kaye, T., Noble, S., and Thackway, R., 1992 Conservation assessment of the Australian coastal zone. Environmental Resources Information Network.

Dunbar, M J., 1972 The nature and definition of the marine subarctic, with a note on the sea life area of the Atlantic salmon. Transactions of the Royal Society of Canada, 10, 249-257.

FirstMark Technologies, 1990 KnowledgeSEEKER: Decision Making software. Product guide and manual. FirstMark Technologies, Ottawa, Canada.

Griggs, D, 1967 Regions, models, and classes. In Chorley, R. J. and Haggett, P. (Eds.), Models in geography, Methuen and Co., London.

Haggett, P., 1965 Locational analysis in human geography. Edward Arnold Ltd., London.

Harris, P. T., Baker, E. K., and Cole, A. R., 1991 Physical sedimentology of the Australian continental shelf, with emphasis on the Late Quaternary deposits in major shipping channels, port approaches and choke points. Ocean Sciences Institute Report No. 51. University of Sydney.

Jones, H. A., 1973 Marine geology of the northwest Australian continental shelf. BMR Bulletin 136.

Kelleher, G. and Kenchington, R., 1991 Guidelines for establishing marine protected areas. Great Barrier Reef Marine Park Authority.

Levitus, S., 1982 Climatological Atlas of the World Ocean. NOAA Professional Paper No. 13, Rockville, Md.

Mondor, C. A., 1991 Planning for Canada's system of national marine parks. In Kelleher, G., and Kenchington, R., Guidelines for establishing marine protected areas. Great Barrier Reef Marine Park Authority.

Morgan, J. R., 1989 Marine regions: myth or reality. Ocean and Shoreline Management, 12, 1-21.

O'Neill, R. V., Johnson, A. R., and King, A. W., 1989 A hierarchical framework for the analysis of scale. Landscape Ecology, 3, 3, 193-205.

Ray, G. C., and McCormick-Ray, M. G., 1992 Marine and estuarine protected areas: a strategy for a national representative system within Australian coastal and marine environments. Consultancy report for ANPWS, Canberra.

Rochford, D. J., 1979 Nutrient status of the oceans around Australia. In Maclean, J. L. (Ed.), CSIRO Division of Fisheries and Oceanography Annual Report 1977 - 1979, 9- 20.

Schneider, P. M., 1985 Report on SP4 maps on the sediments, morphology, and acoustic properties of the southwest Pacific seafloor. Ocean Sciences Institute Report No. 15. University of Sydney.

Schneider. P. M. 1987 Report on SP1 maps on the sediments,morphology, and acoustic properties of the southwest Pacific seafloor. Ocean Sciences Institute Report No. 23. University of Sydney.

Schneider, P. M., Packham, G. H., and Carty, S., 1988 Report on the IN8 maps on the bathymetry, sediment type, sediment thickness, and physiographic provinces of the southern Indian Ocean. Ocean Sciences Institute Report No. 32. University of Sydney.

Sherman, K., and Alexander, L. M., 1986 Variability and management of large marine ecosystems. Westview Press, Colorado.

Steele, J. H., 1991 Marine ecosystem dynamics: comparison of scales. Ecological Research, 6, 175-183.

Walker, P. A. and Cocks, K. D., 1991 HABITAT: a procedure for modelling a disjoint environmental envelope for a plant or animal species. Global Ecology and Biogeography Letters, 1, 108-118.

Walker, P. A., and Moore, D. M., 1988 SIMPLE: an inductive modelling and mapping tool for spatially oriented data. International Journal of Geographical Information Systems, 2, 4, 347-363.

United Nations, 1983 The Law of the Sea : United Nations Convention on the Law of the Sea. United Nations, New York.

The Development of a Representative System of Marine and Estuarine Protected Areas for New South Wales

E. Ortiz and D. Pollard
Habitat Management Unit
New South Wales Fisheries, Sydney

AIMS AND BACKGROUND OF PROJECT

Since the amendment of the NSW Fisheries and Oyster Farms Act in 1979 allowing for the creation and management of Aquatic Reserves, NSW Fishes' Aquatic Reserves Program has been working toward the development of a comprehensive system of Marine and Estuarine Protected Areas (MEPAs) in state waters. Eight MEPAs have so far been declared under this legislation, the multiple-use Solitary Islands Marine being the most recent and largest (100,000 ha).

To date, MEPAs declared by NSW Fisheries have mainly been selected on the basis of their 'uniqueness'. However, there is a recognition that establishing a biogeographically and ecologically representative system of MEPAs is a necessary basis for *in situ* biodiversity conservation, and also an important step towards ensuring the sustainable development of the NSW coastal zone and its resources.

Following the 1991-1992 budget, the Department for the Arts, Sport, the Environment and Territories (DASET) started a ten-year marine conservation program called Ocean Rescue 2000 (OR2000). Under this program, NSW Fisheries received initial funding for the development of such representatives system of MEPAs in NSW.

The aims of the project were thus the application of a biophysical classification system to the NSW coastline and inshore marine and estuarine ecosystems. This classification system is aimed at the identification of a set of areas representing the diversity of marine, estuarine and coastal environments found in NSW, and the development and application of a systematic approach for the selection of specific areas for future MEPA declaration.

The first and most important step in achieving a representative system of MEPAs is the scientifically based identification of a set of areas covering the full range of marine and estuarine environments to be protected. In this paper, a systematic approach for the identification of areas in NSW is outlined. It uses the theoretical framework provided by the hierarchical concept of ecosystems to develop a biophysical classification of coastal environments. The results of this classification will provide a systematic arrangement - based on biological and physical similarities and differences - of all coastal marine and estuarine environments that need to be protected in NSW.

To guide the identification of such a representative system, an integrative holistic approach involving biology, oceanography, physiography and climatology was adopted to develop a three level biophysical classification of coastal, marine and estuarine environments. The hierarchical levels (scales) were not designated a *priori,* but were extracted from empirical data related to biological and physical coastal processes operating at different spatial and temporal scales.

The first level identified coastal biophysical regions (bioregions), providing a broad strategic environmental framework necessary for the conservation and management of NSW coastal resources. The second level, when complete, will identify local scale functional ecosystem units with recognisable natural boundaries and internal homogeneity, suitable for MEPA declaration. The third level, when complete, will permit the implementation of tactical site management actions directed to address specific objectives of coastal resource management and biodiversity conservation.

Based on progress to date in applying this approach, three biophysical regions have been preliminarily identified in NSW - a Northern Bioregion covering the coastal zone between the Queensland border and Sugarloaf Point (32°26'S); a Central Bioregion covering the coastal zone between Sugarloaf Point and Jervis Bay (35°00'S); and a Southern Bioregion covering the coastal zone between Jervis Bay and the Victorian border.

Sixty four percent of all MEPAs declared to date in NSW are located in the Central Bioregion. The current study also highlights the fact that the existing MEPAs cover only a proportion of the range of environments found in NSW.

It is recommended that the present system in NSW be expanded at least to include one sample of each type of biophysical unit found within each identified bioregion.

GENERAL CONCLUSIONS TO DATE

1 The Systematic approach developed for the identification of a set of areas covering the full range of coastal, marine and estuarine environments found in NSW has a theoretical scientific basis and was found to be a viable management tool.

2 For the development of a National Representative System of MEPAs, this pilot study provides a general scientific methodology for the identification of areas to be included in such a system. It is comparative, robust and flexible enough to be applied in other states or even at the continental scale. To be applied at the continental scale, the approach would need to incorporate large scale (thousands of kilometres) oceanographic, climatologic and physiographic features.

3 At the highest level (meso-scale), the results of the biophysical classification of coastal environments will provide a board strategic environmental framework on a scale which matches the scale of coastal ecosystems.

At the middle level (local scale), the results will provide a set of functional ecosystem units with recognisable natural boundaries and an internal homogeneity, suitable for MEPA declaration.

At the lowest level (small scale), the result will permit the implementation of tactical site management actions directed to address specific objectives of coastal resource management and the conservation of biodiversity.

4 The developed methodology will indicate priorities for action. For example, the preliminary results obtained during the pilot study indicate a high priority for MEPA declaration in the southern part of the state, to the south of Jervis Bay.

5 An initial assessment of the representativeness of the present system of MEPAs shows that 64% of all MEPAs declared in NSW are found in the Central Bioregion and 72% of those are in the Sydney area. It also highlights the fact that the existing MEPAs cover only a small proportion of the range of coastal, marine and estuarine environments found in NSW.

Queensland Marine Habitats - A Biophysical Classification at the Meso-scale for Conservation Planning

Tim Stevens
Queensland Department of Environment and Heritage, Brisbane

ABSTRACT

Published methodologies for selection of nature conservation reserves have as a common first step the definition of biogeographic regions. In planning for conservation of marine environments in the Australian context this first step has not generally been taken, although initial work is in progress in a number of states. In contrast, this framework has been available in the terrestrial situation in Queensland for 15 years.

As an initial attempt at defining such regions, a classification of Queensland marine habitats at the meso-scale (100's of km) was performed using a range of physical and biological parameters. Parameters were selected on the basis of availability in the current literature, relevance to marine biodiversity and coverage across all Queensland and adjacent waters. Each parameter was mapped and overlaid on a 30 minute (30') square grid array. Numerical classification techniques were used to derive groups of grid cells with similar attributes, which were then plotted and boundaries smoothed. The resultant map represents the first quantitative attempt at a classification of all Queensland marine environments at this scale. The classification reveals several distinct coastal habitat types, differentiated primarily on the basis of rainfall, tidal range, mangal community structure and decapod biogeography. Offshore habitat types are differentiated primarily by substrate (mud and carbonate) composition and reef structure.

Further work is required to refine the classification. Specifically, the range of parameters must be extended and the available datasets updated. The classification will then be performed at a finer scale to test for the validity of derived boundaries. This classification will then enable an evaluation of the degree to which the major habitat units are represented in marine conservation reserves.

INTRODUCTION

THE NEED FOR A CLASSIFICATION

Published methodologies for selection of nature conservation reserves or the assessment of the conservation significance of a particular area, species or feature have as a common first step the definition of biogeographic regions (eg. Bolton and Specht 1983; Blackman *et al* 1992). In planning for conservation of marine environments in the Australian context, and indeed internationally, this first step has not been taken until very recently, although initial work is now in progress in a number of states (eg. Ortiz and Burchmore 1992). In contrast, this framework has been available in the terrestrial situation in Queensland for 15 years since the work of (Stanton and Morgan 1977), and well recognised internationally for over 20 years (UNESCO 1974, cited in Kelleher and Kenchington 1992).

Marine resource managers have highlighted the need to approach marine conservation within a structured framework, with the aim of representing all marine habitat types with reserve systems (the biosphere approach, Kelleher and Kenchington 1992). This is a major change in emphasis from the priority placed on protection of high productivity areas (eg. seagrasses, mangroves, coral reefs) embodied within fisheries management and presents new challenges for marine resource evaluation and marine reserve planning (Stevens *et al* in press).

The systematic identification and classification of regional and local biophysical and ecological units which can be incorporated into planning is one of the major challenges facing marine conservation. However, the paucity of natural resource data, inadequate understanding of ecological processes and incomplete understanding of life-cycles and species specific information has hitherto impeded the construction of biophysical classifications and strategies for the conservation of biodiversity at useful levels of detail. Similarly, assessment of the significance of the loss of marine habitats to development projects within a wider regional or national context is virtually impossible within any structured context, and remains largely intuitive and qualitative. This is a matter of major concern in view of the intensity of development pressures and impacts of pollution along much of the Australian coast. There can be little doubt that some habitats are being lost before they are even described.

A BRIEF HISTORY OF MARINE CLASSIFICATION

The Swedish naturalist Sven Petrus Ekman (1953) examined patterns of distribution of major marine biota and produced a general account of the zoogeography of marine environments on the global and continental scale (see also Briggs 1974).

Ray (1975, 1976) developed the concept of an hierarchical classification of coastal and marine environments as a "basis for the establishment of a system of preserves by means of which marine ecosystems will eventually be conserved, studied, and monitored." (Ray 1975, page 5) These concepts were further discussed and refined at the 3rd World Congress on National Parks in Bali in 1982 (Ray *et al* 1984), leading to the

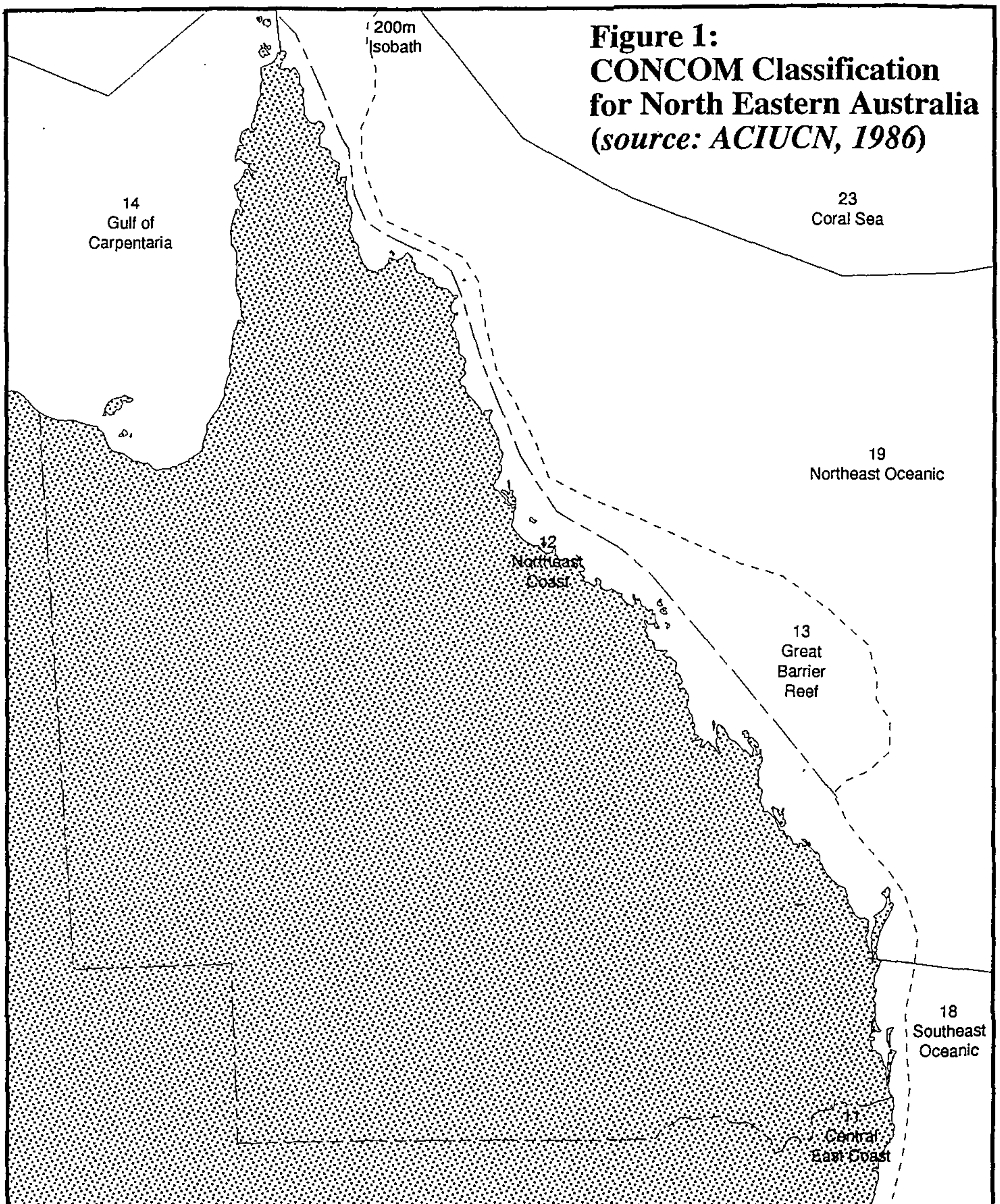


FIGURE 1. CONCOM Classification for North Eastern Australia (source: ACIUCN,1986)

publication by IUCN of *Marine and Coastal Protected Areas: A Guide for Planners and Managers* (Salm and Clark 1984).

Ray and Hayden (1987) further refined marine and coastal classification systems, proposing a meso-scale (regional) classification which subdivides coastal provinces primarily on the basis of ecological processes. The classification was world wide and did not consider the biogeography of species assemblages "because these assemblages are not repeated from continent to continent or realm to realm" (*ibid,* page 4).

In the Australian context, a classification derived from Ray's (1976) model was adopted by the Council of Nature Conservation Ministers (CONCOM) in 1985. This classification was subsequently modified to recognise 32 marine geographic zones, of which 14 were coastal (from high water to the 200m isobath) (CONCOM 1985; ACIUCN 1986). It should be noted that 9 of these marine geographic zones relate to Australian external territories and islands, the boundaries and classification of which are to an extent determined by jurisdictional boundaries, rather than a biotic classification. The boundaries of this classification as it applies to the Queensland situation are illustrated in figure 1.

The scale of the CONCOM classification and the limited resource data on which it was based mean that it is of limited value for marine conservation planning. Kelleher and Kenchington (1992) and Ray and McCormick-Ray (1992) highlight the inadequacies of the CONCOM classification and argue for an increased emphasis on representation of biogeographic types within broad-scale protected areas (the biosphere approach). Ray and McCormick-Ray (1992) propose a multilevel, hierarchical classification incorporating biogeographic and physical elements ('biophysical') from global to local scales as a critical tool to ensure the identification and protection of representative examples of all marine environments.

This paper represents an initial attempt to derive a meaningful classification for Queensland waters at a regional or meso-scale (see below) to enable conservation planning within the framework of biophysical regions, in a similar manner to that available in the terrestrial situation through the work of Stanton and Morgan (1977) and Bolton and Specht (1983). The work presented in this paper is a very brief exploration of an approach to developing such a classification. As such the results are not intended to be definitive, but to provide a basis for discussion and future directions for data gathering.

SCALE

This paper uses the terminology adopted by Ortiz and Burchmore (1992) to describe a hierarchy of functional scales for biophysical mapping. The definitions and attributes of each scale are presented in the table on the following page.

This paper is concerned with the derivation of a biophysical classification at the meso-scale (100's of km). This will provide the framework for future studies to derive local-scale (10's of km) classifications within each biophysical region, using a consistent set of locally relevant parameters. This hierarchical approach has already been developed and successfully applied to terrestrial and some estuarine areas by Blackman *et al* (1993). It is at this scale that planning decisions for the locations, selection, zone boundaries and management prescriptions of marine reserves designed to maximise the representation of each structural unit within each biophysical region. At the smallest scale, individual habitats are recognised and can be managed to control site specific concerns, for example anchor damage at a popular reef viewing sites.

TABLE 1: **Hierarchy of biophysical classification units**
(from Ortiz and Burchmore 1992, pages 4 and 5)

Scale	Size	Attributes
Meso-scale	100's of km	Based on major discontinuities in biogeography, oceanography and physiography
Local scale	10's of km	Based on functional structural units with recognisable natural boundaries and internal homogeneity
Small scale (sites)	10's - 1000's of m	Based on individual physical and biologicalhabitats (eg. reefs, algal beds)

DATASETS - SELECTION AND SOURCES

SELECTION CRITERIA

This initial classification is based on available existing interpretations of data, rather than reinterpretation of new data collection. To be of value in deriving a classification over all Queensland waters, datasets had to satisfy the following criteria:

- All or most of Queensland waters should be covered
- Spatially and temporally separated data should be collected using comparable methods and interpretations, at least at a gross scale.
- Data and interpretations should be relevant to the patterns of distribution and/or abundance of marine organisms, communities and habitats.
- Data should be quantitative in form, and able to be mapped and used in numerical classification techniques.
- Datasets should be sufficiently well documented to allow future updates to be carried out with confidence that they will be comparable.

SELECTED DATASETS, COVERAGE AND SOURCES

The data layers selected for analysis, that were available from extant and readily accessible sources, are listed in table 1 with their sources. A brief description of the type and relevance of each dataset is given below.

TABLE 2. **Selected Data Layers and Sources**

Data Layers	Sources
Physical parameters	
Tidal Ranges	Bird 1984
Rainfall	Bureau of Meteorology data and reports
Cyclone incidence	Lourensz 1977.
Sedimentary Basins	Maxwell 1968
Mud and Carbonate distributions	Maxwell 1968
Bathymetry	Maxwell 1968
Biogeographic parameters:	
Mangroves and Saltmarsh	Saenger *et al* 1977, Buckley 1983
Hermatypic Corals	Veron 1985
Reef Morphology	Maxwell 1968
Littoral Crabs	P. Davie - Qld Museum (pers. comm)

PHYSICAL PARAMETERS

Tidal Ranges

The range of tidal variation along the Queensland coast and associated shoals and islands is included as a forcing function for intertidal distributions. Tidal range is obviously a major factor in determining the extent of intertidal communities, especially in areas of low slope. In association with the degree of exposure of coastlines, it can also be of importance in determining erosion and sediment transport characteristics, and supra littoral faunal and floral distributions.

Rainfall

Rainfall patterns are of interest primarily for their effect on major river flow volumes, but also in the distribution of coastal lowland swamps, soaks and other supra-tidal wetlands (see Blackman 1993). Not surprisingly, a strong correlation appears to exist between rainfall, size and complexity of coastal wetland systems, and diversity of faunal elements within those wetlands.

Cyclone incidence

A substantial body of literature exists on the role of perturbation in maintenance of biological diversity in complex ecosystems. Olsen (1989) has examined the effects of natural disturbances such as cyclones of the structure of rainforest communities (see also Marshall and Swaine 1992). A similar relationship is found in high diversity marine systems, especially coral reefs. It is logical to assume that cyclones also have a major effect on coastal erosion patterns and the evolution of coastal landforms. Information on the incidence and intensity of cyclones is therefore relevant to a classification.

Sedimentary Basins and Mud / Carbonate distributions

The type of substrate underlying marine and intertidal communities will have a major effect on distributions of benthic organisms, and so influence higher trophic levels. The effect is derived through three main ways; viz: strategies for attachment to / embedding in substrate for sessile species, strategies for dealing with sediment load for sediment-sensitive species (eg. corals, photosynthesisers), strategies for extracting nutrient in filter feeding organisms. In the case of sediment substrates (as against rock or coral), the type (grain size distribution, etc) will, in association with local water movement, determine turbidity and sediment loads on sessile species, and the availability of nutrients for filter feeders.

Bathymetry
The vertical distribution of substrate is an important determinant in the distribution of light-dependent species and consequently on those dependent on them. Marine plants are particularly strongly depth stratified, as are, by association with their resident zooxanthellae, many species of corals. Other taxa are found exclusively in deep-water soft-bottom habitats; this is a set of habitats that is very poorly known, except from a fisheries point of view.

BIOGEOGRAPHIC PARAMETERS

The datasets included are most likely to be constrained by the availability of data. There are few groups of organisms whose distribution and affinities are known at any but very gross levels of detail over the entirety of Queensland marine and estuarine areas. The datasets compiled are therefore necessarily variable in their accuracy and applicability to the classification. In the selection of faunal and floral groups, care must be taken not to base the selection of preconceptions about the nature of the communities that might be derived from the classification, or a meaningless circular argument develops. To an extent, however, this is unavoidable, since these are often the groups for whom the best data exist. For instance, the point was made above that existing marine conservation efforts are largely directed at mangroves, seagrass beds and coral reefs, to the exclusion of lesser known habitat types, such as inter-reefal soft bottom communities. Consequently, the literature on the biology, energy flux, systematics, biogeography, etc of these groups is extensive, while that on biota that may be characteristic of other habitat types is strikingly poor, although they may have no less conservation value. The following groups were those available for which meso-scale interpretation of biogeography had been performed.

Mangroves and Seagrasses
The importance of these two major floral elements to estuarine productivity and faunal diversity is well documented. The structure and complexity of mangrove communities also varies considerable with latitude, exposure, tidal regime, and coastal topography (Saenger *et al* 1977). Davie (pers. comm.) has also illustrated an apparent correlation between the diversity of littoral decapods contained in mangrove wetlands and the size and complexity of those communities.

Hermatypic corals
The biogeography of reef building corals is obviously important in determining where reefs will occur. However, the affinities of various groups within the corals is also of interest, for example in determining the distribution and community structure

of reefs in inshore, turbid environments, or in areas close to the extremes of range of some species. Most published material on coral biogeography is at the continental scale, however some trends are apparent within Queensland and adjacent waters.

Reef Morphology
The shape, orientation and developmental state of reef structures reflects differing oceanographic and climatic conditions (Maxwell 1968), but also the geological history of the surrounding inter-reefal platform. In turn the morphology of the reef structure and its neighbours determines the range of conditions available for settlement of coral, algae and other sessile benthos, affecting biodiversity at the local level.

Crustacea - Littoral Decapods
With the exception of commercially important species, the diversity and biogeographic affinities of decapod crustaceans have not been greatly studied. This group plays a critical role as lower to middle trophic level consumers and has in fact a vast diversity, although this is not well known. There is considerable potential for some decapod groups to be used as indicators of biodiversity. Additionally, any attempt to conserve representatives of the range of biodiversity must eventually take account of this group. The dataset used was the only coverage of a decapod group (other than commercially important species) available state-wide at the time these analyses were carried out and was provided by Peter Davie of the Queensland Museum.

ANALYSES

DATA STORAGE AND MANIPULATION

Maps of the distributions of the data layers were scanned or hand digitised into a Macintosh-based graphics package, over a base map derived from the AUSLIG supplied coastline. An array of uniquely identified 30′ grid squares was set up over the area of Queensland coastal waters to the 200m isobath. A total of 217 grid squares was necessary to cover the required area.

The grid square array was then overlaid on the maps of each data layer, and each grid scored as a value corresponding to the category within each data type. Where more than one category occurred within the grid square, the category with the largest area represented was used. The scores thus formed a matrix of 217 instances (grid squares) by 10 attributes (data layers). The data were categorical rather than meristic.

CLASSIFICATION METHODS

Two approaches were taken to reducing the multiple layers of data to a single, meaningful classification.

The first was a purely intuitive approach, based on the major physical forcing functions such as geology, bathymetry, tidal range, cyclone incidence and rainfall, with the biogeography of selected taxa overlaid to separate, for instance, the complex wet tropical coast mangrove communities from the relatively simple south-east

Queensland communities. The classification derived was qualitative in nature but was useful in framing hypotheses to be tested using numerical techniques. This intuitive classification was presented at a workshop conducted in March 1993 to discuss techniques for classification and conservation planning of marine areas.

The next step was to apply numerical classification techniques to the data matrix to test the intuitive classification.

A variety of numerical classification techniques were used with similar sets of attributes. The data matrix was analysed using the Statistical package SYSTAT. Agglomerative cluster analyses were performed using a number of similarity measures and sorting strategies. The results were varied but broadly similar. In some analyses different data layers were omitted or differentially weighted to examine their effect on the data. The analyses finally chosen for interpretation were those which showed resilience in data layers, that is, in which the deletion or re-weighting of a data layer did not drastically alter the composition of the derived groups. The technique settled on was to use the normalised percentage difference algorithm to derive similarity measures from the categorical data. The Group Average sorting strategy was used to sort the clusters. The resultant dendrograms were interpreted at the level of approximately 16 - 18 groups, based on some obvious patterns within the classification, and from the intuitive "eyeball" classification performed previously (above).

As a check, the "KMeans" divisive classification technique was employed on the same data. Whilst different in some details, the main groups were very similar.

The groups produced by the clustering process were then plotted on to the 30′ grid overlay, with squares within a group each shaded identically. "Singles" resulting from the analysis were grouped with those groups to which they were most similar (from examination of the dendrograms) or ignored. The outlines of each group were then plotted and smoothed. There was a need for some interpolation due to the gross scale of the grid cells (30′). The location of the boundaries of the derived regions can therefore be considered at best approximate. Then derived boundaries were overlaid on a chart and adjusted where necessary to correct anomalies caused by the scale of the mapping.

The results of this draft classification are illustrated in figure 2; descriptions of the regions derived are given on the following pages.

Descriptions of Biophysical Regions

TABLE3: **Queensland Biophysical Regions**

Name (Number)	Geographical Extent	Attributes
Offshore Gulf (1)	Gulf of Carpentaria except (2), (3) and (4)	Sedimentary basins: Carpentaria Basin Mud fraction in sediments: No data Sediment origin: No data Reef morphology type: No data Mangrove/Saltmarsh biogeography: Not applicable Littoral crab biogeography: Not applicable Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: Between 3 and 4 metres Cyclone incidence: Between 10 and 20 cyclones/decade Rainfall: No data
Inshore Gulf (2)	Inshore and island waters of the Gulf of Carpentaria from approximately Weipa to the Qld/NT border	Sedimentary basins: Carpentaria Basin Mud fraction in sediments: No data Sediment origin: No data Reef morphology type: No data Mangrove/Saltmarsh biogeography: 12 mangrove tree species, 17 tree plus understorey species, 10 saltmarsh species. Forms dense coastal or riverine fringe, backed by wide (20 km or more) saltpans. Littoral crab biogeography: Area 5 (Davie, pers. comm.) Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: Between 3 and 4 metres Cyclone incidence: Between 10 and 15 cyclones/decade. Higher in Weipa area. Rainfall: From less than 1000 mm in the south to over 1400mm in the north.
Torres Strait (3)	Reefs, island and waters of Torres Strait including the Queensland coast from approximately Weipa to the Escape River, east to the Warrior Reefs and western margins of the Fly River Delta, but not including the major inner island groups	Sedimentary basins: None Mud fraction in sediments: No data Sediment origin: No data Reef morphology type: Large planar reefs in shallow water, and medium sized lagoonal and planar reefs to the east. Mangrove/Saltmarsh biogeography: 20 - 27 mangrove tree species; 26 - 37 tree plus understorey species, 6 saltmarsh species. Forms tall very complex closed forest communities, although stunted or open communities found in marginal areas. Littoral crab biogeography: Area 5, marginal 4 (Davie, pers. comm.) Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: Between 3 and 5 metres Cyclone incidence: Between 5 and 10 cyclones/decade Rainfall: Between 1400 mm and 2000 mm.

West Cape York (4)	Inshore and Island waters from approximately Cape Keerweer to the tip of Cape York, including the major inner island groups of Torres Strait	Sedimentary basins: Carpentaria basin south of Port Musgrave Mud fraction in sediments: Low mud (0-10%) Sediment origin: Mostly terrigenous, some transitional around Torres Strait Islands Reef morphology type: Some large planar reefs off the tip of Cape York. Mangrove/Saltmarsh biogeography: 20 mangrove tree species, 26 tree plus understorey species, 6 saltmarsh species. Forms tall very complex closed forest communities, although stunted or open communities found in marginal areas. Littoral crab biogeography: Area 5 (Davie, pers. comm.) Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: About 3 metres Cyclone incidence: Between 10 and 20 cyclones /decade. Lower in north. Rainfall: Between 1400 and 2000 mm.
Inshore East Cape York (5)	Inshore and island waters from the northern tip of Cape York to Rattlesnake point.	Sedimentary basins: Mostly None, Laura Basin in Flinders Group area Mud fraction in sediments: Mostly high mud (40-100%). Sediment origin: Mostly high carbonate, transitional along the coast. Reef morphology type: Medium sized planar or lagoonal reefs, with senile reefs, shoals, low wooded cay reefs and some planar reefs in Princess Charlotte Bay. Mangrove/Saltmarsh biogeography: 27 mangrove tree species, 37 tree plus understorey species, 6 saltmarsh species. Forms tall very complex closed forest communities, although stunted or open communities found in marginal areas. Littoral crab biogeography: Area 4 (Davie, pers. comm.) Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: Between 2 and 4 metres Cyclone incidence: Between 10 and 15 cyclones/decade. Lower in north. Between 1400 mm and 2000 mm, except less than 1400 mm in Princess Charlotte Bay.
Offshore East Cape York (6)	Offshore Reefs, islands, shoals and shelf waters from the northern limits of the GBR, including the Detached reef complexes, Raine Island, to the southern extent of the ribbon reef complexes offshore from Cape Tribulation.	Sedimentary basins: Mostly None Mud fraction in sediments: Mostly low mud (0-10%) except high mud (40-100%) offshore Cooktown. Sediment origin: High carbonate Reef morphology type: Outer fringe of ribbon reefs as far north as Cape Grenville, then small planar reefs. Poorly developed reefs behind the fringe, with large karstic banks and submerged platforms. Reef development rates slow. Mangrove/Saltmarsh biogeography: Not applicable Littoral crab biogeography: Not applicable Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: Between 2 and 3 metres Cyclone incidence: Between 10 and 15 cyclones/decade. Lower in north. Rainfall: No data

Wet Tropic Coast (7)	Inshore and island waters from approximately Cooktown to Lucinda.	Sedimentary basins: None Mud fraction in sediments: High mud (40-100%) on coast, moderate mud (10-40%) just offshore. Sediment origin: Terrigenous Reef morphology type: Poorly developed inner shelf reefs adjacent to Cooktown. No data on fringing reef types. Mangrove/Saltmarsh biogeography: 27 mangrove tree species, 37 tree plus understorey species, 6 saltmarsh species. Forms tall very complex closed forest communities, although stunted or open communities found in marginal areas. Littoral crab biogeography: Area 3 (Davie, pers. comm.) Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: Between 2 and 3 metres Cyclone incidence: Approximately 15 cyclones/decade. Slightly higher in Cairns area, lower towards Hinchinbrook and Cooktown. Rainfall: From 2000mm to more than 4000mm in the Innisfail - Tully area.
Central Great Barrier Reef (8)	Mid-shelf and offshore reefs, cays, soft substrate habitats and waters from a latitude just south of Cairns to the mid-shelf area seaward of the Whitsundays, and extending to offshore reefs north of the Hard Line.	Sedimentary basins: Mostly None, except Halifax Basin offshore Hinchinbrook Mud fraction in sediments: Mostly low mud (0-10%), some moderate (10-40%) to high mud (40-100%) offshore from wet tropic coast and Bowen. Sediment origin: High carbonate Reef morphology type: Mostly juvenile or early mature reefs, larger in mid-shelf areas. Poor reef development at the shelf edge, characterised by small submerged reefs and reef patches. Mangrove/Saltmarsh biogeography: Not applicable Littoral crab biogeography: Not applicable Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: Between 2 and 3 metres Cyclone incidence: Between 15 and 20 cyclones/decade. Higher in south-eastern extremity. Rainfall: No data
Lucinda-Mackay Coast (9)	Inshore and Island waters from Lucinda to approximately Mackay, and including the Whitsundays and Cumberland Groups.	Sedimentary basins: Mostly None, except Proserpine Basin in Repulse Bay area Mud fraction in sediments: High mud (40-100%) in Repulse Bay / Bowen area, moderate mud (10-40%) elsewhere. Sediment origin: Mostly terrigenous, some transitional in areas immediately north and south of the Whitsundays Reef morphology type: No data on fringing reef types Mangrove/Saltmarsh biogeography: 20 mangrove tree species, 25 tree plus understorey species, 8 saltmarsh species. Forms lower closed to open forest communities along sheltered coasts and rivers. Littoral crab biogeography: Area 2 (Davie, pers. comm.) Hermatypic coral species richness: More than 70 genera of hermatypic corals Tidal range: Mostly between 3 and 4 metres, up to 6 metres at southern end Cyclone incidence: Between 10 and 15 cyclones/decade. Slightly higher in Whitsundays. Rainfall: Mostly between 1000mm and 1400mm, except 1400mm to over 2000mm in the Whitsundays - Mackay area.

Mackay-Capricorn Mid-Shelf (10)	Mid-shelf waters, reefs and soft substrate habitats from the mid-shelf areas seaward of the Whitsundays, extending south to the latitude of Rodd's Peninsular, and including the Capricorn-Bunker Group.	Sedimentary basins: None Mud fraction in sediments: Moderate (10-40%) to high mud (40-100%) except low mud (0-10%) in inner reef area (Capricorn-Bunker group and shoal grounds to the north) Sediment origin: High carbonate, except a small terrigenous area offshore from Keppel Bay Reef morphology type: Few isolated reefs and high islands, except the Capricorn Bunker group in the south, composed of late-mature medium sized reefs. Also contains numerous submerged reefs. Mangrove/Saltmarsh biogeography: Not applicable Littoral crab biogeography: Not applicable Hermatypic coral species richness: From 60 to just more than 70 genera of hermatypic corals Tidal range: Between 3 and 6 metres. Great est range in the middle of the area, lesser at the extremities. Cyclone incidence: Between 15 and 20 cyclones/decade Rainfall: No data
Southern Great Barrier Reef Offshore (11)	Offshore reefs, cays and waters from the offshore reefs seaward of the Whitsundays to the Swains, including the Hard Line, Pompey and associated reef complexes.	Sedimentary basins: Mostly None, except Capricorn Basin in inner Swains area. Mud fraction in sediments: Low mud (0-10%) except high mud (40-100%) adjacent to southern GBR embayment. Sediment origin: High carbonate Reef morphology type: Many large to medium sized reefs dominate the northern part (Pompey Complex) with many medium to small sized lagoonal and planar reefs in the south (Swain Reefs). Mangrove/Saltmarsh biogeography: Not applicable Littoral crab biogeography: Not applicable Hermatypic coral species richness: From 60 to just more than 70 genera of hermatypic corals Tidal range: Between 3 and 5 metres Cyclone incidence: Between 20 and 25 cyclones/decade Rainfall: No data
Shoalwater Coast (12)	Inshore and island waters from approximately Mackay to Rodd's Peninsular.	Sedimentary basins: None Mud fraction in sediments: Low mud (0-10%). Sediment origin: High carbonate north of Townshend Island, terrigenous to the south Reef morphology type: No data on fringing reef types Mangrove/Saltmarsh biogeography: 20 mangrove tree species, 25 tree plus understorey species, 8 saltmarsh species. Forms lower closed to open forest communities along sheltered coasts and rivers. Littoral crab biogeography: Areas 2 and 1 (Davie, pers. comm.) Hermatypic coral species richness: From 60 to 70 genera of hermatypic corals Tidal range: Between 4 and 9 metres. Greatest range (8 to 9 metres) centred on Broad Sound. Cyclone incidence: Between 10 and 15 cyclones/decade Rainfall: From 1000mm to over 1400mm.

Southern Great Barrier Reef Embaymen t (13)	Deep water embayment extending into the Southern GBR between the Swains complex and the Capricorn Bunker Group.	Sedimentary basins: Capricorn Basin Mud fraction in sediments: No data Sediment origin: Terrigenous Reef morphology type: No reefs Mangrove/Saltmarsh biogeography: Not applicable Littoral crab biogeography: Not applicable Hermatypic coral species richness: No reefs Tidal range: Between 2 and 3 metres Cyclone incidence: Between 15 and 20 cyclones/decade Rainfall: No data
Southern Sand Coasts (14)	Inshore and sand island waters from Rodd's Peninsular to the Qld/NSW Border	Sedimentary basins: Mostly Maryborough Basin, Ipswich Clarence Basin at southern end. Mud fraction in sediments: No data Sediment origin: No data - assumed terrigenous. Reef morphology type: No data on fringing reef types Mangrove/Saltmarsh biogeography: 8 mangrove tree species, 11 tree plus understorey species, 14 saltmarsh species. Forms low closed to open forest communities along sheltered coasts and rivers. Narrow saltpans may form at the landward margin. More diverse north from the Great Sandy Strait. Littoral crab biogeography: Area 1 (Davie, pers. comm.) Hermatypic coral species richness: From less than 50 in the south to more than 60 genera of hermatypic corals in the north. Tidal range: Between 1 and 3 metres Cyclone incidence: Between 10 and 15 cyclones/decade. Slightly higher on northern end of Fraser Island. Rainfall: Mostly from 1400mm to 2000mm, except less than 1400mm north of Fraser Island.

DISCUSSION

The derived meso-scale classification provides a level of detail not previously available to marine conservation planning; it does not contradict the CONCOM classification but refines it considerably.

The classification provides for the division of major habitat types along the coastline. These are primarily related to physical parameters, especially rainfall and tidal range, but are correlated with littoral decapod diversity and mangal biogeography. This relationship is to be expected, but has not previously been taken into account in a conservation planning framework in Queensland. Similar groups showing good correlation between biotic (fish species assemblages, estuary type) and oceanographic (East Australian current) distribution patterns were derived by Ortiz and Burchmore (1992) for the New South Wales coastline.

The groups derived by this classification in offshore areas relate primarily to sedimentary basins and sediment facies, reef morphology (within the GBR) and to a lesser extent hermatypic coral biogeography and tidal range. The groups provide for representation of cross shelf variation illustrated within the GBR by a number of authors (eg. Done 1982; Dinesen 1983; Wilkinson and Cheshire 1989). Soft bottom community types both within and outside the Great Barrier Reef are also represented.

The classification process also highlights the extremely poor state of knowledge of the marine resources of the Torres Strait and Gulf of Carpentaria, at least as reported in the available literature. Groups derived in these areas are based on at best sparse information. The Gulf and Torres Strait areas are renowned for their complex tidal regimes and current patterns, and at times extreme climatic conditions. Considerable further investigation is required to derive groups that can be considered meaningful with any great confidence.

Given the complexity of the range of available habitats, the suite of derived groups is seen as being a reasonable approximation of real-world patterns at the scale utilised. The classification will be of value in planning for conservation of biodiversity across the whole range of Queensland and adjacent marine environments. Specifically, while further work is required to refine the meso-scale classification (see below), it will serve as a framework for further studies at the local scale to define structural units within each biophysical region. These can be readily applied to decisions on the boundaries and management prescriptions of marine reserves as implemented in Queensland and the Great Barrier Reef. The attributes of marine ecosystems and the need to apply broad scale multiple-use management strategies rather than terrestrially derived discrete reserve models are discussed by Stevens *et al* (in press).

FUTURE WORK

The spatial representation of habitat types at the meso-scale will allow analysis of the representation of current conservation reserves with the classification area. This work is underway. The method involves using GIS techniques to overlay the derived classification of digitised boundaries of Fisheries Reserves, Coastal National and Environmental Parks, and Marine Park Zoning Plans.

This draft classification as stated previously, is indicative of a possible method, rather than purporting to present definitive conclusions. More work is required to refine the classification in two directions: (a) expanding the range and relevance of datasets used, and (b) refining the scale of the classification.

We are aware that a great deal more data than we have utilised is available; however most requires re-interpretation to provide mapped data layers that we can use in the classification process. There also remains the need to collect more data on epi-benthic distributions, especially relating to deeper water / soft bottom habitats.

Work is underway to improve the scale of the classification, and relate it more clearly to real-world features. The next cut will probably involve 10′ grids, with the aim of producing a classification whose boundaries can be reasonably accurately located "on-the-ground", and hence tested by more detailed field survey.

ACKNOWLEDGMENTS

Marine Parks colleagues, especially David Perkins and Andrew Page; also Gavin Blackman (Q.DEH Townsville), Peter Davie (Queensland Museum), Karen Danaher (Q.DPI Fisheries & Wetlands), Jenny Le Cusson (Q.DEH Cairns).

The work was funded from the Commonwealth Government's Ocean Rescue 2000 program.

REFERENCES

ACIUCN (1986) *Australia's Marine and Estuarine Areas — A Policy for Protection.* Australian Committee for the International Union for Conservation of Nature and Natural Resources. Occasional Paper Number 1. 32 pages

Bird E.C.F. (1984) *Coasts: an introduction to coastal geomorphology.* Australian National University Press, Canberra. 320 pages

Blackman J.G., Preece H.J. and Gardiner, S.J. (1993) *Delineation of a coastal zone for the Queensland coast from the Northern Territory-Queensland border to Aurukun.* Unpublished report to Director, Coastal Management Branch, Queensland Department of Environment and Heritage. 16 pages

Blackman J.G., Spain A.V. and Whiteley L.A. (1992) *Provisional Handbook for the Classification and Field Assessment of Queensland Wetlands and Deep Water Habitats.* Unpublished Text, Queensland Department of Environment and Heritage. : 101 pages

Bolton M.P. and Specht R.L. (1983) *A method for selecting nature conservation reserves.* Australian National Parks and Wildlife Service - Occasional Paper No. 8. 32 pages

Briggs J.C. (1974) *Marine Zoogeography.* McGraw-Hill, New York. 475 pages

Buckley R. (1983) *Biogeography of mangroves on northern Great Barrier Reef islands.* Bulletin of Marine Science. 33(3): 767 - 776

Bureau of Mineral Resources (BMR) (1973-) *Continental shelf sediments [map].* Bureau of Mineral Resources, Geology and Geophysics; Canberra.

Council of Nature Conservation Ministers (CONCOM) (1985) *Technical Conference Program - Summary Report of the second Technical Workshop on the selection and management of Marine and Estuarine Protected Areas.* Canberra College of Advanced Education Field Station, Jervis Bay. 51 pages

Dinesen Z.D. (1983) *Patterns in the distribution of soft corals across the central Great Barrier Reef.* Coral Reefs. **1**: 229 - 236

Done T.J. (1982) *Patterns in the distribution of coral communities across the central Great Barrier Reef.* Coral Reefs. **1**: 95 - 107

Ekman S.V. (1953) *Zoogeography of the sea (translated from the Swedish by Elizabeth Palmer).* Sidgwick and Jackson, London. 417 pages

Hopley D. (1982) *The geomorphology of the Great Barrier Reef: Quaternary Development of Coral Reefs.* Wiley - Interscience, New York. 453 pages

Kelleher G. and Kenchington R. (1992) *Guidelines for establishing Marine Protected Areas.* A Marine Conservation and Development Report. IUCN, Gland, Switzerland. 79 pages

Lourensz R.S. (1977) *Tropical Cyclones in the Australian Region July 1909 to June 1975. Meteorological Summary.* Department of Science; Bureau of Meteorology. Australian Government Publishing Service, Canberra. 111 pages

Marshall A.G. and Swaine M.D. (Eds) (1992) *Tropical rainforest: disturbance and recovery: proceedings of a royal Society discussion meeting held on 18 and 19 September 1991.* Royal Society, London.

Maxwell W.G.H. (1968) *Atlas of the Great Barrier Reef.* Elsevier, Amsterdam; London; New York. 268 pages

Olsen M.F. (1989) *Aspects of the ecology and physiology of rainforest systems following large scale natural disturbance.* Ph.D. Thesis, Univeristy of Queensland.

Ortiz E. and Burchmore J. (1992) *OCEAN RESCUE 2000 - The Development of a Representative System of Marine and Estuarine Protected Areas for New South Wales.* Report prepared by NSW Fisheries for Australian National Parks and Wildlife Service. 37 pages

Ray G.C. (1975) *A Preliminary Classification of Coastal and Marine Environments.* IUCN Occasional Paper No. 14, International Union for the Conservation of Nature and Natural Resources, Morges, Switzerland.

Ray G.C. (1976) *Critical Marine Habitats: Definition, description, criteria and guidelines for identification and management. - in Proceedings of an International Conference on Marine Parks and Reserves held at Tokyo, Japan 12 - 14 May 1975.* IUCN Publications New Series . **37**: 15 - 59

Ray G.C. and Hayden B.P. (1987) *Biogeographic Differentiation of the Coastal Zone.* Symposium on the Ecological Management of Coastal Zones; Furtado J.I. (ed.). 21 pages

Ray G.C. and McCormick-Ray M.G. (1992) *Marine and Estuarine Protected Areas: a strategy for a national representative system within Australian coastal and marine environments.* Consultancy Report for the Australian National Parks and Wildlife Service. 53 pages

Ray G.C., Hayden B.P. and Dolan R. (1984) *Development of a Biophysical Coastal and Marine Classification System. in McNeely J.A. and Miller K.R. (eds) Proceedings of the World Conference on National Parks. Bali, Indonesia, 11-22 October 1982.* Smithsonian Institution Press, Washington D.C. 39 - 46

Saenger P., Specht M.M., Specht R.L. and Chapman V.J. (1977) *Mangal and coastal salt-marsh communities in Australasia.* in Wet Coastal Ecosystems. (Ecosystems of the world 1) Chapman V.J. (ed); Elsevier Scientific Publishing Company, Amsterdam. **1**: 293 - 345

Salm R.V. and Clark J.R. (1984) *Marine and Coastal Protected Areas: A guide for planners and managers.* IUCN, Gland Switzerland.

Stanton J.P. and Morgan M.G. (1977) *The rapid selection and appraisal of Key and Endangered Sites.* University of New England, Armidale.

Stevens T.F. (1994) *A biophysical classification of Queensland marine habitats at the meso-scale.* Paper to joint Scientific Conference on Science, Management and Sustainability of Marine Habitats in the 21st Century: James Cook University of North Queensland, Townsville, Australia, 8-11 July 1994.

Stevens T.F., Perkins D.L. and Page A.J. (in press) *Assessment of the biological significance of marine environments and its application to conservation planning.* Advances in Nature Conservation. **2**:

UNESCO. (1974) *Task Force on Criteria and Guidelines for the Choice and Establishment of Biosphere Reserves.* MAB Report Series no 2.

Veron J.E.N. (1985) *Aspects of the biogeography of hermatypic corals.* Proceedings of the Fifth International Coral Reef Congress, Tahiti. **4**: 83 - 88

Wilkinson C.R. and Cheshire A.C. (1989) *Patterns in the distribution of sponge populations across the central Great Barrier Reef.* Coral Reefs. **8**: 127 - 134

The Western Australian Marine Regionalisation Project

Hugh Chevis
Department of Conservation and Land Management, Western Australia

ABSTRACT

The Western Australian government is carrying out a major study to identify candidate areas for a representative marine reserve system in State waters. This study has used the delphic approach in identifying the candidate areas. The study has been carried out by a group of the leading marine scientists in the State. Their brief was to prepare a technical report identifying areas worthy of adding to the reserves system, either as representative of particular systems or for their unique values. The group developed their proposals through a number of workshop sessions. The group recognized a heirarchical classification, firstly of four biogeographic regions, secondly of major distinctive coastal types reflecting geomorphic criteria and a third level of classification of ecosystems. An attempt was made to relate this classification to legislative classifications.

It is intended that the report will now be circulated to key interest groups and then released for public comment. It should then act as a source document from which to draw individual reserves proposals to be considered for declaration.

It is hoped that the classification system might be extended into adjacent Commonwealth territory, especially given the advantages of contiguous reserves in State and Commonwealth waters.

INTRODUCTION

The Western Australian government is currently involved in a major study to identify candidate areas for a representative reserve system in State waters. This study commenced in 1986 and has used the delphic approach (i.e. relying on the collective wisdom of a group of experts) in identifying these candidate areas. The process is far from complete as the study was technically oriented and the next phase is to seek public input into the process and modify the recommendations to accomodate social and economic factors.

History of marine reserves in WA

Until 1984, when the Conservation and Land Management Act was promulgated there was no piece of legislation which allowed specifically for the declaration of marine conservation reserves for the purposes of conservation, recreation or multiple use. The CALM Act included provisions for the declaration of marine parks and marine nature reserves. The Fisheries Act 1905 had provision for aquatic reserves but these were seen as being oriented towards protecting commercial fishing stocks, and in fact no aquatic reserves had been declared as at 1984.

A number of studies prior to 1984 included recommendations for marine conservation reserves. The most notable of these studies was that carried out by the Environmental Protection Authority through the Conservation Through Reserves Committee(CTRC) which was set up in 1971 to review and make recommendations to the Authority on the adequacy of existing reserves and proposals for additional reserves in WA. Regions of the State were adressed progressively over time and the study concluded in 1984. All of the eight currently declared marine conservation reserves were recognized in the CTRC reports although implementation was initially limited by the lack of appropriate legislation. Prior to declaration some of these marine conservation reserves were further developed in regional studies, such as the Shark Bay Regional Plan for Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve.

The Marine Parks and Reserves Working Group

The MPRWG was convened as it was recognized that the previous studies had not systematically reviewed the whole coastline in proposing a marine reserves system. Western Australia has a small and closely knit marine science community and it was the view of this group of people that further work needed to be done.

A group of the leading marine scientists in the State was convened under the chairmanship of Dr Barry Wilson, who was at that time the Director of Nature Conservation with CALM. Members came from State and Commonwealth agencies, academic institutions and private business. The group reported to the Minister for the Environment. Their brief was to prepare a technical report identifying areas worthy of adding to the reserves system, either as representative of particular systems or for their unique values.

The initial discussions of the group were focussed on the approach to be taken to the study. Western Australia has a long, and in places indented, coastline. Some parts of the coast are highly urbanized, other sections have been developed as a result of specific projects while vast sections are remote with little, if any, development. Knowledge of the coast and it's resources is not uniform. Localized data have been collected by private companies and government in response to the need to manage development pressures. Academic studies by members of various institutions have been carried out in a range of locations including in some remote areas.There is a large amount of information which is unpublished . Luckily there are a number of individuals in the marine science community who have a great depth of knowledge of the Western Australian marine environment. All of these factors contributed to the group adopting a delphic approach to their deliberations (although the members would be too modest to consider they were oracles).

The group held a number of workshop sessions to consider information gathered on stretches of the Western Australian coast from the Kimberley to the Great Australian Bight. Drafts were prepared after each session for further discussion at successive meetings until the group was satisfied with the results.

The working group adopted a modified version of the two-tiered CONCOM classification of coastal biogeographical regions (i.e. geographical zones and secondly habitat types). This was modified to recognize four biogeographic regions; Kimberley, Canning-Pilbara, West Coast and South Coast, the boundaries between these representing points where significant changes in biota occur. The changes were considered to be due to geological history, climate and other environmental conditions.

Subsequent levels of classification were recognized. The second level was of major distinctive coastal types, reflecting geomorphological criteria. An example is the type composed of the intertidal, mangal and supratidal zones of Exmouth gulf. Within these coastal types it was recognized that a number of 'ecosystems' occur (eg coral reefs, mangals). These 'ecosystems' represent the third level of classification.

An attempt was made to relate this biological and goemorphic classification to legislative classifications. All of State waters were viewed as equivalent to a commons and subject to sectoral management. Distinctive coastal types could be managed as a multiple use reserve (should such a category be enacted) while sections of these with the right combination of biological, geomorphic and social criteria could be managed as a marine park. Ecosystems or areas of distinctive coastal types with extreme conservation values or sensitivity could be reserved as marine nature reserves or as sanctuary zones within marine parks.

Design and selection criteria for individual proposals must involve both biological/geomorphic and socio-economic factors. The working group, being technical in nature concentrated on biological factors (diversity, representativeness, naturalness and effectiveness), with some regard to recreational use but in the full knowledge that as individual proposals are developed socio-economic factors will to a large degree determine configuration and purpose of the final area reserved.

The report is presented in a format reflecting the heirachical classification . It is divided into parts with a part for each biogeographic zone. Each part then deals with the distinctive coastal types in that biogeographical zone and finally with the individual reserves proposals.

Current status of the report

While some social factors, like recreational use were considered by the working group in their deliberations it was accepted that they did not have a political brief.

The opinions of the public and key interest groups have a crucial impact on the likelihood of a particular reserves proposal proceeding and the form in which it is ultimately declared. It is intended that the report of the working group will be circulated to these key interest groups and then released for public comment. The report should then act as a source document from which to draw individual reserves proposals to be considered for declaration.

It is accepted that the recommendations will take many years to be acted upon and that the final reserves system may look somewhat different than that envisaged by the working group. That is the experience from the CTRC recommendations. What is also clear from the CTRC experience is that the recommendations do form a very useful reference point from which to judge the adequacy and representativeness of the reserves system at any given point in time.

Issues and problems

The delphic approach is by definition prone to subjectivity and one of the challenges for the committee was to come to some concensus. Interestingly there was more debate about relating the biogeographical heirarchy to the legislative classifications than about the biological values of a particular area. Debate about the former issue would be equally as vigorous regardless of whether the delphic or multivariate approach was being used.

In ancient Greece the Delphic Oracle was able to foretell future events. This would be a very usefull skill in planning a marine reserves system. Who, for example, would have predicted the profile that the dolphins at Monkey Mia have gained or the consequent infrastructure and management arrangements. In our more secular world some collective wisdom and a little intuition are very useful commodities.

Any system of reserves proposals needs to be flexible enough to incorporate new data, socio-economic issues which are constantly evolving, and the possibility of changes to management arrangements for the reserves themselves. These issues can have a major effect on the outcome of individual reserves proposals regardless of the degree of rigour of the classification process.

The system report also needs to be available to be used as a political tool in the debates about resource allocation, the timetable for which is set independant of the pace of scientific studies. Expediency is sometimes necessary to ensure the timely implementation of a reserves system.

Contribution to a national biogeographic framework

It is hoped that the system of biogeographical classification prepared by the working group is robust enough to be extended into adjacent Commonwealth waters and form a framework for reserves selection there. Any opportunities to verify the classification using data available to the Commonwealth should be pursued(eg. the CAMRIS model developed by the CSIRO).

Equally, it would be desirable to have a compatible system with adjacent States although the length of common border between the States is much less (3 nautical miles in the case of WA with SA and NT) than between the State and the Commonwealth.

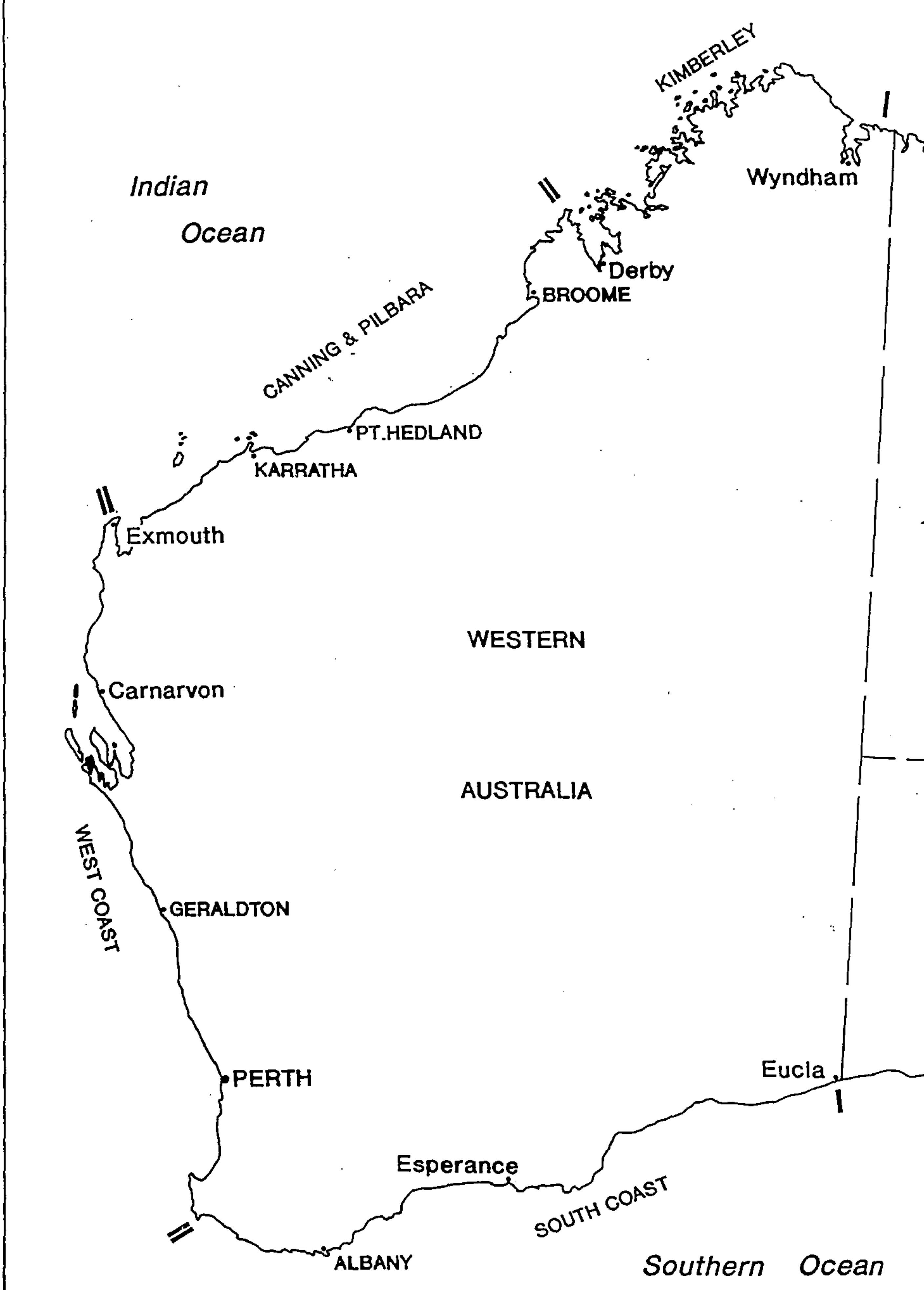
There are advantages in declaring contiguous reserves in State and Commonwealth waters, both because the 3 mile limit is an artificial boundary in ecological terms but also because contiguous reserves present opportunities for co-operative and efficient management of the national reserves system. Such co-operative arrangements are being put in place to manage the State and Commonwealth sections of Ningaloo Marine Park.

Conclusion

The size of Western Australian coastal waters means that the reserves system within it could contribute significantly to the total national complex. It will therefore be of interest nationally as well as to the Western Australian community.

The delphic approach has been chosen as the appropriate model for developing a marine reserves system in Western Australian State waters. It has provided a working document to promote such a system while allowing for refinements as further data becomes available.

FIG. 1 MARINE BIOGEOGRAPHIC REGIONS in W.A. State Waters



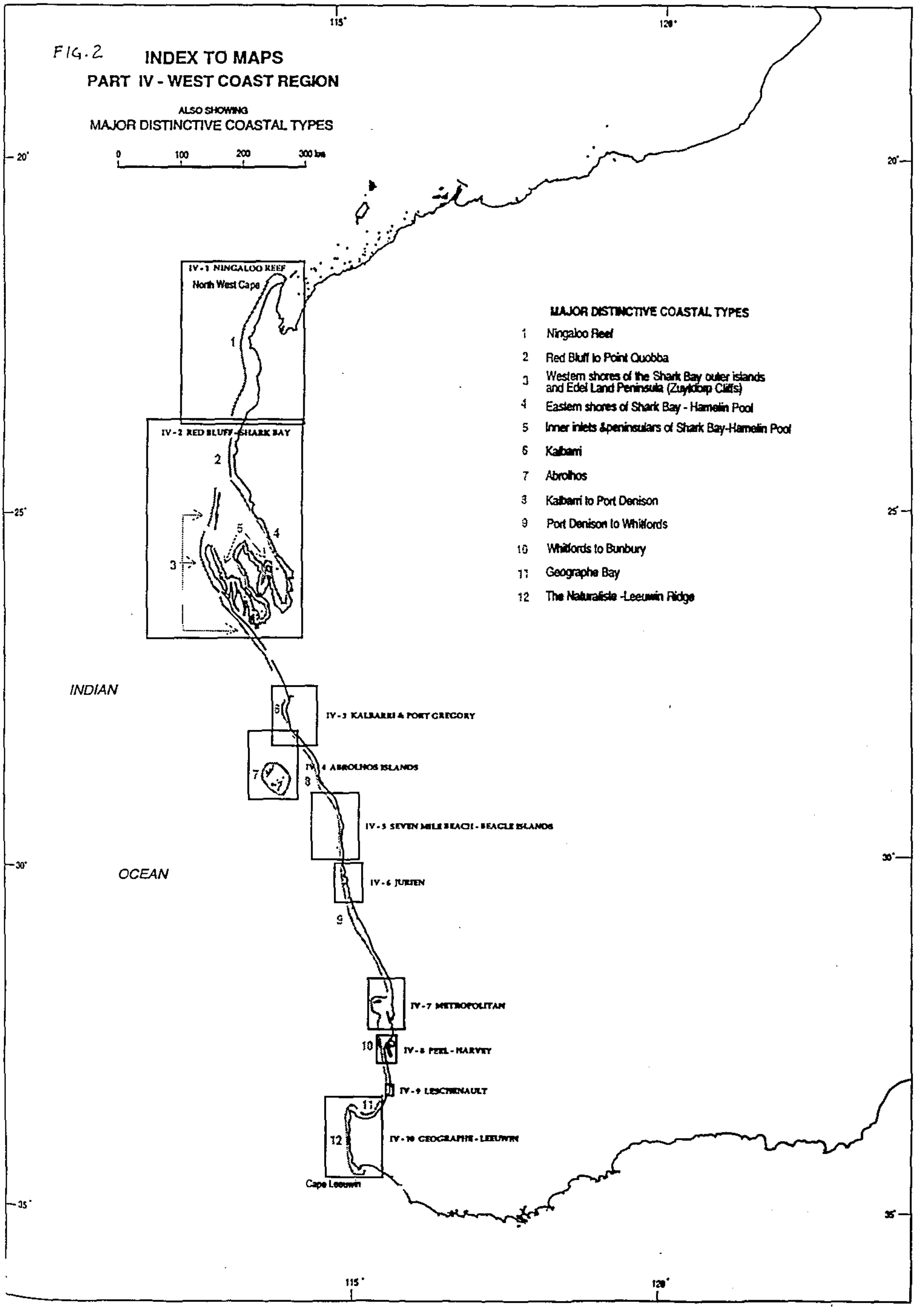


FIG. 2
INDEX TO MAPS
PART IV - WEST COAST REGION
ALSO SHOWING
MAJOR DISTINCTIVE COASTAL TYPES
0
100
200
300 km
115°
120°
20°
25°
30°
35°
IV-1 NINGALOO REEF
North West Cape
IV-2 RED BLUFF-SHARK BAY
IV-3 KALBARRI & PORT GREGORY
IV-4 ABROLHOS ISLANDS
IV-5 SEVEN MILE BEACH - BEAGLE ISLANDS
IV-6 JURIEN
IV-7 METROPOLITAN
IV-8 PEEL - HARVEY
IV-9 LESCHENAULT
IV-10 GEOGRAPHE - LEEUWIN
Cape Leeuwin
INDIAN
OCEAN
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

The South Australian Marine Regionalisation Project

KS Edyvane and J Baker
South Australian Research & Development Institute (Aquatic Sciences), Henley Beach SA

ABSTRACT:

In the development of a representative system of Marine Protected Areas (MPAs) in South Australia, both a delphic and an analytic approach have been adopted. At the mesoscale, and `expert panel' approach identified 4 major coastal biophysical regions or bioregions (Eyre, Gulfs, Kangaroo Island, and Coorong), which have been further classified in to a total of 23 biophysical units. This preliminary hierarchical classification principally used existing physical, coastal geomorphological information at the mesoscale and the local scale (geology, coastal landforms, wave climate) and was supported by existing coastal habitat (mangroves, seagrass, algal biogeography) and oceanographic information (sea temperature, currents, upwellings). Analytical procedures are now being utilised to validate this preliminary bioregionalisation and establish a scientifically defensible approach to the identification and delineation of potential MPAs. To this end, a program of systematic benthic surveys has been initiated along the coast of South Australia to, validate the 'predictions' of the preliminary biophysical classification; determinate the occurrence of habitat categories in unknown coastal regions; and provide important baseline information on resources present in future MPAs. In addition, existing and current survey information is presently being analysed using multivariate, classificatory procedures to test the concept of 'ecological representativeness' by examining benthic diversity at a number of spatial and temporal scales and develop sampling methodologies for survey and monitoring programs. Presently, a lack of resources is significantly restricting progress in two areas: (1) a comprehensive, quantitative bioregionalisation using existing physical and biological information and (2) the collection of biological information from unknown coastal regions of South Australia. Of less immediate concern are the significant biological information, which exist in the offshore, oceanographic regions of South Australia.

INTRODUCTION

Recognition of the spatial and temporal scales of ecosystems, ecological processes, resources distributions and human impacts is critical for the establishment and management of Marine Protected Areas (Ray & McCormick-Ray 1992). In conserving biological diversity it is important to recognise that diversity is defined at the ecosystem, seascape/landscape, species and genetic level (O'Neill et al. 1986). Marine and coastal systems are extraordinarily diverse at all these levels (Grassle et al. 1991, Steele 1991). However, at the level of the landscape or seascape, the measurement of diversity is approachable and practical (Ray 1991). Because of the nested hierarchical structure of ecosystems, management needs to examine and occur within several temporal and spatial scales (Ray & McCormick-Ray 1992). As such, regional, large-scale, or higher-level attributes can provide the organisational framework for lower level patterns of organisation. The emerging discipline of landscape or seascape ecology embraces principles and practices for management that specifically consider the scale properties of human-ecosystem interactions. Among these principles seascape ecology recognises, that biogeography and habitat diversity is intrinsically related to coastal structure; that hierarchically scaled, spatial and temporal processes result in the hierarchical structure of biodiversity, ecosystems and seascapes; that species assemblages can act as boundary indicators between functional units; and the role of species/communities responses and ecological feedbacks within the physical framework (Ray 1991).

The biogeographic classification of environments is a fundamental tool for both, landscape and seascape ecology and is essential if the management of ecosystems is to proceed within a bioregional framework. In 1985 conservation ministers and the Australian Committee for IUCN recognised the need for such a classification on which to base a national, representative system of Marine Protected Areas. While the present biogeographical classification addresses diversity at the bioregional level (100 kms), it fails to address diversity at scales appropriate for functional, ecosystem-level management (1-10 kms) and also, habitat or site-based management (10-100s of metres) (Figure 1). This hierarchical structure of biodiversity is intrinsically linked to the level of functional diversity or ecological processes and attributes.

During the 1990's, South Australia aims to establish, as part of the federal 'Ocean Rescue 2000' initiative, a representative system of MPAs as a strategic tool for the integrated management and conservation of it's coastal and marine environments is an important initial step in achieving this goal. As such, a hierarchical biophysical classification of the range of coastal and marine environments in South Australia will be used to assist in the identification of ecologically or biogeographically representative areas. Hence, bioregionalisation is integral to both an assessment of the 'ecological representativeness' of existing MPAs and also, the identification of ecologically or biogeographically representative areas. Hence, bioregionalisation is integral to both an assessment of the 'ecological representativeness' of existing MPAs and also, the identification of potential MPAs. In South Australia potential sites for MPAs will also be identified on the basis of representing 'critical habitats' (ie. endangered habitats, nursery areas, etc.).

The approach used in South Australia will ideally, form part of the nationally coordinated, standardised approach to bioregional data collection, database organisation and information systems. This approach will be an essential element in the management framework within which bioregional and local level planning can incorporate not only ecological objectives, but also socio-political, economic and cultural objec-

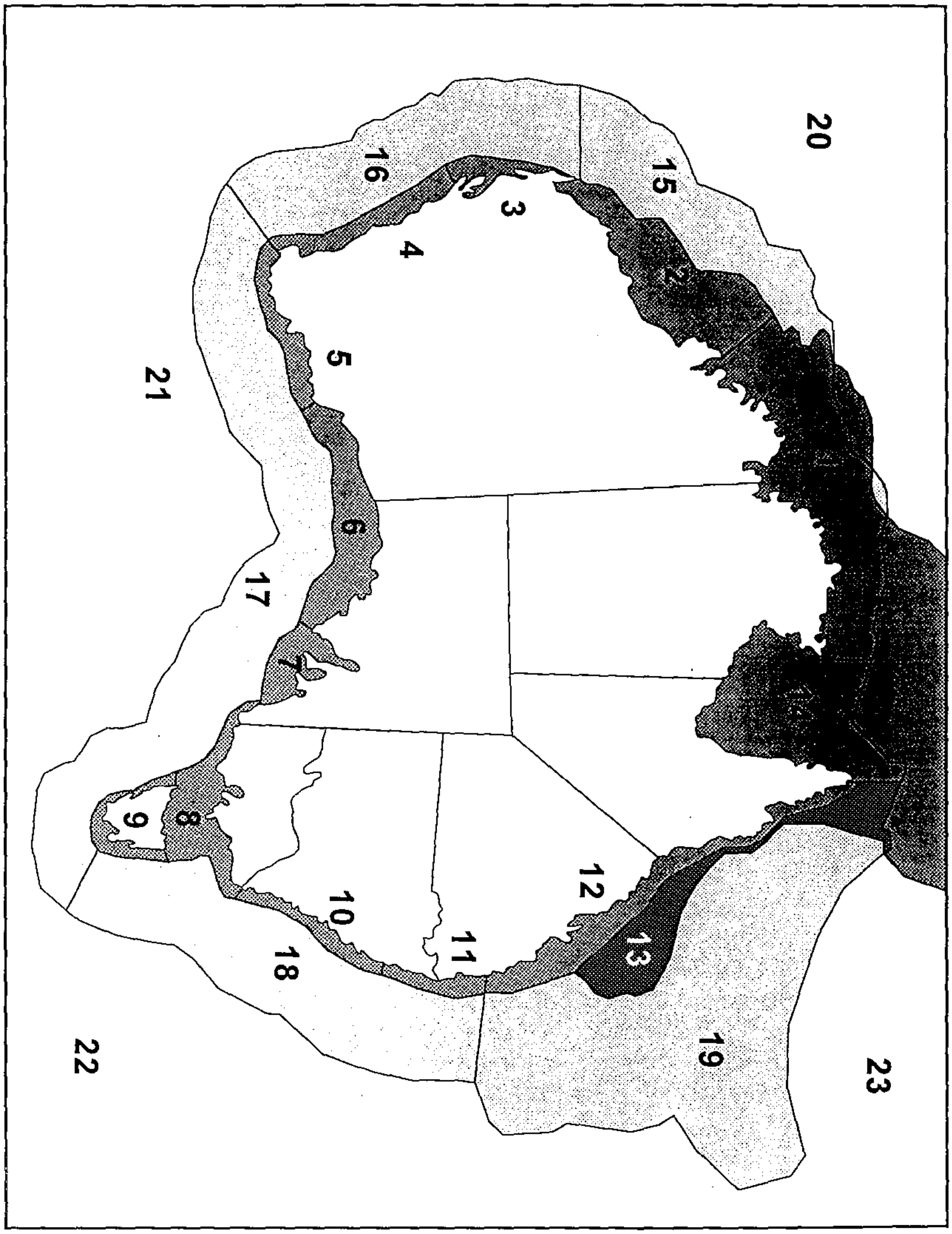


FIGURE 1. ACIUCN/CONCOM Biogeographical Classification of the Coastal and Marine Habitats of Australia

tives associated with MPA establishment and management. The current strategy for bioregional identification and classification in South Australia is a systematic hierarchically scaled one, with a focus on the conservation of biodiversity in the context of ecosystem structure and function. This approach is essentially identical to that which has been recently undertaken in NSW by NSW Fisheries (Ortiz 1991). The aim is to identify a set of natural environmental units defined by biophysical parameters.

The approach uses the hierarchical concept of ecosystems to develop a three level biophysical classification, at the level of Biophysical Regions (100s of kms), which provides a broad scale strategic framework for ecological sustainable management of coastal resources ; Biophysical Units (1-10s kms), which identified functional ecosystem-level management units suitable for MPA declaration (eg. rocky shores, estuaries, reefs, etc.); and habitats (10-100s of metres), which provides information to address tactical site management issues at the habitat level, such as fishing closures.

The approach to bioregionalisation to be adopted in South Australia can be summarised in 4 steps:

(1) preliminary classification at the bioregional (100s kms) and biounit (1-10s of kms) level, utilising (i) `expert panel' information, and (ii) existing descriptive, spatially referenced, biophysical coastal and marine data;

(2) refinement and validation of the preliminary bioregional and biounit classification, by (i) collating existing biological and physical description and classification data (ii) analysing datasets using standard multivariate classificatory procedures, and (iii) production of individual and composite maps of physical (sea surface temperature, coastal currents, bathymetry, etc.) and biological descriptors (habitat types, species ranges, etc) using a Geographical Information System (GIS);

(3) refinement, and spatial and temporal validation of the bioregional and biounit classification, by (i) undertaking systematic field surveys to fill the spatial and temporal gaps, and (ii) integrating the survey results with the initial bioregional and biounit classification, and refining the analysis to identify all functional biophysical units;

(4) integration of the long-term, on-going MPA identification and declaration program with the results of the bioregional classification process, by (i) assessing the ecological and biogeographical representativeness of existing MPAs, and identifying "critical areas" which have not yet been given MPA status (or have been under-represented as MPAs in the past); (ii) identifying potential MPAs at the bioregion and biounit level, and (iii) according to established selection criteria, identifying potential MPAs at the habitat level (within the biounits).

The identification of natural biophysical units will not only assist in the preservation of coastal and marine biodiversity at the ecosystem, seascape, species and genetic level (including `critical' habitats; processes; rare species, etc.), but will also support the effective management of coastal and marine ecosystems at the regional and local level for the benefit of all user groups.

With the assistance of funding from `Ocean Rescue 2000', a number of key elements essential to the development of a representative system of MPAs in South Australia have either been initiated or completed. For steps (1), (3) and (4) in the bioregionalisation process, specific tasks have either commenced, or are almost completed, in South Australia during the past three years. The progress on marine regionalisation to-date is outlined below.

PRELIMINARY BIOREGIONAL CLASSIFICATION OF MARINE AND COASTAL HABITATS

'Delphic' Approach

In South Australia, preliminary regionalisation or classification of coastal habitats and ecosystems has adopted an 'expert panel' or 'delphic' approach, utilising existing 'qualitative' biophysical/biogeographical information and the best technical judgements of local experts. This involved the formation of a specialist, SA MPA Technical Working Group and the hosting of a technical workshop on the biophysical classification of South Australian marine and coastal environments (Table 1); the identification of potential MPAs by the SA MPA Technical Working Group; and regular technical reviews of the proposed scientific framework and potential MPAs by the SA MPA Technical Working Group.

TABLE 1. **List of participants at the South Australian Marine Protected Areas Workshop held in November 1991.**

Name	Affiliation	Expertise
Dr Alan Butler	University of Adelaide	benthic invertebrates
Dr Tony Cheshire	University of Adelaide	algal ecology
Dr Hugh Possingham	University of Adelaide	conservation ecology
Ms Deborah Nias	University of Adelaide	tributyl-tin pollution
Dr Chris von der Borsch	Flinders University	coastal geomorphology
Prof John Bye	Flinders University	oceanography
Prof John Lennon	Flinders University	oceanography
Ms Janine Baker	SA Fisheries	Blue Swimming Crab
Mr Kevin Branden	SA Fisheries	benthic invertebrates
Mr Barry Bruce	SA Fisheries	larval fish ecology
Mr Neil Carrick	SA Fisheries	prawn biology/ecology
Mr Steven Clarke	SA Fisheries	seagrass/algal ecology
DrKaren Edyvane	SA Fisheries	algal/mangrove ecology
Dr Patrick Hone	SA Fisheries	abalone/oyster ecology
Mr John Johnson	SA Fisheries	marine ecology
Dr Keith Jones	SA Fisheries	marine scalefish
Mr Rod Grove-Jones	SA Fisheries	abalone ecology
Ms Mervi Kangas	SA Fisheries	prawn biology/ecology
Mr David McGlennon	SA Fisheries	marine scalefish
Mr Vic Neverauskas	SA Fisheries	seagrass loss
Dr Peter Petrusevics	SA Fisheries	oceanography
Dr Tony Belperio	Dept. Mines & Energy	coastal geology/geomorphology
Dr Doug Fotheringham	Dept. Env. & Planning	coastal geomorphology
Mr Ian May	Dept. Env. & Planning	coastal parks/reserves
Ms Ena-mai Oks	Dept. Env. & Planning	marine pollution outfalls
Mr Tony Robinson	Dept. Env. & Planning	marine mammals, seabirds
Prof Bryan Womersely	SA Herbarium	algae, seagrasses
Dr John Ling	SA Museum	marine mammals
Dr Wolfgang Zeidler	A Museum	marine invertebrate

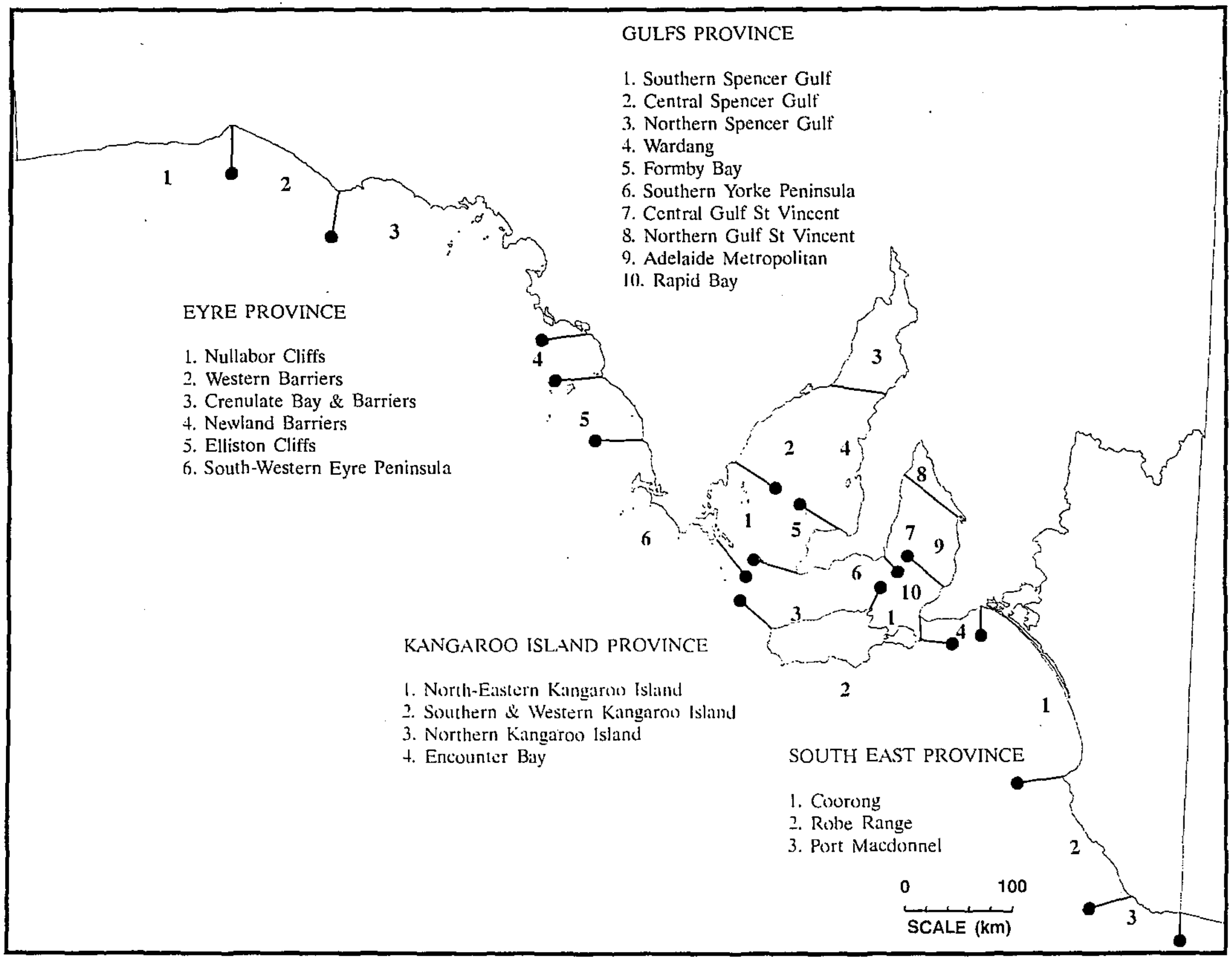


FIGURE 2. Coastal Geomorphological Provinces of South Australia

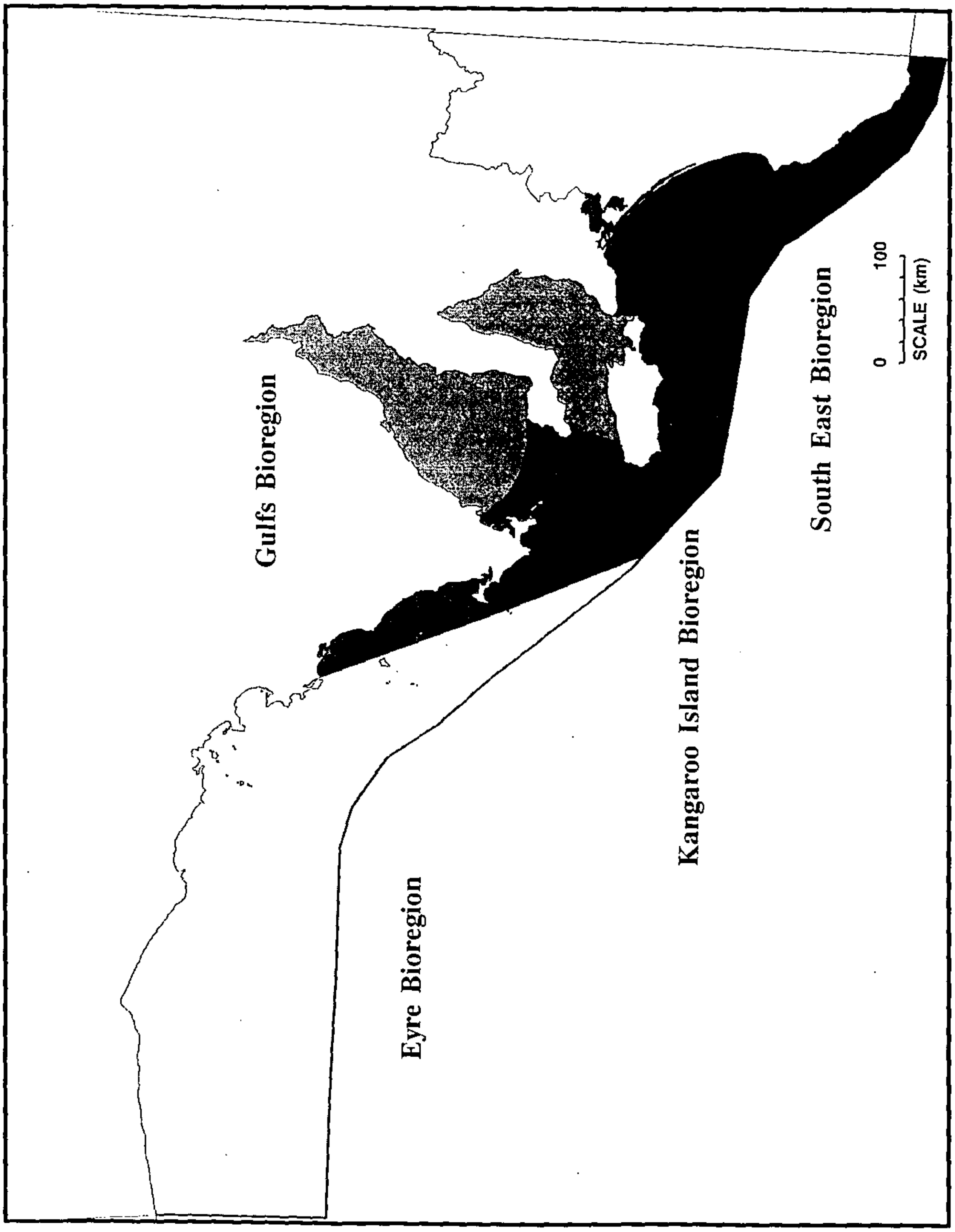


FIGURE 3. Marine Coastal Bioregions of South Australia

The preliminary coastal bioregionalisation is based principally on the existing geomorphological classification of the coastal habitats of South Australia by Short et al. (1986) (see Figure 2). The principal descriptors used in the coastal geomorphological classification included wave environment, geology, coastal landform and coastal orientation. Additional qualitative oceanographic (water temperature, currents, upwellings), habitat (mangrove, seagrass) and biogeographic (macroalgae) information was also used to assist in the identification of bioregions and biounits.

Preliminary Biophysical Regions and Units

In South Australia, this `expert panel' approach identified 4 major coastal biophysical regions or 'bioregions' (Figure 3) (Eyre, Gulfs, Kangaroo Island and Coorong), which have further been analytical procedures are now clearly needed to support these intuitive judgements, particularly at the biounit level, and to establish a scientifically defensible approach to the identification of MPAs.

Eyre Bioregion

The Eyre Bioregion extends from the head of the Great Australian Bight (pass the West Australian border) to Baird Bay (on the west coast of Eyre Peninsula). Compared to the rest of the State, this province contains some of the most remote, uninhabited, and rugged coastal regions of South Australia. Along this highly variable coastline there are spectacular limestone (dune calcarenite) cliffs (up to 90 m high) and headlands, numerous offshore islands, surf pounded beaches and small sheltered embayments, containing the most westerly distribution of temperate mangroves in South Australia. For the most part however, this extensive province faces the full force of the Southern Ocean and as such, experiences some of the highest wave energies in the State.

The Eyre Bioregion has a semi-arid climate and a west coast swell environment, with coastal processes dominated by persistently high southwest to westerly swells. Coastal geology is dominated by Tertiary limestone cliffs, Precambrian bedrock (usually capped by dune calcarenite); and Pleistocene dune calcarenite, usually fronted by well developed shore platforms and reefs. The sandy sections include numerous beaches with backing foredunes and transgressive dunes, finer sediments composing bay shores and usually vegetated with mangroves; and lagoonal deposits. The sandy and rocky sections are often found together, with beaches fronting stranded dune calcarenite cliffs, reefs commonly occurring off beaches, and many of the dune calcarenite cliffs capped by Holocene clifftop dunes. This bioregion also contains numerous coastal saline lakes (often in the lee of many of the sand barriers) and many offshore islands (including true granitic inselbergs) and reefs.

Marine flora and fauna within this bioregion is typically the warm temperate element of the Flindersian Province. The marine flora on exposed coasts is typically dominated by Ecklonia radiata and Sctyothalia dorycarpa communities with numerous species of Sargassum and Cystophora as sub-dominants. Seagrass communities dominate on sheltered coasts, particularly Posidonia sinuosa.

Within the extensive Eyre Bioregion, three coastal biounits, have been recognised: Nullarbor Cliffs, Western Barriers, and Crenulate Bay and Barriers.

Gulfs Bioregion

Extending from Tumbay Bay, on the eastern side of Eyre Peninsula, to Rapid Head on the Fleurieu Peninsula, the Gulf's Bioregion includes South Australia's two large sheltered gulf ecosystems; Spencer Gulf and Gulf St Vincent, and also Backstairs Passage and Investigator Strait. The boundaries of this bioregion are defined by the oceanographic exchanges of gulf waters with oceanic waters. Within the sheltered gulf waters occur some of the largest temperate seagrass ecosystems in the world. The sheltered waters also provide an ideal habitat for extensive, intertidal forests of the Grey Mangrove, most of which occur in this region. Together, these coastal ecosystems are of immense ecological and economic importance, providing the essential basis for much of South Australia's commercial and recreational fisheries. The coastal areas of the gulfs however, also support the major urban and industrial cities of South Australia. Historically, this region is also of the greatest maritime significance, reflecting essentially the early European settlement of this region. However, present and future urban and industrial activity in this region, also places this region under thegreatest threat from human activity.

The Gulfs Bioregion has a semi-arid climate and low wave energy environment, with coastal processes dominated by tidal movements (including `dodge tides'), advective and evaporative processes and current systems which provide for exchange of warm saline gulf waters with oceanic waters. Both gulfs are `reverse estuaries' with highest salinities and temperatures occurring at the upper reaches of the gulfs. Rocky headlands consist of exposed Precambrian crystalline rock, while the beaches have coastal dunes developing behind them. Within both gulfs, low wave energies, large tidal ranges and sedimentary processes have resulted in extensive tidal and mudflats. This has resulted in extensive mangrove and coastal samphire communities within this bioregion. Within Spencer Gulf there are 31 offshore islands and 5 large embayments. In contrast, Gulf St Vincent is relatively free of embayments.

Marine flora and fauna within this bioregion is typically the warm temperate element of the Flindersian Province. The marine flora in both gulfs is dominated by extensive seagrass communities (ie. commonly, species of Posidonia and Amphibolus), interspersed with reef communities dominated by species of the fucoid Sargassum and Scaberia agardhii. Under moderate wave energies, Seirococcus axillaris, Acrocarpia paniculata, Ecklonia radiata and several species of Cystophora dominate. Relict tropical elements are present in both, the benthic fauna and flora of northern Spencer Gulf (eg. Sargassum decurrens, Hormophysa triquetra).

Within the Gulf's Bioregion, 13 coastal biounits have been recognised, plus a further two biounits that do not adjoin coastal land: Southwest of Spencer Gulf, Southern Spencer Gulf, Central Spencer Gulf, Northern Spencer Gulf, Wardang, Formby Bay, Southern Yorke Peninsula, Central Gulf St Vincent, Northern Gulf St Vincent, Adelaide Metropolitan, Rapid Bay, Spencer Gulf Waters (not land based), Gulf St Vincent Waters (not land based), North-Eastern Kangaroo Island and Northern Kangaroo Island.

Kangaroo Island Bioregion

The Kangaroo Island Bioregion comprises the south coast of Australia's third largest Australian isle (following Melville Island and Tasmania) and the southern coast of the Fleurieu Peninsula (including Backstairs passage), from Cape Jervis to Cape Jaffa and also the western coast of Eyre Peninsula to Baird Bay. The region encompasses some of South Australia's most popular tourist destinations (such as Seal Bay and Victor Harbor) and is well-known for its spectacular coastline and coastal wilderness areas (such as the Flinders Chase National Park). It is also a region of considerable significance for marine fauna and flora, particular mammals, and includes not only major breeding areas for the rare Australian Sea Lion and the New Zealand Fur Seal, but also areas which are regularly frequented by the endangered Southern Right Whale on their northward migration to the calving and breeding areas at the Head of the Great Australia Bight. Historically, Encounter Bay and the rugged western coast of Kangaroo Island comprise some of the major sites of maritime significance in South Australia. The latter, containing an unusual concentration and density of shipwrecks of high cultural value.

The Kangaroo Island Bioregion is also characterised by spectacular coastal landforms such as the Coorong lagoons, which not only support extensive populations of migratory waterbirds, but also preserve important records of our Pleistocene history.

The Kangaroo Island Bioregion has a distinctly cool-temperate climate and a wave climate dominated by prevailing and almost persistent southwest to westerly swells. This bioregion is also influenced by a coastal summer upwelling of cooler water, along the western coast of Eyre Peninsula. Coastal geology is dominated by Precambrian bedrock (usually capped by dune calcarenite); and Pleistocene dune calcarenite, usually fronted by well developed shore platforms and reefs. The sandy sections include beaches with backing foredunes and transgressive dunes, finer sediments composing bay shores; and lagoonal deposits. The sandy and rocky sections are often found together, with beaches fronting stranded dune calcarenite cliffs, reefs commonly occurring off beaches, and many of the dune calcarenite cliffs capped by Holocene clifftop dunes. This bioregion also contains many offshore islands and several coastal estuaries.

Kangaroo Island itself has a strong influence on the oceanography, and thus geomorphology, of the South Australian coastline, particularly the Gulfs Bioregion. Situated at the head of the gulfs region, the large island essentially shelters the adjacent mainland coastal regions from the high wave energies of the Southern Ocean.

Marine flora and fauna of the Kangaroo Island Bioregion is typically the cool temperate element of the Flindersian Province. The marine flora on exposed coasts is dominated by Sctyothalia dorycarpa and Carpoglossum confluens on granitic boulders, with species of Cystophora as sub-dominants. Diverse red algal assemblages dominate in deeper waters, commonly on flat limestone reefs. The extensive sandy bottoms in this region commonly comprise Caulerpa-dominated communities and mixed Posidonia species.

Six coastal biounits have been recognised for this bioregion: Newland Barrier, Elliston Cliffs, Southwestern Eyre, South-Western Kangaroo Island, Encounter Bay[1] and Coorong.

South East Bioregion

The South East Bioregion extends from Cape Jaffa eastwards, to at least the Victorian border. The coastal waters of this region represent some of the most diverse and productive waters of South Australia. As such, this region contains one of the highest centres of algal or seaweed diversity in the world. This diversity is, in part, due to the overlap of two major biogeographical regions, the warm-cool temperate and the cold-temperate waters of the Flindersian (sometimes referred to as the Maugean Subprovince). Unlike the rest of South Australia, the fauna and flora east of Robe is akin to the biota of the cooler waters of Victoria and Tasmania, while west of Robe the biota is typical of the warmer waters of western South Australia and Western Australia.

The South East Bioregion is also a region of considerable coastal productivity, providing some of South Australia's most productive fisheries, in particular the Southern Rock Lobster and Abalone fisheries. This productivity is primarily a result of the unique nutrient-rich coastal upwellings which occur in this region. These nutrient-rich upwellings represent the most significant upwellings to be found along the whole of the Southern Australian coastline.

For the most part, the bioregion is oriented in a south and southwesterly direction into the Southern Ocean. The South East Bioregion has a distinctly cool-temperate climate and a wave climate dominated by prevailing and almost persistent southwest to westerly swells. This bioregion is also influenced by significant coastal summer upwellings of cooler nutrient-rich waters. Coastal geology is characterised by Pleistocene dune calcarenite, usually fronted by well developed shore platforms and reefs, and beach-ridge plains (a result of sea level changes during the Holocene). The sandy sections include beaches with backing foredunes and transgressive dunes, finer sediments composing bay shores; and lagoonal deposits. This bioregion also contains many offshore fringing reefs, several embayments and relatively few coastal estuaries.

Marine flora and fauna of the South East Bioregion is typically the cold- temperate element of the Flindersian Province (ie. the Maugean Subprovince). The marine flora on exposed coasts is dominated by Durvillea potatorum and Phyllospora comosa in the upper sublittoral and Macrocystis angustifolia forests in deeper waters. In less exposed areas, mixed fucoid communities dominated by Carpoglossum confluens, Seirococcus axillaris, Acrocarpia paniculata and species of Cystophora occur. Diverse red algal assemblages dominate in deeper waters, commonly on flat limestone reefs. The extensive sandy bottoms in this region commonly comprise Caulerpa-dominated communities and mixed Posidonia species.

---

[1] The Encounter Bay biounit was included in the Kangaroo Island Bioregion by the SA MPA Technical Working Group, by virtue of its geological and geomorphological similarities, and also because of the regular movement of Southern Right Whales between Encounter Bay and Kangaroo Island.

Within the South East Bioregion, two coastal biounits have been recognised[2]: Robe Range and Port MacDonnell.

DISCUSSION

On the basis of this preliminary regionalisation, ecologically and biogeographically, many habitats and bioregions are under-represented as MPAs in South Australia (Figure 4). In particular, kelp communities, soft-bottom benthos, estuaries, beach habitats and wave-exposed cliffs habitats, are significantly under-presented in South Australia. Biogeographically, major provinces and bioregions are either not represented or poorly represented as MPAs. This includes the habitats, communities or ecosystems of the cold temperate Maugean Subprovince of the south-east (east of Robe), and also, the marine habitats, communities and ecosystems associated with the spectacular limestone cliff formations and dune transgressions on the west coast of South Australia.

Significant/critical ecosystems and habitats for establishment as MPAs were also identified by the 'expert panel' (Table 2). In the review process, significant data gaps were also identified. Specifically, biological data, particularly for subtidal habitats and offshore areas, was considered poor or inadequate for many marine habitats in South Australia. As a consequence, the preliminary bioregionalisation was considered principally a coastal rather than an oceanographic classification.

Most of the existing 'qualitative' physical and biological information for each bioregion and the 23 biounits has been collated by SARDI (Aquatic Sciences) in the preparation of an 'Ocean Rescue 2000' funded, 'Inventory of Marine and Coastal Resources and Uses' (Table 3). This information has also recently been incorporated into a GIS-based 'Coastal Resources and Activities Atlas' being prepared by the Department of Marine and Harbours (DMH) to assist in the management of oil spills. Significantly both the inventory and the associated GIS-based atlas will form the basis for future marine and coastal information systems in South Australia for both, planning and management at a regional and local scale. Whilst the use of an 'expert panel' and the collation of existing biophysical/oceanographic data has assisted in the preliminary identification/classification of the major coastal bioregions in South Australia, there are significant gaps/deficiencies in this preliminary classification. These include, the need to extend the classification to the biounit and habitat level; the need for validation of the preliminary classification using standard, analytical classificatory procedures; and the lack of biological descriptors in the preliminary classification.

The preliminary classification is based principally on physical descriptors (ie. coastal geomorphological features and oceanographic influences). A quantitative approach to regionalisation will require detailed information for both, key physical descriptors (ie. oceanography, climatology, physiography, geology, geomorphology) and key biological descriptors (ie. habitat types, fish, macroalgae). As such, there is a need to include major biological/ecological descriptors such as habitat types (estuaries, reefs, mangroves, limestone cliffs, tidal channels, etc.), and species distributional data

[2] South East Coast Protection District Study Report 1982

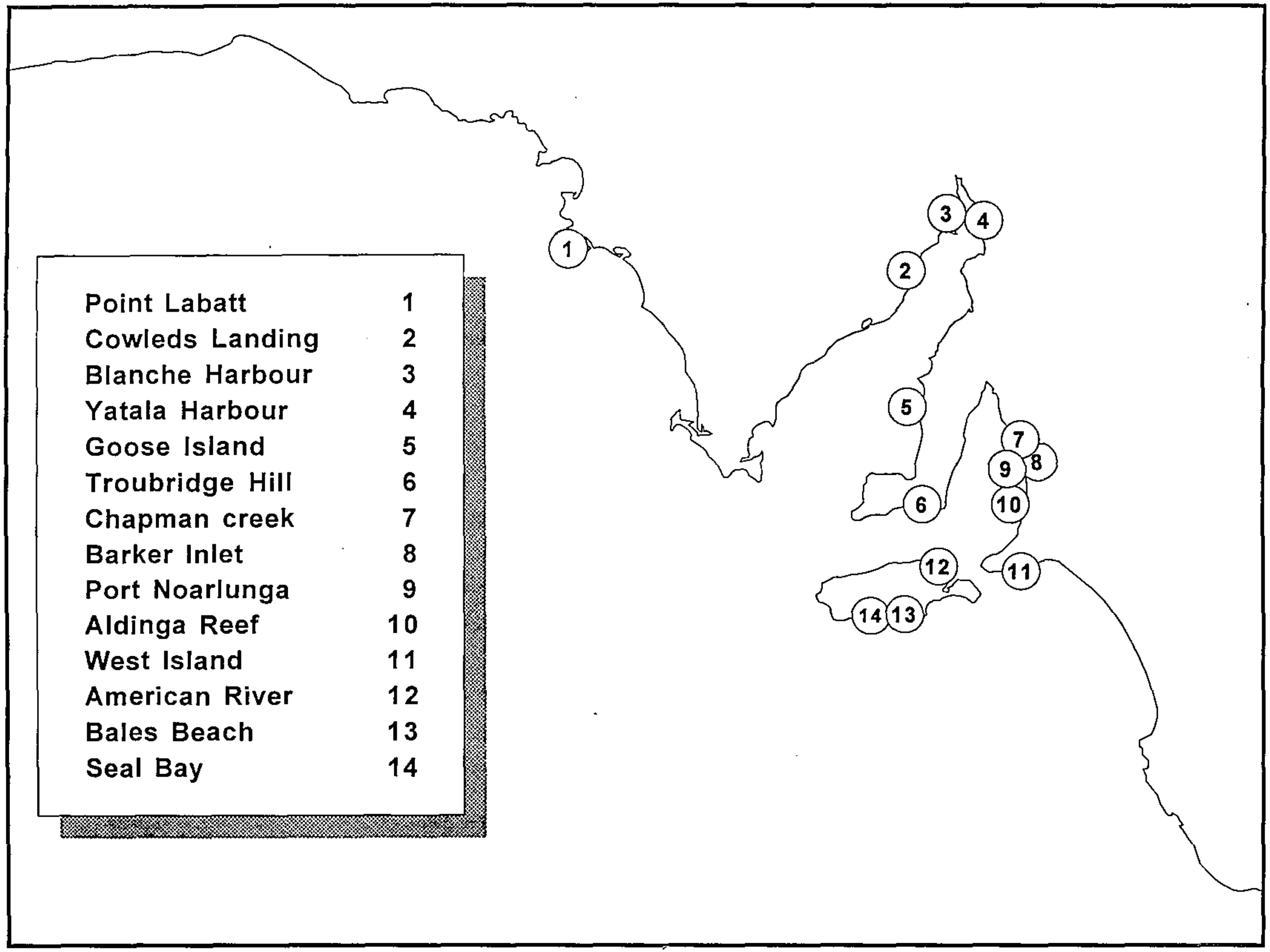


FIGURE 4. Aquatic Reserves in South Australia

TABLE 2. South Australian MPA Workshop - Key Recommended MPAs

I. EYRE BIOREGION (swell environment, semi-arid)

- Great Australian Bight (adjacent Nullabor National Park)
- Tourville Bay
- Coffin Bay (adjacent Coffin Bay National Park, Kellidie Bay Conservation Park)
- Venus Bay (adjacent Conservation Park)
- Lake Newland (adjacent Conservation Park)
- 'Leeuwin Current'

Offshore Islands

- Investigator Group (adjacent Conservation Park)
- Top Gallant Island, Pearson Island (Investigator Group)
- Nuyts Archipelago (adjacent Conservation Park)
- Neptune Islands (adjacent Conservation Park)
- Whidbey Isles, Four Hummocks (adjacent Whidbey Isles Conservation Park)
- St.Francis Island (adjacent Isles of St Francis Conservation Park)
- 'sea mounds'

II. GULFS BIOREGION (low wave energy, mediterranean climate)

- upper Spencer Gulf (adjacent Munyaroo, Winninowie, Franklin Harbor Conservation Parks)
- Sir Joseph Banks Group (adjacent Conservation Park)
- Port Noarlunga-Moana
- Gulf St Vincent (adjacent Clinton, Port Gawler, Torrens Island Conservation Parks)
- Wedge Island
- Thistle Island
- Tiparra reef
- Stenhouse Bay (adjacent Innes National Park)
- Troubridge Shoals (adjacent Conservation Park)
- Middle Bank (Spencer Gulf)
- 'soft-bottom habitat' (ie. trawlable)

III. KANGAROO ISLAND BIOREGION (variable wave climate, cool temperate climate)

- Encounter Bay (Waitpinga-Murray Mouth)
- American River (adjacent Pelican Lagoon Conservation Park)
- South-West Rocks (adjacent Kelly Hill Conservation Park)
- south coast (adjacent Cape Hart, Cape Gantheaume, Seal Bay, Kelly Hill Conservation Parks)
- Snug Cove (adjacent Western River, Cape Torrens Conservation Parks)

IV. COORONG BIOREGION (swell environment, cool temperate climate)

- 'south-east upwelling' (adjacent Beachport, Canunda, Nene Valley, Little Dip, Piccaninnie Ponds Conservation Parks)

TABLE 3. **South Australian Coastal Resources & Activities Inventory**

Bioregions

- Oceanography
  - wave climate
  - water temperature and salinity
  - currents and upwellings
  - groundwater drainage
- Climate
- Geology and Coastal Geomorphology
- Biology
- Significant Biological/Physical Features
- Significant Cultural/Historical Features
- Current MPA Status

Biounits

- Oceanography
- Geology and Coastal Geomorphology
- Biology
  - Major Habitats
  - Rivers/Estuaries
  - Coastal and Offshore Islands (or Reefs)
- Significant Biological/Physical Features
- Commercial Fisheries
- Mariculture
- Recreation/Tourism
- Scientific Research/Education
- Adjacent Landuse
  - National and Conservation Parks
  - Agriculture/Industry
  - Urban Centres
- Significant Cultural/Historical Features
  - Aboriginal
  - European
- Current MPA Status
- Potential MPAs
  - Marine Parks
  - Marine Reserves

Note: Navigation, Shipping and Defence Areas, due to their limited extent in South Australian waters, have not been considered as a separate activity category.

(ranges and boundaries) for key groups of biota, such as fish, macroalgae, echinoderms, ascidians. Of particular importance is the relationship between the physical and biological classifications, ie. the ranges and boundaries for each functional or ecological unit.

FUTURE REGIONALISATION IN SOUTH AUSTRALIA

Following preliminary classification of South Australia marine and coastal environments, there is now a clear need to produce a hierarchical, regional biophysical classification of South Australian coastal marine environments at the meso-scale and local scale using standard and broad community and physical descriptors using existing (and additional) biological, geological and physical information.

Regionalisation at the bioregional level using standard classificatory procedures will entail a thorough compilation and detailed analysis of existing physical and biological process and description data at the bioregional level. The compilation stage will require ongoing liaison with relevant State and Commonwealth agencies (eg. minerals, land management, fisheries), museums, herbaria and research organisations (institutes, universities). Data analyses, classification and mapping will be carried out using resources available within SARDI, DMH, and the GIS-section of the Department of Environment and Natural Resources (DENR).

An essential part of the bioregionalisation process, will be the collation and analysis of all existing relevant biophysical data at the biounit (ie. ecosystem) level. Much of the existing relevant range and distribution data for South Australia's coastal and marine biounits are available in the form of published research papers (eg. Womersely & Edmonds 1957, Butler et al. 1976, Shepherd & Sprigg 1976, Shepherd 1983, Shepherd & Thomas 1982, 1989), unpublished government reports, and museum and herbarium records (eg. range/distribution/occurrence records for particular floral and faunal taxa in South Australia's coastal and marine environments) from the SA Museum, SA Herbarium and Zoological Catalogue of Australia. Coastal vegetation data is available in the form of comprehensive aerial photography from the Coastal Management Branch (DENR) and also the published reports of Short et al (1986). While detailed information on South Australian estuaries is available from Bucher & Saenger (1989). Other sources of information include unpublished survey data gathered by fisheries and conservation agencies (eg. 1980's Upper Spencer Gulf biological survey; GARFIS records from which fish and commercial invertebrate distributions can be derived), other relevant government bodies, research institutes, university studies and consultants' reports.

Abiotic variables which could be used at the bioregional level of discrimination include, sea temperature data, currents, salinity, wave climate. Limited bathymetric data is available from the Department of Marine & Harbours, while broadscale sea surface temperatures and sea surface salinities is available from NOAA or Landstat. The range and boundaries of key biological descriptors (eg. habitat types, fish, macroalgae) will also be incorporated into the bioregional classification, to produce broad-scale composite maps of the variation in physical and biological descriptors between bioregions. Existing data for key biological and physical descriptors will be quantified as far as possible, using principally presence/absence data and (where appropriate) abundance data, to identify biounits and validate the preliminary biounit classification (and modify it if necessary).

Multivariate procedures of ordination and classification will mainly be used to determine biounit and biohabitat patterns both from the survey data and collated existing information. The results from the survey data will be integrated with the biounit classification and database created from existing data, and individual and composite maps of major species assemblages/community structure for each area will be produced. Over time, as more range and distributional data become available (from both finer scale analysis of existing range data and survey/field study data), they will be incorporated into the database and mapping system, to improve the detail and scale at which relevant biophysical information can be accessed and utilised for management (eg. range data for particular fish species, molluscs, crustaceans).

Spatial mapping forms an important component of bioregional classification. As such, layered, ordinated physical data will eventually be incorporated into a geographical information system[3], to produce spatial maps of the resulting bioregions, from which finer scale analyses (ie. at the local scale) may proceed. The resulting biounit classification will also be integrated into the GIS-based Coastal Resources and Activities Atlas, and will provide much of the more detailed spatially-referenced biophysical information that is currently required for the assessment of potential MPAs within South Australia's marine and coastal environments.

ASSESSING REPRESENTATIVENESS

Following an analytical, hierarchical approach to bioregionalisation of South Australia's coastal and marine environments, there is a need to quantitatively test the representativeness of the existing MPAs in South Australia at a range of spatial scale (ie. at the bioregional and local level) using standard multivariate classificatory and ordinating procedures. Assessing the ecological and biogeographical representativeness of the existing MPAs in South Australia, and identifying representative or 'critical areas' which have not yet been given MPA status (or are "under-represented") are tasks which both depend upon the implementation (or completion, in some cases) of the bioregionalisation objectives discussed above. The process of MPA identification and selection is a long term one which must be validated and regularly refined as information becomes available. As mentioned previously, critical gaps exist in the present system of MPAs in South Australia. For example, kelp communities, soft-bottom benthos, estuaries, beach habitats and wave-exposed cliff habitats are significantly under-represented. A prospective bioregion and some major biounits are either, not represented or are poorly represented as MPAs (eg. the cold temperate Maugean Subprovince area in the south-east of South Australia, and the habitats and biounits associated with the spectacular limestone cliff formations and dune progressions on the west coast of South Australia.

Refinement and validation of the bioregional classification will be a major contribution towards establishing a more encompassing, representative system of MPAs in

South Australia. To this end, the 'bioregional framework' must be defined before the socio-political, economic and cultural aspects of MPA establishment can be fully addressed. Following bioregionalisation, ongoing consultation and discussion with all marine and coastal user groups will form an important part in the selection and establishment of a representative system of MPAs in South Australia.

SUMMARY

The present system of MPA in South Australia is under-representative in both biogeographically and in terms of accepted MPA management objectives. This has resulted from a non-systematic and sporadic approach to the establishment of MPAs in South Australia. Bioregionalisation provides both a scientific approach to the identification of ecologically representative MPAs and also, a planning or management framework for the ecological sustainable use of South Australia's marine and coastal resources. The implementation of a bioregional management framework will involve both a scientific approach to the identification of ecologically representative MPAs and also, a planning or management framework for the ecological sustainable use of South Australia's marine and coastal resources.

The implementation of a bioregional management framework will involve both the establishment of large, multiple use MPAs which address sustainable resource use at a regional level and also, a network of smaller, high protection MPAs which address tactical site management at a habitat level. As such, a representative system of MPAs in South Australia should:

(i) provide for the preservation and sustainable use of South Australia's coastal and marine biodiversity, at both a regional and local level; and

(ii) satisfy the ACIUCN/CONCOM and NACMPA management objectives, identification and selection criteria for MPAs, to ensure that user groups and the general community benefit from the establishment of MPAs.

(Editor's Note: This is a shortened version of the original paper presented at the workshop. A complete copy of the paper can be obtained from Dr. Karen Edyvane.)

REFERENCES

Butler AJ, Depers AM, McKillup SC & Thomas DP. 1977. Distribution and sediments of mangrove forests in South Australia. Trans.R.Soc.S.Aust. 101:35-44

Clark KR. 1993. Non-parametric multivariate analyses of changes in community structure. Aust.J.Ecol. 18:117-143.

Clark KR. & Ainsworth M. 1993. A method of linking multivariate community structure to environmental variables. Mar.Ecol.Prog.Ser. 92:205-219.

Field JF., Clarke KR & Warwick RM. 1982. A practical strategy for analysing multi-species distribution patterns. Mar.Ecol.Prog.Ser. 8:37-52.

Grassle JF, Laserre P, McIntyre AD & GC Ray. 1991. Marine biodiversity and ecosystem function. Biology International, Special Issue 23.
Hurlbert SH. 1984. Pseudoreplication and the design of ecological field experiments. Ecol.Monogr. 54:187-211.

James FC & McCulloch CE. 1990. Multivariate analysis in ecology and systematics: panacea of Pandora's box? Ann.Rev.Ecol.Syst. 21:129-66.

Keough MJ & Quinn GP. 1991. Causality and the choice of measurement for detecting human impacts in marine environments. Aust.J.Mar.Freshw.Res. 42:539-54.

Kruskal JB. 1964. Multidimensional scaling by optimising goodness of fit to a non-metric hypothesis. Psychometrica 29:1-27.

Kruskal JB & wish M. 1978. Multidimensional Scaling. Sage University Papers. Sage Publications, California, USA.

Marchant R. 1990. Robustness of classification and ordination techniques applied to macroinvertebrate communities from the LaTrobe River, Victoria. Aust.J.Mar.Freshw.Res. 42:493-504.

O'Neill RV, DeAngelis DL, Waite JB & TFH Allen. 1986. A Hierarchical Concept of Ecosystems. Princeton University Press, Princeton, New Jersey.

Ray GC. 1991. Coastal-biodiversity patterns. BioScience 41(7):490-498.

Ray GC & MG McCormick-Ray. 1992. Marine and Estuarine Protected Areas: a Strategy for a National, Representative System within Australian coastal and marine environments. Report to the Australian National Parks and Wildlife Service, Canberra.

Shepherd SA. 1979. The ecology of a deep water red algal community off Cape Northumberland, South Australia. MSc thesis, Deakin University. SA Department of Fisheries Internal Report No.4.

Shepherd SA. 1983. Benthic communities of upper Spencer Gulf, South Australia. Trans.R.Soc.S.Aust. 107:69-85.

Shepherd SA & Sprigg RC. 1976. Substrate, sediments and subtidal ecology of Gulf St Vincent and Investigator Strait. In: Twidale C.R., Tyler M.J. and Webb B.P. (Eds.), Natural History of the Adelaide Region, pp. 161-74. Royal Society of South Australia.

Shepherd SA & Womersley HBS. 1970, The subtidal algal and seagrass ecology of Waterloo Bay, South Australia, Aquat.Bot. 11:305-71.

Short AD & Hesp PA. 1984. Beach and dune morphodynamics of the south east coast of South Australia. University of Sydney. Coastal Studies Unit Technical Report, 84/1.

Short AD, Hesp PA & Fotheringham D. 1986. Morphnodynamics and hazard assessment of the Eyre coast. University of Sydney. Coastal Studies Unit Technical Report, 86/1.
Steele JH. 1991. Marine functional diversity. BioScience 41:470-474.

Stewart-Oaten A, Murdoch WW & Parker KR. 1986. Environmental Impact Assessment. pseudoreplication in time? Ecol. 67:929-40.

Underwood AJ. 1990. Experiments in ecology and management: their logic, functions and interpretations. Aust.J.Ecol. 14:365-89.

Underwood AJ & Fairweather PJ. 1986. Intertidal communities: do they have different ecologies or different ecologists? Proc.Ecol.Soc.Aust. 14:7-16.

Warwick RM & Clarke KR. 1991. A comparison of some methods for analysing changes in benthic community structure. J.Mar.Biol.Assoc. U.K. 71:225-244.

Warwick RM. 1993. Environmental impact studies on marine communities: pragmatical considerations. Aust.J.Ecol. 18:63-80.

Womersley HBS & Edmonds SJ. 1958. A general account of the intertidal ecology of South Australian coasts. Aust.J.Mar.Freshw.Res. 9:217-260.

Womersley HBS. 1967. A critical survey of the marine algae of Southern Australia II. Phaeophyta. Aust.J.Bot. 15:189-270.

Biophysical Classification of Victoria's Marine Waters

Don Hough - *Land Conservation Council*
Garry Mahon - *Department of Conservation and Natural Resources*

SUMMARY

Victoria's marine waters consist of the bays, inlets and estuaries; and for the open coast, a 2000 km long triangular prism of water and underlying sea floor between the high tide line and the three nautical mile territorial limit.

The development of a classification of Victoria's marine waters was conceived as long term multistage project. The results of the first stage, task 1 - identification of relevant variables, task 2 - the production of a 'first-cut' classification and task 3 - review process, are described.

When work started in 1992 the immediate interest was to develop a 'first-cut' and establish clear objectives for its ongoing refinement. The classification would be used as a tool to assist with a major three year sea-use planning exercise by the Land Conservation Council to be completed by the end of 1994.

The first task had two parts. The first, to identify the relevant physical biological and chemical variables that were needed to build a marine classification. The second, to assess the availability of relevant data.

The variables identified as a result of this process were: bathymetry, geology and geomorphology, tidal characteristics, water currents, waves, inputs, and patterns of biological variability. Seasonal migration patterns, and rare and endangered species were also identified as variables but more to be used to test the classification rather than to build it.

The first task showed that;

- for variables that directly measured ecological processes e.g. connectedness of geographic regions by pelagic dispersal, the data was either non-existent or so fragmentary to be of no immediate application. This required to the use of ecosystem related variables outlined above.
- there was considerably more physical than biological data
- the utility of the data was scale dependent, with much of it of coarse resolution.

Having identified the variables and the constraints set by available data, other parameters set for the marine classification were that it be insensitive to natural changes over a 20 to 50 year time frame and that its resolution be relevant to marine planning in Victoria.

The second task was to develop a 'first-cut' the biophysical classification.

Initially the classification was to be developed using an intuitive approach based on expert knowledge and visual assessment of graphed patterns of variability.

Two forums of marine experts were held to review work in progress. Following the first forum a decision was made to shift to a more quantitative approach.

The physical classification was based on an intuitive approach, supplemented by a limited statistical consideration of some data from the open coast. The data were sampled at 5 km transects and from different locations on the transect, from the shoreline up to 15 km off-shore. The variables included in the statistical analysis were: bathymetry; coastal orientation; tidal sea levels and tidal currents for the five dominant tidal constituents in Bass Strait; wave energy; and sea surface temperature.

The physical classification produced four primary classes and two transition zones.

The classes were:

- bays, inlets and estuaries
- South Australian Border to Cape Otway
- Cape Otway to Wilsons Promontory
- Wilsons Promontory to the New South Wales Border

The two transition zones were:

- Cape Otway transition zone (approximately 25 km wide)
- Wilsons Promontory transition zone (approximately 75 km wide).

The biological classification was based on a limited multivariate analysis which used the distribution of 282 conspicuous intertidal invertebrate species, with data grouped into 10' square grids.

Most (but not all) the variability in species composition appears to be related to substrate differences rather than differences in location along the coast.

In terms of geographic location, the biological classification produced two primary classes supported by species from soft and hard substrates. These were:

- bays/inlets/estuaries; and
- open coast

For hard substrates on the open coast it was evident that those in the east of Victoria

(Wilsons Promontory) and in particular the far east are distinct from the central and western sections of the coast. The evidence for a western fauna is weaker.

The biophysical classification was then produced by overlaying the physical classification with the biological classification, see accompanying figure.

The third task - to review of the results of the 'first-cut' classification - is now underway. Three questions for the review are: how robust is the biophysical classification of Victorian waters, how can the classification be related to one developed for south east Australian marine waters, and how are the priorities for further work to be determined.

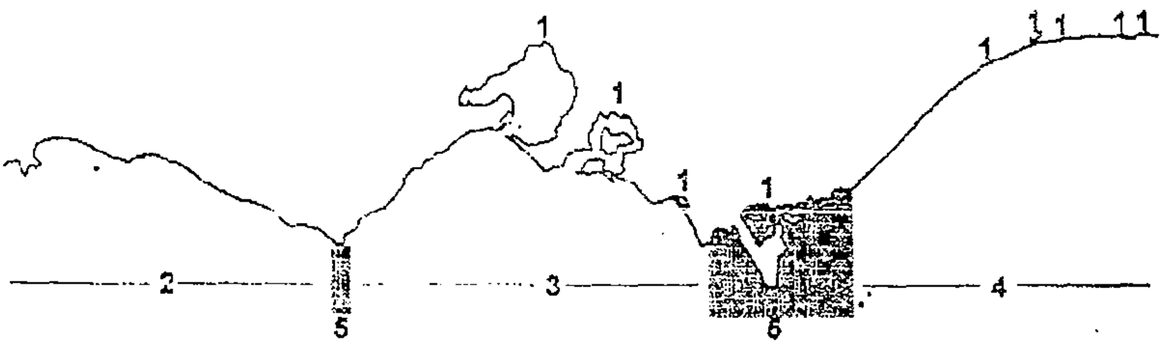
The following points are now being considered:

- the effect of using higher resolution data, in both space and time scales, in the long-shore and off-shore direction
- using different data sets to describe the same variable
- the impact of major data gaps, for off-shore biology for example
- integration within a coastal classification of Victoria
- integration within a regional based classification

The classification has and is expected to continue to evolve as:

- existing data is consolidated in useable formats
- data sets improved in resolution
- data for previously unrecorded variables became available
- analytical techniques shifted from intuitive to qualitative to quantitative regional (south-east Australia) as and continental scale marine and coastal classification
- conceptual thinking about classifying coastal environments evolves.

BIOPHYSICAL CLASSIFICATION OF VICTORIA'S MARINE WATERS



Classes
1. Bays/estuaries/inlets;
2. Open coast west of Cape Otway;
3. Open coast between Cape Otway and Wilsons Promontory;
4. Open coast east of Wilsons Promontory;

Transition Zone
5. Transition zones: around Cape Otway and Wilsons Promontory

[ADM-D285] ww/jn 16/3/94

Development of a Terrestrial Biogeographic Regionalisation for Australia

R Thackway and I Cresswell
Australian Nature Conservation Agency, Canberra

ABSTRACT

This paper presents the methodology used to develop a terrestrial Interim Biogeographic Regionalisation for Australia (IBRA). The IBRA is an initiative of the States and Territories and the IBRA map and report are the result of collaborative efforts between Commonwealth and State and Territory nature conservation agencies. The IBRA comprises data and methods used by the State and Territory nature conservation agencies. The IBRA was developed for use in the National Reserves System Cooperative Program (NRSCP) where it will be used to provide a framework for identifying gaps in the national system of protected areas and for establishing priorities for delivering the NRSCP. The IBRA represents a significant step forward by nature conservation agencies in the development of an agreed integrated regionalisation of Australia's broad ecosystems or 'natural' regions. The IBRA was derived by compiling the best available continental scale data and information for each State and Territory including field knowledge, published reports, and biogeographic regionalisations, as well as continental data sets. Estimates of reservation within protected areas and the bias in representativeness of environmental and ecological data were calculated for each IBRA region respectively. A range of issues are also presented regarding the assumptions behind and limitations in the use, of the IBRA.

1. INTRODUCTION

Regionalisations provide a useful framework for focussing attention, summarising patterns, aggregating information, and for allocating resources and priorities. In the 1970's the Commonwealth government initiated numerous 'natural' regionalisations. However, these attempts to develop national regionalisations, and to have these widely accepted and used by State and Territory governments for the delivery of Commonwealth and State and Territory government programs, have generally not succeeded.

In the mid 1980s the Australian Nature Conservation Agency (ANCA) initiated the National Index of Ecosystems (NIE) as a cooperative project between the Commonwealth and the States and Territory nature conservation agencies to establish methodologies for classifying environments as a basis for developing a representative reserve system for Australia (ANPWS 1988). Some progress was made toward developing methodologies and providing national overviews on the conservation of selected ecosystems. Two reviews of the NIE showed that the Commonwealth and State and Territory nature conservation agencies agreed a national classification of ecosystems was required as a framework to develop a truly national system of protected areas which represented the diversity of major ecosystems in Australia (Thackway 1989; Kestel Research 1991). The establishment of the NIE and its contribution to developing a national system of reserves was, however, hampered due to a lack of adequate resources.

In 1989 the NIE was incorporated into the Environmental Resources Information Network (ERIN) where work commenced on implementing the NIE as a modelling application on a GIS platform. The methodology, implemented by ERIN, for developing environmental regionalisations was based on the numerical classification of known physical environmental determinants. A national workshop on environmental regionalisations was held in 1992 in an attempt to establish an agreed national framework for developing regionalisations for use in national and regional conservation assessment and planning, including planning a representative system of reserves (Thackway 1992). That workshop showed a reasonable agreement between the existing State and Territory biogeographic or 'natural' regionalisations in terms of scale, attributes, as well as the methodologies used to derive these regionalisations (Thackway 1992). However, one major outcome of that workshop no agreement could be reached on a suitable methodology or environmental regionalisation which could be used as a framework for identifying the gaps within the existing protected areas and for setting priorities in developing a representative system of protected areas.

Two Federal Parliament inquiries by the House of Representatives Standing Committee on Environment, Recreation and the Arts (HoRSCERA 1992, 1993 a and b) on the role of community based action and protected areas systems to maintain biodiversity and ecosystem function, recommended a bioregional approach to assessment planning and management. The Prime Minister in his Environment Statement in December 1992 committed the Commonwealth to the progressive establishment, in cooperation with the States and Territories, of a comprehensive, adequate and representative system of protected areas by the year 2000. The development and implementation of a bioregional approach to the identification of protected areas was endorsed in the Statement.

A total of $16.85m over four years was provided in the Environment Statement for a range of programs to support implementation of the initiative. The bulk of the funding is administered by the Australian Nature Conservation Agency as the National Reserves System Cooperative Program (NRSCP).

In the case of the NRSCP an initial assessment of the comprehensiveness of "natural regions" represented in the existing system of protected areas was undertaken by the Commonwealth (ERIN 1993) using three continental regionalisations, namely biophysical regions (Laut *et al* 1975), environmental regions (Thackway and Cresswell 1992) and natural vegetation (AUSLIG 1991). Generally the response of the State and

Territory stakeholders to this analysis was provide an alternative a national biogeographic regionalisation, specific to the NRSCP, comprised primarily of State and Territory data and information.

In response to a general consensus from the State and Territory agencies, ANCA agreed to convene a technical meeting in February 1994 to address these issues. The South Australian Department of Environment and Land Management offered to provide the venue and office facilities.

2. METHOD

2.1. Setting the scene

An outline of the product required for the IBRA was drafted by the ANCA consisting of a map of the bioregions at a scale to fit Australia onto an A3 page with accompanying region names; a report describing the background, methods, results with a discussion of how the IBRA might be used for the NRSCP. One of the key features of the map was that the names and region boundaries needed to be clearly identifiable by the wider community.

The audience for the map and report, in the first instance is the Australian and New Zealand Environment and Conservation Council (ANZECC) and their respective Heads of Agencies. The custodian of the product is envisaged to be both the Commonwealth and all the States and Territories nature conservation agencies.

A maximum of two participants per jurisdiction in the technical meeting was set to ensure a viable working unit. Each agency nominated its respective participants based on individual knowledge and experience of the ecosystems in their State or Territory, as well as their understanding of the principles of biogeography.

Each nature conservation agency also authorised it's participants to reinterpret their jurisdiction's existing biogeographic regionalisations and to negotiate appropriate changes to enable their respective regionalisations to be integrated with those of adjacent jurisdictions. This authorisation was essential as it enabled the IBRA to be developed in the meeting.

In addition, following the technical meeting participants were expected to:

- periodically refine and revise the IBRA for their jurisdiction,
- inform relevant stakeholders of the IBRA and its intended applications in nature conservation assessment and planning,
- gain the support of their agency for the IBRA, and
- brief their ministerial representatives in the ANZECC forum.

2.2. Defining an Agreed Procedure for Developing the IBRA

The meeting decided to use specific examples to provide the framework for developing the constraints and uses of the IBRA. In the first instance, cross-border matching of regions between the Northern Territory / South Australia / Western Australia were examined, and from these investigations, discussion proceeded to broader issues which needed to be resolved. The procedure agreed to by the participants for the technical meeting is presented in Table 1.

2.3. Comparison of Biogeographic Terms Used Within Each State and Territory

Numerous systems of land classification have been developed by research institutions, land management and nature conservation agencies, as well as, private consultants. One of the first tasks of this meeting was to determine;

- what hierarchical levels were present within the respective mapping systems of each jurisdiction;
- whether a standard hierarchy with respect to existing taxonomy for regions could be synthesised from these classification systems; and
- what was the most appropriate hierarchical level for developing the IBRA.

TABLE 1: **Agreed procedure for developing the IBRA**

1. Compare the spatial regions mapped and described by each agency at various landscape scales eg province, region, land system, land unit etc.
2. Delineate a series of region boundaries at the continental scale from available maps and digital regionalisations at approximately 1 to 3 million scale. Ensure the boundaries are consistent within and between States and Territories based on an interpretation of existing biogeographic regionalisations, geology, geomorphology, climate, present and natural vegetation, and biogeographic knowledge of flora and fauna).

   Commence with a north-south band through central Australia ie SA and NT, moving then to WA and QLD, and then to NSW, ACT, VIC & TAS.
3. Develop an agreed set of names for the biogeographic regions. As a guideline use the accepted common names where the region is most extensive within a particular S/T.
4. Develop a brief description of each region based on dominant or overriding diagnostic criteria.
5. Describe each region using where appropriate knowledge of:

   Climate
   Lithology
   Geomorphology
   Landform
   Vegetation
   Flora and Fauna
   Landuse
6. Develop an index of heterogeneity to describe the variability within each biogeographic region based on more detailed spatial data eg land systems, vegetation etc. The index should be capable of being plotted adjacent to a region as a pie or bar chart.
7. Develop a reservation index to describe the level of representation of each biogeographic region within the protected areas estate. The index should be capable of being plotted within or adjacent to a region as a pie or bar chart.
8. Develop an agreed statement to describe how the IBRA should and should not be used, including a process of seeking ratification.

2.4. Nominal Resolution of the Data Used in the IBRA

The resolution of the input data used in the IBRA varied between States and Territories but was nominally about 1:500,000 scale. A flexible procedure for incorporating new or more detailed data was proposed. Where possible, data layers and procedures were linked to State and Territory and Commonwealth GIS facilities. The IBRA regions were plotted at 1:3 million scale and verified with other data sets and expert knowledge.

2.5. Procedure for Delineating IBRA Region Boundaries

The IBRA was derived by compiling the best available data and information about each State and Territory including field knowledge, published resource and environmental reports, and biogeographic regionalisations for each State and Territory, as well as continental data sets.

Two main methods were used to derive the IBRA map unit boundaries:

1. map unit boundaries and descriptions were interpreted / integrated and transferred onto paper maps or drafting film, and then these boundaries were digitised, as in the case of NT, WA, ACT, NSW and QLD;
2. where finer scale GIS data were available, these were interpreted and aggregated using a combination of paper base maps and GIS; as in the case of VIC, TAS, SA; and;
3. continental scale data sets (such as satellite imagery) were used to refine boundary mismatches.

2.6. Nominal Attributes for the IBRA

Each region is described according to its IBRA name, a unique code number, plus, where available, existing State and Territory biogeographic regionalisations. It is envisaged that further work on the IBRA could include more details on environmental attributes to describe each region.

2.7. Nomenclature of IBRA Regions

Where possible region names and descriptions for the IBRA utilised existing common names and referenced source documents. Where no appropriate names and descriptions were available field knowledge was used to generate these.

Where region names were restricted to a particular State or Territory, and where these terms were relative to a particular jurisdiction, eg South West Slopes (NSW) and South East Slopes (Vic), these names were revised to provide a more meaningful name in the IBRA context eg Lachlan-Midlands.

2.8. Building the IBRA as a GIS Data Set

Biogeographic data sets were supplied as GIS coverages to ANCA prior to the Adelaide technical meeting to enable these data sets to be loaded into the Arc/INFO GIS platform on the ERIN facilities. Thackway and Cresswell (1994) document the systematic procedure which was used by ANCA to collate, build, check, edit, document the IBRA.

2.9. Determining Reservation Status and the Bias within the Protected Area System

The IBRA was developed specifically to provide a framework for determining reservation status and for identifying deficiencies in the national system of protected areas. Reservation status was determined by calculating the area of each IBRA region conserved in protected areas.

Because it is widely acknowledged that the system of protected areas does not comprise a representative sample of the heterogeneity of environments and landscapes an index of bias of representativeness was calculated to determine the extent of this bias. Bias is defined as the extent to which the existing system of protected areas provides a representative and adequate sample of the nation's biodiversity.

The index of bias was estimated or calculated within each biogeographic region using data and information on the existing protected areas network and environmental and / or biological entities. The index was determined within each IBRA region using finer scale State and Territory data by calculating the extent to which the known heterogeneity is captured within the system of protected areas.

3. RESULTS

The IBRA was developed at the *Region* level because the existing State and Territory biogeographic classification systems showed a convergence at this level.

Map 1 presents the IBRA regions for Australia and Table 2 presents a list of the 80 IBRA regions. Each IBRA region has been described (Thackway and Cresswell 1994) by the relevant State and Territory nature conservation agencies.

Table 3 presents a summary of the numbers of existing biogeographic regions defined by State and Territory nature conservation agencies compared with those defined for the IBRA. The table shows that most State and Territory agencies gained additional regions for the purpose of the IBRA. Most increases resulted from recognising patterns previously classified as sub-regions within existing State and Territory regionalisations as extensions of regions largely lying outside that State or Territory.

TABLE 3: **Comparison of the existing number of State and Territory biogeograpic regions with those agreed to for the IBRA.**

	Existing Numbers Biogeographic Types	**IBRA Regions**
Northern Territory (Region)	16	23
South Australia (Region)	35	15
Western Australia (District)	20	26
Victoria (Natural Region)	16	10
Queensland (Region)	13	17
New South Wales & Australian Capital Territory (Region)	17	17
Tasmania (Regions)	11	8
Total (Australia)	**128**	**80**

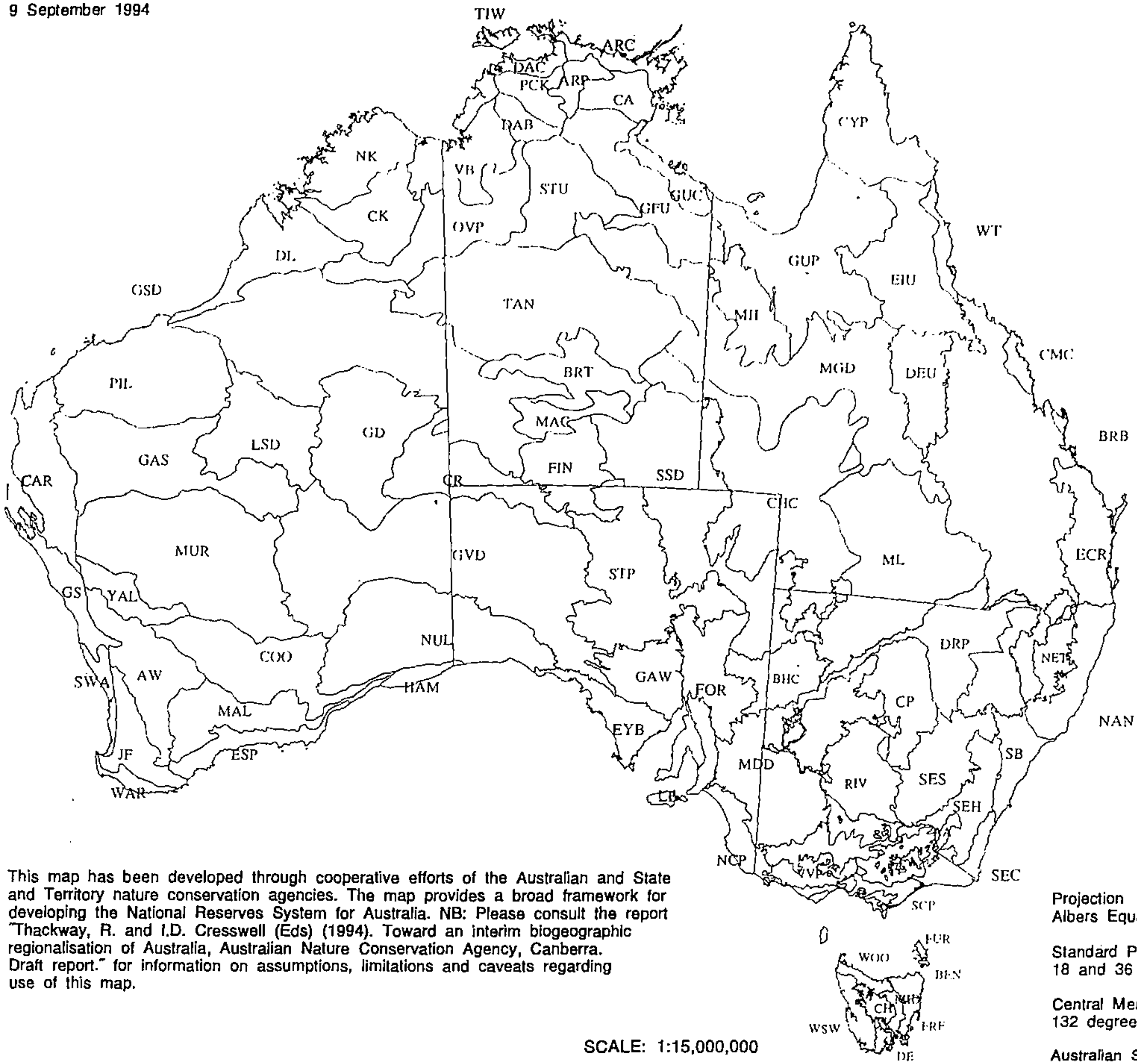
NB: 1. This total is less than the cumulative total due to the overlap of regions between States and Territories.

Table 3 shows that the largest number of IBRA regions occur in Western Australia and the Northern Territory, with 26 and 23 regions respectively. South Australia, Produced by the Reserve Systems Unit

Australian Nature Conservation Agency

9 September 1994

Boundaries of IBRA Regions



This map has been developed through cooperative efforts of the Australian and State and Territory nature conservation agencies. The map provides a broad framework for developing the National Reserves System for Australia. NB: Please consult the report "Thackway, R. and I.D. Cresswell (Eds) (1994). Toward an interim biogeographic regionalisation of Australia, Australian Nature Conservation Agency, Canberra. Draft report." for information on assumptions, limitations and caveats regarding use of this map.

SCALE: 1:15,000,000

Projection
Albers Equal Area.

Standard Parallels
18 and 36 degrees South.

Central Meridian
132 degrees East.

Australian Spheroid.

IBRA CODE: IBRA NAME

AA: Australian Alps
ARC: Arnhem Coast
ARP: Arnhem Plateau
AW: Avon Wheatbelt
BEN: Ben Lomond
BHC: Broken Hill Complex
BRB: Brigalow Belt
BRT: Burt Plain
CA: Central Arnhem
CAR: Carnarvon
CH: Central Highlands
CHC: Channel Country
CK: Central Kimberley
CMC: Central Mackay Coast
COO: Coolgardie
CP: Cobar Peneplain
CR: Central Ranges
CYP: Cape York Peninsula
DAB: Daly Basin
DAC: Darwin Coastal
DE: D'Entrecasteaux
DEU: Desert Uplands
DL: Dampierland
DRP: Darling Riverine Plains
ECR: East Coast and Ranges
EIU: Einasleigh Uplands
ESP: Esperance Plains
EYB: Eyre and Yorke Block
FIN: Finke
FOR: Flinders and Olary Ranges
FRE: Freycinet
FUR: Furneaux
GAS: Gascoyne
GAW: Gawler
GD: Gibson Desert
GFU: Gulf Fall and Uplands
GS: Geraldton Sandplains
GSD: Great Sandy Desert
GUC: Gulf Coastal
GUP: Gulf Plains
GVD: Great Victoria Desert
HAM: Hampton
JF: Jarrah Forest
LB: Lofty Block
LSD: Little Sandy Desert
MAC: MacDonnell Ranges
MAL: Mallee
MDD: Murray-Darling Depression
MGD: Mitchell Grass Downs
MID: Midlands
MII: Mount Isa Inlier
ML: Mulga Lands
MUR: Murchison
NAN: Nandewar
NCP: Naracoorte Coastal Plain
NET: New England Tablelands
NK: Northern Kimberley
NUL: Nullarbor
OVP: Ord-Victoria Plains
PCK: Pine Creek
PIL: Pilbara
RIV: Riverina
SB: Sydney Basin
SCP: South East Coastal Plain
SEC: South East Corner
SEH: South Eastern Highlands
SES: South East Inland Slopes
SSD: Simpson-Strzelecki Dunefields
STP: Stony Plains
STU: Sturt Plateau
SWA: Swan Coastal Plain
TAN: Tanami
TIW: Tiwi-Cobourg
VB: Victoria Bonaparte
VVP: Victorian Volcanic Plain
WAR: Warren
WOO: Woolnorth
WSW: West and South West
WT: Wet Tropics
YAL: Yalgoo

TABLE 2: **List of interim biogeographic codes and region names**

IBRA CODE	IBRA NAME	IBRA CODE	IBRA NAME	IBRA CODE	IBRA NAMEPCK
AA	Australian Alps	FIN	Finke	NET	New England Tablelands
ARC	Arnhem Coast	FOR	Flinders and Olary Ranges	NK	Northern Kimberley
ARP	Arnhem Plateau	FRE	Freycinet	NUL	Nullarbor
AW	Avon Wheatbelt	FUR	Furneaux	OVP	Ord-Victoria Plains
BEN	Ben Lomond	GAS	Gascoyne		Pine Creek
BHC	Broken Hill Complex	GAW	Gawler	PIL	Pilbara
BRB	Brigalow Belt	GD	Gibson Desert	RIV	Riverina
BRT	Burt Plain	GFU	Gulf Fall and Uplands	SB	Sydney Basin
CA	Central Arnhem	GS	Geraldton Sandplains	SCP	South East Coastal Plain
CAR	Carnarvon	GSD	Great Sandy Desert	SEC	South East Corner
CH	Central Highlands	GUC	Gulf Coastal	SEH	South Eastern Highlands
CHC	Channel Country	GUP	Gulf Plains	SES	South East Inland Slopes
CK	Central Kimberley	GVD	Great Victoria Desert	SSD	Simpson-Strzelecki Dunefields
CMC	Central Mackay Coast	HAM	Hampton	STP	Stony Plains
COO	Coolgardie	JF	Jarrah Forest	STU	Sturt Plateau
CP	Cobar Peneplain	LB	Lofty Block	SWA	Swan Coastal Plain
CR	Central Ranges	LSD	Little Sandy Desert	TAN	Tanami
CYP	Cape York Peninsula	MAC	MacDonnell Ranges	TIW	Tiwi-Cobourg
DAB	Daly Basin	MAL	Mallee	VB	Victoria Bonaparte
DAC	Darwin Coastal	MDD	Murray-Darling Depression	VVP	Victorian Volcanic Plain
DE	D'Entrecasteaux	MGD	Mitchell Grass Downs	WAR	Warren
DEU	Desert Uplands	MID	Midlands	WOO	Woolnorth
DL	Dampierland	MII	Mount Isa Inlier	WSW	West and South West
DRP	Darling Riverine Plains	ML	Mulga Lands	WT	Wet Tropics
ECR	Eastern Coast and Ranges	MUR	Murchison	YAL	Yalgoo
EIU	Einasleigh Uplands	NAN	Nandewar		
ESP	Esperance Plains	NCP	Naracoorte Coastal Plain		
EYB	Eyre and YorkeBlocks				

New South Wales and Queensland recorded between 15 to 18 IBRA regions. Fewer than 10 IBRA regions were recorded in Victoria and Tasmania.

Table 4 presents a summary, for each State and Territory, of IBRA regions which are restricted to that State or Territory. The Table shows that 50 of the 80 IBRA occur only in one jurisdiction. Western Australia and the Northern Territory have the highest occurrence of restricted IBRA regions, with 18 and 11 regions respectively. South Australia, Tasmania and Queensland have between 4 and 7 restricted regions, and

Victoria and New South Wales have the least number of restricted regions, each recording only two.

TABLE 4: **Summary of IBRA regions restricted and shared between State and Territory jurisdictions.**

	No. of restricted IBRA regions	No. of IBRA regions shared	Total
Northern Territory	11(48)	12	23
South Australia	4 (26)	11	15
Western Australia	18 (69)	8	26
Victoria	2 (20)	8	10
Queensland	6 (35)	11	17
New South Wales &			
Australian Capital Territory	2 (12)	15	17
Tasmania	7 (88)	1	8
Total	**50 (43)**	**66**	**116**

NB:
1. Figures in brackets represent a % of the restricted range IBRA relative to the total number of IBRA regions recorded for a jurisdiction.
2. Total number of IBRA regions for Australia = 80. Therefore the 30 regions which are shared in common occur two or more times giving a total of 66 regions shared in common.

Relatively, Tasmania has the highest proportion of restricted regions (88%), followed by Western Australia (69%) and Northern Territory (48%). New South Wales and Victoria both record 20% or less of their biogeographic regions restricted within their jurisdictions.

3.1. Reservation of Environmental Heterogeneity and Index of Bias within Protected Areas

The measure of environmental heterogeneity and index of bias for each State and Territory were compiled by the respective nature conservation agencies and summarised by ANCA (Thackway and Cresswell 1994). The results show there is more work needed in refining and revising the IBRA, particularly in relation to using consistent methodologies to assess which environmental and biological entities are poorly represented, or are not represented at all with the protected areas network.

4. DISCUSSION

This section details the outcome of the meeting held in Adelaide to develop the IBRA. It discusses the results in the light of the requirements of the NRSCP and presents some of the issues associated with potential uses and misuses of the IBRA, given the limitations agreed to at the meeting. Details of how the IBRA should be validated and how often it should be revised and by whom, are presented as issues that require agreement by all parties involved.

Biogeographic and environmental regionalisations are particularly relevant to government agencies and community groups which have responsibilities for, and interests in, managing natural resources in a sustainable way. Access to meaningful and robust environmental regionalisations is seen as providing a valuable framework for focussing attention, summarising patterns, aggregating information, and allocating resources and priorities.

The process of establishing the IBRA recognises current administrative jurisdictions of nature conservation agencies responsible for managing ecosystems or 'natural' regions. The role of the Commonwealth in the process is that of facilitator to bring the respective custodians together to develop systematic and agreed procedures for assessing ecosystems which are generally not wholly contained within a single administrative jurisdictions but are shared between jurisdictions.

While there are some limitations in the use of biogeographic regionalisations in conservation assessments and planning exercises, they do provide a valued and meaningful basis for decision making. The limitations in aggregating existing biogeographic regionalisations include the following: it is usually not possible to reliably derive the underlying primary attribute data by disaggregating pre-classed environmental or biological data; typically, raw data are absent and the regionalisations are cartographic products with accompanying descriptive reports; existing pre-classed data are usually not complete and have usually not been collected systematically across each jurisdiction; data are usually not consistent in quality between and within different areas of the continent; and the data available from different sources are typically not available in a form which can readily be stored and queried in spatial and/or relational database technologies.

Conversely, it is recognised that considerable knowledge and investment of effort have gone into the development of existing biogeographic classification systems used by the State and Territory nature conservation agencies. Simply 'stitching' these region boundaries together is not an acceptable solution because of problems with scale, type and number of attributes used, temporal differences between data sets and the different analytical methods used to generate the various regionalisations.

Development of the IBRA has required interpretation, reanalysis and revision of the existing biogeographic regionalisations for each State and Territory to form a continental level regionalisation. The approach implemented in the development of the IBRA is a flexible, repeatable and hierarchical procedure. The IBRA can be readily changed depending on changing objectives, taxa and scales both in space and time.

Because the IBRA is based on information and knowledge held by State and Territory jurisdictions about ecosystems and biogeographic data available within their jurisdictions, the IBRA represents a significant step forward by nature conservation agencies in the development of an agreed integrated regionalisation of Australia's broad ecosystems or 'natural' regions.

4.1. Terms and Conditions for Use of the IBRA

The following set of terms and conditions were agreed by the representatives of the nature conservation agencies present at the Adelaide meeting.

1. Parties wishing to use the IBRA shall acknowledge that the IBRA has been

derived by a combination of expert field ecological knowledge and interpretation of existing State and Territory regionalisations.

2. Commonwealth, State and Territory nature conservation agencies acknowledge that the IBRA has been developed for the NRSCP.
3. Any jurisdiction wishing to use the IBRA for purposes other than the NRSCP needs to acknowledge the reason why the IBRA was developed and that it may not be appropriate for purposes other than the NRSCP.
4. Commonwealth, State and Territory nature conservation agencies reserve the right to develop and use regionalisations other than the IBRA for their own purposes.
5. Commonwealth, State and Territory nature conservation agencies recognise that new methodologies and data sets are likely to modify the IBRA and that there is a need to periodically revise the IBRA to reflect these revisions.
6. That the IBRA and biogeographic regionalisations *per se* should not be viewed as the only basis for assessing national reservation priorities and gaps.
7. States and Territories reserve the right to take the IBRA products and resolutions from the Adelaide technical meeting back to the respective States and Territories for ratification.
8. Amendments to the IBRA are to be agreed between respective jurisdictions before they are forwarded to ANCA for loading onto the ERIN network.

4.2. Assumptions Underlying the IBRA and Limitations on the Uses of the IBRA

A number of assumptions underlie the development of the IBRA. These are presented below.

Assumption 1: The IBRA embodies an integrated classification of ecosystems and environmental regions. The delineation of region boundaries and the description of the environmental regions seeks to underpin and explain the distribution of the characteristic biotic elements of each ecosystem.

Limitation: The theory of landscape ecology supports such an assumption but it is recognised that there needs to be more rigorous testing of the boundaries using a range of regional and continental data sets and analytical tools.

The different methodologies used by States and Territories nature conservation agencies to derive their respective regionalisations create inconsistencies relating to scale of attributes and boundaries. The State and Territory regionalisations have been developed using different attributes for different purposes and at somewhat differing scales. These differences have been taken into account in the development of the IBRA.

Given that the State and Territory nature conservation agencies are the custodian of the individual elements which comprise the IBRA, the revision of these elements is the responsibility of the respective State and Territory agencies.

Assumption 2: An implicit hierarchy of natural regions exists and may be delineated in terms of groups of associated environmental attributes eg geology, soils, geomorphology etc which are also evidenced in the patterns of the flora and fauna.

Limitation: The above assumption has not been extensively or rigorously tested at the 1:3 million scale and therefore caution needs to be applied when attempting to fit patterns observed in the biotic environment or to explain patterns of biota in terms of the broad environmental regions of the IBRA. The IBRA regions are at best a convenient approximation of the complexity observed in the real world and should not expect the IBRA regions to yield highly precise answers in all situations. It is recognised that there is a need to periodically test and refine and revise the regions and descriptions.

Assumption 3: That a hierarchy of information exists within and between regions, embodying known levels of heterogeneity.

Limitation: Stringent application of the IBRA hierarchy is unrealistic given the intuitive nature of the process by which the regions and their descriptions have been derived. The hierarchy represents a reasonable rule of thumb which has been repeatedly revised over many years of practical ecological field surveys. It is recognised that there is a need to test or validate this "hierarchy".

Assumption 4: While existing State and Territory biogeographic regionalisations have been developed at different scales, by experts who are specialists in different scientific disciplines, using different data sets and at different times without consultation across jurisdictions, these issues are not sufficient grounds to prohibit the development of a single biogeographic regionalisation of Australia.

Limitation: Caution needs to be exercised in comparing statistics and indices derived for the same type of region between jurisdictions given the disparate nature of their origins. Constraints on the interpretation of such comparisons include the following:

a. There is a strong dependency between classification resolution and derived estimates of reservation adequacy or bias, therefore it should be recognised that the choice of resolution needs to be explicitly defined and justified.

b. The analysis of heterogeneity within each region using data sets which may be restricted to that region may confound comparisons of reservation adequacy or bias between regions. This means that it is not possible to reliably compare indices of heterogeneity of the environments between regions across the continent at any but a categorical level involving 4 or 5 classes.

c. The assessment of heterogeneity within regions will be biased by the level of information available for those regions. That is, well studied or mapped regions will naturally appear more het erogeneous than less well known regions. The crucial point is that estimates of reservation bias will themselves be biased if the regions are not classified to a consistent, and explicitly defined, level of resolution and homogeneity.

4.3. Purposes for which the Proposed IBRA should be Used and should not be Used

IBRA has been developed to assist the State and Territory and Commonwealth nature conservation agencies to identify major deficiencies in the national system of protected areas. It will also assist in the setting of priorities for the NRSCP. Selection of land parcels for inclusion into the protected areas estate needs to occur at a much finer scale. IBRA should not be used as a criteria for selecting areas for reservation.

The meeting agreed that the focus and therefore priority setting of the NRSCP should not be at the level of the IBRA, but at a finer scale within the IBRA regions. The IBRA is only appropriate for use in continental landscape level assessments. Identification of reserves should be conducted within each State and using much more detailed information. It is the topmost rung of an hierarchical classification scheme which should not be used for anything other that continental scale comparisons. The IBRA does not take into account special values which may include outstanding natural features, cultural values, and landscape values.

Endangered species and communities require a separate, technical assessment process. There already exist ANZECC endorsed programs for the conservation of endangered species and communities, the principal program being the ANCA managed Commonwealth Endangered Species Program (ESP). The ESP has legislative backing in the Commonwealth jurisdiction.

It is understood that the IBRA will in part be used to address the reserve selection criteria of comprehensiveness and representativeness. However, given that adequacy requires variables which have not been included in the development of IBRA, therefore it cannot be used to address the criterion of adequacy. Factors such as the level of threat to biodiversity need to be taken into account in developing measures of reserve adequacy.

4.4. Heterogeneity within IBRA regions and bias within the system of protected areas

The level of knowledge of the heterogeneity within each region of the IBRA varies considerably between regions. In order to make some sort of comparison of the level of representation of the variability within each region, a coarse level interpretation of bias for each IBRA region has been determined by each State/Territory. Access to this information enables assessments to be made of what elements of the landscape are included in protected areas.

On-going research by NSW NPWS and others has demonstrated strong interactions between the classification resolution of regionalisations, the homogeneity of classification regions and the estimation of reservation bias in relation to those regions. Although this report attempts to address the problem of the relationship between heterogeneity and the assessment of reservation bias, the approach used represents only a first step in developing a more rigorous approach to this problem.

The existing system of protected areas is biased toward certain environmental elements. For example, areas of high relief, low soil fertility, and steep rainfall gradients are more commonly sampled in protected areas than areas considered important for agriculture or other consumptive landuses. These typically occur on lands of low relief or higher fertility soils. We therefore need to acknowledge this bias and actively seek to design a more representative protected areas system.

4.5. Validation and Maintenance of the IBRA

The IBRA is an interim product and requires validation by stakeholders. There is a need to assess its value for use within the NRSCP. A process should be established for periodic review and revision of the IBRA. The meeting recognised the need to revisit this IBRA within 12 to 24 months time.

Development of what may be termed the *final* biogeographic regionalisation of Australia is dependent on the stakeholders in the NRSCP. It remains to be determined what performance measures or quality checks could be used to determine when we have reached the end point of the development process.

5. CONCLUSIONS

The NRSCP represents an important Commonwealth-State and Territory initiative, and this draft IBRA report is a significant first step in the development of a common conservation planning framework for establishing a truly representative national system of protected areas across the full range of ecosystems in Australia.

The NRSCP should not be entirely driven by the IBRA. It is recognised that other factors need to be taken into account when setting priorities for the NRSCP. These may include the degree of threat to an area, and objective measures of reserve adequacy such as the "irreplaceability" concepts being pioneered by NSW NPWS.

5.1. Issues to be Resolved

There remain a number of issues to be resolved in relation to the further development and application of IBRA as set out below:

1. The purposes for which the proposed IBRA will be used and should not be used, need to be identified.
2. The publication scale may be at a coarser scale, but the rules used to smooth boundaries for publication at coarser scales need to be more clearly stated.
3. There is a need to incorporate into the NRSCP IBRA document a measure of "level or degree of threat" as one of the factors to be considered when setting priorities or conserving IBRA regions.
4. Mechanisms for review, validation and refinement of IBRA need to be established.
5. Mechanisms need to be established to assess the level of land degradation and the degree of disturbance of IBRA regions.

5.2. Overcoming the limitations of the IBRA

There is a need to develop protocols and to review them periodically, as well as developing rigorous methods for validating and testing the veracity of the IBRA, given the purpose for which it was developed.

Each State and Territory nature conservation agency should develop clear procedures for linking their more detailed regionalisations to the IBRA. These procedures should enable the IBRA to be maintained by the State and Territory agencies as a dynamic tool to support decision making.

Acknowledgements

The authors wish to acknowledge the contributions of the following participants in the Technical Meeting: R Coorey (Australian Capital Territory Parks and Conservation); S Ferrier, R Pressey, P Wilson (New South Wales National Parks and Wildlife Service); M Fleming and D Howe (Northern Territory Conservation Commission); G Morgan (Queensland Department of Environment and Heritage); P Copley and K Nicholson (South Australia Department of Environment and Natural Resources); D Peters and P Wells (Tasmania Parks and Wildlife); I Miles (Victoria Land Conservation Council); D Parkes (Victorian Arthur Rylah Institute); N McKenzie (Western Australian Conservation and Land Management); T Bigwood and F Bullen (Commonwealth Department of Environment, Sport and Territories). We also wish to thank the South Australia Department of Environment and Natural Resources for providing the venue and office facilities. We also wish to thank the following individuals for their efforts - Ms Suzanne Chrzaszcz (ANCA) and Mark Wilson (South Australia Department of Environment and Natural Resources) for organising the meeting; Tricia Kaye (ERIN) and Kym Nicholson (SA Department of Planning and Development) for their help in making available computer resources at the meeting; and David Crossley (ERIN) for his tireless effort in bringing together the required continental and State and Territory data sets in a uniform digital format for the meeting.

Critical comments on the draft were provided by Doug Brown, Matt Bolton and David Brunckhorst .

6. REFERENCES

Australian National Parks and Wildlife Service. (1988). *National Index of Ecosystems of Australia & their representation in protected areas.* In: Annual Report 1987-88,23-24

Environmental Resources Information Network, Canberra. *National Reserves System Cooperative Program.* Canberra. ERINYES No.19 December 1993, p3-9.

HoRSCERA (1992). *Biodiversity: The Contribution of Community-Based Programs.* House of Representatives Standing Committee on Environment, Recreation and the Arts. Parliament of the Commonwealth of Australia. AGPS, Canberra. 98 pp.

HoRSCERA (1993a). Inquiry into the Role of Protected Areas in the Maintenance of Biodiversity - Workshop Discussion Paper. Workshop hosted by the House of Representatives Standing Committee on Environment, Recreation and the Arts, Parliament of the Commonwealth of Australia, held at parliament House Canberra, October 1992. (Brunckhorst, D.J., Ed.).63pp.

HoRSCERA (1993b). *Biodiversity: The Role of Protected Areas.* House of Representatives Standing Committee on Environment, Recreation and the Arts. Parliament of the Commonwealth of Australia. AGPS, Canberra. 98 pp.

Kestel Research (1991). *The National Index of Ecosystems: An opportunity for States and Territories collaboration in conservation planning in Australia.* Unpublished consultancy report prepared by Kestel Research for the Australian National Parks and Wildlife Service, Research and Survey Program (Project Number 77: Ref 190/501/7). Volume 1 The Final report and Volume 2 The Appendices.

Laut, P., Margules, C. and Nix, H. (1975). *Australian Biophysical Regions: A Preliminary Regionalisations.* Department of Urban and Regional Development, AGPS, Canberra.

Thackway, R. (1989). *The National Index of Ecosystems - an Approach Taken and Problems Encountered.* Internal ANPWS Report, Canberra.

Thackway R. (1992) Ed. *Environmental Regionalisation - Establishing a Systematic Basis for National and Regional Conservation Assessment and Planning.* An Australian workshop held in Canberra, 11 - 12 May 1992. Environmental Resources Information Network Australian National Parks and Wildlife Service, Canberra, 95pp.

Thackway, R., and Cresswell, I. (1992). *Environmental regionalisations of Australia - A User-Oriented Approach.* Environmental Resources Information Network. Australian National Parks and Wildlife Service, Canberra.

Thackway, R., and Cresswell, I.D. (1994). Ed. *Toward an interim biogeographic regionalisation for Australia: a framework for identifying gaps and for setting priorities in the national reserves system.* Draft Report, Version 3.1, April. Reserves Systems Unit, Australian Nature Conservation Agency, Canberra.

Completing a Network of Protected Areas in British Columbia

Kris Kennett
BC Parks,
Prince George, British Columbia

It's an exciting time in British Columbia, particularly for planning the allocation of protected areas and wilderness in British Columbia and completing a protected areas system in our province.

BACKGROUND

British Columbia is one of the world's most ecologically rich and diverse jurisdictions. It is the westernmost province in Canada, stretching from the Pacific Ocean to the Rocky Mountains, from the United States border to Alaska and the Yukon.

It was a wide variety of physiographic units and ecosystems, ranging from sea level to almost 5,000 metres, from ice caps to desert, from temperate rainforest to cactus and sage in the interior.

The Pacific coastline meanders over 27,000 km, and is mostly fiords.

British Columbia has 26 separate mountain ranges, which include the highest point in the Canadian Rocky Mountains, Mount Robson.

British Columbia is also home to a significant percentage of the world's wilderness dependent species such as mountain goats, caribou and grizzly bears.

British Columbia encompasses 95 million hectares, 93% of which is Crown land. Presently, 7 million hectares, or 7.5% of the province, is protected under legislation as national parks, provincial parks, forest wilderness areas, wildlife management and ecological reserves, with provincial parks making up the largest percentage of this. (BC is approximately the same size as South Australia).

PROTECTED AREAS STRATEGY

In recognising its global responsibility to protect wilderness and ecological integrity and to achieve a sustainable society, the B.C. government is working towards a comprehensive land use plan. This plan will resolve issues and establish certainty for all British Columbians. To aid in this process, the Commission on Resources and

Environment (CORE) has been established to develop a community-based, publicly negotiated provincial land use plan. You can see that an integral part of this is the Protected Areas Strategy (PAS).

Commission on Resources and Environment (CORE) - coordinate the development of public negotiated land use strategy to resolve issues and establish certainty for all sectors. Using the principles established under the Commission, regional round tables representing a wide variety of sectors will make land use recommendations to Cabinet, including those for protection.

Protected Areas Strategy- government wide integrated approach to completing a system of protected areas for British Columbia. Resource agencies including Forests, Fish and Wildlife, Parks, Mines, Lands, Agriculture, Parks Canada are working together in identifying gaps in the current system and recommending the areas that best fill those gaps. This major piece of technical work to feed into the land use strategy.

VISION STATEMENT

Protected areas are a major component of BC's commitment to:

- protecting and restoring the quality and integrity of the environment,
- and to securing a sound and prosperous economy for present and future generations.

B.C. will designate and manage a system of protected areas for the purpose of:

- protecting a diversity of biological, natural and cultural heritage resources
- and providing a variety of outdoor recreational opportunities.

By the year 2000, double the current system by protecting 12% of the province's biological, recreational and culture values.

In this strategy, the B.C. government respects treaty rights and aboriginal rights and interests of the First Nations people. First National participation in Protected Areas Strategy is encouraged and will not limit subsequent treaty negotiations with the government.

DEFINITION OF PROTECTED AREA

As part of this strategy, we have refined the definition of a protected area as land and freshwater or marine areas set side to protect the province's diverse natural, recreational and cultural heritage.

They protect and provide for a spectrum of compatible uses, which include many recreational activities. However, protected areas are inalienable: the land and resource may not be sold. No industrial resource extraction or development is permitted; there will be no mining, logging, hydro-electric dams or oil and gas development within protected areas. This is consistent with the framework set by the World Conservation Union (IUCN).

GOALS

The Protected Areas Strategy has two goals:

1) To protect viable, representative examples of the natural diversity in the province, including major terrestrial, marine and freshwater ecosystems, characteristic habitats, hydrology and landforms, characteristic backcountry recreation and cultural heritage values

2) To protect the special biological, cultural heritage and recreational features. This includes rare, endangered and critical habitats, outstanding or unique botanical, zoological, geological and paleontologocial features, outstanding or fragile cultural heritage features, and outstanding outdoor recreational features.

With this Strategy, the province is moving towards an ecological basis for protection. In the past, British Columbia protected mostly spectacular mountain scenery. This has skewed representation of natural ecosystems towards high elevations and under-represented low elevation communities, old growth forests and predator-prey ecosystems.

The selection process is based on ecoregions and biogeoclimatic zones. The ecoregion classification system divides the province into 100 terrestrial and 10 coastal and marine geographical unique ecosections. The biogeoclimatic classification system provides refinement, by characterising the climates, soils and vegetation within each ecosection.

To appropriately protect representative examples of ecosections, protected areas must be large and should contain examples of the full range of ecosystems. They should also include habitats, animals, plants, hydrology, landforms and cultural heritage backcountry recreation values present in that ecosection.

They must also be natural to protect natural biological processes and backcountry recreation values, so they must be located in areas that have experienced a minimal degree of development and disturbance.

In looking at just the 12% criteria, only 21 of the 100 terrestrial ecosections meet this target. Therefore, at least 79 new areas need to be identified to meet ecosection representation, let alone variant and habitat representation.

Related to the second goal, special features are elements made special by their rarity, scarcity and uniqueness of significance in intrinsic or perceived worth. Most of these areas will be small such as the orca rubbing beach in Robson Bight or abandoned Haida villages on Queen Charlotte Islands. Priority will be set accordingly to the significance of each element globally, nationally, provincially or regionally.

Presently there are seven interagency technical team in the regions assessing the contribution of the current protected areas to these goals and the associated criteria. They are also identifying and evaluating other natural areas to fill the gaps in the current system. Three of the seven regions are the process of a public negotiated land use plan under the guidance of CORE.

CONCLUSION

Looking back on the last one to two years, it has been amazing what we have been able to accomplish. Resource agencies working cooperatively to complete a protected areas system, with a strong ecological basis, which will feed into an overall protected land use strategy. With the support, commitment and leadership of the NDP government, we have been able to take some very positive and exciting steps. I am looking forward to the same next year.

In summary, British Columbia has 7 million ha of legally protected wilderness and much defacto wilderness. As resource uses increase, this unprotected base of wilderness is shrinking. Through the Protected Areas Strategy, British Columbia will double its protected areas by the year 2000. Over 12 million ha, or 12% of the province will be protected and cover the full diversity of biological, recreational and cultural values in the province. This system consists of large intact wilderness areas which will be fully protected to IUCN standards.

PAPERS PRESENTED

Session 3
METHODOLOGY

The Delphic Approach as Applied in Western Australia

Barry Wilson
Murex Consultants Pty Ltd,
Western Australia

When John Gillies rang me to invite me to contribute to this workshop, suggesting that I speak on the "delphic" approach to marine biogeographic regionalisation, I hastily agreed and then rushed off to consult my dictionary to find out what delphic meant. Fortunately, I discovered that it refers, more or less, to what my colleagues and I have been doing in WA for the past few years. It's fun to discover that you are an expert in a methodology you didn't know existed!

On the other hand, I am not so sure that the traditional definition of the delphic approach is so flattering - I discovered that it refers to the ancient procedures of gathering a group of ignorant people together and expecting them to resolve an issue by bringing to it a completely vacant mind-set!

Of course, that is not what we did for our marine park selection project. Our working group were neither ignorant nor vacant-minded. They came from several State and Commonwealth Government agencies, tertiary academic institutions and NGOs and were experts in a range of disciplines related to marine science and planning, that is, marine biologists and geomorphologists with a broad range of expertise. Collectively, they had a comprehensive knowledge of the Western Australian coastline and nearshore waters. Yet, they were mostly fresh to the task of selecting areas for reservation and in that sense they might accept the term delphic to describe their approach to the regionalisation of the coast and the selection of areas worthy of reservation for biological conservation and public enjoyment.

But before I try to do what I am asked, I would like to make it clear that I do not in any way seek to belittle multivariate and other analytical methods for developing biogeographic classifications. Any and every means to get some rigour in biogeography, for ours and any other purpose, have my support and I fully respect the efforts that have been described here by previous speakers.

The essence of my proposition is threefold:

- I question the emphasis that we are giving to biogeographic regionalisation, given that the context of our discussion is development of a national marine reserve system. Biogeographically is but one of the factors that are involved.

- I argue that you can proceed a long way toward the objective by extracting and collating information from existing knowledge contained in the literate and people's heads, and, if you have little time, a large and complex coast to deal with, and mainly subjective data, the delphic approach is a good option.
- I argue that multivariate analyses and statistically based land (water) classifications are helpful tools but, even when these are available, the process of reserve selection that follows becomes, necessarily, a delphic procedure.

In terms of my presentation here, there is a problem at to whether I am speaking about a delphic approach to biogeographic regionalisation, or a delphic approach to marine reserve selection. I will be speaking of both. It is dangerous to talk about a methodology within defining the purpose. Whether the delphic approach is capable of producing sound geographic conclusions is a mute question. But I have not doubt at all that it is an essential feature of the reserve selection process.

Let us consider, first, the objectives of the marine reserves we seek to establish, for that must guide us in determining selection criteria. May I be provocative and say that I think there is a lot of woolly-headedness about this. In spite of our statues, natural scientists are prone to emphasise biological conservation at the expense of other reserve functions.

My own personal primary interest is nature conservation but I must speak here as a manager - a client of the reserve selection process perhaps, one who prepares proposals for submission to Government for approval and implementation. To do this I need a systematic means of selecting areas that provide for certain specified public purposes, namely:

- biological conservation
  - to maintain biotic diversity
  - to sustain ecosystems;
- protection of commercially important natural resources;
- protection of natural areas for public use for recreation and tourism;
- means for assisting resolution of conflict between competing uses of natural areas and resources;
- research and reference.

For most of us, foremost is the need for conservation of marine flora and fauna. Conservation reserves are seen as the provision of natural habitat where native plants and animals can live their lives without disturbance. We usually extend the concept beyond protection of species to the need to protect ecosystems for the general well-being of the coastal environment and its resources and the need for **scientific research and reference sites**. If we are politically sensitive and seek public acceptance of our cause and, consequently, some level of achievement, we might introduce the matter of **endangered species** as a justification for reserve declaration. We might also seek to provide special protection to **breeding sites** for animals, e.g. seabirds and turtles, or the migratory pathways of whales. (We are terrible "classists", prejudiced in favour of our own class, the Vertebrates. This last criterion is rarely applied to invertebrates. Perhaps that is just the distorted perception of a spineless malacologist?) All these reasons for establishing reserves may be lumped as biological conservation.

We might also refer to the need **to protect the habitat and stocks of the nursery sites for fisheries.** This too can be seen as biological conservation although the motive may be to protect a commercial resource rather than nature.

Social factors, such as **public recreation and tourism** are also involved, - often we don't get around to that until the pressure goes on and we feel obliged to justify our objectives in socio-economic terms. Witness the reports of the GBRMPA on the commercial importance of the Great Barrier Reef Marine Park to tourism. But the fact is that the recreation function is written tightly into the statues. We are remiss in not giving it more attention in our academic discussions about reserve selection.

I am not up to date any more with other State's marine reserve legislation, but I imagine that, like WA, everyone has several reserve categories to apply, depending on which of the above purposes are pre-eminent.

In the WA system we have 3 categories, **Marine Nature Reserve** for strictly conservation reserves, and **Marine Park** where there are dual conservation and public recreation purposes, plus **Aquatic Reserves** for fisheries purposes. Our legislators are also talking about *multiple-use marine management areas.* Quite clearly the criteria for selecting an area as a nature reserve are different from those for a marine park - different from a reserve declared to protect fishery stocks - different from a reserve intended to enhance the capacity of management to balance the demands of fishing, tourism and petroleum interests.

In the Western Australian legislation marine parks are defined as having the purpose of biological conservation and such public recreation as may be consistent with that purpose. Nevertheless, although it is secondary, recreation is clearly identified as a function of the parks.

So I want to emphasise at the beginning, that biogeographic regionalisation is relevant only to biological conservation functions of marine reserves, and only part of that. There are other factors involved in marine reserve selection that have nothing to do with biology, let alone biogeography.

In their seminal paper on *methods for selecting nature conservation reserves*, Bolton & Specht (1983) were careful to emphasise that they were referring to a "biologically-based" reserve system, "based on the criteria of **diversity, representativeness, naturalness,** and **effectiveness".** Most accounts of the conservation reserve selection process adopt criteria something like these. We might, perhaps, add the criterion of **endemicity,** that is, the presence of species and higher taxa that are peculiar to an area or region.

So my first point is this - since our primary task is to develop a national marine reserves system, in all its facets, for multiple purposes, not just a conservation reserve system, what is the relevance of a biogeographic regionalisation scheme and the principle of representativeness? Does it help identify the unique site of the world's most important stromatolites, or an area of people/dolphin interaction where management must be put in place to protect both? Does it lead us to conclude that the Marmion Lagoon beside Perth's metropolitan beaches must be reserved to allow us to better manage the increasing interaction of people and the sensitive marine environment? It is clear that, in respect of biological conservation, biogeographical regionalisation helps select representative conservation areas. But, does it also help identify fishery nursery areas, or scientific reference areas, or the breeding sites of important species?

Consider the comparison between the Rowley Shoals and Marmion Lagoon. The former has extreme conservation value as a unique and pristine coral reef system subject to little recreation use - it was reserved to keep it that way. Marmion is representative of the West Coast marine biota and is heavily used for recreation - it was reserved to permit better management. In both cases, representativeness was only a minor factor in the decision to reserve these areas as marine park.

And note that the Rowley Shoals are regarded as having the highest possible conservation value because they are "unique". The concept of "unique" might be regarded as opposite to "representative", if the latter term is interpreted to mean "typical". It is essential that unique features be identified and regarded as part of the natural diversity of the region and that the concept of representativeness be broad enough to encompass them.

Well, I have spent some time getting that off my chest because I am concerned that we must get the roles of biogeographical regionalisation and representativeness into perspective as parts, albeit essential parts, of the reserve selection process, not ends in themselves. We natural scientists are included to put much emphasis on these aspects, sometimes to the detriment of a balanced reserve selection procedures. But, noting the other functions of marine reserves, now I'd like to address the matter of the delphic approach to the selection of biologically-oriented conservation reserves and the role of biogeographic regionalisation.

It seems to me that the logic of the process goes like this:

(i) a principal function of conservation reserves is to preserve biological diversity and protect ecosystems;

(ii) therefore, design of a conservation reserve system should seek to include the largest possible diversity (variety) of plants and animals, that is, it should be representative:

(iii) biogeographical regionalisation is a means of classifying land (waters) into natural areas that reflect the regional diversity of the biota, allowing a representative selection to be made for reservation.

Our first instinct is to use the concept of biogeographic provinces as the first cut of the regionalisation process. This assumes that identification of provinces is a useful first step in the classification of the biological diversity of a region. That has proven to be debatable - biogeographers tend not to agree about the boundaries of provinces, even at a very broad level. Gary Poore made this point in his address. Nevertheless, putting the finer details aside, broad biogeographic provinces are helpful in dividing the Australian coastal waters into sections that are manageable units for the next and most important steps in the process.

In the Western Australian project we found it useful to use the CONCOM biogeographic provinces as the first level of our regionalisation process. The biota of the Kimberley, Pilbara, West Coast and South Coast are different in terms of habitats, biotic composition, and evolutionary history. The differences are derived, I believe, from the separate geological histories of those sections of the continental shelf. These regions are historically and biologically meaningful and useful, although there is minor disagreement about the precise location of the so-called boundaries.

The second level is the critical one. It is at the provincial level that representative reserve selection takes place. As a biogeographer, I don't believe it is possible to subdivide the CONCOM provinces any further, except in terms of habitats and physical descriptors. The patterns of distribution of plants and animals are extremely complex and we do not have enough information to produce a strictly "biogeographic" classification at any finer level than the broad biogeographic province. We found it useful to use geomorphology as an indicator of habitats and as a means to classify our coastal waters into subunits.

Our concept of geomorphology is a broad one, embracing coastal land forms and seabed bathymetry and substrate, as well as such features as coral reefs and mangals. The latter are features formed by a blend of geomorphic and biological attributes, but for our purposes we can regard them as geomorphic units.

We assume that we need in our marine reserve system, examples of the coral reef, mangal, rocky shore, and the other habitat types represented in each of the biogeographic provinces. In so doing we achieve a broad level of representativeness.

Before we can determine what is representative, however, we should know what is present throughout. Here is the hard part. I won't speak for other States and Territories, but I can say that in WA we have very little data on marine biota for most of the State. There are detailed survey data for places like the Monte Bello Islands and Rowley Shoals, but none for most parts of the coast.

So we have two choices:

- go and get the data
- use a surrogate.

Realistically, there is no prospect in a lifetime of getting adequate information for a State-wide biogeographic analysis. So we chose the second approach.

On land this step is usually based on climate, soil and vegetation maps. In particular, vegetation maps have proved to be a good surrogate for faunistic data. For the coastal environment, such maps are neither available nor so relevant - unless you are only interested in seagrasses or mangals.

In using coastal geomorphology for the second level of our analysis, our premise was that geomorphology is a fundamental factor in determining habitat. The more complex the geomorphology, the more diverse the coastal habitats and the greater the biotic diversity. It was surprising how well it worked out.

Our geomorphic analysis was based partly on publications, partly on bathymetric and geological maps, aerial photos and remote sensing imagery, and partly on input from geomorphologists and biologists who have studied the areas. So this is a mixture of objective and subjective delphic methods. We gathered what data we could find for each province and had a jam session. A draft summary was produced and we had another jam session, and so on until we had a consensus.

At each successive meeting we filled in detail. Members followed up items within their expertise and reported back, or submitted written material for incorporation into the draft for discussion at the next meeting.

By this means we divided the coast and continental shelf of each biogeographic province into units. First we identified what we called "major distinctive coastal types". These were roughly equivalent to the "natural systems" recognised in some terrestrial land system classifications. They were usually of large size, an island archipelago for example, or a long stretch of mangal, or a gulf or estuary. Geology, landform, bathymetry, distinctive water mass, and dominant biota (such as corals or mangroves) were usually the main descriptors.

The next break down was also based on geomorphology. In most cases there were two further steps, producing what you could call habitat units. For example, the coral reef systems were classified as atolls, barrier reefs or fringing reefs and these, in turn, were subdivided into lagoonal, back-reef, reef flat, reef-front slope habitats etc. Major mangals were divided into ria shore, delta, gulf and sheltered bay systems, and then further into assemblage types such as muddy flat, tidal creek, alluvial fan and hinterland fringe assemblages. Southern estuaries were classified as of basin or riverine type, and then as permanently open, seasonally open, or permanently closed.

Once a framework for each area was established, local knowledge from CALM regional staff and others was sought. Species lists and other details were rarely considered.

It is true that the classification that were derived could have been achieved with more precision by computer modelling etc. But where were the data? Who would have fitted them to analysis format? And how long would it have taken? Of course, precise analysis of shore types, mangal floristics and structure and similar details would have been enormously useful, and would have been used in the workshop sessions described above, if they had been available. But still, at this second level, the precision we achieved with what we had was usually adequate for the purpose.

The process followed allowed us to identify areas that we believed best represented the geomorphology, and hence the biota, of each of the "distinctive coastal types". One important attribute was habitat diversity. The more diverse the habitat units (that is at the finer scale) included within an area, the greater its biotic diversity was assumed to be and the higher conservation value the area was assumed to have, in terms of the Bolten & Specht criterion of representativeness.

We then debated the relative merits of the selections, trying to ensure that each of the distinctive coastal types, and all habitat types recognised within each distinctive coastal type, were represented within the reserve system at least once. If there were significant regional variations in climate or other physical features, such as the rainfall gradient along the Pilbara coast, we were careful to select examples of the habitat types at several points to cover the likelihood of regional variations in biota.

It was then necessary to superimpose information on other biological and non-biological attributes that qualified the areas as candidates for reservation, in other words, information that carried our project beyond the "representative" criterion. Anyone and everyone was canvassed to identify conservation hot spots, such as important bird and turtle nesting sites, dugong feeding areas, the "best" coral reefs. These data, of course, were entirely subjective.

Because we were conscious that our reserve system was not to be solely biologically-based, we also gathered information on recreational use of the coast, where the dive sites, fishing spots, boat ramps and camp sites were, and on industrial and other uses that might conflict were reserve management objectives.

It was at this point that the "effectiveness" and "naturalness" criteria were considered.

For example, coastal areas adjacent to terrestrial conservation reserves were preferred to those adjacent to town sites and ports. Large areas with some degree of internal, ecological integrity (e.g. a whole mangal with its fronting mudflats and the supratidal slat flats behind) were preferred to small areas that represented a part of recognisable ecosystem. These are "effectiveness" criteria, relating to the manageability of the proposed reserve. But this is a difficult issue. Rowley Shoals, so far offshore, is protected by its isolation but is impossible to police for the same reason. Conversely, the Murion Islands are easily accessible and therefore vulnerable but they are easily policed. Which is more "manageable"?

The "naturalness" criterion is also difficult o apply consistently. Rowley Shoals are almost pristine. Ningaloo Reef is fished, and increasingly so. The fish stocks of Marmion Lagoon are heavily fished and appear to be degraded. Should they have decreasing value as marine reserves accordingly? Marmion is used by thousands of people every fine weekend and desperately needs more management. Should it be at the top of the priority list or at the bottom?

Naturalness is most relevant to a strictly conservation reserve. We found it an important factor in several situations. For example, Normalup/Walpole Inlet and Wilson Inlet on the South Coast are two estuaries of the same type in physiographic terms. But Wilson Inlet is badly polluted and the catchment is within agricultural land. Conversely Nornalup/Walpole is almost pristine and has its catchment in national park and forest land. Both are heavily used for recreation but, naturally, we chose the latter for reservation. On the naturalness and effectiveness criteria, one was suitable and the other not, as noted before. A sensible delphic decision?

Another observation I want to make is that, once you have defined the boundaries of your biogeographic provinces and identified its distinctive coastal types, you often find that you don't really have too many options for selecting areas within them that represent the major habitat types.

I have great faith in the power of informed people to make good judgements. And in my case, once the available information on the biota and geomorphology has been processed by whatever method, the time comes when knowledgeable people have to debate the choices and make decisions. Machine analysis and objectivity then dissolve into the shadows. The human capacity for personal bias, confusing issues, and pragmatism assert themselves. But eventually, commonsense decisions emerge.

It is not a question of *either* delphic *or* objective analysis, but a question of at what stage or stages does the delphic process operate. If time, resources and suitable data are available, the ideal would be to use objective methods to provide a thorough, quantified data base for the Oracles to consider along with the other information available to them. Nevertheless, in my view it is possible to make useful decisions on biogeographic regionalisation by the delphic approach, even without statistical analysis. But once a regionalisation is achieved, by whatever method, a delphic approach is essential for consideration of other kinds of information, addressing other criteria for reserve selection and, eventually, the selection process itself.

So my proposal is that, if you have little data and limited resources it may not be necessary to embark on a long-term "scientific" data-gathering and analysis program. Get your local Oracles together and try to delphic approach. You will be surprised how much you can achieve, and how technically and politically defensible your recommendations will be. A more sophisticated approach can be applied to later refine your proposals and provide support for the weaker ones.

Multivariate Analysis and Biogeographic Regionalisation

Brian H. McArdle
Biostatistics Unit, School of Biological Sciences
University of Auckland,
Auckland

INTRODUCTION

When I was briefed on the requirements of this talk, there were 4 main headings:

(i) What might be a multivariate statistical approach to biogeographic regionalisation?

(ii) What are the strengths and weaknesses of such an approach?

(iii) Why might it be better than alternative methods in particular the Delphic approach?

(iv) Are there related methods?

Multivariate statistical methods evolved as a response to the obvious problem that one cannot describe or analyse even a moderately complex system using only one variable. There are a whole (vast) suite of techniques to handle situations with only one or two variables, but it becomes abundantly clear as soon as you look at a multivariate problem that this is a whole new can of worms.

The main problem is that while for one or two variable systems we can look at the data simply, for multivariate data this is not true. Attempting to visualise data that can only be plotted in 10 dimensional space is likely to lead to severe mental damage. Similarly while a summary of the data in the form of a mean, confidence interval and standard deviation is succinct and easy to appreciate when there is only one variable; when there are over 100 the so called summary becomes rather overwhelming. The aim therefore of most multivariate techniques has been to provide succinct summaries of the data and to allow the data to be displayed to the human eye.

There has also been a historical component to the evolution of these methods. For many years multivariate methods were not the favoured domain of theoretical statisticians (with a few notable exceptions) and many, if not most, mathematically trained statisticians were not exposed to them. As a result of most of the impetus for their development came from numerate scientists and the few statisticians who worked closely with them. This explains the strong predominance in the modern multivari-

ate armoury of clustering (classification) and dimension reducing (ordination) methods - promoted and developed in particularly by the ecological botanists, and latent variable modelling (factor analysis) pioneered and nearly ruined by the psychologists. These techniques evolved because that is what these people needed. As a result multivariate methods have been largely oriented towards data display and exploration; rather than the hypothesis testing and analysis that has come to dominate univariate methods. I confess a distaste for this dominance of hypothesis testing (a distaste shared with many statisticians), and so I am very happy with the descriptive exploratory emphasis of multivariate methods.
As I shall explain below, I feel that multivariate methods can best be used in biogeographic regionalisation as a way of making complex information more accessible to the decision makers, and also as a way of making certain thought processes and value judgements more explicit, rather than a way of making the decisions themselves. For this reason I shall concentrate the discussion on the clustering and dimension reducing methods. One feature that I will emphasise is that the successful application of multivariate methods requires a sequence of decisions that can only be taken in full knowledge of their consequences.

DIMENSION REDUCTION (ORDINATION)

Most marine biologists have an at least nodding acquaintance with classification and ordination. Classification (clustering or partitioning) aims to identify groups of multivariate observations that are in some sense more similar to others of the same group than they are to those of a different group. Ordination aims to reproduce in fewer dimensions (usually 2 or 3) as accurately as possible the relative similarity of the observations. So that observations that are similar to each other should appear close together in a 2 (or 3) dimensional plot, while those that are dissimilar should be far apart.

For example let us consider a data set collected by one of my MSc students, Rendt Gorter. He collected physiographic, biological, and habitat information from a number of subtidal transects at nine sites around New Zealand (Figure 1). Though not really suitable for bioregionalisation these data can show us some of the capabilities of multivariate methods. The data set consisted of 41 observations (transects) on 21 variables (Figure 2). This is a small data set by any standards, but the data table (861 numbers) is virtually unreadable. It is clearly desirable to display what the data table is trying to tell us in a more "user friendly" fashion. The final recipients of the data must be able to extract the information that they require with a minimum of effort.

Figure 3 shows the results of an ordination on the data (a principal components analysis in this case), showing the sites. The 21 dimensional data have been condensed down to two dimensions (losing about 50% of the information - the least important half, we hope). There is quite reasonable agreement within sites at least on the second axis. If we go to the biogeographic scale and plot which island each observation comes from, we see good separation between the two main islands.

At first sight there seems to be some interpretation of the two islands. However if we use the third component (the third best axis for summarising the data) and a bit of modern technology (Brush and spin using SAS/INSIGHT) to look at the data cloud from a number of different directions we can see that actually the two islands are quite separate (Figure 5) - definitely encouraging!

There are a number of ways we could investigate which variables are responsible for the differences we observe, interpreting the eigenvectors, biplots, canonical discriminate analysis and a slew of others. The simplest is graphical, bubble plots. Figures 6 - 10 show some of the variables that seem to relate to the differences.
I am not suggesting that the analysis is showing anything an observant diver would not have concluded for themselves (though further investigation does actually suggest one or two differences that are mildly surprising). I am suggesting that ordination techniques can provide a simple and direct way of communicating these patterns to other people, the decision makers perhaps.

Clustering, partitioning or classification.

One major problem with using the ordination techniques to look for clusters is that you never know whether important discontinuities between groups might not exist on some of the dimensions that you have dropped. It can therefore be useful to combine the ordination approach with a clustering technique. This family of techniques (and it is a large family) is designed specifically to identify groupings in the data.

The aim of the techniques is to allocate the observations so that observations within a group are more similar to each other than they are to members of other groups. Unfortunately, there are so many techniques using different criteria for measuring the similarity between groups that it is hard to know which to use. There are two main groups of techniques: hierarchical clustering methods and partitioning ones. The hierarchical methods produce clusters that nest inside each other and produce a dendrogram, a form of data presentation familiar to most ecologists (Figure 11). The partitioning methods (sometimes known as *k*-means clustering techniques) optimise the allocation of the observations into a particular number of groups. The strength of the hierarchical methods is that the dendrogram allows you to explore the possibility of different numbers of clusters. The strength of the partitioning methods is that they try to get the optimum allocation of the observations unconstrained by the necessity to have one clustering solution nested inside another. With modern computers it is possible to run the partitioning program many times to find the number of clusters that gives the clearest, most useful, clustering. Unless you believe that your data must be hierarchically organised it is probably more sensible to use a partitioning algorithm to find your groups. This is especially true if you have a large number of observations where *k*-means method perform particularly well.

Both the *k*-means method and Wards hierarchical method suggest 5 as the best number of clusters (2 is also a good solution). If we look at the 5 groups formed by plotting the group identity on the PC plot (Figure 12), the groupings are at least plausible. We can further check to see which sites are representative of their groups by looking at the distance each value is from the centre (mean) of their group (Figure 13). Observations close to the centre could be taken as a representative of the group. We can now look at the characteristics of the clusters. While there are a number of ways to do this, the simplest is undoubtedly to look at the table of cluster means on each of the variables (Figure 14). This allows us to assemble a table summarising the regions and their characteristics (Figure 15).

This analysis I have presented here is only one of the many ways to approach the problem. It is not necessarily the best but is undoubtedly one of the simplest.

STRENGTHS AND WEAKNESSES OF THE MULTIVARIATE APPROACH

Weaknesses

The main problem with any of these multivariate methods is that different methods lead to different results. These differences are nearly always produced mainly be disagreement among methods over what is considered to be the "similarity" between observations, or between clusters.

There are a number of factors that influence this measure in Biogeographic regionalisation. I will mention 4 of them.

(i) What you measure.

There are two features of this.

a) The spatial scale at which you measure characteristics at each site.

   Are you measuring the types of broad habitat that are present: estuaries, reefs, sandy beaches? Or are you looking at spatial scales of single transects where you record the type of substrate, the physiography, the biota.

b) What characteristics of an area are you recording, what types of variables will you record. Are you looking at all the major organism groups present in an area or just macroalgae and inshore fish? Different subgroups of variables will obviously lead to different relationships between the sites.

ii) How you measure it

Many variables can be measured in a number of ways. Recording fish abundances as presence/absence, a rank value (Absent, rare, common, very common), or as counts can influence the similarities between sites. As can the transformation of data: log transformed abundances will usually not give the same measured similarities as the raw counts.

It is often not understood that many multivariate statistical methods impose their own transformation or standardisation on the data. Most of the differences between methods is related to the implicit standardisation imposed by the methods. For example experience over the years has shown ecologists studying communities that Correspondence Analysis (and techniques based on it like TWINSPAN) and multidimensional scaling methods using compositional similarity (a particular popular similarity measure) both give more relevant and interpretable results (for them) than alternative methods. This is largely because such methods are transforming the data into proportions first, and, for community ecologists at least, ecological similarity seems most appropriately measured with proportions. Different transformations or standardisations will lead to different results. Notice that virtually every measure of similarity (and there are over 70 of them) has its own standardisation or transformation. It is important to choose your standardisation or transformation to bring out those features of the data that are considered relevant to the problem, and to know what effect it is having on your data.

iii) How you weight it.

It is not immediately appreciated that if your are mixing variable types: say physiographic and biotic variables into one measure of similarity, if you have more biotic variables than physiographic ones you are tending to weight the analysis towards reflecting biotic similarity. If that is what you want, well and good, but it should be a reasoned decision not an accidental result of the way the data is coded. This is particularly true if you are using what are called dummy variables (a way of coding in qualitative variables).

Implicit in the discussion of transformations and standardisations above is the fact that the larger the range of the variable the more effect or influence it will have on the analysis. We can think of this as a form of self weighting. A variable with a large range is heavily weighted, one with a small range less so. If the data are measured on different scales then variables that range from 0 to 100 will have much more effect on the overall measure of similarity then ones ranging from 0 to 1. This is one reason for the convention that if your variables are on different scales they should be standardised in some way (e.g. by their ranges, or standard deviations) so they all contribute equally.

iv) The meaning of double zeros

Ecologists have long been aware of this problem. If two sites are missing the same species, using most measures of similarity they will be regarded as similar as if they had the species present in the same numbers at each site. Imagine two ends of a gradient, perhaps a transect down the shore in an intertidal community. Sites at the top and bottom of the shore will be missing the species from the mid-tide zone, should they be regarded as more similar as a result? Ecologically, of course not. The community above the high tide mark is ecologically more similar to the mid tide zone than to the subtidal; using an inappropriate distance measure could obscure that fact. Of course with some variables, if two sites have zero values then they should be regarded as similar as a result. For example sites missing some habitat type perhaps ought to be regarded as more similar as a result, it will depend on the variable. A decision has to be made for each variable to establish whether double zeros are meaningful or not.

I hope I've made it clear that the way in which the similarity measure is assembled is of great importance. It may require variables (groups of variables) to be treated in different ways - some being standardised other incorporating double zeros, others being weighted in a particular way. In essence this means that the similarity measure being used by every variable has to be thought about carefully, and then combined in one final similarity measure for analysis. There is currently only one similarity measure that has the necessary flexibility to handle this situation: Gower's (see Digby and Kempton 1989 for a discussion).

The most important drawback to the multivariate approach is that it cannot be done quickly or without a good understanding of the methods involved.

a) For example some of the more useful techniques of clustering and ordination, e.g. *k* means clustering and multidimensional scaling are iterative and can be seduced into local minima. That is, repeated runs with random starting points might (and often do) give very different results.

b) Your choice of hierarchical clustering will usually effect the results (e.g. single linkage clustering will seldom give the same solution as average linkage or Ward's).

c) Even techniques that are often used blind, in rote fashion, e.g. detrended Correspondence analysis (DECORANA), there are important decisions to be made that workers are often unaware of, for instance the size of the detrending window can have a major effect on the results.

The applications of any multivariate method requires the making of many choices, and they must be made in an informed way so that you achieve the specific aims of your analysis. Alternatively by trying a number of alternatives at each decision point, you can attempt to show that the important results are robust to the particular methods used.

One final point that is often forgotten by the end of a long and difficult analysis (and they all are to a degree) is that the results can only be as good as the data that went into it (they are often a lot worse). Therefore considerable care has to be taken in the design and execution of the sampling program. One consideration that is particularly important in a spatially distributed program necessary for regionalisation, is that there be no spatial pattern in the way the data are collected. For example if teams with different areas of expertise are used in different areas, patterns may emerge in the data (say in the number of species of fish) that are due to differences in the teams' abilities to recognise and locate the species. Even differences in the amount of time invested in the different classes of information could lead to spurious patterns. For example a team that spent more time searching its invertebrate quadrats would find more species than one that was more cursory. These and other similar considerations mean that multivariate analyses on their own should never be regarded as sufficient evidence for the existence and definition of regions.

Strengths

The strengths of the approach is that useful summaries of very complex, large bodies of information can be condensed and displayed to the decision makers. These summaries may bring out relationships or patterns in the data that even experienced field biologists had not noticed, (because of their scale perhaps), or had forgotten or ignored. These summaries can be used to communicate the important features of the system to other workers in a graphical and systematic fashion. It is however worth mentioning here that I have a motto for multivariate analysis "I don't believe it unless I can see it - but I don't believe it just because I can see it".

Even if the summaries themselves are too unclear to be of direct help, as will often happen (real data is often noisy, and the signal obscure) the analyses often suggest which variables are most useful to examine and may offer starting points for exploratory univariate analyses.

Alternatives

As I mentioned above, multivariate analysis is a vast and growing discipline. There are many more sophisticated techniques than can be mentioned here that could be used to address the problems of designating biogeographic regions. Fuzzy clustering for example does not fall into the trap of assuming that there are clear discontinuities between clusters (regions). All the standard clustering methods assume that a site can be in one region and one only. It is not allowed to be intermediate. Fuzzy clustering allows the site to share information with more than one region. It measures the amount of information that a site shares with the different regions. This allows sites typical of a region to be identified, as well as drawing attention to the existence of intermediate sites. This may call into question the existence of any real discontinuity between some of the regions.

Biogeographic regionalisation, along with most ecological problems is explicitly spatial. There are a number of multivariate methods that incorporate into the analysis the spatial information that is implicit in the data set, for example, Pierre Legendre's constrained clustering (Legendre 1987) only allows clusters to be formed of spatially contiguous points. It therefore divides the map up into discrete regions. Its disadvantage (corrected to some extent in Bouragault, Marcotte and Legendre 1992, and McArdle unpublished) is that there is no possibility for two spatially disjunct areas to be identified as being in the same group. One region broken in two by an area with different characteristics cannot be identified by this method.

An alternative approach is to use a more classical biogeographic approach rather than the ecological one described in the rest of this paper. By recognising that biogeographic regions arise from different historical processes, the methods of historical reconstruction (cladistics or phylogenetics) could be applied. This approach is particularly appropriate if endemism or other evolutionary aspects of the regions are considered important.

Finally I must mention the Delphic approach. I confess, when first I heard this mentioned in the context of marine reserves my mind was invaded by images from my classical education. The Pythia, the prophetess at Delphi, produced utterly incomprehensible gibberish while stoned out of her mind on burning Laurel leaves (cyanide poisoning), which obliging and politically astute priests of Apollo interpreted for the supplicant so that whatever actually happened no blame could come back on them, the original teflon bureaucrats. The thought of groups of Marine Scientists getting stoned out of their minds at meetings and the hovering bureaucrats interpreting the resulting advice to their ministers so that none of the blame would attach to them is too far fetched...

I then remembered that the origin of the modern meaning of the Delphic method was back in the sixties where it was discovered that if you asked a very large number of people who knew little or nothing about a subject to estimate some value then the consensus value was often uncannily close to the true mark. The example used then was asking US undergrads (several thousand) how many telephones there were in Thailand. The thought that groups of marine scientists were being invited to offer regionalisations that were then built into a consensus, led to the interference that whoever originally applied to the term Delphic to the process had a very low opinion of marine scientists!

After more reading and after talking to an ex-student who is market research data analyst I became aware that the Delphic approach these days simply refers to a consensus solution produce by a group of people who do know something about the subject. Relying on their experience and knowledge they build a consensus picture that allows the regions to be identified. At this point I realised that this was not an alternative to the multivariate approach, it complemented it perfectly. The sampling programs that multivariate analyses demand and the results of the analyses can augment the experience and intuition of field workers. They can provide a core of "objective" information around which the discussion can focus. They also make explicit at every stage, from the design of the sampling program to the design of the similarity measure, what features of the system under study are regarded as important and what should be their relative weighting in defining regions. It is well known phenomenon of committee work that arguments arise not because people are working from different data bases but that they weight the parts of them differently. Making the relative weights explicit makes arguments more constructive as they are now focussed, and therefore resolvable (you hope).

REFERENCES

Bourgault, G., Marcotte, D., & Legendre, P. 1992. The multivariate variogram as a spatial weighting function in classification methods. Mathematical Geology, 24: 463-477.

Digby, P.G.N. & Kempton, R.A. 1987. Multivariate Analysis of Ecological Communities, Chapman and Hall, London.

Legendre, P. 1987. Constrained Clustering. In P. Legendre and L.Legendre (Eds) Developments in Numerical Ecology, NATO series. Vol. G 14; Springer-Verlag, Berlin,p 289-307.

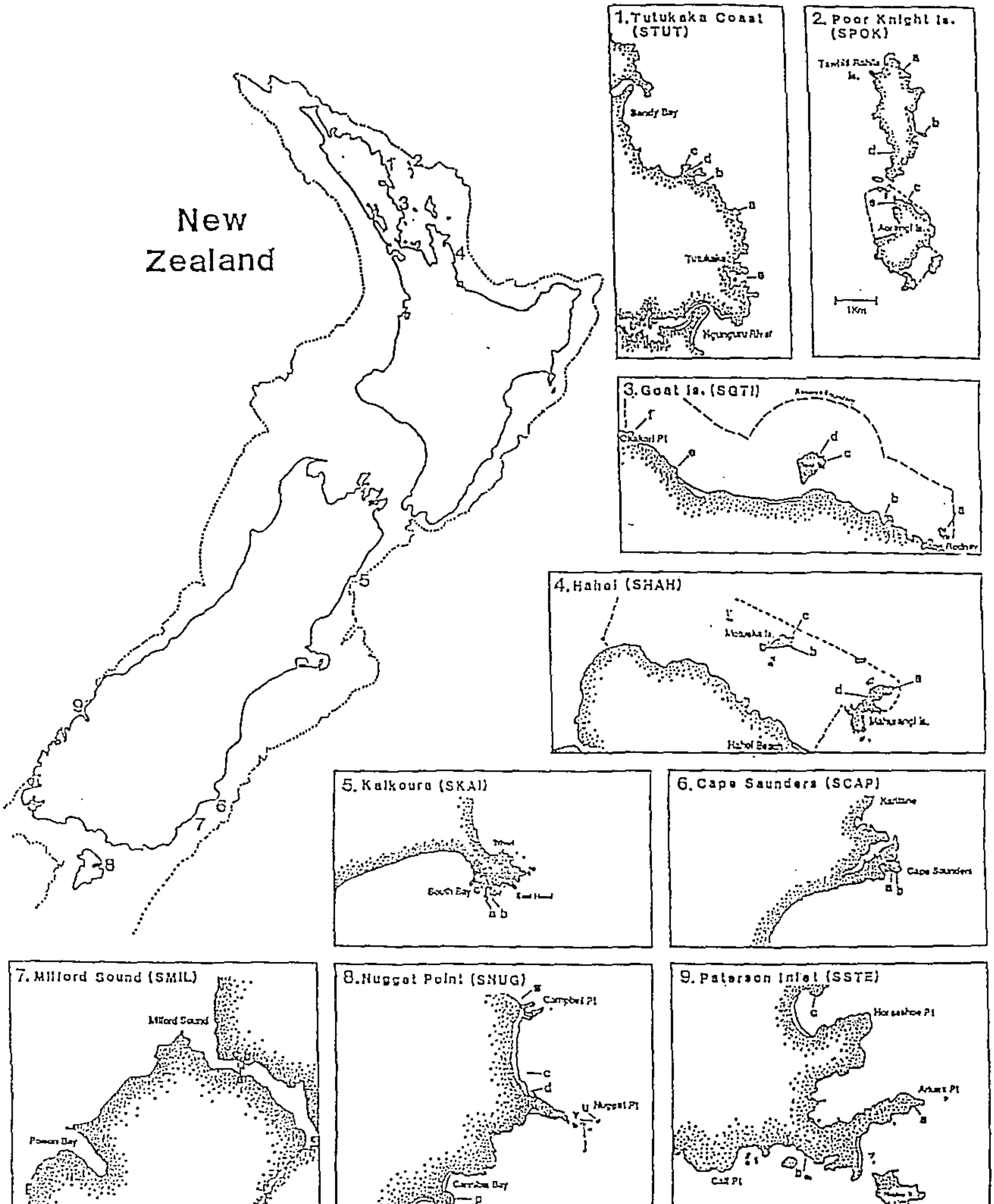

New Zealand
1. Tutukaka Coast (STUT)
Sandy Bay
Ngunguru River
2. Poor Knight Is. (SPOK)
1Km
3. Goat Is. (SGTI)
4. Hahei (SHAH)
Hahei Beach
5. Kaikoura (SKAI)
South Bay
6. Cape Saunders (SCAP)
Cape Saunders
7. Milford Sound (SMIL)
Milford Sound
8. Nugget Point (SNUG)
Nugget Pt
9. Paterson Inlet (SSTE)
Horseshoe Pt

FIGURE 1.

One observation was made for each 5x5m quadrat.

Variable	Definition	Values
Depth	measured at the shoreward edge of a quadrat	meters
Terrain features:		
Meso-structures	Crevices and overhangs with dimensions that would allow a medium sized fish (30 cm S.L.) to shelter within it.	pres/abs
Macro-structures	Gullies at least one metre deep and wide, Ledges and Pinnacles at least two metres high. Any structure had to be either at least half within the quadrat or be of sufficient length/width (2m+) to be recorded.	pres/abs
Canopy	defined as percentage macroalgal cover obscuring understorey and substratum in the ranges: >75%, 25-75%, <25%, 0%	dense, medium, sparse, nil
Substratum:		
Bedrock	unmovable	Ranked: 1ry, 2ry, present, or absent
Sediment	includes, mud, silt, sand, shell debris and gravel	(as above)
Boulders	detached, with at least hand-sized gaps	(as above)
Cobble	detached, with at least finger-sized gaps	(as above)
Aspect:		
Horizontal	0-15°	Ranked: 1ry, 2ry, present, or absent
Sloping	15-75°	(as above)
Vertical	75°+	(as above)
Cover type:		
Bare	No live cover other than microscopic and interstitial life (eg on sand or gravel)	Ranked: 1ry, 2ry, present, or absent
Encrusting corallines		(as above)
Turfing algae	consisting of various red, green and brown plants, up to 35cm high (e.g. turfing forms of *Corallina officinalis*, *Gigartina* spp., *Plocamium* spp. *Hymenocladia lanceolata*, *Laingia hookeri*, *Hymenena* spp., *Glossophora kunthii*, *Desmarestia firma*, *Chaetomorpha* spp., *Caulerpa brownii* and *Bryopsis* sp.)	(as above)
Canopy forming algae	large, erect macroalgae forming a distinct sub-canopy space - *Ecklonia radiata* and *Macrocystis pyrifera*.	(as above)
Other macroalgae	Brown fucoid and laminarian macroalgae over 35cm, including *Marginariella boryana*, *Xiphophora chondrophylla maxima*, *Carpophyllum* spp., *Cystophora* spp., *Sargassum sinclairii* and *Lessonia variegata*	(as above)
Encrusting filter-feeders	**Sessile, plankton feeding fauna.** Includes sponges, ascidians, coelenterates, tube-forming polychaetes and attached bivalves.	(as above)
Mobile fauna:		
Echinoids		Very abundant (>25), abundant (3-25), present (1-2), absent
Gastropod grazers	Only larger species not requiring close-up searching were recorded (i.e. *Turbo* spp., *Trochus viridis*, *Cantharidus* spp., *Haliotis* spp., *Scutus breviculus*, *Cellana* spp., *Maurea* spp.)	(as above)
Benthic carnivorous fish	*Cheilodactylus spectabilis*, *Coris sandageri*, *Latridopsis* spp., *Notolabrus* spp., *Pagurus auratus*, *Parapercis colias*, *Parika scaber*, *Pseudolabrus miles*, *Upeneichthys lineatus*	Very abundant (>4), abundant(2-3), present (1), absent
Planktivorous fish	*Caesioperca lepidoptera*, *Chromis dispilus*, *Decapterus koheru*	(as above)
Herbivorous fish	*Girella tricuspidata*, *Odax pullus*, *Parma alboscapularis*	(as above)

FIGURE 2.

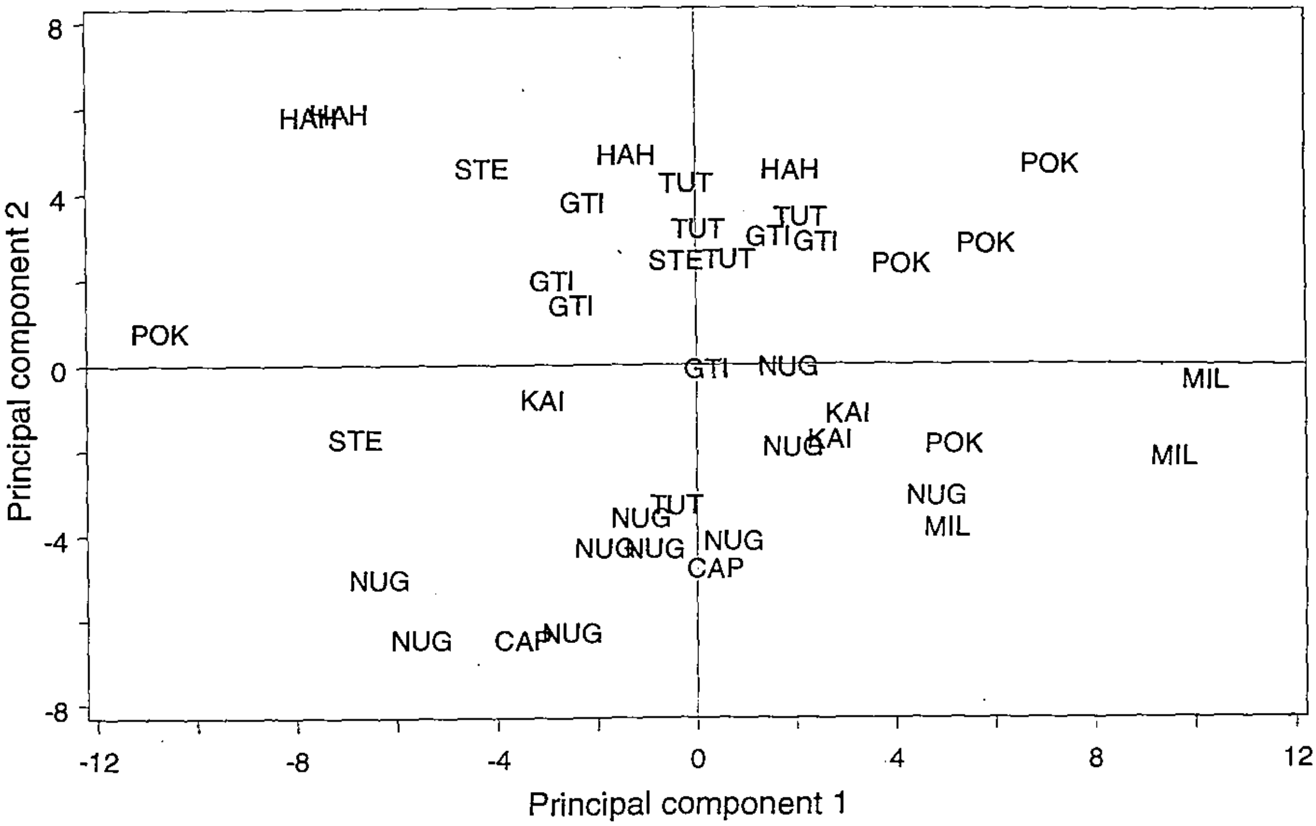


FIGURE 3. Ordination of sites: 1st two principal components.

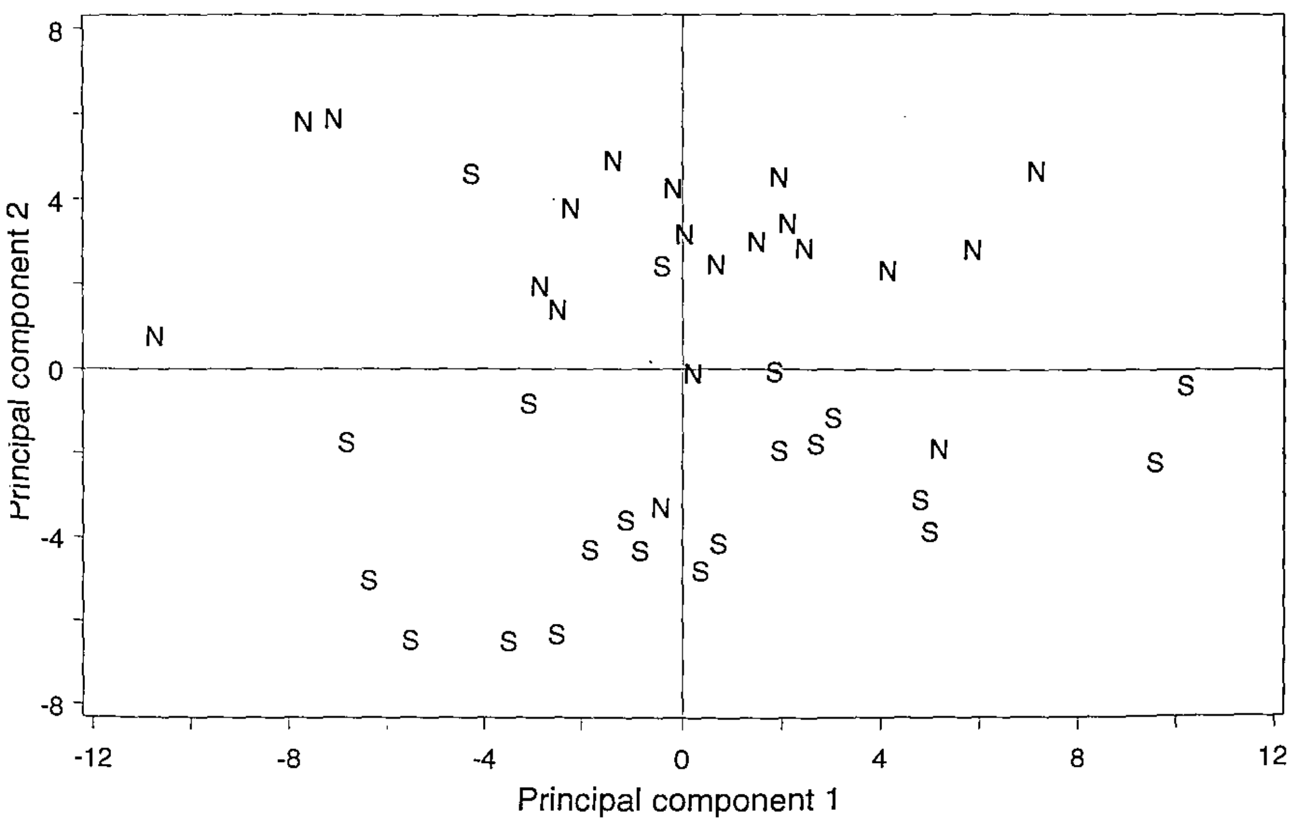


FIGURE 4. Ordination: 1st two principal components: North and South Islands

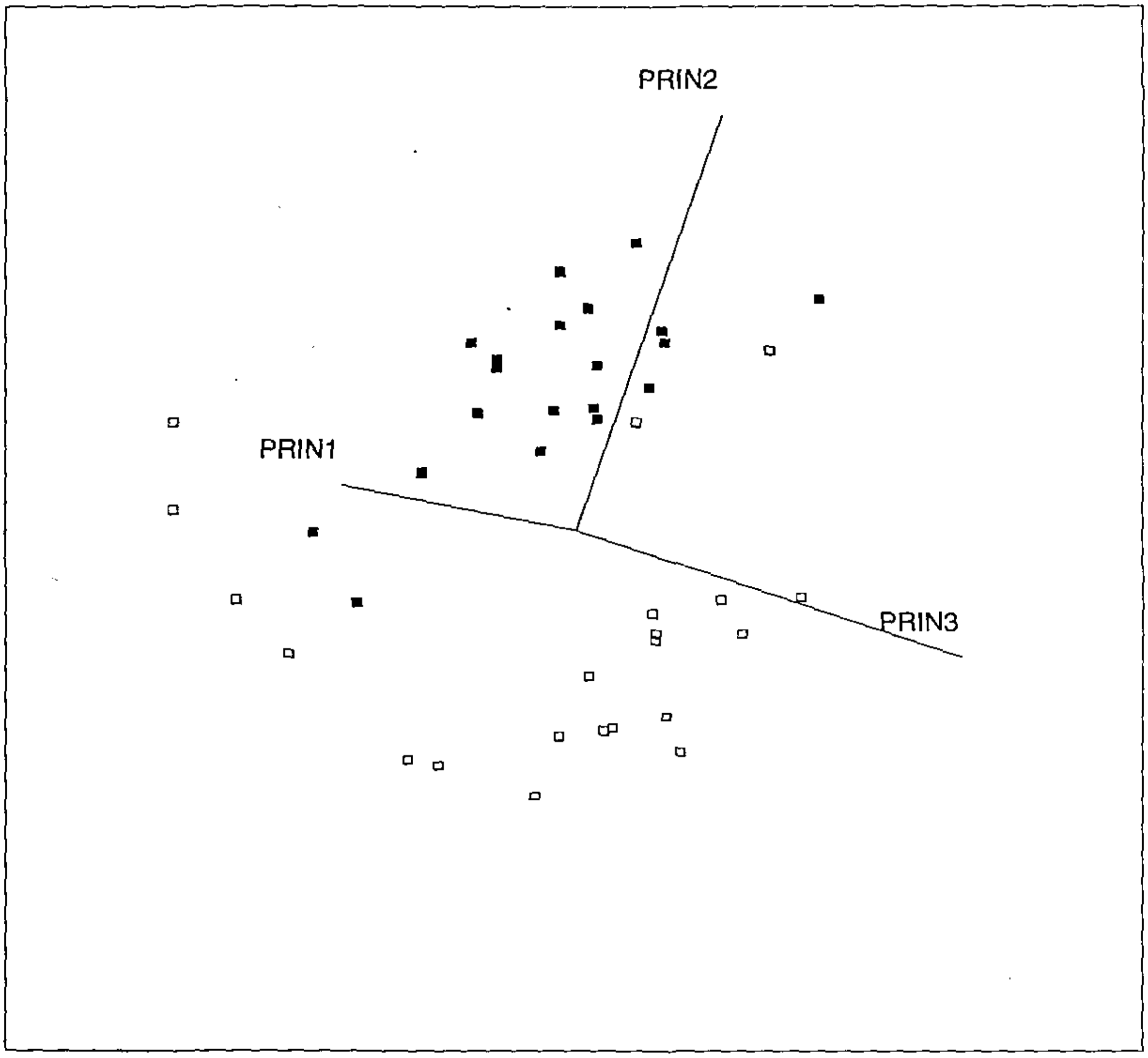


FIGURE 5. Ordination. 1st three principal components (rotated in a brush-and-spin program). Empty squares South Island. Filled squares North Island.

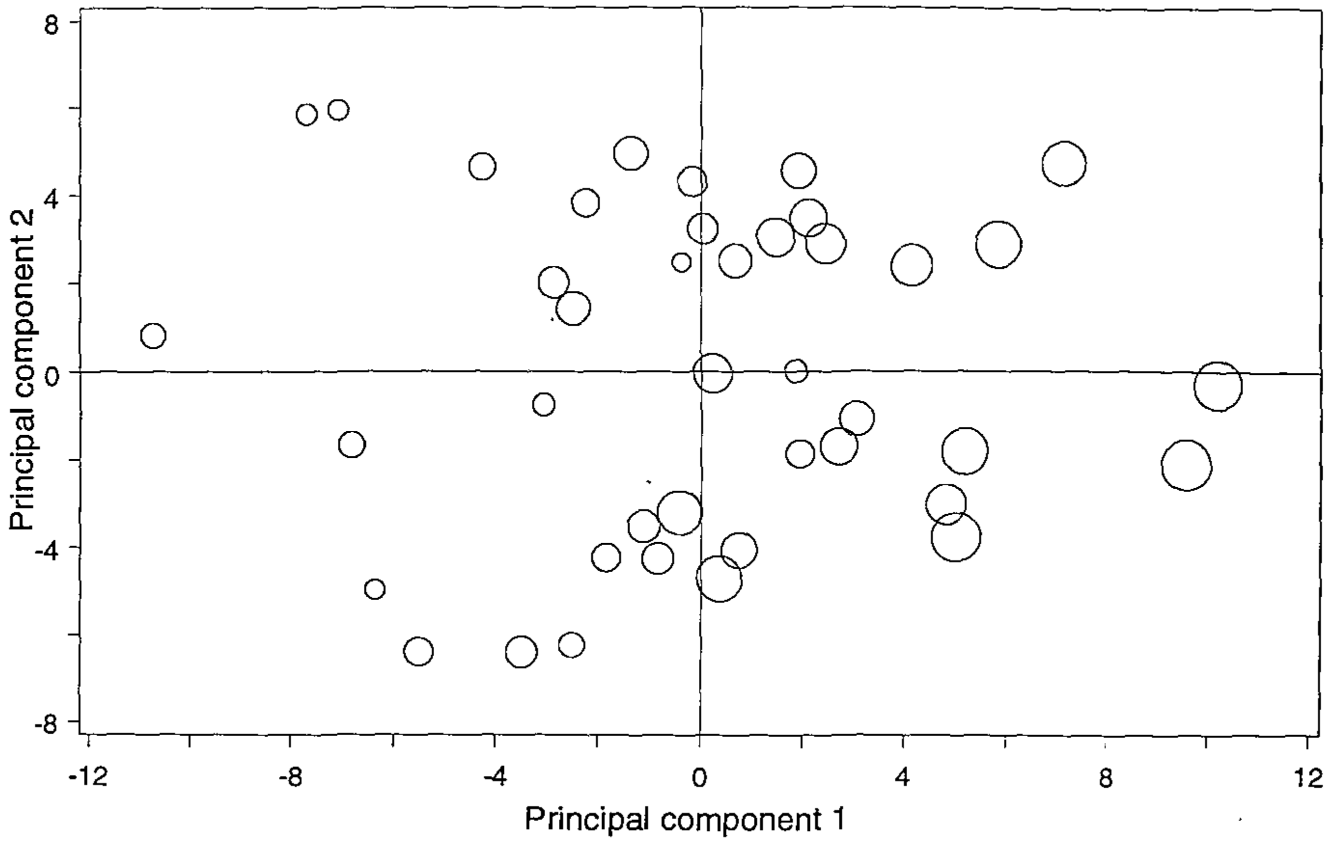


FIGURE 6. Ordination bubble plot. 1st two principal components: Average depth.

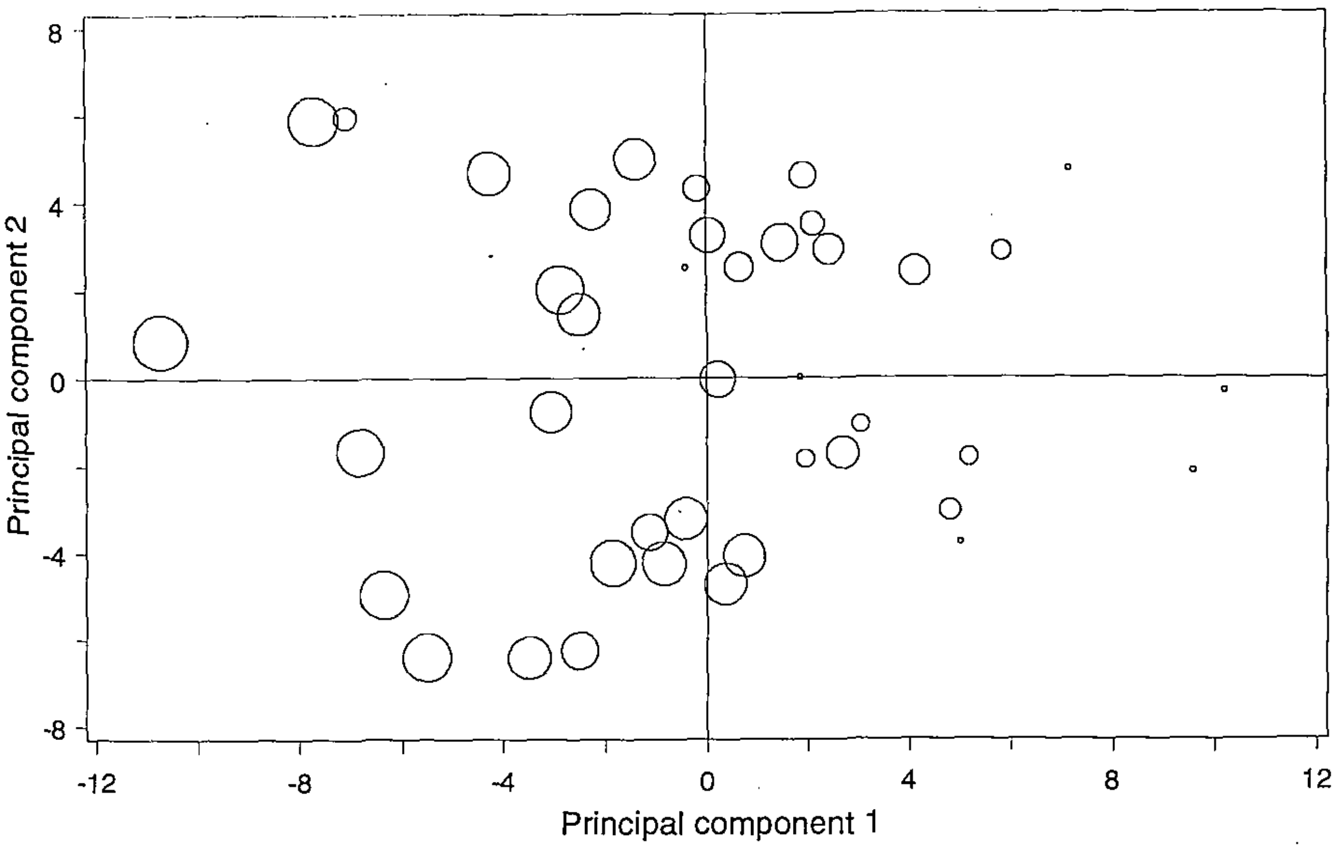


FIGURE 7. Ordination bubble plot. 1st two principal components: Horizontal aspect.

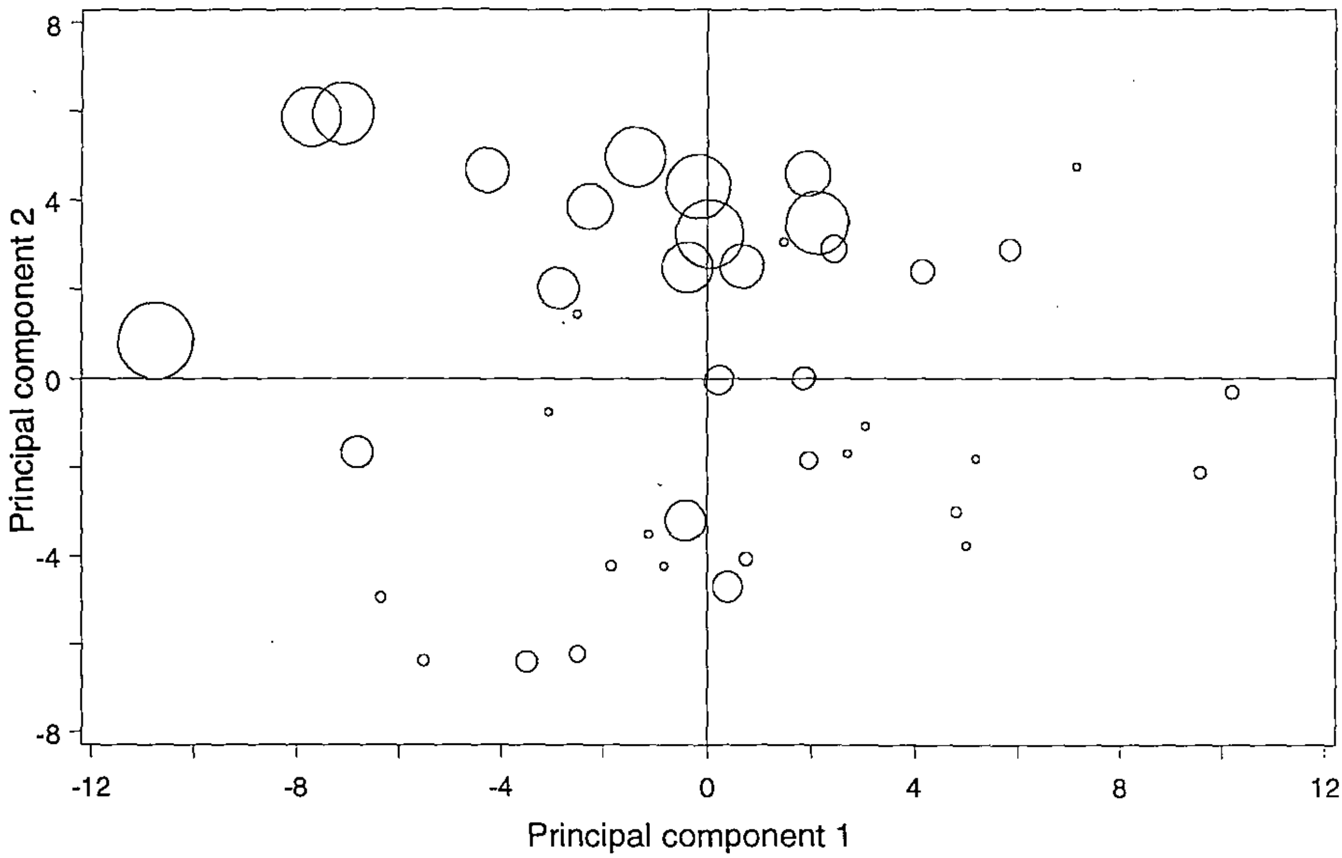


FIGURE 8. Ordination bubble plot. 1st two principal components: Grazing gastropods.

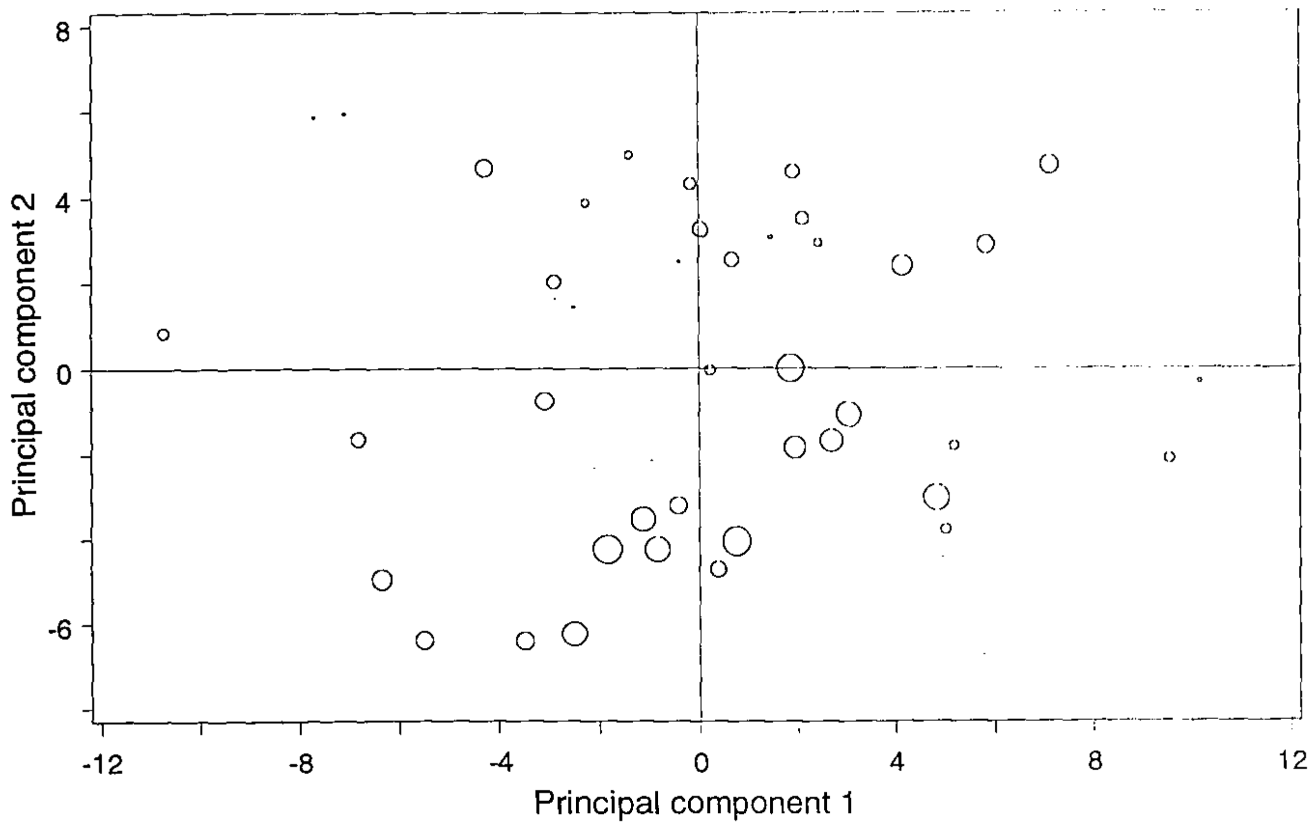


FIGURE 9. Ordination bubble plot. 1st two principal components: Turfing Algae.

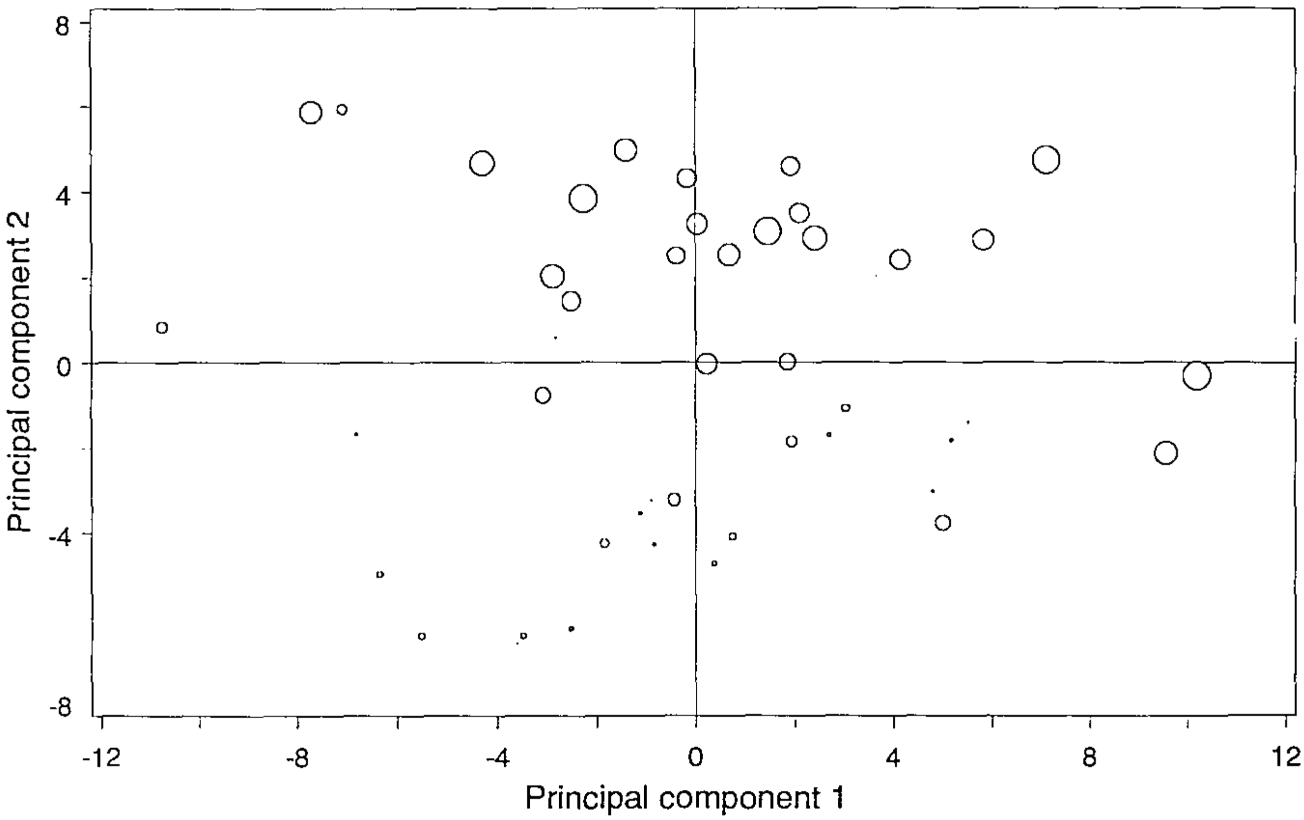


FIGURE 10. Ordination bubble plot. 1st two principal components: Coralline paint.

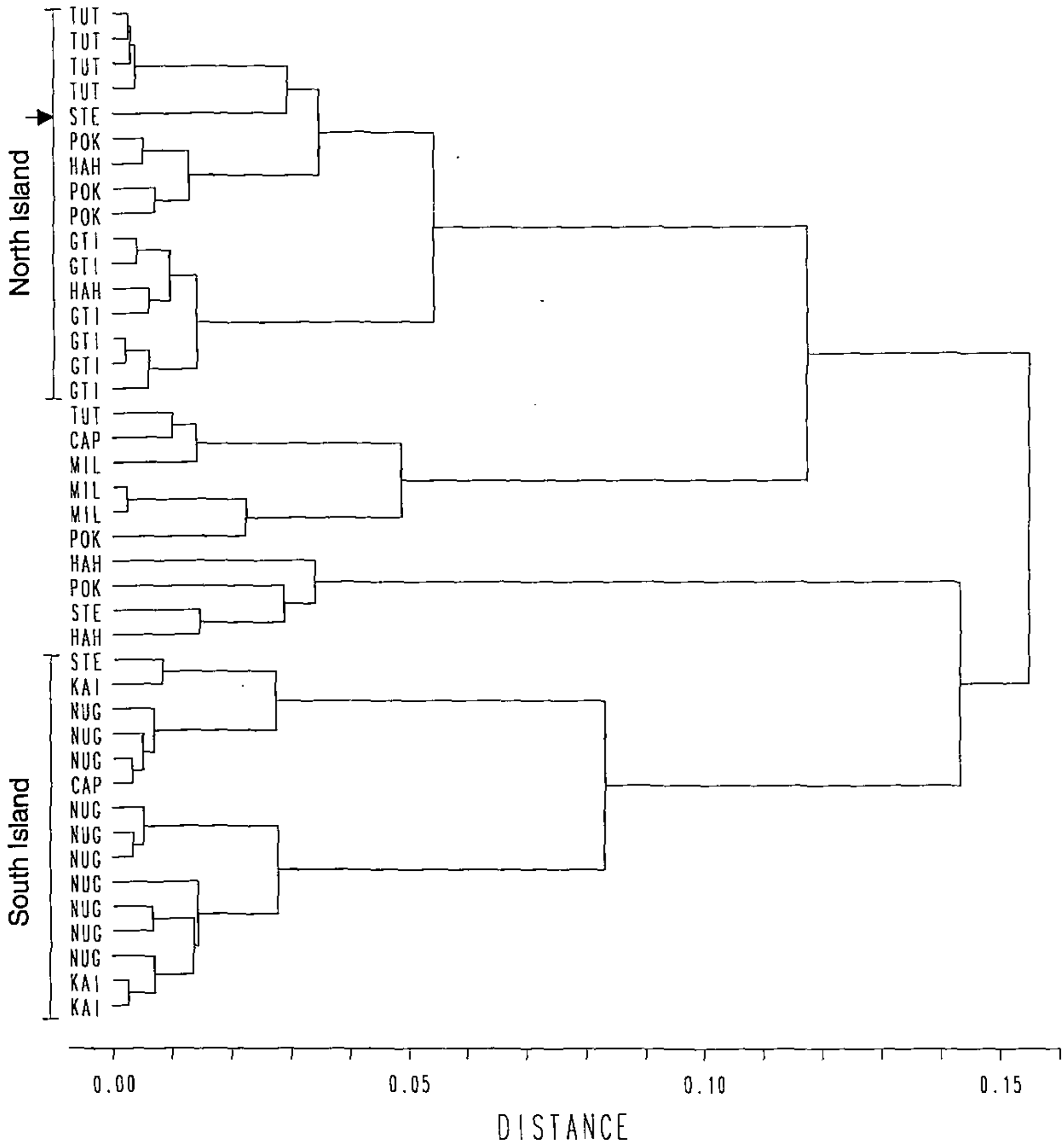


FIGURE 11. Classification. Dendogram derived by Wards method.

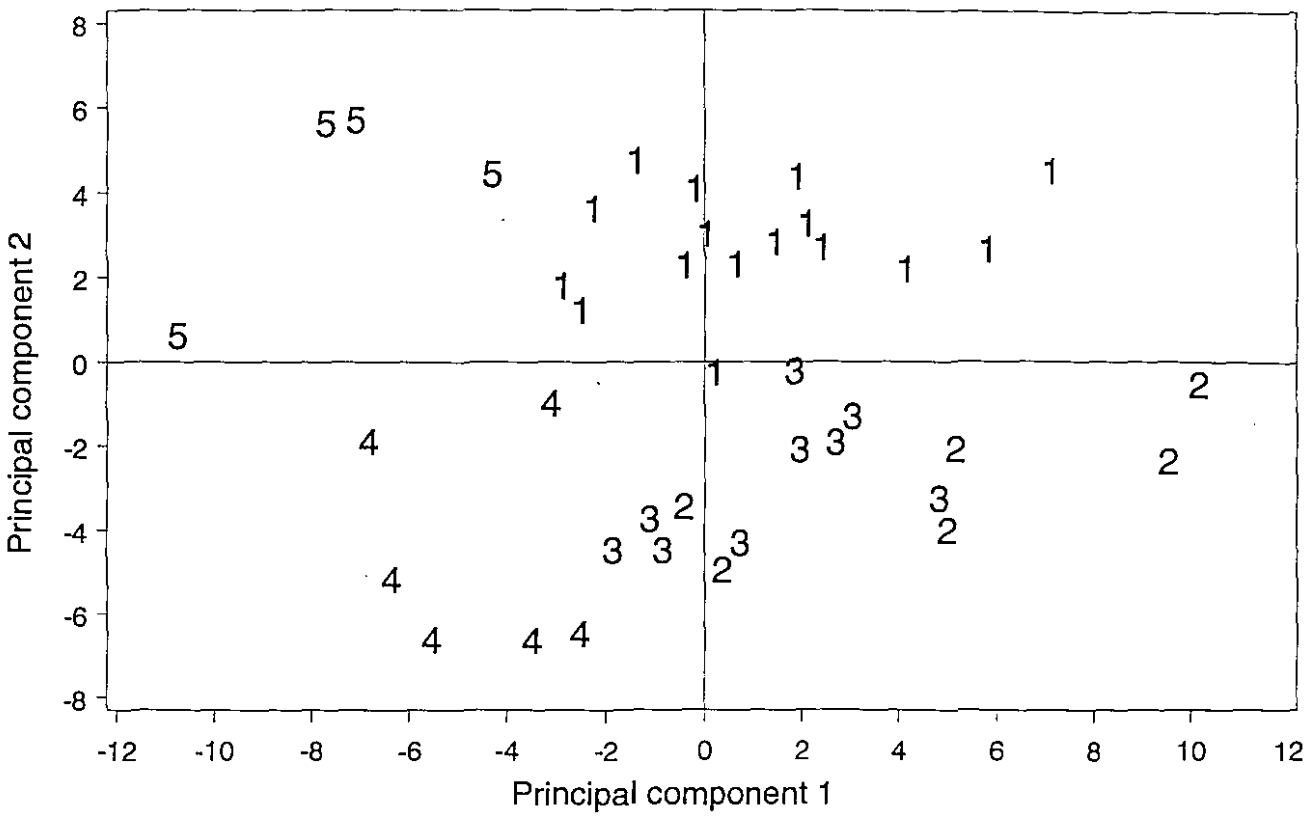


FIGURE 12. Ordination: classification superimposed

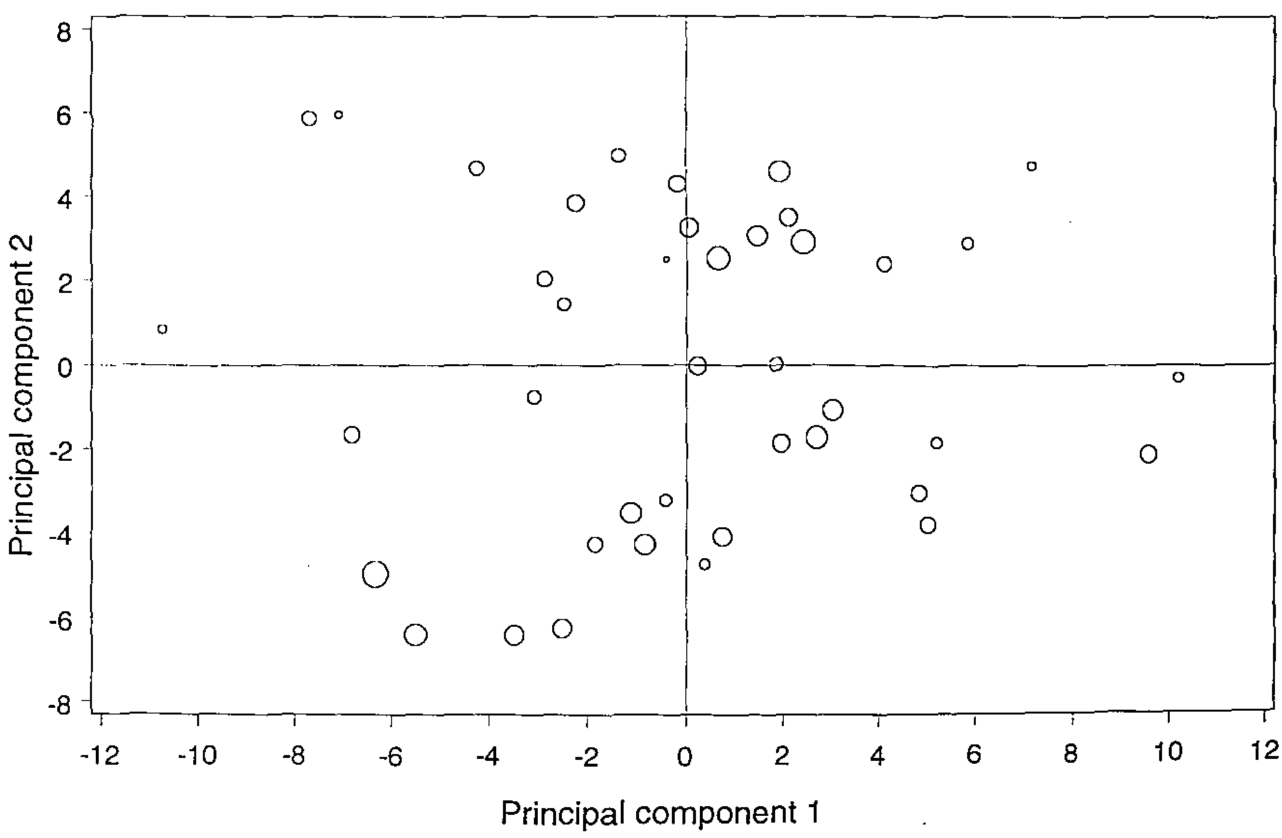


FIGURE 13. Closeness to centroid

Table 3.7: Cluster means for all sites
Means of clusters of k-means clustering of sites. (For definition of categories see Table 3.2)

Cluster	Freq	Depth	Horiz	Slope	Wall	Rock	Sed	Cobb	Bould	Meso-structures	Macro-structures	Canopy
1	16	6.18	3.08	5.26	1.42	8.18	0.93	0.19	0.27	0.49	0.38	2.56
2	6	10.94	1.95	1.78	5.81	6.36	2.58	0.23	0.82	0.33	0.14	1.10
3	9	5.18	3.12	4.99	3.48	8.59	0.87	0.27	0.45	0.79	0.43	1.99
4	6	3.24	5.98	2.96	2.20	5.26	4.64	0.17	0.20	0.44	0.40	2.00
5	4	2.71	5.89	4.52	0.51	2.58	0.56	1.03	6.63	0.94	0.28	3.73

Bare	Corr Paint	Turfing Algae	Encr. Filterfeed.	Macro-algae	Canopy-algae	Echinoids	Gastropods	Omnivore	Planktivore	Herbivore
0.94	4.53	1.54	2.79	1.13	2.67	2.06	1.92	1.41	0.34	0.15
1.94	2.66	1.39	4.11	0.13	0.45	0.51	0.49	0.77	0.84	0.12
0.88	0.55	6.63	2.99	2.68	0.00	0.55	0.11	1.04	0.00	0.30
4.11	0.50	3.51	0.64	2.61	0.80	0.12	0.31	1.15	0.00	0.27
1.18	2.97	1.01	1.28	3.38	2.50	2.20	4.09	3.34	1.01	0.86

Cluster summary:

Cluster	Sites	Characteristics
1	Tutukaka a-d; Goat Island all; Hahei a,c; Poor Knights a-c; Stewart Island b	Coralline paints dominate, Canopy algae common, Echinoids, Gastropods, Omnivorous fish
2	Tutukaka e, Poor Knights d, Cape Saunders y, Milford Sound all	Steep profile, deep reefs, little canopy, coralline paint and encrusting filter feeders; omnivorous and planktivorous fish abundant
3	Kaikoura a, d; Nuggets j, p-v	Turfing algae dominate, macro algae but no canopy forming algae; planktivores are absent
4	Kaikoura c; Cape Saunders z, Nuggets c, d, m, Stewart Island c	Mostly shallow, level reefs, with many sediment patches; some turfing and macroalgae; no planktivores
5	Hahei b, d; Stewart Island a, Poor Knights e	Shallow boulder reefs; Dense cover of macro and canopy forming algae, coralline paint, gastropods; omnivorous fish dominate

PAPERS PRESENTED

Session 4
DATA OPTIONS

CAMRIS, NATMIS, and AGSO Coastal and Marine Information Systems

Neil T. M. Hamilton, K. D. Cocks *(CSIRO)*,
J. Busby *(ERIN)*, and R. V. Burne *(AGSO)*

INTRODUCTION

Several scientific organisations at the federal level have developed coastal and marine information systems. Some have a small scale, national level approach, while others are more focussed on specific issues or locations. Each has goals defined by the relevant organisation, but a growing degree of collaboration between agencies has raised the possibility of synergistic associations and outcomes. One such association has developed in the fields of bio- and geoscientific regional planning of the coastal zone, involving the CSIRO Division of Wildlife and Ecology, the Environmental Resources Information Network (ERIN) and the coastal geoscience unit of the Australian Geological Survey Organisation (AGSO). Other collaborations are being actively encouraged with the knowledge that no one agency has the expertise or information to fully explore the possibilities or implications of large spatial modelling exercises. This paper outlines the aims and roles of the CAMRIS (Coastal and Marine Resources Information System), NatMIS (National Marine Information System), and AGSO coastal GIS projects, and describes some of the data sets and projects being undertaken.

CAMRIS

Background

CAMRIS is being developed by several research divisions of the CSIRO as part of a major multi-divisional initiative, the Coastal Zone Program. It is based at the Division of Wildlife and Ecology in Canberra, and includes contributions from the divisions of Soils, Fisheries, Oceanography, and others. The initial goal of the CAMRIS project is to demonstrate that a small scale national maritime spatial analysis system can be usefully used to support the management and allocation of Australia's coastal and marine resources. Attainment of this goal is being achieved via demonstration projects for several selected resource management issues, through application of alternative methodologies and policy options.
CAMRIS is an evolutionary development from "Coastal ARIS", the onshore coastal zone component of the Australian Resources Information System (Cocks et al., 1988). Coastal ARIS was based on an inventory exercise using 1:40,000 aerial photographs around the entire coastline of Australia in the early 1980s by Galloway et al. (1984) in the CSIRO Division of Water and Land Resources. The move to develop CAMRIS arose from the perceptions that ARIS had been successful in providing useful analy-

sis of land-based issues, and that a number of important coastal zone issues would similarly benefit from spatial analysis techniques. Nearshore and offshore resource management issues are still not as public as onshore or hinterland issues, but have been receiving relatively more attention in recent years. Two issues which stand out are overfishing of various commercial species, the threat of land-based sources of pollution to marine fauna and ecosystems such as seagrass, corals, etc.

An early benefit of the CAMRIS project has been the raised awareness of the existence, themes, and coverage of maritime spatial data sets in Australia (Abel et al., 1992). Digital spatial data is expensive to produce and is commonly regarded by its custodians as something to be retained in house for competitive reasons, or to be bartered or sold on a cost recovery or profit making basis. Not all data sets are publicly available, or available at reasonable cost, so identification of relevant data sets is crucial to the project.

CAMRIS has been established as a software and hardware independent entity in an effort to maximise the utility of the data sets and to take advantage of the varied analytical capabilities of different computers and packages. Currently, CAMRIS is using the SPANS geographic information system software running under the Unix operating system on an IBM RS6000 platform. SPANS is a technically advanced GIS with particular emphasis on spatial modelling, for example the capability to address multiple map, attribute, and vector coverages simultaneously, and an ability to calculate solutions for functions with arguments from disparate data sets.

Packages for performing a number of other analytical operations are also available for use in CAMRIS. These include the commercial S-Plus software system for aspatial statistical and exploratory data analysis, and two packages developed in house, namely PATN for multi-variate classification, association, and ordination (Belbin, 1987), and LUPIS for land use / sea use allocation (Ive, 1992). The latter two allow both positive and normative regionalisation tasks to be undertaken (Cocks and Walker, 1987). LUPIS is an established package which allows sub-areas to be differentially allocated between candidate uses or management regimes on the basis of how well alternative allocations collectively satisfy an a priori set of allocation guidelines. The forerunner software to LUPIS, called LUPLAN, was used to demonstrate the production of infromation-rich zoning plans for the Cairns section of the Great barrier Reef Marine Park (Cocks, 1984). Other analytical packages which may be used in CAMRIS exercises include the HABITAT (Walker and Cocks, 1991) and SIMPLE (Walker and Moore, 1988) inductive techniques for modelling disjoint environmental envelopes for species, and the DIVERSITY (Walker and Faith, 1993) package for assessing optimal phylogenetic and environmental diversity sets for particular areas.

Data Sets

The list which follows outlines the Australia-wide data sets held within CAMRIS at the present stage, but is supplemented by a number of local and incomplete coverages which may be used in future studies.

1. Coastal ARIS.

The Coastal ARIS spatial database contains data of two types: section, and point. The section data describes 3027 sections 10km long and 3km (or as far inland as Holocene sediments extend) wide around the entire coast of Australia. Attributes include shoreline characteristics, geology, landforms, and vegetation. Point data comprises 41,721 individual points, approximately 1 per 3km2, each attributed with detailed vegetation, lithology, geomorphology, and land use.

2. Coastline and Australian Fishing Zone
   The AUSLIG 1:100,000 coastline and AFZ boundary files are used in many CAMRIS exercises.
3. Bathymetry
   CAMRIS contains digital contours at depths of 20m, 50m, 100m, 150m, 200m, 250m, and 300m around the entire continent, digitised from the 1:250,000 scale bathymetric series maps. Deep water bathymetry is extracted from a 5 minute global digital elevation model (ETOPO5), and is supplemented in certain areas by detailed bathymetric surveys carried out by the Royal Australian Navy. A typical CAMRIS exercise uses abathymetric point data set of over 600,000 points. The bathymetric data is perhaps the most important fundamental data set for any marine management system.
4. Drainage Basins and River Networks
   Coastal drainage basins from the Australian Water Resources Council are incor porated in CAMRIS, together with the accompanying water resource and useage data. The drainage network is at present being built at a scale of 1:250,000 for each basin.
5. Oceanographic Parameters
   Data sourced from NOAA and CSIRO Oceanography includes instantaneous and long term mean annual, seasonal, and monthly values at up to 33 standard depths for temperature, salinity, oxygen content and saturation, density, at a minimum density of 1 degree average values.
6. Nutrients
   CAMRIS includes the entire ocean nutrient spatial database compiled by CSIRO Oceanography.
7. Substrates
   Substrate maps for the Australian region, produced by the Ocean Sciences Institute (University of Sydney) are available digitally in CAMRIS. Detailed mapping of shallow marine and continental shelf substrates is underway, and will be completed as funds permit.
8. Estuaries
   CAMRIS incorporates the Australian Estuarine Database, which includes the National Estuaries Study (Bucher and Saenger, 1989). Attributes include location, name, climatic parameters, run-off co-efficients, land use, flood frequency, water quality, habitat types, sea grass and mangrove occurrence by species, fisheries/conservation/amenity values, administration, literature, threats, etc.
9. Wetlands
   Several wetlands databases are inclded in CAMRIS. Paijmans et al., (1985) is regarded as the most useful, and has been recoded to reflect the Galloway et al.,

(1984) sections. The ANCA National wetlands data set has recently been acquired.

10. Climate

Coastal climatic variables (Booth et al., 1988) including a large variety of standard temperature and rainfall parameters have been coded to the Coastal ARIS sections. Wind data, as modelled by Laughlin (1990) are accessable.

11. Soils

The digital version of the Northcote soils atlas is available to CAMRIS. Further work is in progress to determine and implement a morphostratigraphic mapping approach around the coast by the Division of Soils.

12. Geology and Geotechnics

The 1:2.5 million geological map of Australia is available, as is the Grant et al. (1984) geotechnical map (digitised in collaboration with NRIC).

13. Topography

The AUSLIG 2.5 km digital elevation model spot heights is available.

14. Gazetteer

The AUSLIG Gazetteer is available

15. Vegetation

The presettlement (1788) and 1988 Carnahan vegetation maps are incuded in CAMRIS

16. River Hydrographs

A database of mean annual flows for major rivers (Finlayson and McMahon, 1988) has been included.

17. Mineral Deposits

The MINLOC deposit occurrence database was purchased from AGSO and has been incorporated into CAMRIS. A database of coastal and offshore deposits, including placers, phospates and manganese nodules, has been built up from a variety of sources.

18. Tides

The Australian National Tide Tables (RAN, 1992) have been incorporated into CAMRIS.

19. Cyclones

All cyclone information collected by the Bureau of Meteorology from 1980 to 1990 has been acquired. Attributes include name, 6 hourly location, and pressure at the eye. Derived attributes in CAMRIS include cyclone density and cyclone hazard.

20. Storm Surge

A number of storm surge models have been developed for the Australian coast. A combination of these has been incorporated in the CAMRIS physical process model.

21. Storms

A historic storms database has been acquired from NOAA, and will be incorporated into the CAMRIS coastal process model.

22. Waves

A complete Australia wide database of long term shallow water wave rider records has been developed by CAMRIS. Deep water wave information has been derived from the GeoSat radar altimeter data set, and includes mean significant wave height, variability, and long term exceedence characteristics.

23. Seagrasses

A unique Australia wide coverage of seagrass distribution has been developed by the CSIRO Division of Fisheries for inclusion in CAMRIS. Detailed mapping is continuing and is being included as available.

24. Petroleum Titles and Sedimentary Basins

The Australian Geological Survey Organisation petroleum titles / sedimentary basins coverages have been acquired for CAMRIS.

25. Beaches

Information about Australia's beaches is being acquired under collaborative arrangements from two sources: the Coastal Studies Unit (University of Sydney) beach safety and management program, and the Surfrider Foundation. The former covers various physical parameters including location, sediments, waves, evolution, and other beach characteristics, while the latter describes beach pollution and development, and beach usage on the most heavily used areas.

26. Population and Administrative Boundaries

Four consecutive census data sets (1971 1986), by census collectors district, have been tied to CAMRIS coastal sections. Demographic regions (Cocks et al., 1988) and local government boundaries are also held.

27. Marine Protected Areas

The current MEPA database has been obtained from ERIN as part of a collaborative research agreement.

28. Birds

As part of a research agreement with the Royal Australian Ornithologists Union, CAMRIS now holds the RAOU bird atlas.

29. Regionalisations

A variety of physical regionalisations have been incorporated into the CAMRIS system, including MacDonald Holmes (1944), Gill (1974), Yapp (1986), CONCOM (1986) and others.

30. Literature

An important component of the CAMRIS system is the introduction of published material into a GIS framework for decision support. At present, over 2500 references covering a wide variety of topics relevant to coastal and marine management are being incorporated, allowing spatial and keyword searching.

Candidate Projects

Four questions usually arise when attempting to apply a spatial analysis system for operations or policy support:

1. What issue is to be addressed?;
2. What goals are sought in relation to this issue?;

3. What type of regionalisation would allow the benefits and disbenefits of alter native programs for achieving those goals to be compared?; and
4. What spatial or other data is needed to produce such a regionalisation?

The starting point for CAMRIS has been a list of twenty significant maritime resource management issues compiled for an Ecologically Sustainable Development working group on coastal issues (Cocks and Crossland, 1991). These are listed in Appendix 1, together with an exemplary policy position for each which a government sensitive to both economic and environmental values might take. There is no suggestion that these policy positions are the only ones which may be taken, or even that they are especially commendable. Their role is to cue the types of regionalisation which CAMRIS may be asked to provide.

Four tasks have been selected as initial applications of CAMRIS. They are (a) selection of candidate sites for marine protected areas; (b) identification of priority areas for management of land-based sources of marine pollution; (c) planning for coastal population growth; and (d) assessment of the synoptic impacts of climatic change in the coastal zone. Each of these issues is described in some detail by Hamilton and Cocks (1993). In brief, some preliminary work has been performed on the coastal zone population growth project (McDonald et al., 1993), and a substantial amount of research has been undertaken to determine appropriate strategies for the conservation of maritime biodiversity through marine protected areas. Preliminary work on assessment of the impacts of climatic change has begun in close collaboration with AGSO.

NatMIS

Background

A number of recent reports have identified the importance of a bioregional planning framework for land / sea use assessment and the development of strategic directions for conservation in the coastal and marine realms. However, as a consequence of a lack of basic or accessible data, there has been limited use of spatial information systems for marine environmental management. ERIN's expertise in strategic platform and infrastructure development provides a sound basis for the National Marine Information System, NatMIS. Creation of the NatMIS entity is seen as a natural extension of ERIN's terrestrial work, recognising the land - sea linkages. The process will include the following tasks:

1. identification of existing data;
2. compilation of a data dictionary;
3. facilitation of collation and translation of existing data;
4. co-ordinate development of standards for 4 dimensional marine data;
5. facilitate co-ordination of data collation methodologies and modelling; and
6. address the needs of key programs such as SOMER, OR2000, the National

Coastal Zone Management Strategy and the National Marine Conservation Strategy. NatMIS aims to progress to the level of "core implementation" within 18 months, including tasks 1, 2, 3, 4, and parts of 5. Longer term plans include augmenting key data sets through collaboration agencies, and upgrading of facilities and modelling tools.

It is a fundamental assumption of the NatMIS program that coastal and marine information systems be developed strategically and with a long term view. This will involve the assessment of existing and potential core, minimum and indicator data sets appropriate for the range of queries to be addressed. Core data is that which will be required by many retrieval, display and analysis tools. Minimum data are those attributes which collectively describe an environment sufficiently to allow other characteristics to be predicted. Indicator data are commonly sought to underpin environmental monitoring, modelling, and state of the environment reporting. Candidates for each data type are discussed below.

Core Data Sets

The following is a preliminary list of core data sets required by NatMIS.

Core data - Minimum sets

1. Coastline
2. 3 and 12 nautical mile limits
3. Economic Exclusion Zone boundary
4. Bathymetry
5. Temperature, sea surface and depth profile
6. Salinity, sea surface and depth profile
7. Oxygen, sea surface and depth profile
8. Currents, sea surface and depth profile, direction, velocity, temporal variability
9. Nutrients, nitrate/nitrite, phosphate, silicate, sulphate
10. Transparency
11. Substrate type
12. Climate, national and world
13. Tides
14. Waves, including height, frequency spectrum, exceedence
15. Coastal drainage hydrology
16. Vegetation
17. Soils
18. Geology
19. Landforms

Core data - Important

1. 1;250,000 map sheet index
2. State boundaries
3. Built up areas
4. LGA / SLA areas
5. Water features
6. Transport routes
7.Marine traffic
8.Nature conservation / managed areas tenure
9. Storm and cyclone frequency and intensity

Important data

1. Coastal and marine mining / exploration areas
2. Pollution, land based point sources
3. Sea dumping grounds

4. Ballast water discharge area
5. Landuse
6. Shipwrecks
7. Upwelling areas
8. Mangroves
9. Wetlands
10. Commercial fisheries
11. Mariculture developments
12. Wolrd heritage areas
13. Biosphere reserves
14. Aboriginal and Torres Strait Islander tenure / communities, sites of significance
15. Water supply reserves
16. Meteorological districts
17. Introduced "pest" species distribution

Interpreted data

1. beach type
2. Galloway data
3. Sea bird distribution
4. Sea mammal sightings
5. Seagrass distribution
6. Photosynthetic activity
7. Estuarine resources
8. Biophysical regions
9. Marine biodiversity
10. Threatened and endangered species distributions

Current Activity

ERIN is in the process of appointing a NatMIS co-ordinator to further develop the framework already in place. Rapid progress through collaboration with other coastal and marine GIS agencies incuding CSIRO and AGSO is anticipated.

AGSO COASTAL GEOSCIENCE

Background

A review of AGSO undertaken by Richards in 1993 was highly supportive of the role of AGSO and the relevance of the geosciences to two of the dominant concerns in society - the desire for economic prosperity, and preserving a worldfit to live in. In highlighting this, he firmly linked geoscientific research andinformation to the sustainable land use and environment protection debate. The report made a number of key recommendations to which the government responded favourably in the 1993 Budget. These included providing increased funding to accelerate the National Geoscience Mapping Accord (NMGA) and theContinental Margins Program. Two new programs were also funded - a program of environmental geoscientific mapping and Environment program, modelled on the NGMA, called the National Environmental Geoscientific Mapping Accord (NEGMA), and a National GeoscienceInformation System program (NGIS).

Richards envisaged the National Geoscientific Information System as the "hub"of a series of interconnected physical and electronic geoscientific data holdings in other Commonwealth and State agencies, CSIRO, universities and industry. The primary aim was to maximising accessibility for all government, business,research and community users. AGSO is currently working on defining a vision and strategy for the new information program. A primary outcome of the program will be an operating Australian National Geoscientific Information System (or ANGIS). Other outcomes might include further funding for the digital capture and archiving of priority geoscience data collections. To achieve this, AGSO will be consultingwidely on what is required, and priorities for development.

It is already clear that as a national information system ANGIS must have thefollowing capabilities:

- . universal access
- . a user/ query analysis system
- . a metadata system
- . a wide area network
- . electronic data storage and physical data collections.

Data Sets

AGSO has a number of mature databases which are relevant to coastal and marine information systems, which could be made available on an up-to-date basis, via electronic networks. These include attribute and standards databases:

Stratdat - interpretive biostratigraphic data relating fossil zones to absolute time scales

PEDIN - national Petroleum Exploration Data Index - magnetic, gravity and well survey data

PORPERM - porosity, permeability, lithology data from on and off-shore wells

Core & cuttings library - 1 250 000 catalogued samples from 5000 wells

Gravity - 60 000 point values over the continent and shelf (11 km grid)

Gamma ray spectrometrics - radiometric imagery aids soil type and water channel definition

Magnetics - as for gamma ray airborne data, has been produced as contour maps

Palaeomagnetics - pole positions, associated geological units, references

Earthquakes - location and details of some 30 000 earthquakes recorded since 1859

Quaternary climates - Australian national reference database for bibliography, geochronology, geochemistry, palaeontology, geomorphology

Coastal Zone - bathymetry, morphology, depositional systems, sediment type, and sea level history of the coastal zone

Great Artesian Basin - hydrogeology, chemistry, discharge, temperature & simulation model

MINDEX - Marine data from AGSO continental margins and coastal surveys - seismic, navigation, gravity, magnetic, bathymetric data

NGMA - field mapping data - site, outcrop and lithological data, linked to laboratory analyses

Authority tables for 1:100 000 and 1:250 000 geological maps, rock types, nomenclature

MINLOC - Mineral Occurrence Locations - covers some 20 000 occurrences
ROCKCHEM - whole-rock geochemistry, 30 000 samples of major/minor/trace & ppb data
OZCHRON - isotope geochronology
RTMAP - regolith-terrain mapping database
GEODX - central register of Australian stratigraphic names - full bibliographic references
STRATA - Stratigraphic Authority on names, provinces and geological time terms
PALAEO - fossil collection - over 15 000 type specimens so far - geology, taxonomy etc
AESIS is Australia's largest earth sciences and related environmental bibliographic database, contributed to by AGSO, and maintained by the Australian Mineral Foundation
GIS - a number of datasets have been integrated to form regional or national GIS or spatial coverages, in conjunction with digitised map holdings

Projects

AGSO has been active in coastal geooscience for the past thirty years, during which time it has mapped the continental shelf and has undertaken detailed studies in Broad Sound, Shoalwater Bay,the Great Barrier Reef, Cape York Peninsula, the Gulf of Carpentaria, the North West Shelf, Shark Bay, south western Australia, the Great Australian Bight, Spencer Gulf, the Coorong, Mallacoota, and the coast of New South Wales. The purpose of AGSO's present Coastal Geoscience Project is to provide, as part of the National Geoscientific Mapping Accord, the baseline geoscientific data necessary for integrated management of the Australisan coastal zone, including the impacts of resource use, developmental and recreational pressures, and environmental change. A further aim is to establish sedimentological and geobiological models of relevant Australian coastal systems to facilitate the interpretation of ancient sediments deposited in analogous environments. The agency also has an obligation to develop an understanding of regional variation in Australian coastal-zone geology, to identify where information is inadequate for management needs and, in collaboration with other Commonwealth and State authorities, to design and implement programs of geological mapping and data base development to fill the information gaps.

The corporate SUN GIS server is the ongoing host of the system. The PC based ArcView package has been used to demonstrate the result, and in its next version will be capable of querying Oracle attribute tables or supporting spatial overlays. A copy of some of the databases developed for Petroinfo has been made available to CAMRIS. Hopefully, as concepts such as NGIS evolve, both these data and those in the Coastal Geoscience GIS can be made available up-to-date, through electronic linkages.

The open hardware, software and networking technology adopted by AGSO is deliberately compatible with the approaches taken by other major government agencies in the GIS business - for example ERIN, with its network of environmental information. This common technology in turn allows groups to undertake specialist studies incorporating all relevant layers of information and models, in providing an integrated scientific view of the policy options and their consequences in the major land use / coastal zone questions that increasingly will be faced by all governments and the community, both in Australia and internationally.

Conclusion: Toward a National Multi-Agency System?

CAMRIS, as noted earlier, is being developed in collaboration with the ERIN unit in the Deparment of the Environment and the Coastal Geoscience Unit of the Australian Geological Survey Organisation. This collaboration between the three agencies is a pointer to future work. There is a pressing need to co-ordinate the collection and processing of data, and an even more important need to improve access to this geocoded marine and coastal resource data in Australia. A large number of organisations are active in marine data acquisition or modelling, but most have a narrow focus in either geographic or disciplinary terms. While collaboration always has a transaction cost, the benefits can include better data, better analytical methods and a better contextual appreciation of one's own work.

It would be a useful step towards comprehensive collaboration if the Commonwealth agencies could better co-ordinate their activities. The recent formation of a marine data working group of the Commonwealth Spatial Data Committee creates an opportunity for this to occur. Similarly, enhanced Commonwealth - State relationships at the technical level would assist in the wider application of models and data sets. Both initiatives should promote an awareness of the importance of coastal and marine management and ultimately lead to improved allocation of a finite resource set.

REFERENCES

Abel, D, Cocks, K. D., and McDonald, W. M., 1992. Requirements for a national marine information system for the Environmental Resources Information Network. A consultancy for the Australian National Parks and Wildlife Service by CSIRO Divisions of Information Technology and Wildlife and Ecology.

Belbin, L., 1987. PATN reference manual. CSIRO Division of Wildlife and Ecology.

Booth, T. H., Wood, N. H., and Cocks, K. D., 1988. Cliamte data for coastal gridcells in the Australian Resources Information System. Working Document 88/2, CSIRO Division of Wildlife and Ecology.

Bucher, D., and Saenger, P., 1989. An inventory of Australian estuaries and enclosed waters, 7 volumes, summary report and computer database. Prepared for the Australian Recreational and Sports Fishing Federation and ANPWS.

Cocks, K. D., Walker, P. A., and Parvey, C. A., 1988. Evolution of a continental scale geographic information system. International Journal of Geographic Information Systems, 2, 3, 263-280.

Cocks, K. D., 1984. A systematic method of public use zoning of the Great Barrier Reef Marine Park, Australia. Coastal Zone Management Journal, 12, 4, 324-359.

Galloway, R. W., Storey, R., Cooper, R., and Yapp, G. A., 1984. Coastal Lands of

Australia. CSIRO Division of Land and Water Resources, Natural Resources Series No. 1

Hamilton, N. T. M., and Cocks, K. D., 1993. A small scale spatial analysis system for maritime Australia. CSIRO Division of Wildlife and Ecology Working Document 93/9.

Ive, J. R., 1992. LUPIS: computer assitance for land use allocation. Resource Technology 92, Taipei: Information technology for environmental management.

Paijmans, K., Galloway, R. W., Faith, D. P., Fleming, P. M., Haantjens, H. A., Heyligers, P. C., Kalma, J., and Loeffler, E, 1985. Aspects of Australian wetlands. CSIRO Division of Land and Water Resources Technical Paper No. 39.

Walker, P. A., and Cocks, K. D., 1991. HABITAT: a procedure for modelling disjoint environmental envelope for a plant or animal species. Global Ecology and Biogeography Letters, 1, 108-118.

Walker, P. A., and Moore, D. M., 1988. SIMPLE: an inductive modelling and mapping tool for spatially oriented data. International Journal of Geographical Information Systems, 2, 4, 347-363.

Appendix 1: Coastal zone issues and candidate policy positions

Issue 1. Protection and utilisation of major coastal ecosystems including coral reef systems, seagrasses, kelp beds and mangroves

Policy: As far as possible, protect or conservatively utilise all occurrences of major coastal ecosystems.

Primary analysis task: Map all occurrences of major coastal ecosystems.

Issue 2. Co-ordination and rationalisation of activities of government agencies with responsibilities in the coastal zone

Policy: As far as possible, ensure that coastal zone activities take place within the framework of a state-wide coastal zone management plan.

Issue 3. Allocation and management of coastal zone areas with high conservation and/or use values

Policy: As far as possible, ensure that areas of high conservation value are protected and that areas of high use value are made available to user groups.

Issue 4. Pollution in the coastal zone

Policy: As far as possible, ensure that major pollution sources and sinks are identified and then managed to minimise pollution levels, particularly in areas of high conservation and/or use value.

Issue 5. Coastal surveillance for defence, customs and quarantine purposes

Policy: As far as possible, identify and monitor coastal areas regarded as important under a `risk management' approach to coastal surveillance.

Issue 6. Designation and management of marine and estuarine protected areas

Policy: As far as possible, include all areas regarded as moderately to highly suitable for this purpose in a co-ordinated reserve system.

Issue 7. Identification, planning and management of offshore areas, from near-coastal to the AFZ

Policy: As far as possible, identify major potential demands on the AFZ and attempt to make attractive areas available for the satisfying of those demands; alternatively, attempt to ensure that such areas are not sterilised by dedication to a pre-emptive use.

Issue 8. Demographic pressure on the coastal zone, including the size and location of coastal settlements

Policy: As far as possible, restrict urbanisation to existing settlements and minimise longshore expansion of existing settlements.

Issue 9. Tourism and recreation in the coastal zone

Policy: As far as possible, ensure that the full recreation and tourism carrying capacity of the coastal zone is exploited but not over-exploited.

Issue 10. Species conservation in the coastal zone

Policy: As far as possible, identify and locate rare and/or endangered coastal species and develop management plans for their protection.

Issue 11. Public and private interests in the coastal zone

Policy: As far as possible, decisions on the allocation of coastal resources should balance public and private interests.

Issue 12. Risk management in the coastal zone

Policy: As far as possible, locate coastal activities so as to minimise risk of major damage from natural disasters.

Issue 13. Fisheries management

Policy: As far as possible, identify sustainable yields for major fisheries and develop management plans for ensuring conformity to these.

Issue 14. Prospects for mariculture

Policy: As far as possible, identify prospective maricultural industries and potential sites for these industries and take action to ensure their continuing availabilty for maricultural purposes.

Issue 15. Degradation of coastal wetlands and coastal landforms

Policy: As far as possible, identify wetlands and landforms suffering significant actual or potential degradation and options for slowing or ameliorating such degradation.

Issue 16. Mining in the coastal zone and offshore

Policy: As far as possible, prospective areas for mining should remain available for that purpose.

Issue 17. Infrastructure, industry and engineering practice in the coastal zone

Policy: As far as possible, infrastructure in the coastal zone should be designed to minimise ecosystem disturbance as well as carrying out its intended function.

Issue 18. Appropriate technologies for coastal zone activities

Policy: As far as possible, technologies selected for implementing coastal activities should be environmentally benign.

Issue 19. EIA procedures for coastal development proposals

Policy: As far as possible, all coastal development proposals should be subjected to an EIA process which is sensitive to a wide range of social and environmental impacts and to the regional context of the proposal.

Issue 20. Impact of climatic change

Policy: As far as possible, coastal areas likely to suffer major impacts under climatic change should be identified and options for their management developed.

Information Available from the Bureau of Resource Sciences for the Development of an Australian Marine Biogeographic Regionalisation

Russell Reichelt and Julie Bowyer
Bureau of Resource Sciences,
Parkes ACT

ABSTRACT

The Bureau of Resource Sciences (BRS) does not hold extensive marine resource data sets but does have access to a range of resource datasets held elsewhere in the Department of Primary Industries and Energy. The Bureau's National Resource Information Centre (NRIC) has the technical capability to process spatial data efficiently and to model regionalisations.

Within the DPIE portfolio there is a range of marine information maintained in numerous databases. The information includes:

In BRS

- Catch statistics for Commonwealth managed fisheries (prawns, tuna, demersal scale fish);
- location of oil wells (and data associated with each well)
- information on the coverage of seismic surveys
- information on petroleum fields (potential and developed)
- some bottom sediment data

In AGSO

- geochemical attributes of water ('sniffer' data)
- some grab sampling of sediments
- bathymetry data associated with the Offshore Resource Map Series.

Some of these data are subject to confidentiality constraints, particularly those where industry activities are recorded. However information can often be released if it is aggregated to some level that protects individual operator's privacy.

NRIC's database management system NDAR allows metadata on Australian resources to be handled at continental scales. Experience with two region scale GISs, Hamelin Pool (WA) and Shoalwater Bay (Qld) indicates that continental scale GIS poses some major difficulties. Although the datasets may be recorded at continental scales with a tool such as NDAR, analysis of marine biogeographic attributes would be better handled on a region by regionbasis.

INTRODUCTION

The Bureau of Resource Sciences (BRS) was formed in October 1992 by merging the resource assessment branches of the then Bureau of Mineral Resources with the Bureau of Rural Resources and the National Resource Information Centre. The BRS is a new group within DPIE with a charter to provide scientific advice to government, industry and the community to support the sustainable development of Australia's agricultural, petroleum, mineral, forestry and fisheries industries.

Within BRS there are 6 scientific Branches:

- Petroleum Resources Branch
- Mineral Resources Branch
- National Resource Information Centre (NRIC)
- Fisheries Resources Branch
- Agricultural Production and Natural Resources Branch
- Animal and Plant Health Branch.

The marine interests (and hence datasets) in BRS lie primarily with Fisheries, Petroleum and NRIC, although the other Branches do sometimes become involved in marine industry issues such as quarantine, food safety and offshore minerals.

Given our uncertainty as to how the workshop will approach the problem of classifying regions, we have described a variety of marine and coastal datasets that are available without pre-judging their relevance.

THE DATA SETS

As with most marine databases the information described in this paper is usually derived from data that are very patchy at the scale of the Australian Fishing Zone (AFZ). This complicates the use of the data for describing regions because it is usually difficult to determine whether the data are fully representative of that region, or whether there may be some missing information which, if it were known, would make that particular region unique or significantly different in some respect, or important in some other way.

BRS does not hold large amounts of resource data but has access to a range of information and could facilitate access to this information. Much of the data we deal with is generated by industry activity and is subject to confidentiality constraints that must be dealt with on a case by case basis.

Fisheries data

BRS has access, through the Australian Fisheries Management Authority (AFMA) to the Commonwealth's database of fisheries catch statistics maintained on a database called AFZIS - the Australian Fishing Zone Information System.

The AFZIS data are derived mainly from vessels' logbooks and are recorded by the vessel master at the end of each fishing operation, or possibly at the end of a trip. The database contains other information, such as licensing data, which is not relevant here.

The last complete "stock take" of data in AFZIS was done in March 1992 and is summarised in Table 1 below.

Access to this database is by application to AFMA only. A user may request AFMA for access, or ask another group such as CSIRO or BRS to access the data on their behalf. In either case, AFMA's permission to use the data is required. Normally there are constraints on publishing any results of analyses of these data unless the identity of invidual operators is protected. The normal convention is to aggregate the detailed shot data into 0.25 degree squares. Even then the information can be published only if there were more than 5 vessels operating in that square for the time period in question.

TABLE 1: **The AFZIS logbooks database** (AFMA's Byte Lines Vol 1, 1992)

Fishery	Origin	Started	Status	Species operations	Number of operations	Logbooks
Domestic trawl	NT	-	Active, new	-	-	NT01
Foreign trawl	NT	1974	Ended Oct 90	2,100,618	262,734	MB01-10
Foreign longline	NT	-	Ended Oct 91	-	-	DLL01
Great Australian Bight	Deep-water	1977	Active	76,133	25,901	GB01
Torres Strait Lobster, Pearl, Mackerel	Thursday Island	-	Active	-	-	TRL01 PS01 SM01
Torres Strait Prawns	Northern Fisheries	1989	Active	53,779	27,361	TS01
Northern Prawn	Northern Fisheries	1980	Active	796,946	496,663	NP01-7
NT Pearl	NT	-	Active	-	-	-
NW Shelf trawl	CSIRO Perth	-	Active	-	-	DWT
Radio Reports	AFZ	1979	Active	123,372	46,456	RR
South East Trawl Fisheries	Southern	1985	Active	853,959	386,984	SE01-3 SET
Southern Shark	MSL Victoria	1980	Active	72,947	38,945	Shnn
Tuna:	Tuna section	1981	Active	512,556	248,452	TL01-2,4
Japan. Longline;						AL02
Aust. Longline;						SF02,4-5
Aust. Purse Seine;						TP03,5-6
Aust. Pole & Bait.						
Foreign Squid	Tasmania	1977	Not active	-	10,727	SQ01-3
Foreign Gillnet	-	1979	Not active	-	25,072	GN01-2,4

Note:
1. "-" indicates data are missing or uncertain
2. Many of these databases were started by CSIRO or AFMA staff, but some were started by state fisheries scientists (eg NT databases and Southern Shark)

The main use of these data is to assess the amount of fish being harvested by various sectors of the fishing industry. The catch data are combined with assessments of the productivity of particular species to determine whether stock is being fished in a way that affects the long term sustainability of the resource. In AFMA's case it is the management agency that collects these data, even though their main use is for scientific analysis.

Each State fisheries agency gathers the commercial catch data for the fisheries they manage, but the data are quite variable in the level of detail (for example, the amount of spatial detail that is collected). In some cases the industry is required to submit a monthly return, in which the total catch is aggregated.

GEOSCIENCE DATASETS

BRS's role is to conduct assessments of resources with particular focus on trends in their quantity and quality. The geological Branches of BRS, the Mineral Resources Branch and Petroleum Resources Branch, maintain a number of marine geoscientific databases. These include:

- location of oil wells (and data associated with each well)
- information on the coverage of seismic surveys
- information on petroleum fields (potential and developed).

The Petroleum Resources Branch produces Oil and Gas Resources of Australia annually where summaries of the data described above are included as Appendices.

AGSO conducts a range of geoscientific programs, particularly the Continental Margins and Environmental Geoscience programs, collecting a variety of marine datasets (AGSO, 1992):

- geochemical attributes of water ('sniffer' data)
- regional marine seismic data
- some grab sampling of sediments
- bathymetry data associated with the Offshore Resource Map Series.

Of the variety of geological data held in BRS and AGSO, the information on surficial geology, particularly sediment distributions, and the deepwater bathymetry from the Offshore Resource Map Series may be of most interest for marine biogeographical regionalisation.

NATIONAL RESOURCE INFORMATION CENTRE

NRIC was created as a "joint facility" of the former BMR and BRR, but it is now a Branch of the Bureau of Resource Sciences. NRIC has, over the last few years, committed its limited resources to the servicing of major land-based environmental issues. Nevertheless, NRIC is aware of the complexity of problems arising from the marine environment and of the need for a national approach to a marine GIS.

A National Marine GIS?

In October 1991, NRIC hosted a meeting to discuss options for a marine GIS. It was agreed that NRIC would undertake a feasibility study using the model that had been developed for the Australian continental GIS as a starting point (Bradbury, 1992). In 1992 work began in collaboration with BMR but after 2 months it became clear that the enormity of the problem called for a more regional approach.

At that time it appeared that the first major client of the system was likely to be the offshore petroleum exploration industry. This industry has a good understanding of the geological aspects of offshore exploration but a lesser appreciation of its environmental dimensions. The regions of interest included:

- west Otways
- Northwest shelf
- South Perth basin.

The major layers that were identified for inclusion were:

- bathymetry
- hydrography
- oceanography
- jurisdictional boundaries including exploration tenements, marine environment protected areas, state and commonwealth boundaries, port authorities
- surficial geology
- structural geology from seismic profiles
- hydrocarbon traces from 'sniffer data'
- fisheries catch distributions
- fisheries species distributions
- fishing activity distribution, including gear type and frequency
- ecosystem regionalisation (the topic of this workshop)
- rare or threatened species
- oil spill risk surfaces
- coastal zone land uses.

Database management - *NDAR*

NRIC manages the National Directory of Australian Resources (NDAR). this system facilitates access to natural resources and related data by providing spatially searchable descriptions of datasets. It is linked to similar directories in other Commonwealth and state agencies and through these links provides up-to-date information on what resource data are available, who is responsible for them, where they are located and how they may be accessed (Shelley and Johnson, 1991).

NDAR is based on the FINDAR software package, developed for NRIC by Wizard Information Services Pty Ltd. The directories consist of three parts: tables which describe the attributes of the datasets in detail, a structured thesaurus of keywords with which to describe datasets, and a gazetteer of spatial definitions. FINDAR allows complex searching of a directory on the basis of dataset attributes, keywords and location (Shelley and Johnson, 1991). FINDAR uses a particularly sophisticated spatial searching facility based on the SIRO-DBMS software, developed by CSIRO's Division of Information Technology (Abel, 1989).

NDAR currently contains only limited information relevant to coastal resources. However, the existing charter could encompass the establishment and maintenance of a national register of coastal resources. NDAR could become the hub of a network that enhances communication between data collectors and data users. In addition NDAR could provide useful information for planning and coordinating datasets required for marine biogeographic regionalisation.

REGIONAL DATABASES

NRIC has been involved in two coastal resource studies: Hamelin Pool in Western Australia and Shoalwater Bay in Queensland.

Hamelin Pool, Shark Bay, Western Australia
The project first involved construction of a GIS for Hamelin Pool in Shark Bay, Western Australia, in collaboration with the Australian Geological Survey Organisation (AGSO). The aim was to provide base-line environmental data to assist the then Commonwealth Department of the Arts, Sports, the Environment, Tourism and Territories with the drafting of the World Heritage nomination and the WA Department of Conservation and Land Management with the management of the area.

The marine data layers in the Hamelin Pool GIS were:

- coastline (1:100,000)
- bathymetry of Hamelin Pool (1:50,000)
- enhancements and interpretations of Landsat Thematic Mapper imagery which inferred sea bed environments and bathymetry.

The Hamelin Pool project integrated the necessary hardware, software, datasets and expertise, and provided a basis on which a National Coastal Information System could be established (Byrne and Veitch, 1991).

Shoalwater Bay Military Training Area, Queensland
NRIC, and other branches of BRS, collaborated with AGSO and the Australian Bureau of Agricultural and Resource Economics (ABARE) to construct a GIS database for the Commonwealth's Military Training Area in Shoalwater Bay, central Queensland.

The aim of the project was to provide an economic and scientific analysis of current and alternative use and management strategies for the Military Training Area.

The following marine data layers were collected for the Shoalwater Bay GIS:

- bathymetry (1:250,000)
- hydrographic point data, including monthly averages of wind speed, wave height, atmospheric pressure at sea level, air and sea temperature and currents
- marine sediments (at various scales)
- average tidal conditions
- seagrass distribution
- sea bottom mapping interpreted from Landsat Thematic Mapper data.

A regionalisation was produced for both the terrestrial and marine components of the Military Training Area. The terrestrial regionalisation benefited from the existence of several geo-environmental datasets of adequate spatial extent and accuracy and descriptive detail. The regions were defined through characteristics such as topographic relief, dominant soils, drainage, vegetation distribution, vertebrate fauna distribution and agricultural and pastoral potential.

In contrast, the marine regionalisation suffered from a scarcity of datasets that had adequate spatial and temporal extent, spatial accuracy or descriptive detail. As a result the regionalisation was based mainly on bathymetric data with descriptions of the regions being supplemented by sedimentological and biological information gleaned from the literature.

The results of this resource assessment have been published and provided to the Commission of Inquiry into Shoalwater Bay (ABARE et al, 1993).

USE OF MARINE RESOURCE DISTRIBUTION DATA IN REGIONALISATIONS

Marine systems at the regional scale can be highly variable. Even though much of the variability is periodic in some way, either at seasonal or longer time scales (El Nino, etc), the poor understanding of this temporal variability makes classification difficult. If we add the effect of human activity to our sources of variance then the problem becomes extremely difficult.

Fisheries

We note the following aspects of fisheries catch and effort information such as that held in AFZIS:

- the "samples" taken by the fishing industry are probably the most extensive biological datasets for the marine ecosystem
- in particular, these data are probably the best available fauna information for the offshore pelagic systems (tuna and billfish)
- the data are unevenly distributed over the AFZ
- the data are useful for documenting industry activity but note that fishing gear can be a very selective sampling device
- the stock assessments that have been done using catch data are becoming increasingly complex as more is learned of the species' behaviour (eg migrations).

The fisheries catch and effort data held by the states is similar in quality and variability to the Commonwealth. At a national level, steps are being taken to improve the data quality and to encourage the adoption of standards. The Commonwealth and States are cooperating on the problem through the National Fisheries Statistics Working Group, which was established by the Standing Committee on Fisheries and Aquaculture and is presently chaired by BRS.

NRIC's regional studies

There were a number of difficulties encountered in the Shoalwater Bay project. In particular, the inherent limitations in the data included:

- patchy spatial coverage (eg detailed bathymetry)
- inadequate sampling density (eg seagrasses, sediments)
- inadequate sampling period (eg tides)
- lack of ground truth data (seagrass and seabed mapping in general).

A more general problem encountered in all of the Bureau's studies is the fact that regional studies of marine systems must represent 3 spatial dimensions and the added dimension of time. The existing software tools for building GIS do not handle these 4 dimensions very well. Modelling studies of fish populations have tended to be aggregated in space (or in the case of equilibrium models, time). Some work has been done on spatial simulations for some commercial species but these tend to be intensive studies of one or a few species rather than ecosystem scale models.

CONCLUSION

In light of the complexities of classifying marine systems, the options for determining biogeographic regions may be handled most easily using the "indicator" approach adopted in State of the Environment reporting by CEPA and by BRS in its assessment of the sustainability of agricultural practices. Some gross simplifications will be needed to make the problem tractable. If the ecosystem is simplified for the sake of analysis, then the assumptions and aggregations that are made should be continually reported and reviewed.

REFERENCES

ABARE, BRS, AGSO. 1993. *Shoalwater Bay Military Training Area Resource Assessment.* Australian Bureau of Agricultural and Resource Economics, Bureau of Resource Sciences and Australian Geological Survey Organisation, Canberra, 1993. 290 pp, with map.

Abel, D.J. 1989. *SIRO-DBMS: a database toolkit for geographical information systems.* International Journal of Geographical Information Systems 3(2).

Australian Geological Survey Organisation. 1992. AGSO Work Program. AGSO Record 1992/90, Department of Primary Industries and Energy, Canberra.

Bradbury, R.H. 1992. *Towards a National Marine GIS for Australia.* Paper presented to the ICLARM coral Reef Resource Systems Workshop at the Australian Institute of Marine Science, Townsville.

Byrne, R.V., Veitch, S.M. 1991. *Towards a national coastal geoscientific information system.* Remote Sensing and Geographic Information Systems for Coastal Catchment Management, Conference Proceedings, Centre for Coastal Management and Greening Australia Limited, pp 174-185.

Kailola, P.J., Williams, M.J., Stewart, P.C., Reichelt, R.E., McNee, A., Grieve, C. 1993. *Australian Fisheries Resources.* Bureau of Resource Sciences and Fisheries Research and Development Corporation, Canberra, Australia.

Shelley, E.P., Johnson, B.D. 1991. *Towards a national directory of natural-resources data.* Proceedings of National conference on the Management of Geoscience Information and Data, Adelaide, pp 19-29, Australian Mineral Foundation, Adelaide.

WORKSHOP OVERVIEW

ANZECC's Marine Biogeographic Regionalisation Workshop

Jim Muldoon - *Great Barrier Reef Marine Park Authority, Canberra*
John Gillies - *Department of the Environment, Sport and Territories, Canberra*

SUMMARY

A workshop was held at the North Head Quarantine Station in Sydney from 23-25 March 1994 under the auspices of the Australian and New Zealand Environment and Conservation Council (ANZECC) to assess and advise on approaches for developing a national and agreed marine biogeographic classification system which could form the basis of a national representative system of marine protected areas.

The workshop recommended that the ANZECC National Advisory Committee on Marine Protected Areas (NACMPA) note that:

a) A meso-scale regionalisation map and supporting explanatory material should be produced as a collation of current State Northern Territory and Commonwealth efforts;

b) A technical meeting should be held in 12-18 months time, of appropriate State, NorthernTerritory and Commonwealth representatives, and should be the initial step in implementing recommendation a);

c) The technical meeting would:

- require participants to bring their data in an appropriate format which would permit its use at/during the meeting;
- develop a preliminary integrated national map, i.e. a map output of an Australian marine biogeographic regionalisation; and
- consider common revision principles,

d) The Commonwealth should facilitate the national regionalisation process by providing funding and technical material as appropriate; and

e) That the need to collate existing data and acquire new data was recognised (particularly geological).

INTRODUCTION

In August 1991, the Commonwealth Government announced that it would establish a 10-year marine conservation and sustainable resource use program called Ocean Rescue 2000. The program has as its prime objective the conservation and sustainable use of the marine environment of Australia and its territories. The establishment of a national system of marine protected areas was seen as a major contribution toward achieving this objective.

The development of a national representative system of marine protected areas has now been endorsed by all Australian governments as part of the National Strategy for Ecologically Sustainable Development (ESD). The national representative system of marine protected areas will include marine areas chosen on the basis of representing marine biogeographic regions around the Australian coastline, offshore and in territorial waters. Elements of this system already exist including the Great Barrier Reef and Ningaloo Marine Parks and the many other marine parks and reserves in State, Northern Territory and Commonwealth waters.

The State and Territory agencies responsible for marine protected areas have responded positively to this objective. The Australian and New Zealand Environment and Conservation Council (ANZECC) established a National Advisory Committee on Marine Protected Areas (NACMPA) to coordinate the development of the system. At its inaugural meeting in June 1993, NACMPA identified as its highest priority the organisation of a workshop involving representatives of State, Northern Territory and Commonwealth government agencies with marine interests to advise on approaches to developing a national marine biogeographic classification system which could form the basis of a national representative system of marine protected areas.

ANZECC's Standing Committee on Conservation endorsed NACMPA's proposal and the Marine Biogeographic Regionalisation Workshop was held from 23-25 March 1994 at the North Head Quarantine Station, Sydney.

This paper summarises the workshop discussions.

WORKSHOP OBJECTIVES

The objectives of the workshop were to:

a) Review existing biogeographic regionalisations,
b) Review the various approaches to developing a biogeographic regionalisation,
c) Identify and assess the utility of the data sources that could be used to assist the development of a marine biogeographic regionalisation, and
d) Make recommendations on how a national biogeographic regionalisation could be developed so that it:
   - can be the basis of a national representative system of marine protected of 24 March 1995areas for Australia;

- can be used by other elements of the Ocean Rescue 2000 program (and other programs if required);
- can be developed largely using existing data sources;
- would be supported by all jurisdictions;
- identifies key steps and a timetable; and
- is realistic and achievable in terms of time, money and expertise.

WORKSHOP PARTICIPANTS

Workshop participants were invited from State, Northern Territory and Commonwealth government agencies and from universities, research organisations, museums and where applicable, the private sector (Attachment 1). A number of participants from Indonesia, Canada and New Zealand were also invited. The areas of expertise represented included:

- technical or policy experience in establishing and operating biogeographical regional planning processes;
- multivariate statistical techniques;
- marine park planning and management; and
- individuals with a knowledge on the status of available data sources.

WORKSHOP PROCESS

The workshop was structured so that speakers on the first day addressed a number of key areas including:

- overseas and Australian applications of the regionalisation process;
- an examination of case studies involving the development of biogeographic regionalisations;
- consideration of the various methods and techniques that could be used to develop a marine biogeographic regionalisation; and
- identification and assessment of the utility of the data sources that could be used to assist the development of a marine biogeographic regionalisation.

The second day primarily involved an exercise in which the participants were split into groups with each group addressing similar questions. The questions were:

Q1 What is the value of a regionalisation and how can it best be used in defining a national representative system of marine protected areas?

Q2 Can you identify and assess the utility of the data sets and sources that could be used to assist the development of a marine biogeographic regionalisation?

Q3 What is the best way to develop a coordinated nationwide approach to marine biogeographic regionalisation and how should a program for an Australian marine biogeographic regionalisation be organised?

On the final day there was discussion of each groups views and of the overall workshop views and recommendations were developed.

OUTPUTS AND OUTCOMES

Each work group addressed the three questions in a slightly different way. The results have been compiled with the results of general discussion as follows.

Q1 What is the value of a regionalisation and how can it best be used in defining a national representative system of marine protected areas?

A regionalisation can make an important contribution to the selection of candidate sites for marine protected areas and their subsequent management.

- Regionalisation allows biological units to be separated and arrayed over space.
- Regionaisation allows assessment of variation to identify representativeness and increase biodiversity capture.
- Biological factors are able to be used for site selection and need to include:
  - human use;
  - geological values; and
  - cultural values.
- Regionalisation allows management to relate to appropriate environmental scales.
- Regionalisation promotes an environmental framework for management decision-making.
- Regionalisation provides a hierarchical process of spatially defining homogeneity at different levels of scale.

Regionalisation was seen as a hierarchical process of spatially defining areas and homogeneity at different levels of scale, for example:

TABLE 1. **Example of Levels of Regionalisation**

LEVEL	TYPE	ELEMENT
1	National (macro-scale)	Ecosystem
2	Regional (meso-scale)	Broad biogeographic units
3	Sub-regional (micro-scale)	Smaller biogeographic units characterised by dominant biological or physical features, such as coral reefs, limestone cliffs etc i.e. habitats
4	Unit	Individual reefs, estuaries, etc. for example.

However, it should be recognised that regionalisation is only one input to marine protected area site selection because regions may mask details at a finer scale (i.e. at the sub-regional scale), that is to say there may be surrogate representations not obvious at some scales.

Any approach also needs to take into account both the dynamism of organisms and biogeography to ensure that the picture presented is substantially representative of any derived classification.

Participants felt that there was a need to nominate a time frame and data sets for nationwide/continental application, which needed to include geology, geomorphology, climate and oceanography to get the full picture as this could define distribution of coastal types in terms of patterns of habitats.

There was a view that physical and biological data needed to be considered separately although CSIRO participants pointed out that they have used a pragmatic approach with land units by using both geomorphic and biotic data.

Q2 Can you identify and assess the utility of the data sets and sources that could be used to assist the development of a marine biogeographic regionalisation?

Existing data sets were considered to be adequate to undertake an initial meso-scale biogeographic regionalisation using both physical and biotic data, as indicated in the following table (Table 2), which summarises responses to questions about the availability of national data sets.

TABLE 2. **Availability of National Data Sets**

Data set	Necessary for meso-scale regionalisation?	Adequate national data set available?
Physical	Yes	Yes
Oceanographic (temperature, salinity, currents, nutrients, upwellings)	Yes	Yes
Bathymetry	Yes	Yes
Geomorphology	Yes	Yes
Climate (rainfall, waves, winds, tides, cyclones)	Yes	Yes
Geology	Yes	Yes
Sediments/substrates	Yes	Yes
Biotic	Yes	Sufficient
Key taxa range (>species)	Yes	Possibly
Key species range	No	No
Dominant structural elements	Yes	Probably
Dominant species (abundance)	Yes?	Probably
Charismatic fauna	No	Yes
Historic biogeography	Yes	Yes
Offshore (benthic, pelagic, planktonic)	Desirable	No

The adequacy of the biological data was questionable at the species level. Some participants believed that biological data were inadequate in terms of taxonomy and spatial and temporal coverage. However, it was recognised that there is a point of diminishing return for the effort required to collect further data.

In some cases when a particular data variable was unavailable a data surrogate could be useful in developing a regionalisation, subject to testing of the relationship between the data surrogate and the variable being represented.

Biological data may also need to be treated differently to physical data because of deficiencies in the data sets.

There will also be a need to check the congruence of physical and biological boundaries in any regionalisation adopted.

There may be benefits in identifying data sets with a nationwide/continental application (e.g. geology, geomorphology, climate and oceanography) that will allow definition of coastal types.

Mechanisms and/or actions to improve data set accessibility and distribution are required. In particular, some participants believed that great effort should be put into collecting data on geomorphology, sediments and bathymetry. It was noted however that the Commonwealth holds a significant number of data sets and should produce a directory which identifies and describes those data sets and their custodians.

Q3 What is the best way to develop a coordinated nationwide approach to marine biogeographic regionalisation and how should a program for an Australian marine biogeographic regionalisation be organised?

The issues identified by participants which will affect or influence any approach to biogeographic regionalisation included:

- the need to standardise the use of definitions and terms;
- operating scale - tens, hundreds or thousands of kilometres;
- the need for a standardised and formal system/process which is testable and repeatable;
- the need to avoid the process becoming an intellectual and academic exercise and to ensure that outcomes are responses to management needs;
- the question of whether areas should be targeted because they are species rich, or because of species importance;
- that any process should be iterative and improved through data collection and analysis;
- knowledge (or lack of it) about species distribution;
- the use of surrogates and proxies and the need to test them;
- the problem of diminishing returns from data collection efforts;
- ecological representation needs to consider both spatial and temporal variability; and

- that regional boundaries may be subject to change depending on environmental conditions.

There was some discussion about the approaches being used by various jurisdictions and their progress. It was clear that each of the States and the Northern Territory are working at different levels of detail. This needed to be taken into account in the development of any approach to regionalisation.

Optimum use needs to be made of expert opinion (a delphic process) during the regionalisation process, coupled with quantitative analysis to ensure that outcomes were based on science, management experience and other necessary considerations e.g. political, socio-economic.

It was also seen to be important that links to terrestrial regionalisations were validated to ensure the completeness of the process.

The 1985 regionalisation by the Council of Nature Conservation Ministers (CONCOM) is a useful starting point for the development of a new regionalisation although the CONCOM classification has not received the widespread support of the States or the Northern Territory.

The major weakness of the 1985 CONCOM classification was that the precise reasons for its boundaries were not documented and therefore the basis for the decisions are not clear. Other approaches to biogeographic classification have been developed and there is now substantially more information available.

The regionalisation needs to function at two levels:

- national at a scale of 100s of kilometres; and
- regional/local at 10s of kilometres.

For national reporting a scale with regions in the order of hundreds of kilometres was appropriate but this was not of much value for marine protected area identification or for determining representativeness of coverage.

Consideration needs to be given to the issue of fuzzy boundaries, which reflects the mobility of marine systems and highlights the mobility of boundaries between them.

A major concern of workshop participants was the range of confusing and duplicating terminology being used to describe regionalisation and related subjects. Terms being used include meso-scale, micro-scale, region, sub-region, bio-unit, bio-region, eco-region, national, regional, etc. It will be necessary to critically define terminology to ensure that the level of national understanding is consistent and that there is a minimum use of jargon to avoid confusion with/by non-technical people.

Priority for data processing should be driven by specific questions designed to address management needs.

A detailed regionalisation does not have to be extensively developed before the rest of the process starts, as regionalisation is only part of the marine protected area selection process and assists to refine the selection process rather than being the selection process itself.

As the Commonwealth holds the physical data sets, the technology and the tools for developing a nationwide approach, then it should identify all available data sets and advise the States and the Northern Territory of their availability for development of meso-scale regionalisations and work at other scales.

There is a need to identify and describe databases and contacts so that problems with access and data availability are minimised.

There is a need to review the planning needs of both the Commonwealth, States and the Northern Territory to ensure that any approach is comprehensive and endorsed by all. The States and the Northern Territory should continue to develop their own informal links and enhance these wherever possible. They should not be constrained by boundaries and should consider extending their own knowledge into other State/Territory and Commonwealth waters.

An agreed macro-scale classification of south-eastern Australia is an important and high priority task which needs to be undertaken as an important early step in the process.

It was generally agreed that a technical meeting, similar to that conducted for the Interim Biogeographic Regionalisation for Australia in 1994, should be held to prepare an interim marine and coastal regionalisation using a delphic/quantitative approach. This should be done within 12-18 months. The States and the Northern Territory were happy with this process, believing it required strong commitment by all participants to ensure joint ownership of the output. The meeting needs to be undertaken in the near future. The problems of dealing with differences adjacent to jurisdictional boundaries are less likely to occur for the marine environment because these boundaries are considerably shorter than for the terrestrial environment.

Matters that will need consideration include identifying an agency to organise this and subsequent meetings, a funding source for this meeting; and agreement on custodianship for the resulting maps and other outputs. CSIRO should be involved in the process because they are major data providers/holders.

Other points noted by the workshop included the following.

- There was a need to establish connections between marine and terrestrial regionalisations.
- Regionalisation should be seen as a tool for conserving biodiversity, not just to select marine protected areas.
- It was essential that all parties adopt ownership of any classification.
- There is a need to include coastal wetlands in any classification system.
- There were two clients - the Commonwealth and the States/Territory.
- There is a need to avoid use of the term maritime as the classification process

included substantial coastal features and programs and needs to be based on managerial and political issues.

- Standardised procedures were going to be required to validate any regionalisation.
- A standardisation of approaches between agencies was required.
- This should be a dynamic and continuing process.
- Regionalisation needs to relate to appropriate scales.
- A multistage approach was necessary i.e. initially a meso-scale layer and then a finer scale layer.

The following principles were recognised for implementing a marine biogeographic regionalisation.

- ANZECC should take the leadership role in facilitating the regionalisation process but because of the importance of the marine protected area selection process, it should have full cross-agency involvement and endorsement (including other relevant ministerial councils).
- Ownership by clients of the process is imperative.
- The process must be iterative and continuing.
- The process must include full community consultation.
- The process must be subject to scientific peer review.
- The process must be transparent and efficient.
- All relevant technical experts/expertise should be used in the process.

RECOMMENDATIONS

As a result of discussions about the three questions posed to the workshop it was recommended that the ANZECC National Advisory Committee on Marine Protected Areas note that:

a) A meso-scale regionalisation map and supporting explanatory material be produced as a collation of current State, NorthernTerritory and Commonwealth efforts;

b) A technical meeting, in 12-18 months time, of appropriate State, Northern Territory and Commonwealth representatives should be the initial step in implementing recommendation a);

c) The technical meeting would:

   - require participants to bring their data in an appropriate format which would permit its use at/during the meeting
   - develop a preliminary integrated national map, ie a map output of an Australian marine biogeographic regionalisation, and
   - consider common revision principles.

d) The Commonwealth should facilitate the national regionalisation process by providing funding and technical material as appropriate; and

e) The need to collate existing data and acquire new data was recognised (particularly geological).

APPENDICES

WORKSHOP PROGRAM

WORKSHOP PARTICIPANTS

Workshop Program

DAY 1	**23 March 1994**
8.30am	**Registration**
9.00am	**Introduction**
	Introduction of the workshop outline and objectives by Mr Ian Carruthers, Chair, ANZECC's National Advisory Committee on Marine Protected Areas.
Session 1 -	**Background**
	(Objective: to examine both overseas and Australian applications of the regionalisation process.)
	Session Chair: Mr Ian Carruthers
9.10am	Development of marine Protected Area System Planning Regional Frameworks in Canada. (*Dr Doug Yurick - Chief, New Park Proposals, South Parks Canada, Canada*)
9.50am	The New Zealand Experience in Developing a Marine Biogeographic Regionalisation. (*Ms Kathy Walls - New Zealand Department of Conservation*)
10.30am	Morning Tea
10.45am	Biogeography and Diversity of Australia's Marine Biota. (*Dr Gary Poore - Museum of Victoria*)
11.15am	Uses and Mis-uses of Regionalisations: Experience Gained From Terrestrial Environments. (*Mr Richard Thackway - Australian Nature Conservation Agency*)
Session 2 -	**Case Studies**
	(Objective: to examine case studies involving the development of a bio geographic regionalisation.)
	Session Chair: Dr Doug Cocks
11.45am	The Application of Marine Biogeographic Techniques to the Oceanic Environment. (*Dr Doug Cocks and Dr Neil Hamilton - CSIRO, Division of Wildlife and Ecology*)
12.10pm	A Land/Seascape Approach to the Biogeographic Regionalisation of Coastal New South Wales. (*Mr Ernesto Ortiz - NSW Fisheries*)
12.35pm	The Queensland Marine Regionalisation Project. (*Mr Tim Stevens - Queensland Department of Environment and Heritage*)
1.00pm	Lunch

2.00pm The Western Australian Marine Regionalisation Project. (Mr Hugh Chevis - Western Australian Department of Conservation and Land Management)

2.25pm The South Australian Marine Regionalisation Project. (Dr Karen Edyvane and Ms Janine Baker - South Australian Research and Development Institute)

2.50pm Biophysical Classification of Victoria's Marine Waters. (Mr Don Hough - Land Conservation Council and Mr Garry Mahon - Victoria Department of Conservation and Natural Resources)

3.15pm Development of a Terrestrial Biogeographic Regionalisation for Australia. (Mr Richard Thackway and Mr Ian Creswell - Australian Nature Conservation Agency)

3.40pm Afternoon Tea

Session 3 - Methodology

(Objective: to examine the various methods and techniques that can be used to develop a marine biogeographic regionalisation.)

Session Chair: Mr Richard Thackway

4.00pm Delphic and Related Approaches to Biogeographic Regionalisation. (Dr Barry Wilson - Murex Consultants Pty Ltd)

4.35pm The Application/Relevance of Multivariate Statistical Techniques to Development a Biogeographical Regionalisation. (Dr Brian McArdle - University of Auckland)

5.10pm Finish Day 1

7.00pm Workshop Dinner

DAY 2 24 March 1994

Session 4 - Data Options

(Objectives: to identify and assess the utility of the data sources that could be used to assist the development of a marine biogeographic regionalisation.)

9.00am Perspectives From the State of the Marine Environment Report (SOMER) on a Australian marine Biogeographic Regionalisation. (Dr Leon Zann - Great Barrier Reef Marine Park Authority)

9.30am Data sets in the CAMRIS, NATMIS and AGOS Systems. (Dr Doug Cocks and Dr Neil Hamilton - CSIRO, Division of Wildlife and Ecology, Dr John Busby - Environmental Resources Information Network and Dr R Burne - Australian Geological Survey Organisation)

10.00am	Information Available From the Bureau of Resource Sciences for the Development of an Australian marine Biogeographic Regionalisation. (Dr Russell Reichelt and Dr Julie Bowyer - Bureau of Resource Sciences)
10.30am	Morning Tea
10.45am	**Session 5 - Workshops**
	Introduction by Mr Peter Ottesen of the workshop session outline and objectives. Three workshops operating concurrently will address identical questions. Questions to be addressed:
	a) How can a marine biogeographic regionalisation be best used in defining a national representative system of marine protected areas?
	b) What is the best way to develop a coordinated nationwide approach to marine biogeographic regionalisation
	c) Identify and assess the utility of the data sources that could be used to assist the development of a marine biogeographic regionalisation.
	d) How should a program for an Australian marine biogeographic regionalisation be organised?
12.30pm	Lunch
1.30pm	Resumption of Workshop Session
3.30pm	Afternoon Tea
3.45pm	Resumption of Workshop Session
6.00pm	Finish Day 2

DAY 3 25 March 1994

Session 6 -	**Presentation & Discussion of Workshop Reports**
	Session Chair: Dr Doug Cocks
8.30am	Presentations of the workshop reports
9.30am	Open discussion on workshop reports
10.30am	Morning Tea
10.45am	Open discussion on workshop reports
12.45pm	CLOSING
	Closing statements
1.00pm	Lunch