MARINE RESERVE IMPLEMENTATION PROGRAMME

ASSESSMENT OF A SPATIAL ANALYSIS MODEL TO PROVIDE DECISION SUPPORT FOR CALM'S MARINE RESERVE IMPLEMENTATION PROGRAMME

Report: MRIP- 09/1997

Prepared by E Bruce and J S Burt
Marine Conservation Branch

August 1997

Marine Conservation Branch
Department of Conservation and Land Management
47 Henry St
Fremantle, Western Australia, 6160

ACKNOWLEDGEMENTS

Direction

- Kieran McNamara - Director, Nature Conservation Division.
- Dr Chris Simpson - Manager, Marine Conservation Branch (MCB), Nature Conservation Division.

External Collaboration

- Dr Julie Delaney - Department of Geography, University of Western Australia.

Funding

- The project was undertaken using a Research Grant of $5 000, provided by the MCB, to the Department of Geography, University of Western Australia.

This report may be cited as:

Bruce E and Burt J S (1997). Assessment of a spatial analysis model to provide decision support for CALM's Marine Reserve Implementation Programme. Report MRIP - 09/1997. (Marine Conservation Branch, Department of Conservation and Land Management, 47 Henry St., Fremantle, Western Australia, 6160). Unpublished report.

Copies of this report may be obtained from:

Marine Conservation Branch
Department of Conservation and Land Management
47 Henry St.
Fremantle, Western Australia, 6160

Ph: 61-9-4325100
Fx: 61-9-4305408

CONTENTS

FIGURES

TABLES

APPENDICES

1. Introduction

One of the most effective mechanisms, recognized both nationally and internationally, for protecting biodiversity while enabling the sustainable use of natural resources is the establishment of marine protected areas (MPAs; Mutton, 1996). There is a hierarchy of environmental management philosophies and government initiatives which determine the establishment and management of MPAs. These include the broad framework for Ecological Sustainable Development, the National Programme for MPAs, and the State Marine Reserve Implementation Programme. An understanding of these philosophies and initiatives is important to the implementation of marine reserves in Western Australia.

Ecological Sustainable Development (ESD) is defined as a pattern of development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (State of the Environment Advisory Council, 1996). The principle of ESD was adopted by Australian governments as a major national strategy in 1992. This strategy recognizes global obligations which are outlined in the *Australia State of the Environment Report* (State of the Environment Advisory Council, 1996). The three core objectives in this national strategy are:

- to protect biological diversity and maintain essential ecological processes and life support systems (**maintenance of ecological integrity**);
- to provide for equity within and between generations (**maintenance of intra-generational equity**);
- to enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations (**maintenance of inter-generational equity**) (State of the Environment Advisory Council, 1996; CALM, 1996).

It is recognized in the *Australia State of the Environment Report* (State of the Environment Advisory Council, 1996) that ecologically sustainable development requires the maintenance of four key components of the environment: biodiversity; ecological integrity; natural capital; and social integrity (Figure 1). The principles of ESD provide a framework for managing the environment including marine areas. In the marine environment the establishment of MPAs provides an approach for ensuring ESD. The main function of MPAs is to separate elements of biodiversity from ecologically threatening processes (Pressey and McNeill, 1996).

The Ocean Rescue 2000 program is part of the National Strategy for ESD initiated by the Commonwealth in 1991, and has commitments under the Intergovernmental Agreement on the Environment and National Strategy for the Conservation of Australia's Biological Diversity (Lewis, 1996; Mutton, 1996). It aims to establish a *National Representative System of Marine Protected Areas* (NRSMPA) around Australia that will provide for the conservation of representative ecosystems within biogeographical regions (Thackway, 1996a). Despite international commitments for ensuring ecological representativeness it has recently been established that 21 out of the 32 biogeographic regions around Australia lack any significant protected areas (Ivanovici, 1993). Although approximately 5% of Australia's waters had been reserved by 1995, about 99.5 % of this area occurs in tropical waters, principally within the Great Barrier Reef Marine Park (Edyvane,

1996). This highlights the importance of ensuring adequate representation of biogeographic regions in a marine reserve system.

A principal goal of the Draft Western Australian State Conservation Strategy is the establishment of a conservation reserves system, representative of the State's flora, fauna and habitats (CALM, 1994). In June 1994, the Marine Parks and Reserves Selection Working Group released a report on *A Representative Marine Reserve System for Western Australia*. The report identified over 70 areas as worthy of consideration for reservation. This proposed system of marine reserves forms part of the broader NRSMPA for Australia. In November 1994, the State Government released the *New Horizons in Marine Management* that outlines policy initiatives and legislative changes necessary for the establishment of a representative system of marine reserves in Western Australia.

The *New Horizons* document embraces a commitment to a high level of public participation in determining future marine reserve areas in Western Australia (Government of Western Australia, 1994). This commitment is reflected in the State Governments proposed amendments to the *Conservation and Land Management Act (1984*), which will establish a statutory requirement for a formal marine reserve public planning process. The Government also considers multiple-use management of marine reserves as a central concept to the State's marine reserves programme and this will be achieved through the development of management zones which separate incompatible uses either spatially or temporally. The requirement for a public planning process combined with the development of management zones within a marine reserve highlight the need for a tool which facilitates community involvement.

The Department of Conservation and Land Management has identified the need to develop a generic spatial decision support system to assist with the Departments Marine Reserve Implementation Programme (MRIP). This report outlines a conceptual model for establishing the boundaries and management zones of marine reserves, reviews existing approaches for the establishment and zoning of conservation reserves, examines the potential for incorporating existing decision support software to facilitate model development and provides recommendations for future direction.

A process for the establishment of marine reserves in Western Australia has been described in this report. This process is consistent with the key steps in the Strategic Framework of the MRIP which addresses the legislative amendment to the *Conservation and Land Management Act 1984* (WA). There are three phases to the programme: preliminary consultation and liaison; resource assessment; and public planning. The conceptual marine reserve zoning model is designed to facilitate the Resource Assessment and Public Planning Processes. It is critical that the model provides techniques which are transparent and have a participatory focus. An open and transparent process that clearly enunciates the technical rationale supporting a draft marine reserve management plan is fundamental to the long-term success of a management plan. Furthermore by developing simple techniques for zoning marine reserves provides greater opportunities for community involvement during the planning process giving the plan more acceptability and 'ownership' by the local community.

1.1 Objectives

The marine reserve zoning model will provide a tool for assisting CALM's Marine Reserve Implementation Programme. The objectives of this tool are to:

- provide a simple and transparent approach to establishing marine reserve boundaries and management zones;
- quantify the implications of zoning options through the use of technical and scientific data;
- facilitate public involvement in the planning process;
- enable decision makers and the public to better understand the rationale and process for establishing marine reserves.

1.2 The Zoning Scheme

In accordance with the *New Horizons* document four zones will be created under the Marine Parks system: Sanctuary Zones; Recreation Zones; General Use Zones and Special Purpose Zones. The adopted techniques and data sets in the marine reserve zoning model reflect CALM's broad objective of marine reserve planning and the functions of different zone types.

Sanctuary Zones are "look but don't touch" areas managed solely for nature conservation and low-impact tourism (Government of Western Australia, 1994). The main roles of Sanctuary Zones are to provide refugia, sources of replenishment and scientific reference areas. To ensure this Sanctuary Zones should be representative of major marine habitats in the reserve particularly areas of high biodiversity and primary productivity and outside the 'zone of influence' of potential threatening uses. Allocation of Sanctuary Zones requires data on major habitat types in the reserve and the spatial distribution of potentially threatening human activities.

Recreation, General Purpose and Special Purpose Zones provide for a variety of different uses within a marine reserve however these must be consistent with the environmental values of the reserves. Recreation Zones provide for recreational use. These zones need to be established in high use areas for activities which are generally compatible with other recreation activities. General Purpose Zones provide for recreational and commercial uses such as commercial fishing and petroleum exploration and production within sustainable limits.

Areas in which marine planning objectives can not be met by Sanctuary Zone, Recreation Zone or General Use Zone status, Special Purpose Zones can be assigned. Special Purpose Zones are managed for a particular priority use or issue, for example habitat protection, seasonal events (whale-watching) or a particular type of commercial fishing (Government of Western Australia, 1994). These zones allow uses that are consistent with the stated purpose of the zone which may also include commercial and recreational activities. Protection of areas of cultural significance such as shipwrecks and Aboriginal sites may require Special Purpose Zone status.

1.3 Summary of Model Structure

A summarized description of the model structure and process is presented to demonstrate the conceptual framework which provides the basis for techniques developed in later sections (Figure 2). The marine reserve zoning model is divided into three major components which represent distinct phases of the Marine Reserves Implementation Programme:

1. Site Selection Process
2. Resource Assessment Process
3. Public Planning Process

The flow diagram outlines the procedures involved in preparing a draft zoning map. In the Resource Assessment and Public Planning Processes the procedures which require modeling using GIS based decision support software are presented as six major steps. Each step has a specific outcome which is highlighted in the flow diagram as a bold box. Components of the model which require external input from managers and planners, government ministers or the reserve users are shaded. During the Conflict Resolution Stage and Public Planning Process this involves interactive querying.

2 Site Selection Process

The initial phase in the model is to determine the boundaries of proposed marine reserves. This procedure is designed to ensure a system of representative reserves which conforms with the principles and objectives agreed to by State and Commonwealth Governments (Section 1). Reserve boundaries are based on proposed marine reserve areas identified in the *A Representative Marine Reserve System for Western Australia* report (CALM, 1994). The Site Selection Process is not a reserve selection procedure however reserve selection concepts and algorithms (Cocks and Baird, 1989; Scott *et al*., 1993; Pressey *et al*., 1995; Pressey and McNeill, 1996) can be applied. Once the proposed boundaries are established they will provide a spatial basis for the collection of data sets required for the Resource Assessment Process (Figure 2).

The representativeness of the proposed marine reserve system will be assessed at the ecosystem and community levels and measured as the proportion of each bioregion within State Waters covered by marine reserve areas, and the proportion of major habitat types within the marine reserve respectively. Bioregions are defined in the *Interim Marine Bioregionalisation for Australia* report (CSIRO Division of Fisheries and CSIRO Division of Oceanography, 1996). A *bioregional representativeness value*, of say 10 %, provides a standard for ensuring adequate protection of each bioregion. For example, if the area of marine reserves proposed for the South Western Zootone, along Western Australia's Central West Coast, were implemented the *bioregional representativeness value* would be 14 %. Linking of the proposed Jurien and Beagle Islands marine reserves would increase the value for that bioregion to almost 20 %. Interactive identification of marine reserve boundaries through the use of spatial decision support facilities will quantify the implications for community representativeness of different boundary alternatives.

2.1 Objectives

- Determine the boundaries of proposed marine reserves. This will provide reserve location and size.
- Ensure the marine reserves are representative of the major habitat types within the bioregion and together with the area of other marine reserves covers an 'adequate' proportion of the bioregion.

2.2 Method

The following steps are proposed to achieve the above objectives:

1. Identify the main purpose of the marine reserve. The purpose of a reserve area will influence size and location The primary value of a marine reserve will vary between nature conservation and recreational usage.
2. Evaluate the ecosystem representativeness of a proposed marine reserve.
3. Collate regional biological and human-use data sets. The regional area of proposed reserves will be defined by the oceanographic processes which influence biological connectivity.
4. Overlay regional biological and human-use data sets.
5. Interactively select marine reserve boundaries based on the purpose of the reserve.
6. Determine the community representativeness of the proposed marine reserve.
7. Through an iterative process derive a marine reserve boundary which maximizes the representation of major habitat types and ensures an acceptable *bioregional representation value*.
8. Confirm proposed boundary and calculate the total area of the reserve.

The outcome of the site selection process is an Indicative Marine Boundaries map which is used to identify the study area for the subsequent Resource Assessment Process.

3 Resource Assessment Process

The Resource Assessment component of the model provides both strategic direction for CALM's Marine Reserve Implementation Programme and a base zoning map from which areas of conflict can be identified. This component of the model will be generic for application to different proposed marine reserves in Western Australia. The Resource Assessment Process can be undertaken for marine reserves which will be implemented within the next five years or a larger time frame for data sets which do not require significant updating (i.e. temporally stable). Results of the assessment will provide an indication of the level of resource conflict and the opportunity, through the provision of more detailed information, to resolve these conflicts. Furthermore, this will indicate the complexity of reserve implementation within each reserve area. The establishment of different marine reserves along the Western Australian coastline can then be prioritized according to the time predicted for implementation based on the degree of conflict.

As outlined in the *New Horizons*, before the Minister for the Environment creates any marine reserve or management zone within a reserve that would preclude mining or commercial fishing activities, consent

must first be obtained from the Ministers for Mines and Fisheries. This requires areas in which Sanctuary Zone, Recreation Zone and Special Purpose Zone overlap with important mining and commercial fishing areas to be identified in the Resource Assessment Process.

The initial procedure is to locate proposed Sanctuary, Recreation and Special Purpose Zones. These zones can then be compared with areas of important mining or commercial fishing operations to identify the spatial extent of potential conflicts. During this process proposed zone boundaries are modified to reduce the level of conflict.

3.1 Objectives

The Resource Assessment Process is separated into three stages, each with a main objective, these include:

Stage 1: Preliminary Zone Delineation

- Broadscale identification of the distribution and nature of major resource conflicts, for example Recreation Zones proposed within commercial trawling grounds. Identification of use conflict requires: (1) the identification of possible Sanctuary, Recreation and Special Purpose Zones; (2) the comparison of these areas with important mining or commercial fishing areas.

Stage 2: Conflict Resolution

- Broadscale resolution of major resource conflicts.
- Preparation of an indicative zone map for each marine reserve area which can be used in the public planning process (Section 3).

Stage 3: Government Consultation

- Prepare a Resource Assessment Report detailing the results of Stages 1 and 2 to be presented Government. This review process will determine the ‘acceptability’ of the indicative zone plan insofar as it is compatible with the Governments strategic interests.

3.2 Method

3.2.1 Step 1: Allocation of Possible Sanctuary Zones

The objective of this analysis module is to identify areas suitable for sanctuary zones based on the role of Sanctuary Zones outlined in Section 1.2. The main factors for determining their location include: representativeness of major habitat types; the distribution of threatening human processes; biological diversity; and presence of rare or endangered marine flora or fauna. These factors direct the following main procedures of Step 1:

- Map major benthic habitat types and important biological resources.
- Map broadscale water circulation patterns.
- Identification of existing or future threatening processes (Human-Use Pressure map)

Several data sets are required to generate the Human Use Pressure map. Mining, commercial fishing operations, industrial development, shipping operations, coastal infrastructure (e.g. marinas) and recreational activities etc can have a direct and indirect impact on the marine environment. Determining the zone of influence of these activities requires an understanding of general water circulation patterns within the marine reserve.

- Delineation of Possible Sanctuary Zones

The above data sets are combined to identify suitable areas for Sanctuary Zones. Sanctuary Zones should be: (1) outside areas highlighted in the human use pressure map; (2) within each biophysical subregion; (3) representative of major marine habitats; (4) within areas of high biological diversity and (5) protect rare and endangered wildlife. To delineate Sanctuary Zones based on these five criteria the following steps are proposed:

- Overlay the biophysical subregions, marine habitat, biological diversity and wildlife sensitive areas and mask out all areas identified in the human use pressure map. This highlights areas for the selection of Sanctuary Zones.
- Delineate possible Sanctuary Zones.

The outcome of Step 1 is a map showing possible Sanctuary Zone areas.

3.2.2 Step 2: Allocation of Possible Recreation Zones

CALM is required to manage Recreation Zones in an equitable and ecologically sustainable (Section 1). The following steps are designed to ensure that these objectives are met in the delineation of proposed Recreation Zones:

- Identify the main recreational activities within the marine reserve.
- Map the distribution and intensity of each activity to provide a series of data layers.
- Select priority areas for each recreational activity, these may be based on intensity of use or the relative importance of an area to the users. For each recreation activity all areas in which it occurs would be assigned a value indicating level of use. Areas above a set use level would then be selected as priority use. In subsequent conflict resolution modeling, the priority recreation areas of different activities may be in competition for Recreation Zone status. To ensure equitable representation of priority areas for each activity the size of priority areas should be determined relative to the area covered by that activity.
- Priority areas for each activity are then combined into one data set (Recreation Use). This ensures all activities are represented in the initial allocation of Recreation Zones.
- These combined areas are then assigned to possible Recreation Zones.

In marine reserve management plans some recreational activities will not be permitted within Recreation Zones, for example motorised water sport. To identify incompatible recreational activities a table of allowable uses within each zone type is required. A standard table of permitted uses could be established for

application to all marine reserves along the Western Australian coast. Alternatively permitted uses within zones may be identified as specific to each reserve area. Recognition of incompatible recreation activities in a use table will enable these activities to be prevented from being assigned Recreation Zone status. If this information is not available areas of incompatible recreational use will be included in the proposed Recreation Zone. Separating incompatible uses at a later stage will involve either preventing these activities in their high use areas or changing the area to General Use status. This increases the error associated with the proposed Recreation Zone and reduces the level of equity with which recreation uses are considered in the zone plan. Therefore it is advantageous to define the uses permitted within different zones prior to this stage.

Information required for Step 2 should be collected through visitor use surveys. Surveys could be used to identify the main recreation activities, determine the distribution and intensity of these activities and establish areas of aesthetic importance.

3.2.3 Step 3: Allocation of Possible Special Purpose Zones

Areas of recognized cultural significance such as ethnographic and archaeological Aboriginal sites, historic European sites and shipwrecks can be protected under Special Purpose or Sanctuary Zoning. In this model procedure, cultural areas are recognized and assigned possible Special Purpose Zoning with the potential for Sanctuary Zoning depending on compatibility with other uses.

Data sets containing information on cultural sites are combined to create a cultural data set (Cultural Use). Areas identified in this data set are then zoned as possible Special Purpose Zone areas.

3.2.4 Steps 4 and 5: Identification of Conflict Areas

Areas of conflict between different uses within the marine reserve are identified by overlaying the possible zone data sets generated in Steps 1, 2 and 3 with important mining and commercial fishing activities (Figure 2). This enables the possible impact of the establishment of Sanctuary, Recreation and Special Purpose Zones on existing and potential mining and commercial fishing operations to be identified. In determining the implications of zoning on mining and commercial fishing the need to modify zones can be recognized and the acceptability of proposed plans can be demonstrated.

Step 4 requires two extra data sets: the distribution of important commercial fishing areas and mining operations. The distribution and economic value of each commercial fishing industry should be mapped as individual data layers. Areas of high commercial fishing priority for each fishery is then identified as a new data layer and these priority areas are then combined to provide an important commercial fishing area data set. A value is assigned to commercial fishing areas for each fisheries according to current or potential economic importance. These values should be determined relative to the regional area of the fisheries and not in relation to areas within the reserve. This will prevent areas within the reserve which have low fisheries value on a regional scale being assigned high priority within a reserve area. Areas above a defined value set by the Fisheries Department are selected as high priority. This technique ensures that all fisheries are adequately represented in the identification of resource conflict areas.

Mining operations both existing and potential provide the second data set which may provide a possible constraint to zoning. All mineral and petroleum exploration and production areas should be identified and the importance of these areas ranked. This information will be provided by the Department of Minerals and Energy and will determine the areas in conflict with the proposed zones.

The data sets generated in Step 1, 2 and 3 are combined with the important commercial fishing and mining data set to generate a resource conflict map. Areas of overlap between these operations and proposed zones become identified areas of conflict which require resolution. The impacts of proposed management zones to commercial fishing and mining activities can be calculated through spatial analysis. Initial resolution of these conflicts is conducted through an iterative 'what if' scenario querying process in which the conservation, recreation and economic implications of altering the proposed zones are quantified. More detailed resource data may be required in specific areas to assist in conflict resolution.

The main outcome of Step 4 is a resource conflict map. This map will contain the area and type of use conflict requiring resolution for a proposed zoning. Areas which are not zoned Sanctuary, Recreation or Special Purpose are assigned General Use status. Following a review stage (Step 5) in which zone alternatives are trialed and assessed using an interactive decision support system a proposed zone plan is produced. In this plan major conflicts have been attempted to be removed.

A resource assessment report is then prepared from the proposed plan in which areas of remaining conflict are highlighted. This is then presented to the Minister for Environment who must seek approval from the Ministers for Fisheries and Mines for the indicative zone plan to proceed. Approval will be based on the level of use conflict resolution. There are three possible outcomes of the Government Consultation Stage: (1) unacceptable level of conflict in which there is no resolution; (2) a proposed zoning map with acceptable levels of conflict; and (3) a proposed zoning map with no areas of conflict (Figure 2). If the first outcome occurs CALM's Marine Reserve Implementation Process does not proceed. However, if the proposed plan has been approved either with acceptable levels of conflict or no conflict it proceeds to the public planning phase.

4 Public Planning Process

Community involvement in the establishment of draft marine reserve management plans is a critical component of the Governments reserve implementation programme. The allocation of management zones in the Resource Assessment phase of the model is to identify conflicts between the implementation of a marine reserve and the State's other strategic interests. The Public Consultation Process of the Marine Reserve Implementation Programme enables finalisation of a draft marine reserve management plan During this process the community and users of the marine reserve identify areas of concern and provide input on the delineation of management zones.

4.1 Objectives

- Enable community consultation and involvement in the delineation of marine reserve management zones.

- Establish a draft zone map which provides greatest satisfaction to marine reserve users whilst achieving the environmental values of the reserve.

4.2 METHOD

The proposed Sanctuary, Recreation and Special Purpose Zones identified and resolved in the Resource Assessment Process are shown in the use conflict map. Areas outside these zones are assigned General Purpose status. Following the conflict resolution process of Step 5 minor acceptable levels of remaining conflict are resolved through the public planning process.

The zone structure in the use conflict map provides a base zone plan which can be presented to a community forum. Areas of conflict identified during this process include possible minor areas of conflict not resolved in Step 5 and concerns raised by the reserve users. Conflict areas identified by the community provide a focus for scenario modeling and negotiation between reserve users.

Incompatible recreational uses which were excluded from Recreation Zones, for example recreational fishing charters, should be identified. The area in which they are permitted within the proposed zone plan can then be quantified in relation to priority areas for these activities. This analysis will enable the level to which the demands of these uses are met. Comparison of these values with the satisfaction levels of other recreational users will facilitate decisions on the location of Recreation Zones.

During this forum, alternatives to the proposed plan structure generated to meet different use interests are interactively trialed using spatial analysis tools. These spatial analysis tools are designed to support zone allocation decisions by enabling ‘what if’ scenario modeling. The implications of changes to zone boundaries on individual uses and environmental values can be quantitatively determined. By providing immediate feedback interactive trialing of zone changes enables users to view the consequences of suggested alternatives.

5 Spatial Data Sets

Although physical, biological and human use data sets are required for the Site Selection, Resource Assessment and Public Planning Processes data sets described in this section relate to the later two processes. Regional biophysical and human use data needed for the Site Selection Process will vary according to the reserve area.

The quality of data incorporated in the Resource Assessment Process will determine the level of conflict and alteration of the proposed zone plan during the Public Planning Process. If data sets used to determine major commercial use areas do not provide sufficient level of detail, conflict areas may not be adequately identified in the Conflict Resolution Stage (Stage 2). If these conflicts are not recognized until the Public Planning Process dissatisfaction of the zone plan by the users could cause a second government review. This would reduce the efficiency of the Marine Reserve Implementation Programme and may effect public opinion of the planning process. Data reliability will be the responsibility of the agency providing the source information.

A series of data sets have been identified however this list is not exhaustive and may be updated and modified with further development of the proposed model.

5.1 Physical

Oceanographic data - provides information on general water circulation patterns which can be used to determine the area of influence of different threatening human use activities (e.g. the dispersal of nutrients from aquaculture sites). Includes data such as water depth and sea surface temperature.

5.2 Biological

Habitat Mapping - this categorical information identifies major habitat types which must be represented in the selection of Sanctuary Zones.

Biological Diversity - contains values of biodiversity measured within a set range to provide a continuous data set. This surrogate data can be used to identify areas of high biodiversity for selection of Sanctuary Zones.

Wildlife Sensitive Areas - areas of important wildlife distributions (e.g. Australian Sea Lion colonies) or breeding sites (e.g. seabird nesting sites) are mapped to ensure protection of sensitive areas and high biological diversity.

5.3 Human Use

Cultural Sites - location of archaeological and ethnographic Aboriginal sites, historic European sites (e.g. Pearling Camps) and shipwrecks. This information can be used to identify areas of cultural significance for protection in the selection of Sanctuary and Special Purpose Zones.

Commercial Use - This information is critical for determining high priority commercial fishing areas and mining interests necessary for identifying areas of conflict in the selection of Sanctuary and Recreation Zones. The potential threatening processes to the marine environment caused by extractive industry can also be identified using this data. Commercial Use data is divided into several data sets.

Mining - Operations Data: contains the areas of current and potential mining operations.

Pressure Data: spatial distribution of existing potential threats caused by mining activities.

Fisheries - Economic Value Data: representation of major fisheries (e.g. Rock Lobster, Trawling and Wet-lining) as individual data layers with economic values provided for each grid cell. These values must be relative to the respective fishery on a regional scale. A distinction needs to be made between site specific fisheries (e.g. aquaculture) and fisheries which operate at different intensities across a broad area. Economic values assigned to each fishery will enable the identification of priority fishing areas for individual fisheries and quantify the importance of fishing areas selected for possible Sanctuary Zone status.

Pressure Data: spatial distribution of existing potential threats caused by commercial fishing activities.

Infrastructure - location and description of coastal and marine infrastructure development (marinas, waste outfalls and drains), this information will also show the distribution of possible associated threats to the marine environment.

Industrial Development - location and description of industrial sites along the coast and predicted distribution of potential impact on the marine environment.

Restricted Waters - areas of exclusion and predicted pressure on the marine environment. These areas may include shipping channels, Naval waters, Military areas and Port Authority waters.

Recreational Use - provides information on the level and type of recreational use (*Recreation Data*) across the reserve which can be used to identify potential threats (*Recreational Pressure Data*) to the marine environment and select Recreation Zones. Recreation activities (e.g. sightseeing, diving, fishing and windsurfing) present within the marine reserve are represented as separate data layers in which their importance is indicated spatially through ranging values derived from intensity of use and significance to the users. This information requires visitor survey data which should be conducted to determine the location and intensity of use for each recreational activity.

6 Review of Existing Approaches to Zoning

CALM recognizes the need for a GIS based decision support system for facilitating the planning of marine reserves and enabling effective public participation. The major advantage of systematic interactive computer-based analysis is that it provides flexibility for testing and comparing different design scenarios or options and their associated costs and benefits (Thackway, 1996b). These functions are required within different components of CALM's Marine Reserve Implementation Programme.

A review was conducted of both conceptual and automated approaches to zoning in conservation reserves to identify potential techniques for incorporation in the model. Researchers and managers involved in the application of Decision Support Systems (DSS) to marine zoning were contacted and a request for information was sent to the SEA-GIS user group on the network. This was to determine whether similar applications had been trialed in other states of Australia and overseas. A summary of the response to the internet search and the people contacted is provided in Appendix 2.

A tabular summary of approaches to zoning which have been applied in terrestrial and marine areas is provided in Table 1. For each approach the broad objectives, brief outline of techniques, associated references and the applicability to the marine reserve zoning model is outlined. Several of these approaches have been automated through the use of DSS which have associated software packages, these are summarized in Table 2. Information provided in this review was obtained through discussions with researchers and managers currently developing or trialing these systems and documentation which outlines

the systems methodology, capabilities and applications. As these systems have not been trialed this provides a preliminary review in which the potential for use in the model can be identified however further investigation is required to determine the method and feasibility of application.

Based on the preliminary findings of this review Conservation Tool (Pressey *et al*., 1995; Pressey and McNeill, 1996) was identified as having the potential for meeting objectives of the conflict resolution and public planning components of the model. Like other reserve selection algorithms Conservation Tool facilitates the selection of reserve areas based on a set of conservation targets, for example percentage of threatened species. However, it differs in that the importance of other areas is considered during the selection of reserves through the quantification of irreplaceability. By using irreplaceability, numbers can be provided for the obvious fact that there are no alternative options for reserving some environmental values, for example an offshore island supporting a major Australian Sea Lion colony, but many options for reserving other values, such as seagrass meadows (Pressey and McNeill, 1996). Conservation Tool has been developed over the last few years during which many complex conservation issues have been identified and addressed. Therefore by integrating Conservation Tool as a component of the marine reserve zoning model a high level of resource planning expertise will be incorporated. Capabilities available in Conservation Tool for providing detailed data on the implications of different planning scenarios to the users is also a major advantage to the marine reserve zoning model.

However, Conservation Tool has a few limitations and for this reason it is recommended that if it is to be applied to the marine reserve zoning model it should be modified to meet specific objectives. Conservation Tool focuses on the environmental implications of reserve planning options rather than socio-economic aspects. The next development phase will examine the potential for incorporating socio-economic data sets however, methods for achieving this have not yet been determined. Until now Conservation Tool has been linked with WinERM an in-house GIS package developed by the NSW National Parks and Wildlife Service (NPWS). It is anticipated that it will be linked with ArcView GIS by late 1997. This will greatly facilitate its use but there may be greater spatial analysis capabilities available through Arc/Info GIS. Until Conservation Tool software is trialed its full potential for application to the marine reserve zoning model can not be assessed.

7 Recommendations

A conceptual model for marine reserve zoning has been developed to facilitate the establishment of boundaries and management zones for proposed marine reserves established under the CALM Act (1984) in Western Australia. The principles of ecologically sustainable development, and National and State Government objectives for the establishment of MPAs provide the framework for the model (Section 1). Based on these principles and objectives the model is designed to provide for multiple use management and public involvement in the planning process. The application of Geographic Information Systems (GIS) and decision support software will greatly support these model objectives. Spatial analysis techniques and available software packages which can be used for developing the model need to be identified. Several approaches to conservation reserve zoning in both terrestrial and marine environments were reviewed to provide an indication of possible options for model implementation. This review forms the basis for recommendations for a decision support model for CALM's Marine Reserve Implementation Programme.

GIS provides an analytical environment which can be used to automate the procedures outlined in the conceptual model (Figure 2). However, the conflict resolution components of the marine reserve zoning model may extend beyond the capabilities of current GIS software. These components can be addressed through the integration of existing environmental management Decision Support Systems (DSS) within the GIS environment which provide a higher level of mathematical modeling and a user interface.

Recommendation 1

The proposed marine reserve zoning model should be established within a GIS environment.

Procedures of the Site Selection Process and Stage 1 of the Resource Assessment Process (Figure 2) can be automated within a GIS using customizing facilities such as Arc/Info Arc Marco Language (AML). It is critical that the GIS software adopted is capable of high level spatial modeling, has facilities for customizing analysis procedures and has the flexibility to handle complex high resolution data sets. The current arrangement of GIS facilities at the Marine Conservation Branch will meet both the hardware and software requirements for this recommendation. The GIS facilities include Arc/View software and access to Arc/Info software on a Unix platform. Priority access to Arc/Info software should be obtained to undertake the complex level of spatial modeling needed in the model.

Recommendation 2

Investigate the potential for existing Decision Support Software (DSS) to perform the conflict resolution modeling components (Resource Assessment Stage 2 and the Public Planning Process) of the model.

A DSS integrated within the GIS environment will facilitate the quantification of zoning implications and provide a user interface which will enable interactive involvement in zone allocation during the Public Planning Process. The existing reserve zone planning DSS which should be reviewed include Conservation Tool, Facet Decision System and Calyx. Although these systems may not meet all the requirements for the

conflict resolution procedures of the model they have the capacity to be modified and customized for specific objectives.

8 References

APPEA, 1997. *Potential Management Arrangements for a Marine Management Area Covering the Montebello Islands to Barrow Shoals Region*, Australian Petroleum Production and Exploration Association Limited, Canberra, Australia, 65 pp.

CALM, 1994. *A Representative Marine Reserve System for Western Australia, Report of the Marine Parks and Reserves Selection Working Group*, Department of Conservation and Land Management, Perth, Australia.

CALM, 1996. *Environmental Guidelines and Procedures in Relation to CALM Advice on the Marine Aspects of Aquaculture Proposals in Western Australia*, Report: MPCP/AQU-01/96, Marine Conservation Branch, Department of Conservation and Land Management, Fremantle, Australia.

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):359-383.

Cocks, K. D. and Baird, I. A., 1989. Using mathematical programming to address the multiple reserve selection problem: an example from the Eyre Peninsula, South Australia, *Biological Conservation*, **49**:113-130.

Council of Nature Conservation Ministers, 1985. *Summary Report of the Second Technical Workshop on Selection and Management of Marine and Estuarine Protected Areas*, February 15-21, 1985, Jervoise Bay, Australian National Parks and Wildlife Service, Canberra, Australia.

CSIRO Division of Fisheries and CSIRO Division of Oceanography, 1996. *Interim Marine Bioregionalisation for Australia: Towards a National System of Marine Protected Areas*, The Commonwealth Technical Consortium Ocean Rescue 2000 Project, Component 3, Department of Environment, Sport and Territories, Canberra, Australia, 77 pp.

Edyvane, K., 1996. The role of marine protected areas in temperate ecosystem management, *Developing Australia's representative system of marine protected areas: Criteria and guidelines for identification and selection*, Proceedings of a technical meeting held at the South Australian Aquatic Sciences Centre, West Beach, Adelaide, 22-23 April 1996, Ocean Rescue 2000 Workshop Series, Publication No 2, Department of the Environment, Sport and Territories, Canberra, Australia, pp.53-67.

Faith, D. P. and Walker, P. A., 1995. Integrating conservation and development: effective trade-offs between biodiversity and cost in the selection of protected areas, *Biodiversity and Conservation*.

Government of Western Australia, 1994. *New Horizons in Marine Management*, Government of Western Australia, 10 pp.

Great Barrier Reef Marine Park Authority, 1987. *A User-Based Evaluation of the Zoning Plan and Day-to-Day Management in the Capricornia Section of the Great Barrier Reef Marine Park*, Commonwealth of Australia, Townsville, Australia, 53 pp.

Hatcher, A. I., Wright, G. D., and Hatcher, B. G., 1990. Resolving the conflict between conservation values and extractive use of the Abrolhos coral reefs, *Proc. Ecol. Soc. Aust.*, **16**:55-70.

Ivanovici, A. M., 1993. Planning for a national, representative system of marine and estuarine protected areas: Identification of priority areas. In A. M. Ivanovici, D. Tarte and M. Olson (eds), *Protection of marine and estuarine areas - A challenge for Australians*, Proceedings of the Fourth Fenner Conference on the Environment, Canberra, 9-11 October 1991, Occasional Paper No. 4 Australian Committee for IUCN: Sydney.

Lewis, R., 1996. Setting the scene: The background and issues to establishing a representative system of marine protected areas, *Developing Australia's representative system of marine protected areas: Criteria and guidelines for identification and selection*, Proceedings of a technical meeting held at the South Australian Aquatic Sciences Centre, West Beach, Adelaide, 22-23 April 1996, Ocean Rescue 2000 Workshop Series, Publication No 2, Department of the Environment, Sport and Territories, Canberra, Australia, pp. 18-19.

Margules, C. R. and Redhead, T. D., 1995. *BioRap: Rapid Assessment of Biodiversity Priority Areas: Guidelines for using the BioRap methodology and tools*.

Mutton, D., 1996. Welcome and opening address, *Developing Australia's representative system of marine protected areas: Criteria and guidelines for identification and selection*, Proceedings of a technical meeting held at the South Australian Aquatic Sciences Centre, West Beach, Adelaide, 22-23 April 1996, Ocean Rescue 2000 Workshop Series, Publication No 2, Department of the Environment, Sport and Territories, Canberra, Australia, pp. 15-17.

Pressey, R. L., Ferrier, S., Hutchinson, C. D., Sivertsen, D. P. and Manion, G., 1995. Planning for negotiation: using an interactive geographic information system to explore alternative protected area networks, In D. A. Sanders, J. L. Craig and E. M. Mattiske (eds), *The Role of Networks*, Nature Conservation 4, Surrey Beatty and Sons Pty Limited, NSW, Australia.

Pressey, R. and McNeill, S., 1996. Some current ideas and applications in the selection of terrestrial protected areas: are there any lessons for the marine environment? *Developing Australia's representative system of marine protected areas: Criteria and guidelines for identification and selection*, Proceedings of a technical meeting held at the South Australian Aquatic Sciences Centre, West Beach, Adelaide, 22-23 April 1996, Ocean Rescue 2000 Workshop Series, Publication No 2, Department of the Environment, Sport and Territories, Canberra, Australia, pp. 125-136.

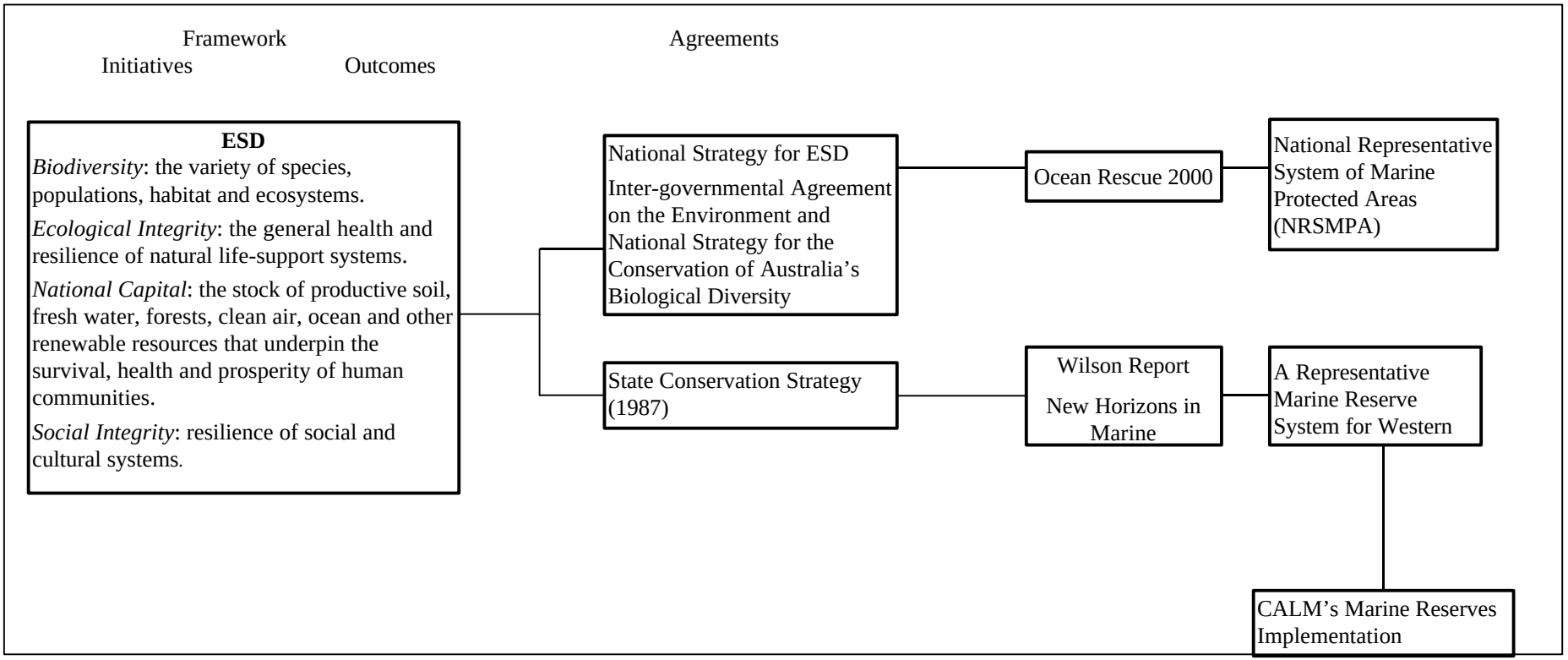
Scott, J. M., Davis, F., Csuti, B., Noss, R., Butterfield, B., Groves, C., Anderson, H., Caicco, S., D'Erchia, F., Edwards, T. C., Ulliman, J. and Wright, R. G., 1993. Gap analysis: a geographical approach to protection of biological diversity, *Wildlife Monograph*, **123**.

State of the Environment Advisory Council, 1996. *Australia State of the Environment 1996: An independent report presented to the Commonwealth Minister for the Environment*, CSIRO Publishing, Collingwood, Australia.

Thackway, R., 1996a. Developing consistent national criteria for the identification and selection of a national representative system of marine protected areas, *Developing Australia's representative system of marine protected areas: Criteria and guidelines for identification and selection*, Proceedings of a technical meeting held at the South Australian Aquatic Sciences Centre, West Beach, Adelaide, 22-23 April 1996, Ocean Rescue 2000 Workshop Series, Publication No 2, Department of the Environment, Sport and Territories, Canberra, Australia, pp. 20-28.

Thackway, R., 1996b. Approaches taken in identifying and selecting terrestrial protected areas in Australia as part of the national reserve system, *Developing Australia's representative system of marine protected areas: Criteria and guidelines for identification and selection*, Proceedings of a technical meeting held at the South Australian Aquatic Sciences Centre, West Beach, Adelaide, 22-23 April 1996, Ocean Rescue 2000 Workshop Series, Publication No 2, Department of the Environment, Sport and Territories, Canberra, Australia, pp. 34-44.

Figure 1. Strategic framework for CALM's Marine Reserve Implementation Programme.



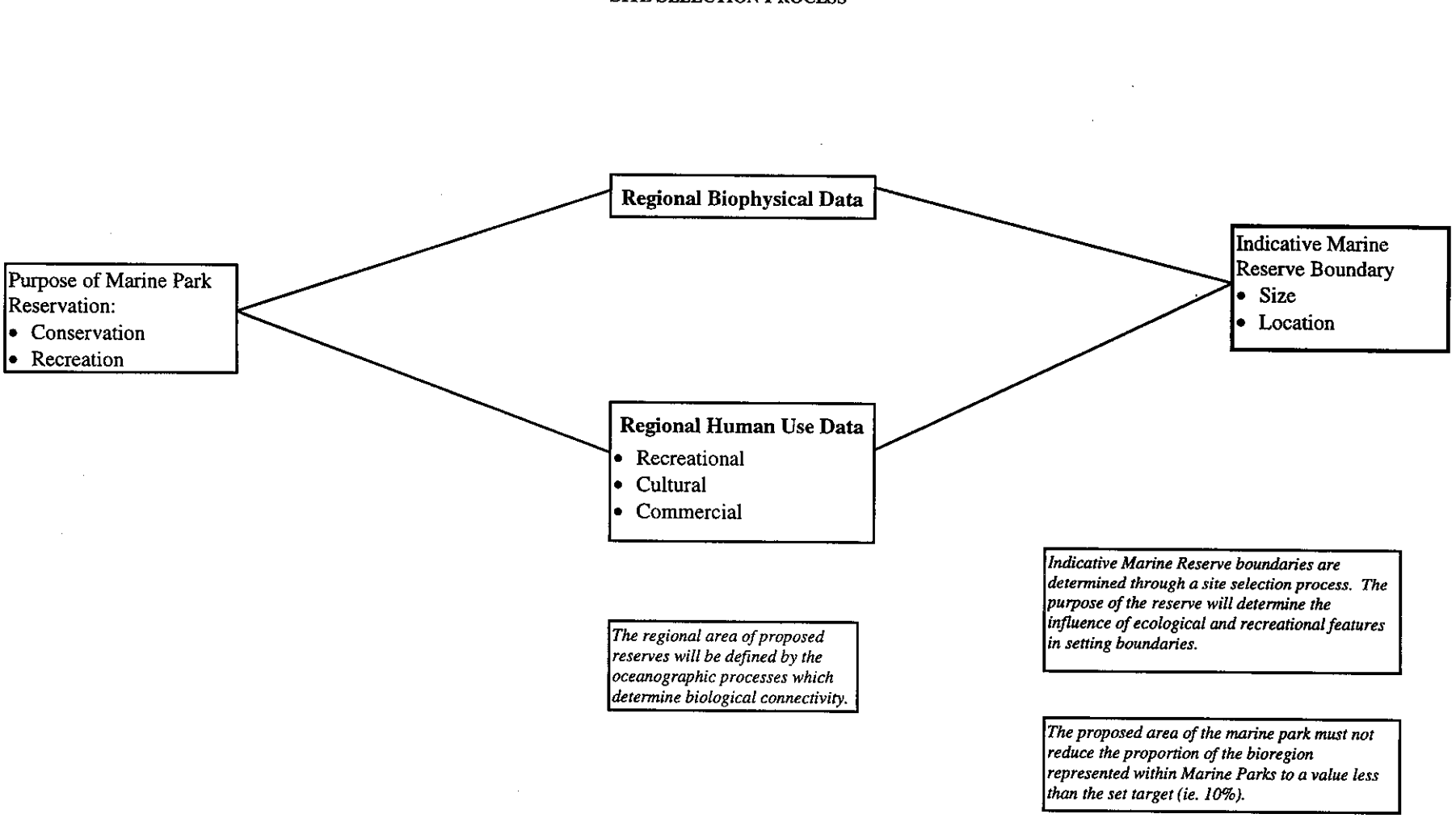


Figure 2. Flow diagram of the proposed marine reserve zoning model.

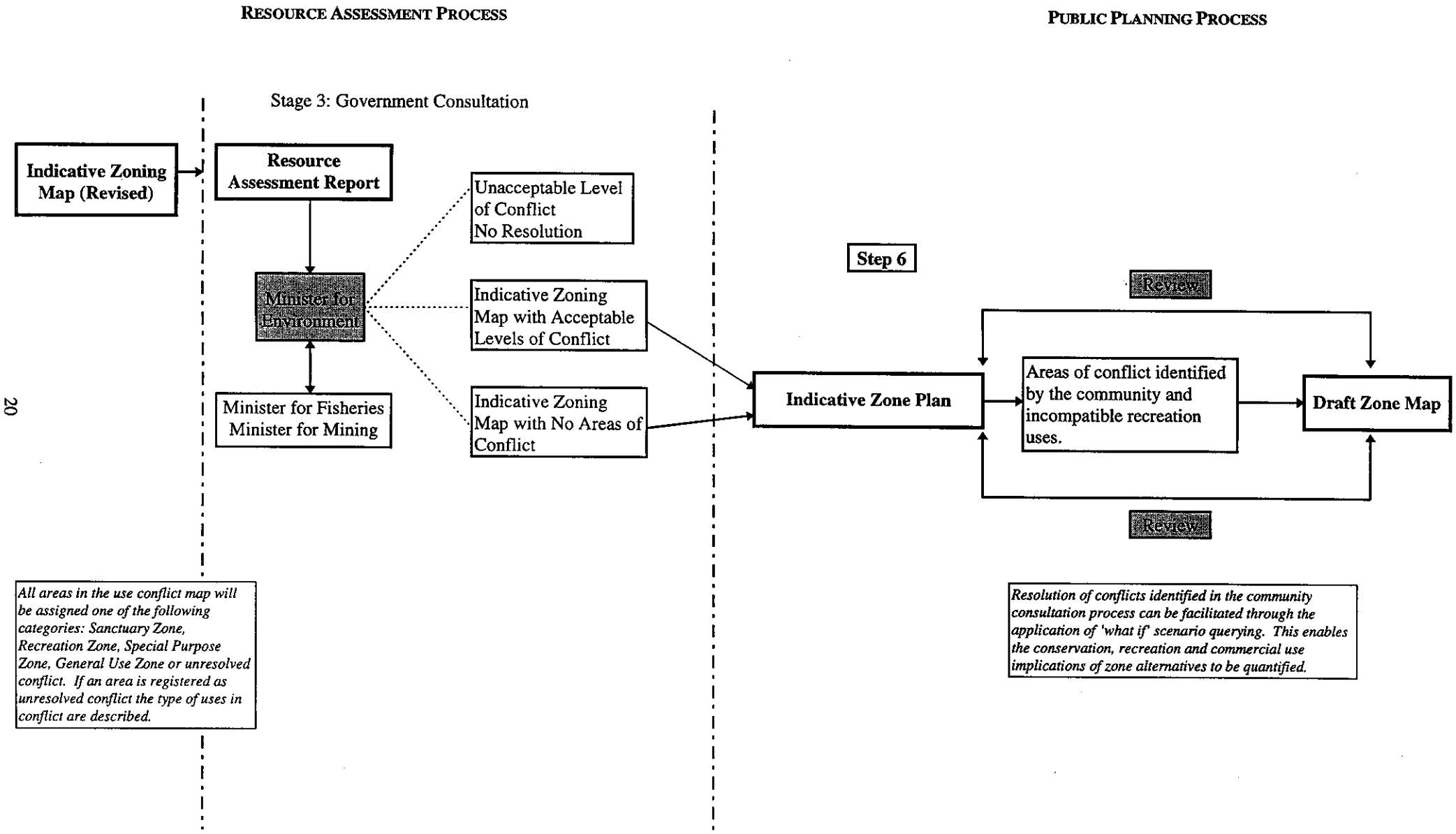


Figure 2. Flow diagram of the proposed marine reserve zoning model.

RESOURCE ASSESSMENT PROCESS

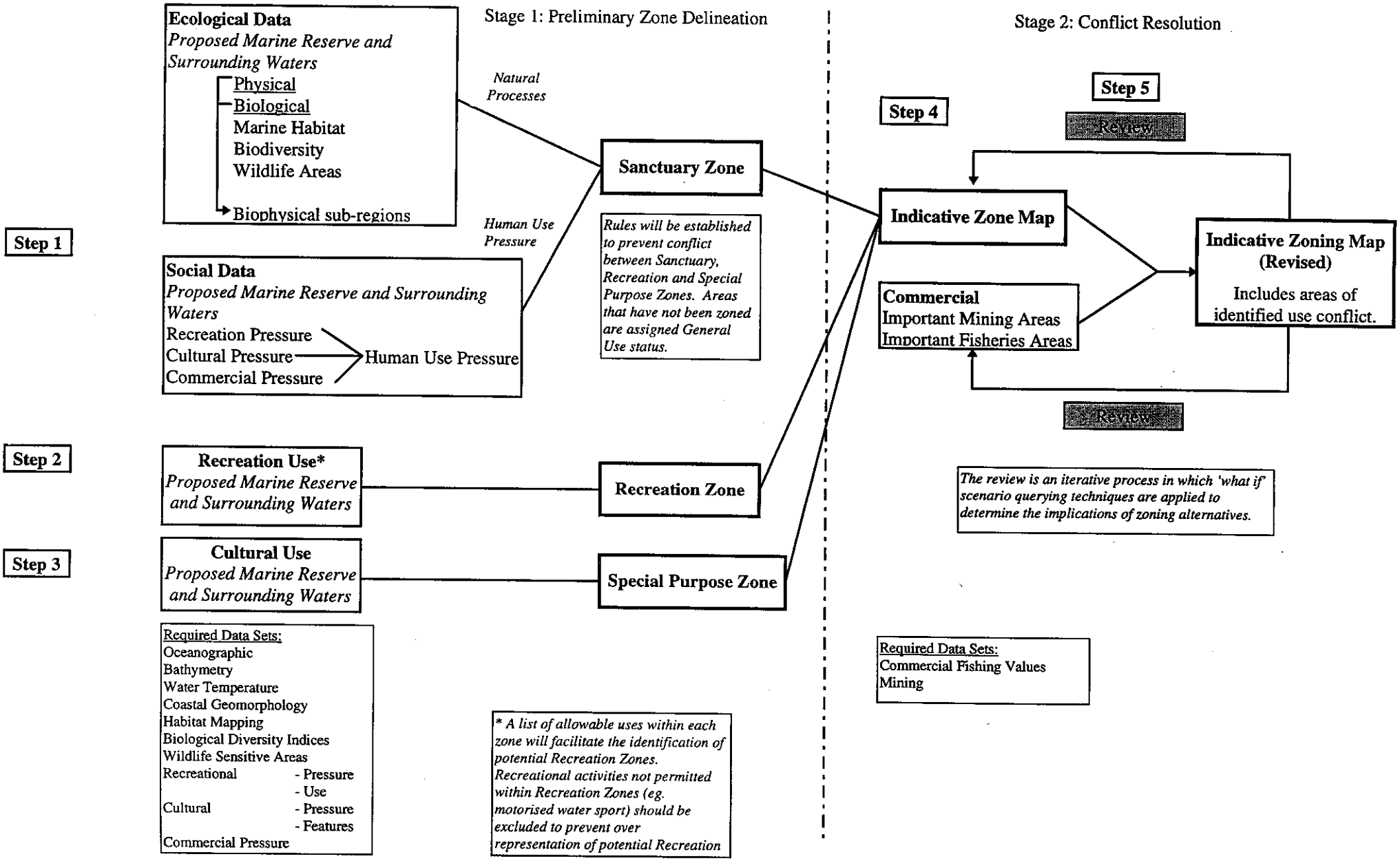


Table 1. Review of approaches to conservation reserve zoning and landuse conflict resolution.

Approaches	Models	Broad Objectives	Techniques	References	Applicability to Model
Reserve Selection Methods	**DIVERSITY**	Exploring alternative allocations of uses in an area based on biodiversity conservation or production. DIVERSITY is a reserve selection tool which has the capability to use surrogate data as measures of biodiversity.		Faith and Walker, 1995	*Reserve selection techniques may be applicable to the selection of possible Sanctuary Zones in Step 1 of the Resource Assessment Process.*
	BioRap	BioRap enables identification of priority reserve areas based on biodiversity levels determined through rapid biological assessment. The reserve selection principles developed in BioRap can be used in planning.	- Provides the methodology and analytical tools for assessing the relative priorities of areas for biodiversity conservation. - Uses existing biological and environmental surrogate data to identify priority areas. - Supports assessments of degrees of threat, feasibility of interventions and economic analyses. * refer to attached documentation.	Margules and Redhead (1995)	BioRap is not a zoning tool however the feasibility analysis techniques may assist comparison of zone options. BioRap could be used to generate surrogate biodiversity data sets required in the Resource Assessment Process. Concepts and techniques developed in BioRap could be used in the 'what if' scenario component of the marine reserve zoning model. *BioRap techniques could be incorporated in the Conflict Resolution Stage of the Resource Assessment Process and the Public Planning Process.*

Approaches	Models	Broad Objectives	Techniques	References	Applicability to Model
Use Conflict Resolution and Zoning	**SIRO-PLAN**	SIRO-PLAN is a landuse planning method which enables the allocation of zones based on the satisfaction of user demands.	- Establish policies for guiding zoning decisions. - Identify and collate data sets. - Calculate policy satisfaction values for the assigning of each zone type to a mapping unit. - Prepare a zone plan based on the maximum satisfaction of all policies.	GBRMPA, Cocks (1984)	The complexity of the SIRO-PLAN approach is designed to deal with diverse community interests and a greater number of use conflicts than present in WA marine reserve areas. SIRO-PLAN procedures are not appropriate for the structure of the marine reserve zoning model which is based on the management philosophy of marine reserves in WA. Techniques developed in SIRO-PLAN for quantifying the level to which the demands of individual uses are met could be applied in the Public Planning Process. However, effective 'what if' scenario modelling should provide this information. *Limited broad application.*
	APPEA Potential Model for Developing a Zoning Scheme	Selection of areas for designation as marine management zones. It is a provisional model for devising a zoning scheme to maximise protection, minimise conflicts and facilitate sustainable use. The procedure is designed to be managed on "delphic" principles involving experts and stakeholders	- Identify natural values to be protected or managed and the range of human activities that are to be permitted. - Identify the location of each of these attributes and assess their relative importance at each site. - Divide study area into grid cells and assign values to each cell for individual attributes (ie. habitat diversity, petroleum exploration,	APPEA, 1997. Potential Management Arrangements for a Marine Management Area Covering the Montebello Islands to Barrow Shoals Region	The data structure used in this approach provides a useful guideline for quantifying the conservation importance and recreational and commercial value of areas. Although this approach provides a detailed basis for establishing the data sets required for zoning it does not provide a quantitative procedure for determining the allocation of zone types.

			of impact rules linked to a database of recommended mitigations. - The *inference engine* identifies potential environmental impacts for example the implications of potential zone options.		*modified to meet the specific objectives of the marine reserve zoning model.*

Approaches	Models	Broad Objectives	Techniques	References	Applicability to Model
	APPEA (cont.)		recreational fishing etc.). - Through overlay analysis determine the compatibility of attributes.		*Data structure techniques can be adopted in the establishment of data sets required for the Resource Assessment Process.*
	Conservation Tool	Reserve Selection and Zoning	- The irreplaceability of each mapping unit is calculated in relation to the representativeness of specified conservation features (ie. vegetation, rare and endangered sp.). - This is quantified for each conservation feature to provide an indication of the biological importance of each area. - Reserves are then selected interactively and irreplaceability values are recalculated. Interactive input enables immediate response to feedback provided by the tool. * in the application of Conservation Tool to the Interim Assessment Process for the NSW Forests the interactive site selection process was conducted in a workshop involving different user groups. The results of each iteration was displayed to the users through 10 linked PCs.	Pressey *et al.*, 1995 Pressey and McNeill, 1996	The advantage of this approach to the marine reserve zone model is the interactive decision support capability which enables the implications of different zoning options to be quantified. The concept of a biological irreplaceability index may be useful in the selection of Sanctuary Zones which are representative of different major marine habitat types. Socio-economic values have yet to be incorporated in Conservation Tool. *Conservation Tool or concepts developed within this tool can be used in the conflict resolution procedures of the model.*

Table 2. Decision support software for environmental management.

Model	Software Package	Applications	Hardware and Software Requirements	Contact
DIVERSITY	DIVERSITY	Faith and Walker (1995)		
SIRO-PLAN	LUPLAN	Cairns Section of GBRMP (1983)	DOS	CSIRO
BioRap	BioRap		IBM compatible 486 PC with 12 MB RAM, VGA screen, 5MB hard disk space, Microsoft Windows 3.1.	CSIRO http://www.erin.gov.au/general/biorap
Conservation Tool	Conservation Tool	North-East Forests Southern Forests (NSW) current applications: Solitary Is. (NPWS) Jervis Bay (NPWS)	- Currently linked with the NSW NPWS in-house windows based GIS (WinERMS). - It is anticipated that a working version will be linked to ArcView 3 by mid 1997.	NPWS NSW Bob Pressey 067 737 128 Tom Barret 067 737 207
Calyx	Calyx EA Calyx GIS		- Calyx GIS is linked to ArcView enabling the incorporation of spatial data. - Calyx EA and Calyx GIS require Windows 3.11, ArcView V 2.0. - both run on industry-standard IBM PC or PC-compatible (486/66 Mhz)	ESSA Software Ltd. Suite 300, 1765 W. 8th Ave, Vancover, B.C. Canada, V615C6 Tel: (604) 733 2996 Fax: (604) 733 4657 calyx@essa.com
Facet	FACET	Integrated Fraser Salmon Model Fraser Basin Canada	*Sun* workstations Solaris operating system - fully optimised for the new *UltraSPARC* line workstations and servers.	Facet Decision Systems, Inc. info@facet.com

APPENDIX I

List of contacts for marine reserve planning

Name	Organisation	Application	Contact Address
Kim Clymont	NSW National Parks and Wildlife Service	BioRap and Conservation Tool	02 9585 6654 kim.mcclymont@npws.nsw.gov.au
Tom Barret Project Leader	NSW National Park and Wildlife Service	Conservation Tool	067 737 207
Bob Pressey	NSW National Parks and Wildlife Service	Conservation Tool	067 737 128
Francis Pantus	Great Barrier Reef Marine Park Authority	Several different methods will be applied in the next few years	077 500 818 fpantus@GBRMPA.gov.au
Sanela Pilav-Savic	Institute for Coastal Resource Management University of Technology, Sydney	BioRap and Conservation Tool Solitary Islands and Jervis Bay	02 9922 7693 borro@msn.com
Helene Durrand	Consultant in GIS	Arc/Info AML	Allee du Terral 34430 St Jean De Vedas tel/fax (33) 04.67.42.61.00 helene.Durrand@teledetection.fr

APPENDIX III

Generic Information Requirements for Marine Reserves in Western Australia
(Draft)

GENERIC INFORMATION REQUIREMENTS FOR THE MANAGEMENT OF MARINE RESERVES IN WESTERN AUSTRALIA

Draft

19 June, 1997

Marine Conservation Branch
Department of Conservation and Land Management
47 Henry St. Fremantle, Western Australia, 6160

INTRODUCTION

In December 1992 Australia, along with 152 other nations, signed the *Convention on Biological Diversity* which committed Australia to protect and maintain the biodiversity of its lands and waters. In November 1994, Western Australia, along with all other states and territories of Australia, agreed to implement the *National Strategy for Ecologically Sustainable Development* which committed Western Australia to ensure that development delivered economic prosperity to the community without compromising the ecological integrity of the natural environment. Both the *Convention on Biological Diversity* and the *National Strategy for Ecologically Sustainable Development* are centered around the dual objectives of bio-diversity conservation and ecologically sustainable human usage of the natural environment. The development of comprehensive, representative systems of terrestrial and marine reserves is accepted, worldwide, as a major mechanism to achieve these objectives.

In June 1994, the Government of Western Australia released a report produced by the Marine Parks and Reserves Selection Working Group entitled *A Representative Marine Reserve System for Western Australia* in which 70 areas were identified as worthy of consideration for marine reserve status under the CALM Act. Later that year the Government released a policy statement entitled *New Horizons in Marine Management* which stated that "*...the central thrust of the [Government's] conservation effort would be though the creation of a statewide system of marine reserves under the CALM Act*". Currently there are seven marine reserves in Western Australia: Hamelin Pool Marine Nature Reserve in Shark Bay and six marine parks.

A comprehensive scientific understanding of the functioning of natural systems and the implications of human usage on these ecosystems are necessary for the effective long-term management of a marine reserve system. Natural systems are usually very complex and the resources to acquire the information necessary to develop an adequate scientific understanding are rarely ever available. As such research and monitoring activities have to be prioritised in relation to management objectives and available funds allocated judiciously to achieve the maximum benefit.

This paper outlines the generic information requirements considered by CALM to be necessary for the effective management of marine reserves in Western Australia and provides the rationale used to identify and prioritise these requirements. Generic priorities are identified. The paper also provides the framework for the development of specific strategic applied research and monitoring programmes for individual marine reserves in Western Australia. In addition, it has the benefit of providing a clear indication of CALM's broad marine research and monitoring priorities to other State Government agencies in Western Australia as well as to local universities and to Commonwealth marine research organisations such as the CSIRO, AGSO and AIMS. In doing so it will, hopefully, facilitate the development of strategic alliances and collaborative projects where responsibilities and/or interests overlap.

GENERIC INFORMATION REQUIREMENTS

The generic information requirements of marine reserve management in Western Australia can be grouped under five broad headings:

- Values
- Management objectives
- Characterisation
- Threatening processes
- Monitoring trends

Values

The values of marine reserves reflect both the implicit ecological attributes and the explicit 'cultural' values of the broader community. In this context the ecological values are defined in terms of the physical, chemical, geological and biological characteristics of an area. The 'cultural' values relate to the social, economic, and scientific values. As many human usages depend on the maintenance of healthy ecosystems and not vice versa, ecological values are, intrinsically, of greater importance than 'cultural' values and this natural priority should be reflected in management priorities.

Ecological values

Ecological values include physical, chemical, geological and biological components. Spatial scales range from local, regional and national to international scales. Temporal scales range from seconds to evolutionary timescales. Ecological components include species, populations, communities and ecosystems.

Criteria to assess ecological value should include:

- ***Uniqueness***: Contains unique species, populations, communities or ecosystems. Global uniqueness would afford an area a conservation value of international significance (eg stromatalites in Hamelin Pool Marine Nature Reserve).
- ***Representativeness***: Representativeness is the degree to which the area in question represents a species, population, community or ecosystem type within a particular marine bioregion. Physiographic features and ecological processes or other natural characteristics can also contribute to the representativeness of an area.
- ***Dependency***: Ecological processes are highly dependent on biotically structured systems. Examples include coral reefs, kelp 'forests', mangrove 'forests' and seagrass meadows. For example, these areas may contain nursery or juvenile areas or contain feeding, breeding or rest areas for migratory marine fish, reptiles, birds or mammals or are a source of larvae for downstream ecosystems.
- ***Diversity***: The area has a high variety of species, populations, communities and ecosystems.
- ***Productivity***: The species, populations, communities or ecosystems of an area have a high natural biological productivity.
- ***Naturalness***: The area has a high degree of naturalness (ie is not disturbed or degraded by anthropogenic activities).
- ***Integrity***: The area is a biologically functional unit, an effective, self-sustaining ecological entity.
- ***Vulnerability***: The area is highly susceptible to degradation by natural events or anthropogenic activities. Biotic communities associated with coastal populations may have a low tolerance to changes in environmental conditions, or may exist close to the limits of their tolerance (defined by water temperature, salinity, turbidity or depth).

Cultural values

'Cultural' values include the entire range of human uses, in the broadest sense, of the natural environment and include social, economic and scientific components.

- ***Social significance***: The area has existing or potential value to the local, regional, national or international communities because of its heritage, historical, cultural, traditional, aesthetic, educational or recreational qualities.
- ***Economic significance***: The area has existing or potential economic value. For example, the area has important commercial activities such as fisheries, aquaculture and nature-based tourism, is a food source and/or a source of income for indigenous communities, or is a nursery area or replenishment area for economically important species.
- ***Scientific significance***: The area has particular significance for scientific study at local, regional, national and international scales.

International and national values

- The area has the potential to be listed on the World or a National Heritage List, declared as a Biosphere Reserve, included on a list of areas of international or national importance or is the subject of an international or national conservation agreement.

Management objectives

Management objectives represent the explicit goals of a management program and relate to the maintenance of the relevant values described above. These include ecological objectives relating to the maintenance of biodiversity and ecological integrity (ie structure and function) and 'cultural' objectives relating to the maintenance of educational, scientific, cultural/heritage, economic and recreation values. In this context *biodiversity* is considered at three levels: genetic diversity, species diversity and ecosystem diversity. *Ecosystem integrity* is defined as "...the ability to support and maintain a balanced, integrative, adaptive community of organisms having a species composition,

diversity and functional organisation comparable to that of natural habitat of the region".

Management objectives need to be clearly enunciated in scientifically measurable terms so that quantitative management criteria can be developed and applied. Monitoring programs (see below) can then be formulated to specifically address the criteria which are used as an indication of management effectiveness and, if necessary, to trigger remedial management action.

Characterisation

The ecological and 'cultural' values of a marine reserve need to be described in both time and space if these areas are to be managed effectively. A comprehensive description of the resources being managed, an understanding of the key ecological processes that maintain these resources and an adequate knowledge of the extent and cause of natural variability, combined with monitoring programs and remedial management strategies, are necessary to detect and ameliorate undesirable impacts on the marine environment resulting from anthropogenic activities.

Resource Inventory

Resource inventories should reflect the values outlined above and provide a more detailed description of the various ecological and 'cultural' resources of the area in question. Comprehensive surveys of marine areas are invariably expensive and, as such, selected components of the environment are usually progressively described.

Research priorities should be based on the ecological and social significance of the marine resources, vulnerability to existing and future threats and recovery potential.

Baselines and natural variability

An essential element in effectively managing the human impacts on natural systems is the development of quantitative baselines of the various physical, chemical, geological and biological components of the system and how these baselines vary in time and space. Without this information it is difficult to understand the significance of short-term effects, or the long-term implications, of human activities on natural systems.

Research priorities should be based on their ecological and social significance of the marine resources, vulnerability to existing and future threats and recovery potential.

Key ecological processes

Key ecological processes are the natural processes related to the growth and reproduction of key species, populations and communities within an ecosystem. An understanding of these processes is therefore essential for the effective management of marine systems. An understanding of how marine ecosystems function also provides greater flexibility in management response to unknown threats than would be the case if this understanding was limited.

Research priorities should be based on existing scientific understanding of the relative ecological significance of the ecosystem components, their relative vulnerability to existing and future threats and recovery potential.

Human Use

Human usage of the marine environment reflects the range of 'cultural' values held by the community. An understanding of these uses, particularly the interaction between competing uses, is essential for effective management of marine systems.

Research priorities, in relation to human usage, should be based on a comprehensive risk assessment and be determined in consultation with the community within an equitable and ecologically sustainable framework.

Threatening processes

Threatening processes are those processes that threaten some or all of the values outlined above. These can be natural physical or biological processes or processes associated with anthropogenic activities. Within the context of this paper, broadscale damage to coral reefs by physical processes, such as cyclonic waves, or by biological processes, such as Crown-of-Thorns starfish predation, are considered natural cyclic events and, as such, are not considered here to be

a threatening process. Similarly, anthropogenic processes operating at greater than regional scales, such as the 'Greenhouse Effect', are not considered to be threatening processes as 'management' of this type of 'threat' requires co-ordinated global-scale action to be effective. Threatening processes are defined here to be regional-scale or less anthropogenic processes that negatively impact one or more of the values outlined above.

A comprehensive database of human usage and, at least, a conceptual understanding of the links and synergies between this usage and the deleterious effects on one or more values is required to identify existing or potential 'threats'. The significance of an existing or potential threat will relate to the ecological or 'cultural' importance of the threatened value/s, the spatial and temporal scales of the threat, the vulnerability of the value/s to the threat and the ability to 'regain' the value/s once the threat is removed.

Monitoring trends

Monitoring programs are an essential component of the management of natural systems. Monitoring provides an assessment of the effectiveness of management in meeting objectives by providing status reports against agreed criteria, detects undesirable trends and, if necessary, provides the trigger for remedial action. Monitoring priorities should address ecosystem components that reflect their ecological and social significance, their vulnerability to existing threats and their recovery potential. To be effective monitoring programs should reconcile the spatial and temporal scales of the values with the spatial and temporal scales of the threatening processes. Monitoring parameters should also be clearly linked to a specific cause-effect pathway and be sufficiently 'early' in this pathway to allow implementation of remedial action.

Surveillance monitoring

Surveillance monitoring programs are generally broad-scale and temporally constrained and are used to provide regular (eg annual) overall status reports on marine systems. Surveillance monitoring programs are generally undertaken by management agencies. As well as providing an assessment of natural or anthropogenic system-wide influences on ecosystem 'condition', surveillance monitoring programs provide the spatial perspective necessary to interpret the results of compliance monitoring programs. The nature, extent and frequency of surveillance monitoring programs will reflect the nature, extent and frequency of natural (eg storm damage, predation) and anthropogenic (eg introduced organisms) influences.

Compliance monitoring

Compliance monitoring programs are generally spatially and temporally constrained and are used to ensure specific commercial activities do not have unacceptable impacts on the natural environment. The nature, extent and frequency of compliance monitoring programs will reflect the nature, extent and frequency of the potentially detrimental influences (eg waste inputs) associated with the commercial activities. In Western Australia marine reserves, compliance monitoring programs are usually part of the conditional approvals granted by the EPA, in consultation with CALM, under the environmental impact assessment process.

PRIORITY FOR ACTION

Values

- **Determine the relative value of each 'Wilson report' area in relation to the criteria outlined above as a guide to implementation priority.**

Management objectives

- **Formulate management objectives in scientifically measurable terms for marine reserves in Western Australia.**

Characterisation

Resource inventory

- **Develop biologically and spatially accurate digital maps of major marine habitats of marine reserves in Western Australia.**

- **Quantitatively describe the major taxonomic groups within each major habitat of marine reserves in Western Australia.**

Baselines and natural variability

- **Quantitatively describe, in space and time, the physical, chemical and geological environment of (in order of priority) the major primary producers and secondary consumers, rare or endangered species, commercial and recreationally important species in marine reserves in Western Australia.**

- **Quantitatively describe, in space and time, the variability in species composition and abundance of (in order of priority) the major primary producers, secondary consumers, rare or endangered species and commercial and recreationally important species in marine reserves in Western Australia.**

Key ecological processes

- **Develop an understanding of the maintenance processes (ie growth and reproduction) for major primary producers, secondary consumers, rare or endangered species and commercial and recreationally important species in marine reserves in Western Australia.**

Human use

- **Develop an understanding of the links between human usage and effects on the natural environment of marine reserves in Western Australia.**

Threatening processes

- **Develop databases of human usage for marine reserves in Western Australia.**

- **Develop prioritised threat databases for each marine reserve in Western Australia.**

Monitoring trends

Surveillance monitoring

- **Implement surveillance monitoring programs for individual marine reserves in Western Australia.**

Compliance monitoring

- **Ensure the objectives of compliance monitoring programs are reconciled with the management objectives of individual marine reserves in Western Australia.**

APPENDIX IV

Marine Conservation Branch Datasets

Marine Conservation Branch Datasets

Note: This list includes only those datasets currently on the Marine Conservation Branch system and does not include many relevant datasets that are available on line from CALM's GIS servers or from departments linked to the WALIS server.

W.A. State Coverage

Bathymetry (5,10,20.50 metre) AMBIS baseline & boundary data
AMBIS boundary and baseline data
Wilson Report recommended areas
WA coastline
WA petroleum titles
WA pastoral lease boundaries
WA native title claims
CALM tenure
Local Government Authority boundaries
National Estate registered areas
Bird habitat
Crocodile habitat
Dugong habitat
Fur seal habitat
Sea-lion habitat
IMCRA Meso Scale Bio-regions

Kimberley Region

Rowley shoals scanned aerial photo cover
Clerke & Imperiuse habitat data

Midwest Region

Shark Bay

Seagrass
Marine habitat
Tenure
Boat Ramps
Mine Tenure
Coral
Dugong
Historical (shipwrecks)
Jetties
Mangroves
Mine site
Navigational aids
Pearls
Recreational (fish, boat, dive, camp etc.)
Bird
Transect
Turtle survey
Cetaceans

Salinity
Zoning
Fishing commercial
Landsat TM imagery
Topography
Bernier- Dorre Island marine habitat
Heritage boundary

Central West Coast

Regional marine habitat
Coastal tenure
Aquaculture sites
Recreational (fish, surf, dive, boat etc.)
Wreck sites
Navigational aids
Roads
Flight paths
Geological Data
Oceanographic data
Regional tenure
Landsat TM imagery
Coast type
Dune type
Coastal stability
Biomass
Species Diversity
Ground truth point source data
Exploration wells
Lobster fishery
Sealion Islands
Whale migratory path
Water penetration aerial photo coverage

South Coast Region

Marine habitat
Point source ground truth data

Pilbara Region

Montebellos marine habitat
Ningaloo mineral leases
North - West Cape Ningaloo tenure
Pilbara - Gascoyne offshore island eco tourism
Whale Shark encounters
Landsat Tm Imagery
Recreational North West Cape

Rottnest

Mooring Data