MARINE MANAGEMENT SUPPORT

PRIORITISING MARINE RESEARCH IN THE DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT:

YEAR 2002 STUDENT RESEARCH TOPICS FOR WESTERN AUSTRALIA'S MARINE CONSERVATION RESERVES

Report: MMS-60/2002

Prepared by
J A Davidson, N D'Adamo and C J Simpson

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

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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: 61-8-9336 0100; Fax: 61-8-9430 5408

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1 INTRODUCTION

1.1 BACKGROUND

Effective management of Western Australia's marine conservation reserves requires an adequate level of understanding of their main physical, biological, geological and social characteristics to ensure that the existing and potential impacts of human activities and natural processes can be properly assessed and managed. The Department of Conservation and Land Management's main efforts in terms of facilitating marine research centers around the strategic and collaborative coordination of external research effort and tactical research conducted through the Marine Conservation Branch (MCB) and coastal district offices of the Department. There is a pressing need to supplement the existing level of management-related marine information through fundamental scientific marine research.

The Western Australian marine research community, including universities, State and Western Australian-based Federal marine research agencies and private organisations, has significant expertise and capacity, relevant to marine biodiversity conservation and the management of human usage of the marine environment. In the past, the local scientific community has undertaken substantial amounts of marine research relevant to marine conservation reserves but with the allocation of resources and expertise being offered on an opportunistic basis and reliant upon the goodwill of the various researchers and institutions involved. As an initiative to help improve the Department of Conservation and Land Management's scientific marine informational base for management, the MCB has initiated a small annual marine research funding program to specifically address the needs of the Department's marine conservation 'program'.

The MCB has identified a range of research topics relevant to the Department's strategic marine informational requirements and will liaise with interested scientists to facilitate this research. Through this initiative, the research community will be able to seek financial, operational and logistical support for priority projects. Direct financial support will generally be limited to seed funding for projects at honours level and, in special circumstances, to supplementary funding of masters or doctoral projects. Apart from direct funding, the MCB will facilitate the commitment of operational and logistical support from the Department's regional and district offices. Furthermore, the MCB will continue to provide written endorsement and assistance for relevant research submissions to external funding sources.

1.2 PURPOSE

The purpose of this report is to:

i) Document the research requirements of Western Australia's existing marine conservation reserves.

ii) Document the prioritisation of research requirements.

iii) List the 2002 student project topics.

2 RESEARCH REQUIREMENTS

This project began with a review and appraisal of existing marine science information, as relevant to the Department's marine management support functions, which was collated in the form of a bibliography. References for inclusion into the bibliography were obtained from libraries (Library Information Services of Western Australia), online databases (Current Contents), State Government organisations (Department of Conservation and Land Management, Department of Environmental Protection, Water and Rivers Commission, Department of Fisheries, Museum of Western Australia), Commonwealth Government organisations (CSIRO, Australian Institute of Marine Science) and

universities (Murdoch University, University of Western Australia, Edith Cowan University and Curtin University of Technology). The bibliography assisted in highlighting gaps in marine research, enabling a prioritisation of the Department's informational requirements for management of its marine conservation reserves.

Management strategies obtained from relevant management plans and any associated draft operational guidelines were condensed into research requirements for each ecological and social value of the respective marine conservation reserves (Appendix I). The papers: *Generic information requirements for the management of marine conservation reserves in Western Australia* (Simpson and Cary, 1998), and *Strategic framework for marine research and monitoring in the Shark Bay World Heritage Property* (Simpson *et al.*, 2002) were used to help prioritise the research requirements (see section 3.1). These papers are re-produced in Appendix II.

3 PRIORITISATION OF RESEARCH REQUIREMENTS

3.1 GENERIC RESEARCH REQUIREMENTS

The prioritisation of generic research requirements and those considered relevant as external (non-departmental) research projects are as follows:

First order priorities

- Develop comprehensive databases of human usage (including attitudinal information).
- Develop, at appropriate scales, biologically and spatially accurate digital maps of the major marine habitats and other major marine resources.
- Develop an appropriate level of understanding of the physical oceanography.
- Develop an understanding of i) the links between human usage and values, and ii) the effects of human usage on the natural environment.

Second order priorities

- Quantitatively describe the major taxa within representative areas of each major habitat. Where quantitative data is not available, qualitative data such as presence/absence data may be adequate.
- Quantitatively describe, in space and time, the physical, chemical and geological environment of (in order of priority) the major primary producers, rare or endangered species and important commercial and recreational species.
- Quantitatively describe, in space and time, the variability in species composition and abundance of (in order of priority) the major primary producers, rare or endangered species and important commercial and recreational species.
- Develop an understanding of the maintenance processes (i.e. growth, feeding, reproduction and recruitment) for (in order of priority) major primary producers, rare or endangered species and important commercial and recreational species.

3.2 VALUE-THREAT-KNOWLEDGE ANALYSIS

A formalised value-threat-knowledge analysis was not possible for the 2001/02 projects, and hence the collective experience and knowledge of MCB and district staff was used to identify the project list for 2001/02.

The finalised framework of Simpson *et al*. (2002) can be used in the future to prioritise research requirements for each marine conservation reserve and for the development of future student project lists.

4 STUDENT PROJECT TOPICS FOR 2002

Of the overall set of information requirements, those relevant to short-term (i.e. <1 year) undergraduate student research for 2002 are as follows:

BIOLOGICAL

1. Characterisation of the flora and fauna of selected intertidal reef platforms within the proposed Jurien Bay Marine Park

2. Development of a cost-effective methodology for the monitoring of sea lions and sea lion pup populations

3. Establishment of baseline physical and chemical water quality characteristics of the proposed Jurien Bay Marine Park

4. The distribution and abundance of the 100M year old living molluscan dinosaur, *Campanile symbolicum*, in the proposed Jurien Bay Marine Park

5. Comparative study of the relative distributions and abundances of *Milo miltonis* and *Syrinx aruanus* in the Shoalwater Islands, Marmion and proposed Jurien Bay marine parks

6. Development of a cost-effective methodology for monitoring Little Penguin (*Eudyptula minor*) populations

7. Assessment of the scientific and ethical issues associated with the use of internet-based cameras as a monitoring tool: a case study - wader and waterbirds of the Swan Estuary Marine Park

8. Characterisation of the distributions and abundances of key prey species of the wader and waterbirds of the Swan Estuary Marine Park

9. Distribution and abundance of the endemic Shark Bay Sea Snake in the Shark Bay marine reserves and assessment of existing or potential impacts of human activities

10. Mapping and vulnerability assessment of the biological values of the intertidal reef platforms of the Rowley Shoals Marine Park, through the use of remote sensing techniques

11. Habitat mapping in Walpole/Nornalup Inlet

SOCIAL

12. Assessment of the nature, level and potential impacts of human activities on intertidal reef platforms within the proposed Jurien Bay marine park

13. Assessment of the social value of the major seascapes of the proposed Jurien Bay Marine Park

14. Understanding the heritage significance of the proposed Jurien Bay Marine Park area to the Elders of the area

15. Understanding the heritage significance of the Swan Estuary Marine Park to the Elders of the area

PHYSICAL

16. Characterisation of the hydrodynamics of the proposed Jurien Bay Marine Park's waters through in-situ monitoring at key sites and complementary numerical modelling of fine scale circulation and flushing patterns

17. Characterisation and numerical modelling of the hydrodynamics of the Rowley Shoals Marine Park

18. Literature review of the climate and oceanography of the Walpole-Nornalup Estuary

19. Modelling nearshore circulation and transport of the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

20. Feasibility study for commercial underwater marine viewing facilities in Western Australian marine conservation reserves

GEOLOGICAL

21. Characterisation of the surficial sediments of the proposed Jurien Bay marine park

22. Assessment of degradation in the coastal environs of the Ningaloo Marine Park

5 REFERENCES

Simpson, C. J. and Cary, J. (1998). Generic information requirements for the management of marine conservation reserves in Western Australia. Marine Conservation Branch, Department of Conservation and Land Management. Perth, Western Australia. DRAFT REPORT.

Simpson, C.J., Colman, J.G. and Hill, A.K. (2002). Strategic framework for marine research and monitoring in the Shark Bay World Heritage Property. Marine Conservation Branch, Department of Conservation and Land Management. Perth, Western Australia.

APPENDICES

APPENDIX I: RESEARCH REQUIRMENTS TO ADDRESS MANAGEMENT STRATEGIES FOR WESTERN AUSTRALIA'S MARINE CONSERATION RESERVES.

The following research requirements were drawn from the management strategies contained in existing management plans and draft management strategies from management plans currently in preparation for the Department of Conservation and Land Management's existing marine conservation reserves. Note that work is currently underway by the Marine Conservation Branch, in collaboration with the Department of Conservation and Land Management's coastal district offices to refine and finalise these lists of strategies. As such, the following lists should be regarded as interim. These are grouped into eight generic categories; oceanography/climate, geomorphology, chemistry, biological processes, biological inventory, social research, and human usage. The categories relate to the broad headings outlined in the draft report titled, *Generic information requirements for the management of marine reserves in Western Australia* (Simpson and Cary, 1998).

The following key was used to define the importance of the research requirements and was adapted from the *Indicative management plan for the proposed Jurien Bay Marine Park*. The high research requirements (H) considered to be critical to achieving the long-term objectives of the marine reserves are defined as key research requirements (H-KRR).

Key:
H = high research requirement
M = medium research requirement
L = low research requirement

PROPOSED JURIEN BAY MARINE PARK

Biological Inventory

Strategy No.	Research Requirement
7.1.2.2 7.1.5.2	Initiate research programs to characterise the flora and fauna of selected intertidal reef platforms (CALM, FWA) (H-KRR) and quantify the floral and faunal diversity in major subtidal macroalgal habitats in the Park in relation to developing management targets (CALM) (H)
7.1.3.4	Map ecological and social values of the Park that are particularly sensitive to oil spills and provide this information to the State Committee for Combating Oil Pollution (CALM, DoT) (H)
7.1.7.2 7.1.8.2	Undertake research programs to characterise invertebrate and finfish diversity and abundance in different zones in the Park (CALM) (H-KRR)

Oceanography/climate

Strategy No.	Research Requirement
7.1.3.2	Develop an appropriate understanding of the circulation and mixing of the Park's waters (CALM) (H-KRR)

Chemistry

Strategy No.	Research Requirement
7.1.3.1 7.1.3.3	Establish and maintain a pollutant inputs database for the Park and establish baseline water quality monitoring programs in relation to nutrient enrichment (CALM) (H-KRR)

Biological Processes

Strategy No.	Research Requirement
7.1.4.4	Monitor seagrass meadows in areas at most risk of mooring and anchoring damage and, if necessary, nutrient inputs (CALM) (H)
7.1.9.3	Monitor trends in sea lion pup production each breeding season (CALM) (H)

Social Research

Strategy No.	Research Requirement
7.1.2.3	Assess the nature, level and potential impacts of human activities on intertidal reef platforms within the Park (CALM) (H)
7.1.5.4	Quantify the level of private algal wrack collection and introduce controls where this is having a significant impact on the nearshore ecology of the Park (CALM) (L)
7.1.7.3 7.1.8.3	Identify invertebrate and finfish species which will be protected from recreational or commercial fishing in the Park and provide the necessary legislative protection to achieve this (FWA, CALM) (H-KRR)
7.1.7.4 7.1.8.4	Quantify the level and significance of by-catch for recreational and commercial fishing activities in the Park and, if necessary in accordance with Fisheries WA By-catch Action Plans, implement measures to progressively reduce the by-catch of invertebrate species in the Park (FWA, CALM) (M)
7.1.9.4	Quantify the level of sea lion entrapment and drowning in commercial fishing gear and, if necessary, investigate ways to reduce this, through the development of a By-catch Action Plan by Fisheries WA and in collaboration with the commercial fishing industry (CALM, FWA. WAFIC) (H)
7.1.10.1	Maintain records of the incidence of entanglement, boat collisions and strandings of cetacean and turtle species (CALM, WAM, WAFIC) (M)
7.2.1.1	Develop, in collaboration with the local indigenous population, an understanding of the significance of the area to Aboriginal people (CALM, local Aboriginal groups) (H)
7.2.3.2	Investigate the level of impact of the rock lobster fishery on the habitats and flora and fauna of the Park (FWA, CALM) (H-KRR)
7.2.3.3 7.2.7.4	Determine the effects of commercial and recreational fishing activity on the Park's values and review management controls as required (FWA, CALM) (H-KRR)
7.2.3.6 7.2.7.6	Monitor commercial and recreational fishing catch/effort within the Marine Park (FWA) (H)
7.2.6.1	Identify and determine the key characteristics and spatial extent of the major seascapes of the Park (CALM, LGA) (H)
7.2.7.2	Evaluate the sustainability of existing recreational fisheries in the Park (FWA) (H-KRR)
7.2.8.2	Determine the nature, spatial patterns, compatibility and potential environmental impacts of all existing water sports in the Park (CALM) (H)

Human Usage

Strategy No.	Research Requirement
7.2.5.4	Identify popular beaches in the Park and beaches which are potentially environmentally sensitive to RV use (CALM, LGA) (L)

ROWLEY SHOALS MARINE PARK

Biological Inventory

Strategy No.	Research Requirement
7.1.2.3	Map ecological and social values of the park that are particularly sensitive to oil spills and provide this information to the State Committee for Combating Marine Oil Pollution (CALM, DoT) (H)
7.1.3.4 7.1.4.7	Produce an accurate habitat map of the Rowley Shoals Marine Park and initiate research programs to characterise the flora and fauna of selected intertidal coral reef flats within the park (CALM) (H-KRR)

Oceanography/climate

Strategy No.	Research Requirement
7.1.2.4	Develop an appropriate understanding of the circulation and mixing of the park's waters (within and outside the lagoon) (CALM) (H)

Chemistry

Strategy No.	Research Requirement
7.1.2.1 7.1.2.5	Establish baseline water quality monitoring programs in relation to nutrient enrichment and establish and maintain a pollution inputs database for the park (CALM) (H-KRR)

Biological Processes

Strategy No.	Research Requirement
7.1.4.2	Monitor coral communities in areas at most risk of mooring and anchoring damage and, if necessary, nutrient inputs (CALM) (H-KRR)
7.1.5.3	Establish monitoring programs for invertebrate species likely to be targeted by illegal commercial and recreational specimen collectors (CALM, FWA) (H-KRR)
7.1.6.2	Undertake monitoring programs to characterise non-target finfish diversity and abundance in different zones in the park (CALM) (H-KRR)

Social Research

Strategy No.	Research Requirement
7.1.3.5	Assess the nature, level and potential impacts of human activities on intertidal coral reef flats within the park (CALM) (H)
7.1.6.3 7.2.1.3 7.2.1.7	Evaluate the impact of recreational fishing on target species within the region and its impact on the park's values and undertake monitoring programs to determine the impact of recreational fishing and status of key fish stocks (FWA) (H)
7.1.6.4 7.2.1.6	Quantify survival rates of fish species targeted by recreational fishers of catch and release and determine the survival rates of protected species which are incidentally caught and released (FWA) (H)
7.1.6.6 7.2.1.5	Monitor recreational fishing catch/effort within the park and undertake by-catch surveys of recreational fishing in the park (FWA, CALM) (M - H)
7.1.7.1 7.1.9.2	Maintain records of the incidence of entanglement, boat collisions with, and stranding of turtle and cetacean species (CALM) (H)
7.2.2.1	Determine the nature, spatial patterns, compatibility and potential environmental impacts of all existing contact recreational activities in the park (CALM) (M)
7.2.3.2 7.2.6.3	Identify and determine the key characteristics and spatial extent of the major seascapes of the park and identify the importance of the wilderness experience to visitors and their perceptions of what is a suitable level of use, before these values are significantly impacted (CALM) (L - H)

NINGALOO MARINE PARK

Biological Inventory

Strategy No.	Research Requirement
CALM 1989 no.2 pg56	Undertake research programs to characterise fish diversity and abundance in different zones within the park (CALM, FWA)

Oceanography/climate

Strategy No.	Research Requirement
CALM 1989 no.1 pg 69	Develop an appropriate understanding and predictive capability of the circulation and mixing of the waters of the park (CALM)

Biological Processes

Strategy No.	Research Requirement
CALM 1989 no.1 pg 69	Implement research programs into the basic ecology of the park (CALM)
CALM 1989 no.2 pg 69	Undertake monitoring of marine flora and fauna at most risk from human activities (CALM)

Social Research

Strategy No.	Research Requirement
CALM 1989 no. 2 pg 56	Initiate monitoring programs for fish populations within the park.
CALM 1989 no. 3 pg 56	Identify fish species which will be protected from recreational or commercial fishing in the Park and provide the necessary legislative protection to achieve this (FWA, CALM)
CALM 1989 no. 3 pg 56, no.4 pg57	Monitor commercial and recreational fishing catch/effort within the park and evaluate the sustainability of these fisheries (FWA)
CALM 1989 section 17 and 18	Determine the effects of commercial and recreational fishing activity on the ecological and social values of the park and review and implement appropriate management measures and controls as required (FWA, CALM)
CALM 1989 no.4 pg 69	Assess the nature, level and potential impacts of human activities on the ecological and social values of the park and review and implement appropriate management measures and controls as required (CALM)
CALM 1989 no.5 pg 69, no.6 pg 69	Initiate research program to determine the relative economic value of the recreational and commercial uses of the park and initiate research to determine the potential socioeconomic benefits and costs arising from the establishment and management of the park (CALM

SHARK BAY MARINE RESERVES

Biological Inventory

Strategy No.	Research Requirement
6.1.2.1 6.1.2.2	Determine the nature and spatial distributions and develop a comprehensive habitat map of intertidal reef platforms within the reserves and initiate research programs to characterise the flora and fauna of selected intertidal reef platforms (CALM, FWA) (H-KRR)

6.1.3.4	Undertake risk assessment and establish a baseline monitoring program for marine pests and pathogens within the reserves (CALM, CSIRO-CRIMP) (H-KRR)
6.1.3.5	Map ecological and social values of the reserves that are particularly sensitive to exposure to contaminants (e.g. waterborne marine pests, wastewater, toxicants) and, with respect to those that are particularly sensitive to oil spills, provide this information to the State Committee for Combating Oil Pollution and ensure the preparation of an adequate oil spill contingency plan for the reserves (CALM, DoT) (H-KRR)
6.1.4.3	Complete the development of a comprehensive habitat map of the seagrass communities within the reserves (CALM) (H-KRR)
6.1.5.1 6.1.5.2 6.1.5.4	Determine the nature and spatial distributions and develop a comprehensive habitat map of mangrove communities within the reserves and initiate research programs to characterise the flora and fauna of selected mangrove communities (CALM, FWA) (H-KRR)
6.1.6.1 6.1.7.1	Develop a comprehensive habitat map of stromatolite communities and algal mat communities within the reserves (CALM, FWA) (H-KRR)
6.1.8.1	Develop a comprehensive habitat map of coral communities within the reserves (CALM, FWA) (H-KRR)
6.1.9.1 6.1.9.2	Develop a comprehensive wildlife distribution map for the seabirds of the marine reserves and identify areas within the marine reserves that are significant for migratory birds covered by the JAMBA and CAMBA agreements, and ensure that commercial and recreational activities do not have significant impacts on the bird populations or their habitats (CALM) (H-KRR)
6.1.10.1	Undertake research programs to characterise invertebrate diversity and abundance in different zones in the reserves (CALM, FWA) (H-KRR)
6.1.11.1	Undertake research programs to characterise finfish diversity and abundance in different zones in the reserves (CALM, FWA) (H-KRR)
6.1.12.1	Undertake research programs to identify and record whale occurrences in the marine reserves and to characterise the location, movement and activities of whale populations in the reserves (CALM, FWA) (H-KRR)
6.1.13.1	Undertake research programs to characterise the distributions and ecology of reptile species in the marine reserves (CALM, FWA) (H-KRR)
6.2.6.1 6.2.7.1	Identify and determine the key characteristics and spatial extent of the major seascapes and wilderness areas of the reserves (CALM, LGA) (H-KRR)

Geomorphology

Strategy No.	Research Requirement
6.1.1.1	Develop an appropriate understanding and predictive capability of the relationships between the hydrodynamics, geomorphology and associated hydrology of the coastal environs of the reserves (CALM) (H-KRR)

Oceanography/climate

Strategy No.	Research Requirement
6.1.3.2 6.2.14.4 6.2.4.2	Develop an appropriate understanding and predictive capability of the circulation and mixing of the waters of the reserves and the flushing of the Monkey Mia lagoon, and use this information to determine the fate and impacts of contaminants introduced from various sources including aquaculture activity (CALM, FWA) (H-KRR)

Chemistry

Strategy No.	Research Requirement
6.1.3.1 6.1.3.3 6.2.14.3 6.2.14.5	Establish and maintain a contaminants input inventory and database for the reserves, including the Monkey Mia lagoon, with reference to existing and potential contaminant sources, and establish baseline water and sediment quality monitoring programs in relation to nutrient enrichment, microbiological and toxic contamination in the reserves (CALM, WRC, DoT, LGA, FWA, AgWA, local commercial operators) (H-KRR)

Biological Processes

Strategy No.	Research Requirement
6.1.4.5 6.1.4.7	Monitor seagrass meadows in areas at most risk to damage from mooring, anchoring, propeller scouring, aquaculture activities and poor water quality and predict the threat of existing and proposed aquaculture activities on the health of seagrass meadows through biological and oceanographic studies (CALM, FWA) (H)
6.1.5.3	Initiate research programs to characterise the ecological role of mangrove communities in relation to the marine ecosystem, the bird and bat ecology and also the ecology of other animals of the reserve (CALM) (H-KRR)
6.1.6.2 6.1.7.2	Initiate research programs to characterise the ecological role of stromatolite communities and algal mat communities in the marine ecosystem of the reserves, with particular relevance to the occurrence and distribution of hypersaline-tolerant marine species (CALM) (H-KRR)
6.1.8.2	Initiate research programs to characterise the ecological role of coral communities in the marine ecosystem o the reserves (CALM) (H-KRR)
6.1.9.3	Develop an implement a research and monitoring program for seabirds of the marine reserves (CALM) (H)
6.1.10.3	Undertake research into the biology of the heart cockle Fragum erugatum and ensure that extraction of the shell of Fragum erugatum is ecologically sustainable (CALM) (H-KRR)
6.1.14.1 6.2.14.5	Undertake research programs to characterise the ecology of Dugong populations in the marine reserves and monitor trends in overall dugong numbers and breeding rates during each breeding season (CALM) (H-KRR)
6.2.13.1	Undertake research programs to characterise the ecology of the Bottlenose dolphins local to Monkey Mia (CALM, FWA) (H-KRR)

Social Research

Strategy No.	Research Requirement
6.1.5.5	Assess the nature and level of existing and potential impacts of human activities on mangroves within the reserves (CALM) (H)
6.1.6.3 6.1.7.3	Assess the nature, level and potential impacts of human activities on stromatolites and algal mat communities within the reserves (CALM) (H)
6.1.8.3	Assess the nature, level and potential impacts of human activities (e.g. mooring activities) on coral communities within the reserves (CALM) (H-KRR)
6.1.10.2 6.1.11.2	Identify invertebrate species and finfish species which need to be protected from recreational or commercial fishing in the reserves and provide the necessary legislative protection to achieve this (FWA, CALM) (H-KRR)
6.1.10.5 6.1.11.3	Quantify the level and significance of by-catch for recreational and commercial fishing activities in the reserves and, if necessary and in accordance with Fisheries WA By-catch Action Plans, implement measures to progressively reduce the by-catch of invertebrate species in the reserves (CALM, FWA) (M)
6.1.12.2	Assess the nature, level and potential impacts of human activities on whale communities within the reserves through, for example, the maintenance of records on the incidence of entanglement, boat collisions and strandings of whale species (CALM, WAFIC) (H-KRR)
6.1.13.3	Monitor the impacts of activities that could entangle and injure/kill sea snakes in the marine reserves (CALM) (H-KRR)
6.1.14.3	Implement a monitoring program to identify the nature and severity of disturbance to Dugong behavior as a result of human activities and implement management measures to minimise disturbance to sustainable levels (CALM) (H-KRR)
6.2.1.1 6.2.1.4	Conduct an assessment of the compatibility of recreational and commercial activities with the indigenous heritage values of the reserves and develop, in collaboration with the local indigenous population, an understanding of the significance of the marine reserves to Aboriginal people (CALM, local aboriginal groups) (H-KRR)
6.2.2.1	Develop, in association with the WA Maritime Museum, an inventory of known and potential items and sites of maritime heritage in the reserves and conduct an analysis of threats to these items and sites by human activities in the reserves (WAMM, CALM) (H-KRR)
6.2.3.1 6.2.8.3	Determine the effects of commercial and recreational fishing activity on the ecological and social values of the reserves and review and implement appropriate management measures and controls as required (FWA, CALM) (H-KRR)

6.2.3.4 6.2.8.1 6.2.8.5	Monitor commercial and recreational fishing catch/effort within the marine reserves and evaluate the sustainability of existing recreational fisheries in the reserves (FWA) (H-KRR)
6.2.9.1	Determine the nature, spatial patterns, capability and existing and potential environmental impacts of all existing water sports in the reserves (CALM) (H-KRR)
6.2.14.2	Ensure human-dolphin interaction activities do not impact adversely on the dolphins, through continued management of interaction activities, appropriate education programs and liaison with charter operators, and maintenance of records of incidences of collisions, entanglement and moralities of dolphins (CALM, WAFIC) (H-KRR)

Human Usage

Strategy No.	Research Requirement
6.1.2.3 6.2.5.4	Assess the nature, level and potential impacts of human activities on intertidal reef platforms, popular beaches and beaches which are potentially environmentally sensitive to recreational vehicle use within the reserves (CALM, LGA) (H, L)
6.1.13.2	Monitor recreational use of turtle nesting sites and associated human disturbance to nesting turtles, and invoke necessary controls on threatening activities (CALM) (H-KRR)

MARMION MARINE PARK

Biological Inventory

Strategy No.	Research Requirement
6.1.2.2 6.1.5.3	Initiate research programs to characterise the flora and fauna of selected intertidal reef platforms within the park (CALM, FWA) (H-KRR) and quantify the floral and faunal diversity in major subtidal macroalgal habitats in the park in relation to establishing management targets (CALM) (M)
6.1.3.5	Map ecological and social values of the park that are particularly sensitive to oil spills and provide this information to the State Committee for Combating Oil Pollution (CALM, DoT) (H)
6.1.7.2 6.1.8.2	Undertake research programs to characterise invertebrate and finfish diversity and abundance in different zones in the park and to characterise the 'cave' fauna (CALM, FWA) (H-KRR)
CALM 1992. No. 6 pg 33	Initiate research programs to determine the status of marine mammal populations in the park (CALM)

Geomorphology

Strategy No.	Research Requirement
CALM 1992. pg. 27, No. 3 pg 33	Develop an appropriate understanding and predictive capability (for future developments) of the relationships between the hydrodynamics, geomorphology and associated hydrology of the coastal environs of the marine park (CALM)

Chemistry

Strategy No.	Research Requirement
6.1.3.1	Establish and maintain a pollutant inputs database for the park (CALM) (H-KRR)
6.1.3.2 6.1.3.3	Establish monitoring programs in relation to compliance of the management targets for wastewater discharges (nutrients, toxicants and pathogens) from the Beenyup wastewater outfalls (WC, CALM, DEP), and establish monitoring programs in relation to nutrient enrichment and toxicants (CALM) (H-KRR)
6.1.3.4	Establish monitoring programs in relation to pathogens along the shoreline at the popular swimming beaches and ensure data is collected and reviewed (CALM, Health Dept, LGA) (H-KRR)

6.1.3.7	Determine, in liaison with local with Authorities, the level of pollution inputs to the Marmion Marine Park from discharge via local rivers and drains (such as the Swan River) (CALM, WRC, LGA, AgWA) (M)

Biological Processes

Strategy No.	Research Requirement
6.1.4.1	Monitor seagrass meadows in areas at most risk of nutrient inputs and mooring and anchoring damage (CALM, WC, DoT) (H)
6.1.5.1 6.1.7.3	Monitor the effect of nutrient inputs from the Beenyup outfall on macroalgal and invertebrate communities (WC, CALM) (H)
6.1.8.3	Monitor the effect of wastewater from the Beenyup wastewater sewage outlet on finfish diversity and abundance.
CALM 1992. No. 1 pg 59	Develop an appropriate understanding of the relationships and interactions between ecological and oceanographic processes of the Park (CALM)
CALM 1992. No. 4 pg 59	Implement monitoring programs to determine habitat and species diversity within Sanctuary Zones of the marine park and compare with Recreation and General Use Zones of the park (CALM)

Social Research

Strategy No.	Research Requirement
6.2.7.4 6.2.7.2	Determine the effects of recreational and commercial fishing activity on the park's values and review management controls as required (FWA, CALM) and evaluate the sustainability of existing recreational fisheries in the park (FWA) (H-KRR)
6.1.2.3	Assess the nature, level and potential impacts of human activities on intertidal reef platforms within the park (CALM) (H)
6.1.7.4 6.1.8.4	Identify invertebrate and finfish species which will be protected from recreational or commercial fishing in the Park and Provide the necessary legislative protection to achieve this (FWA, CALM) (H-KRR)
6.1.7.5 6.1.8.5	Quantify the level and significance of by-catch for recreational and commercial fishing activities in the park and, if necessary and in accordance with Fisheries WA By-catch Action Plans, implement measures to progressively reduce the by-catch of invertebrate species in the park (FWA, CALM) (M)
CALM 1992. No. 6 pg 33. No. 2 pg 42. No. 6 pg 43	Assess the nature, level and potential impacts of human activities on wildlife including marine mammal and seabird populations in the park and initiate monitoring programs of marine mammal populations in the park (CALM)
CALM 1992. No. 2 pg 38, no. 2 pg. 44	Implement monitoring programs on commercial and recreational fishing, including abalone and rock lobster fishing catch/effort within the marine park and evaluate the sustainability of existing commercial and recreational fisheries in the park and monitor the impact of fisheries within the park on the ecological and social values of the park (FWA, CALM) (H-KRR)
CALM 1992. No. 6 pg 40	Investigate ways to improve access to reefs suitable for diving and snorkelling, for example diver access to Boyinaboat reef, dive trails in appropriate areas (CALM, DoT)

Human Usage

Strategy No.	Research Requirement
CALM 1992. No. 3 pg 59	Implement monitoring programs to determine the nature and spatial patterns of human usage in the marine park and to determine impacts of human usage in and adjacent to the marine park (CALM) (H-KRR)

SWAN ESTUARY MARINE PARK

Biological Inventory

Strategy No.	Research Requirement
Invertebrate communities	Undertake research programs to characterise invertebrate diversity and abundance in the park (CALM) (H-KRR)
Migratory birds	Undertake research programs to characterise the diversity and abundance of migratory birds in the park (CALM) (H-KRR)
CALM 1999 no. 1 pg 6	Identify and map areas of low lying vegetation such as samphire flats important for waders and water birds in the Marine Park, and seek MPRA and NPNCA endorsement to extend the three land-based reserves from high water mark to include these areas
CALM 1999 no.2 pg 6	Assess and document other areas important for waders and waterbirds of high conservation and recreation value and where appropriate add to the Swan Estuary Marine Park, particularly those areas adjacent to the Marine Park or adjacent to important foreshore conservation areas
CALM 1999 no. 3 pg 14	Develop a comprehensive map of the ecological and social values of the park and develop management recommendations for their conservation
CALM 1999 no. 1 pg 19	Identify, map and maintain records of all known weeds and introduced species

Geomorphology

Strategy No.	Research Requirement
CALM 1999 no. 1 pg 11	Identify important geomorphologic features within or near the reserve system that are valuable and vulnerable to damage, including the sand and mud flats in each of the three areas and the fossil sites at Point Waylen and Alfred Cove.

Chemistry

Strategy No.	Research Requirement
Water quality	Establish and maintain a pollutant inputs database for the park (CALM)
Water quality	Monitor water quality data collected by other government agencies to ensure that the seagrass, benthic infauna communities and migratory birds are not being impacted (CALM, WRC)
CALM 1999 no. 2 pg 16	Ensure the existing water quality monitoring program is adequate for the Marine Park's management requirements

Biological Processes

Strategy No.	Research Requirement
CALM 1999 no. 8 pg 14	Initiate monitoring programs for benthic fauna and to assess impacts from human activity
CALM 1999 no. 5 pg 15	Initiate monitoring programs for wader and waterbird numbers, dynamics, feeding and breeding in the park and establish management strategies to enhance waterbird use of the reserve system

CALM 1999 no. 2 pg 20	Monitor feral animal populations and regularly assess the effectiveness of control programs as well as possible threat from the control programs to non-target species
CALM 1999 no. 3 pg 30	Monitor the impact of moorings on seagrass beds and prohibit the construction of new moorings

Social Research

Strategy No.	Research Requirement
CALM 1999 no. 1 pg 17	Conduct an assessment of the compatibility of recreational and commercial activities with the indigenous heritage values of the reserves and develop, in collaboration with the local indigenous population, an understanding of the significance of the marine reserves to Aboriginal people
CALM 1999 no. 2 pg 21	Determine the effects of recreational and commercial fishing activity on the ecological and social values of the reserves and review and implement appropriate management measures and controls as required, and evaluate the sustainability of recreational and commercial fishing including line, cobbler, prawn and crab fishing in the park.
CALM 1999 no. 5 pg 23, no. 3 pg 23	Assess the nature, level and potential impacts of human activities on the ecological and social values of the marine park
CALM 1999 no. 3 pg 23	Monitor the impact that observation and interaction activities have on wildlife within the park
CALM 1999 no. 2 pg 33	Monitor local property owner and visitor expectations and perceptions of reserve management and equity of use

SHOALWATER ISLANDS MARINE PARK

Biological Inventory

Strategy No.	Research Requirement
6.1.2.2 6.1.5.2	Initiate research programs to characterise the flora and fauna of selected intertidal reef platforms and quantify the floral and faunal diversity in major subtidal macroalgal habitats within the park in relation to establishing management targets (CALM) (H-KRR)
6.1.8.2 6.1.9.2	Undertake research to characterise invertebrate and finfish diversity and abundance in different zones in the park (CALM, FWA) (H-KRR)
6.1.3.4	Map ecological and social values of the park that are particularly sensitive to oil spills and provide this information to the State Committee for Combating Oil Pollution (CALM, DoT) (H)

Oceanography/climate

Strategy No.	Research Requirement
6.1.3.2	Develop an appropriate understanding of the circulation and mixing of the park's waters (CALM) (H-KRR)

Chemistry

Strategy No.	Research Requirement
6.1.3.1 6.1.3.6	Establish and maintain a pollutant inputs database for the park (CALM) (H-KRR) and determine, through liaison with local authorities, the level of pollutant inputs to the Shoalwater Island Marine Park from discharge via estuaries and drains (such as the Peel-Harvey Inlet) (CALM, WRC, LGA, AgWA) (M)
6.1.3.3	Ensure water quality monitoring programs in relation to nutrient enrichment are maintained (CALM) (H-KRR)

Biological Processes

Strategy No.	Research Requirement
6.1.6.1	Monitor seabird populations in the park and assess impacts by human disturbances (CALM) (H-KRR)
6.1.7.1 6.1.7.2	Monitor little penguin populations and breeding success in the park (CALM) (H-KRR)
6.1.4.4 6.1.4.6	Monitor seagrass meadows in areas at most risk of mooring and anchoring damage and, if necessary, nutrient inputs (CALM) (H) and monitor seagrass meadows in areas at most risk to human impacts from aquaculture and predict the threat of existing and proposed aquaculture activities on the health of seagrass meadows through biological and oceanographic studies relating to the effects of contaminants from aquaculture activities (FWA, CALM) (H)
6.1.5.3	Monitor the effect of nutrient inputs from the Point Peron ocean outfall on macroalgal communities (CALM, Water Corp) (M)
6.1.10.1	Monitor trends in sea lion populations (CALM) (H-KRR)

Social Research

Strategy No.	Research Requirement
6.2.3.2 6.2.7.4 6.2.7.4	Determine the effects of commercial and recreational fishing activity on the park's values and review management controls as required and evaluate the sustainability of existing recreational fisheries in the park (FWA, CALM) (H-KRR)
6.1.2.3	Assess the nature, level and potential impacts of human activities on intertidal reef platforms within the park (CALM) (H)
6.1.8.3 6.1.9.3	Identify invertebrate and finfish species, which will be protected from recreational or commercial fishing in the park and provide the necessary legislative protection to achieve this (FWA, CALM) (H-KRR)
6.1.8.4 6.1.9.4	Quantify the level and significance of by-catch for recreational and commercial fishing activities in the Park and, if necessary and in accordance with Fisheries WA By-catch Action Plans, implement measures to progressively reduce the by-catch of invertebrate and finfish species in the park (FWA, CALM) (M)
6.1.11.1	Maintain records of the incidence of entanglement, boat collisions and strandings of cetacean and turtle species (CALM, WAFIC) (M)
6.2.1.2	Develop, in collaboration with the local indigenous population, an understanding of the significance of the area to Aboriginal people (CALM, local Aboriginal groups) (M)
6.2.3.5 6.2.7.6	Monitor commercial and recreational fishing catch/effort within the marine park (FWA) (H)
6.2.6.1	Identify and determine the key characteristics and spatial extent of the major seascapes of the park (CALM, LGA) (H)
6.2.8.2	Determine the nature, spatial patterns, compatibility and potential environmental impacts of all existing water sports in the park (CALM) (H)

APPENDIX II: A STRATEGIC FRAMEWORK FOR MARINE RESEARCH AND MONITORING IN THE SHARK BAY WORLD HERITAGE PROPERTY (SIMPSON *ET AL.*, 2002).

A STRATEGIC FRAMEWORK FOR MARINE RESEARCH AND MONITORING IN THE SHARK BAY WORLD HERITAGE PROPERTY

A project funded by the World Heritage Unit, Environment Australia

C.J. Simpson, J.G. Colman, A.K. Hill

May 2002

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

GOVERNMENT OF WESTERN AUSTRALIA
DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

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EXECUTIVE SUMMARY

This report outlines a framework for identifying marine research and monitoring priorities for the conservation and management of the Shark Bay World Heritage Property. A methodology to assess and rank research and monitoring projects seeking World Heritage funding is also outlined. The framework provides clear direction to potential applicants for funding regarding both research and monitoring priorities and the process by which projects are assessed by the Department of Conservation and Land Management (the Department) and the Shark Bay World Heritage Property committees. Significant aspects of this framework are derived from the outcomes of a workshop on this issue held in Perth in February 1998 and attended by members of the Shark Bay World Heritage Property Scientific Advisory Committee and over thirty scientists and managers.

Of highest priority are the development of Property-wide primary physical, biological and social datasets and a comprehensive database of past and current research. This information provides the basis for a risk assessment framework from which research and monitoring priorities are derived. These datasets include an adequate understanding of the physical environment (e.g. water circulation and transport), comprehensive marine resource inventories (e.g. habitats, marine wildlife seasonal movements etc) and human usage patterns, trends and implications of this use on the ecology. An understanding of the nature and extent of current scientific knowledge is also essential. Without this basic information it is difficult to develop meaningful research and monitoring programs. As such, the acquisition of these primary datasets should be the highest priority for funding.

Fundamental research priorities should be based on the relative conservation and socio-economic significance of the values of the Property and on an assessment of the adequacy of existing information, with the most significant values that are least understood being the highest priority for funding. Applied research priorities should be determined on the basis of the relative conservation and socio-economic significance of the values, the level of human pressure on these values and an assessment of the adequacy of the existing information from which to manage these pressures. Again, the most significant and most threatened values that are least understood should be the highest priority for funding.

In determining tactical or applied research priorities, it is also critical to apply research 'stopping rules', as too much research on a particular issue can be as inappropriate as too little because other equally important research areas are deprived of funds. A practical approach available to managers in dealing with this difficult issue is to ensure all tactical research is directly linked to the achievement of management objectives. Once the information requirements for the formulation of monitoring programs of a particular value are met, the research program should cease as the knowledge base is, for management purposes at least, considered to be 'adequate'. These requirements include inventories, baselines and the identification of key monitoring parameters and sufficient predictive capacity to set management 'triggers' and targets.

Monitoring priorities should be determined on the basis of the relative conservation and socio-economic significance of the values and the relative level of human pressure on these values. In this case, the most significant and the most threatened values should be the highest priority for funding.

1. INTRODUCTION

Shark Bay was included on the World Heritage List in December 1991 on the basis of its outstanding natural values. The Shark Bay World Heritage Property (the Property) is one of only 13 locations on the World Heritage List to satisfy all four natural criteria for listing. The Property covers approximately 2.2 million ha, of which about 71 percent consists of marine waters. Under the World Heritage Convention, Australia is obliged to ensure the conservation, protection, presentation and transmission to future generations of the Property's World Heritage values. It is the role of the Western Australian Government to manage the Property to fulfill these obligations. The Department of Conservation asnd Land Management (the Department) is the lead agency in relation to overall management of the Property. Commercial and recreational fishing, aquaculture and pearling in the Property are under the jurisdiction of the Western Australian Department of Fisheries (WADF).

Management goals, objectives and strategies for the Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve, which lie within the Property, are detailed in the Department's Shark Bay Marine Reserves Management Plan (CALM, 1996), prepared in liaison with WADF. Management goals, objectives and strategies for the fish resources and associated social values of the Property are detailed in the WADF Management Paper for Fish Resources (WADF, 1996), prepared in liaison with the Department. These management plans outline broad areas of research and monitoring interest but currently there is no systematic basis for prioritising within or between these broad areas. At present, therefore, there is an absence of a clearly defined framework to identify and prioritize marine research and monitoring projects in the Property

Currently, the Department co-ordinates the process of compiling a listing of all projects received in a funding round, including the comments of the Shark Bay World Heritage Scientific Advisory Committee and the Shark Bay World Heritage Community Consultative Committee and the department's own views. The Department ranks proposals after due consideration of the comments received and forwards the list to Environment Australia's World Heritage Unit. The Unit consults with the Department if necessary, and the list of proposals is submitted to the Commonwealth Minister for the Environment for consideration. The Minister decides which proposals will receive funding.

This report outlines a framework for identifying marine research and monitoring priorities in the Shark Bay World Heritage Property and also provides a basis for assessing research and monitoring projects seeking World Heritage funding. In doing so, it provides clear direction to potential applicants on priorities and on the project assessment process. The framework also draws on the outcomes of a workshop held in Perth in February 1998 and attended by members of the Shark Bay World Heritage Property Scientific Advisory Committee and over thirty scientists and managers (Colman, 1998).

Although the framework has been developed for the Property it is, necessarily, generic, and as such provides a framework for the development of marine research and monitoring plans in all existing and future CALM Act marine conservation reserves in Western Australia. The framework also provides a mechanism for the Department to integrate other existing and proposed research work in the Property as well as providing the basis for servicing requests for the Department's support for externally funded research projects. It is hoped that an additional benefit will be through the generation of increased research interest/effort in the Shark Bay area by scientists involved in the formulation of the framework and, hopefully, a degree of adherence to the identified priorities.

This project was supported by a grant from the Shark Bay World Heritage Property fund and by the Department's Marine Conservation Branch.

2. THE LINK BETWEEN MANAGEMENT AND RESEARCH AND MONITORING

The management objectives of existing CALM Act marine conservation reserves in Shark Bay are described in very general terms in the management plans and performance measures and management targets are not defined. As such, marine research and monitoring programs have, in the past, often been more influenced by the curiosity/professional interests of individual scientists or by public concern rather than through a systematic approach that addresses the strategic and tactical information needs of the managing agencies. A management framework that directly links information needs with management response is required to develop research and monitoring programs that yield information

that informs management action, evaluates management effectiveness and provides improved understanding for future management decisions.

Management objectives represent the explicit goals of a management program and relate specifically to the management of major threatening processes or pressures. More emphasis on management outcomes (i.e. using performance measures and management targets) than on management strategies will facilitate a more meaningful assessment of whether management goals are being achieved. The focus of research and monitoring programs must be complementary to this management framework if this approach is to succeed.

A 'best practice' model for facilitating better natural resource management can be found in the report *Best Practice in Performance Reporting in Natural Resource Management* (ANZECC, 1997).

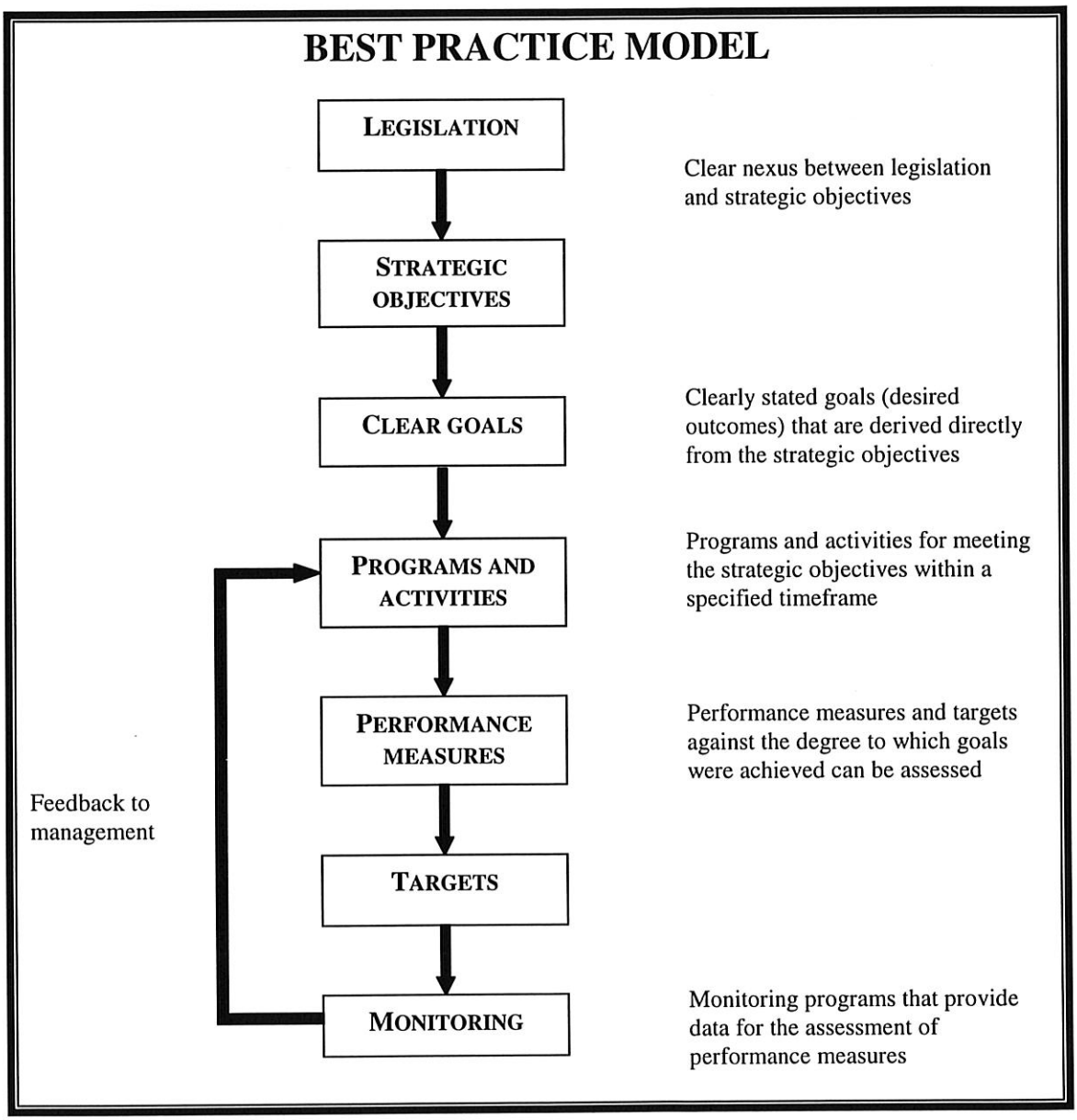

Figure 1: Best Practice Model (ANZECC, 1997)

The ANZECC document outlines the rationale for an outcome-based management approach that will facilitate more effective auditing of management performance and, as such, provide better management

outcomes. Figure 1 illustrates the major components of a Best Practice Model, which is now being used by the Department in developing management plans for marine conservation reserves.

Research is required to identify appropriate performance measures (i.e. indicators) early in the human pressure - value pathway/s and provide the predictive capacity for setting management targets (usually the 'natural' state or some acceptable departure from the 'natural' state). Long-term monitoring programs of key performance measures in 'undisturbed' (i.e. 'control or reference') areas of the Property are needed to establish 'natural' baselines. Research is needed to develop monitoring methodologies that reconcile the minimum detectable difference (i.e. monitoring precision) with the magnitude and time and space scales of human-induced change and remedial action. Monitoring programs using the above research outputs can then provide an assessment of management effectiveness.

Management action needs to focus on the key management issues, particularly when resources for management are limited. To do this, a risk assessment approach is necessary and depends upon the following information being available:

- A comprehensive inventory of the key ecological values;
- a comprehensive inventory of the relative level of anthropogenic pressure/s on the values (i.e. from the nature, patterns and implications of human activities);
- an adequate understanding of key physical processes;
- an understanding of the outcomes of historical ecological and social research; and
- a knowledge of the extent and cause/s of natural variability of key ecosystem values.

A risk assessment approach will highlight anthropogenic activities that pose a significant risk to the values, identify activities that are considered to be a minor threat and those for which existing knowledge is inadequate to make a useful assessment. This approach provides a more rational basis for formulating management priorities and developing complementary research and monitoring priorities.

Management regimes should have sufficient flexibility to respond to new information resulting from research and monitoring studies (i.e. management should be adaptive). Management goals and objectives may well be altered in the light of more detailed information provided by the results of such studies. Similarly, management strategies may be modified or refined according to new knowledge derived from research and monitoring programs.

Priority for Action:
A high priority should be given to clearly expressing operational management objectives in scientifically measurable terms so that performance measures (i.e. indicators) and management targets can be developed and applied spatially to the Property. Research programs can then focus on developing appropriate performance measures (i.e. monitoring parameters) and sufficient predictive capacity so that management 'triggers' and targets can be indentified . Monitoring methodologies and monitoring programs can then be formulated to specifically address management targets as an indication of management effectiveness.

3. RESEARCH AND MONITORING

The role of environmental research and monitoring is to understand the structure and functioning of ecosystems and the implications of human usage on the environment. This allows any undesirable impacts of human activity on the environment to be managed more effectively. **Research** should be focused on identifying and filling gaps in basic knowledge of the ecological and social values and processes of an area and on understanding the natural and anthropogenic pressures on these values. **Monitoring** provides information on patterns and trends in the 'health' of ecosystem values and on the pressures that influence their 'condition'. Research and monitoring provide management agencies with a greatly improved capacity to identify and manage undesirable trends early and, thereby, prevent serious environmental problems from developing. Effective management of marine conservation reserves requires integration of management goals and strategies with research and monitoring and an appropriate balance between shorter-term applied (i.e. tactical) research and longer-term fundamental (i.e. strategic) research and monitoring.

Research can be broadly classified as:

- **Inventory:** 'snap-shot' descriptions of the ecological and social values of an area;

- **Baseline:** the variability, in space and time, of the ecological and social values of an area;
- **Process:** research linking natural or human 'forcing factors' with changes in the ecology or human use of an area; the ultimate target being clear cause-effect links but this may not always be possible; and
- **Prediction:** models, risk assessments and other attempts to predict the future responses of natural systems to existing or proposed pressures from natural or human sources.

Key characteristics of monitoring include:

- a design that relies on a synthesis of inventories, baselines, process studies and predictions;
- assumptions that key causal links exist; and
- a primary focus on key causal links with some 'hedging of bets' in recognition of uncertainty.

For the purposes of this report, it is necessary to clearly differentiate between 'so-called' fundamental (or basic) research, applied research and monitoring although it should be remembered that these categories are, to some degree, arbitrary.

3.1 Fundamental Research

Research programs that characterise the ecological and cultural values of an area, through resource inventories and social surveys, investigate key ecological and social processes and establish the spatial and temporal extent of natural variability (i.e. baselines) are examples of what is commonly called fundamental or strategic research. The outcomes of this research can generally be described as 'descriptive knowledge' and typically do not address specific management concerns but provide the necessary fundamental understanding of natural systems that is required for effective management. Fundamental research is often dismissed by managers as esoteric and of little practical relevance. This is a serious misunderstanding of how this type of research relates to management and often reflects a pre-occupation by managers with the 'here and now'. As well as providing a better understanding of how natural systems function and the necessary broader context for current management concerns, the improved knowledge and understanding resulting from on-going fundamental research programs can significantly enhance management capability and flexibility to address 'problems' that can not be anticipated. This last point is obviously crucial if management is to be proactive and avoid repeating the mistakes so often seen when management does not have a sound scientific underpinning.

3.2 Applied Research

Research that provides information that advances the understanding of how natural systems respond to human pressures is often called applied or management-oriented research. Studies that investigate human usage patterns and attitudes, human pressure-value pathways and synergistic relationships between pressures and values are examples of applied research. The outcomes of this type of research can generally be described as 'functional or applied knowledge', and typically address existing or foreseeable specific management concerns.

3.3 Monitoring

Monitoring provides ongoing information about interactions between the natural system and human usage. Monitoring trends in key indicators (i.e. performance measures) to assess changes in the natural system, human uses and pressures is an essential component of management. Monitoring provides an assessment of the effectiveness of management in meeting objectives by providing the basis for status reports against management targets, detecting undesirable trends and, if necessary, providing the trigger for remedial action.

The design of monitoring programs should reconcile the spatial and temporal scales of the values under threat with the spatial and temporal scales of the identified pressure/s. Monitoring parameters should also be clearly linked to a specific human pressure-value pathway and should provide information sufficiently 'early' in this pathway to allow effective implementation of remedial action. Similarly, monitoring programs should be designed to ensure the minimum detectable difference of the monitoring parameter/s (i.e. the 'sensitivity' of the monitoring program in detecting change) is reconciled with the time and space scales of decline and remedial action.

Both surveillance and compliance monitoring programs are necessary in the management of marine conservation reserves.

Surveillance monitoring

Surveillance monitoring programs are generally broadscale, on-going and are generally used to provide regular (e.g. annual) overall status reports on the health of natural systems and as a 'safety net' to account for uncertainty in our understanding and predictions. Surveillance monitoring programs are generally undertaken or coordinated by management agencies. As well as providing an assessment of natural and human influences on ecosystem 'condition', surveillance monitoring programs provide the spatial context necessary to interpret the results of local-scale compliance monitoring programs. The nature, extent and frequency of surveillance monitoring programs will reflect the nature, extent and frequency of natural and human pressures.

Compliance monitoring

Compliance monitoring programs are used to assess industry compliance (or otherwise) with agreed environmental management targets for specific approved activities (e.g. aquaculture). Compliance monitoring programs are generally spatially and temporally constrained. The nature, extent and frequency of compliance monitoring programs will reflect the nature, extent and frequency of the pressures (e.g. waste inputs) associated with the approved activities. In Western Australian marine conservation reserves, compliance monitoring programs are an essential part of the conditional approvals process undertaken by appropriate State and Commonwealth regulatory/management agencies, in consultation with the Department and the Marine Parks and Reserves Authority.

4. A FRAMEWORK FOR SETTING RESEARCH AND MONITORING PRIORITIES

The framework for setting research and monitoring priorities, proposed here, uses a combination of the relative significance of the ecosystem values/attributes (V), pressures (P) [on these attributes] and the adequacy of existing knowledge (K). The process for assigning relative rankings to the attributes and pressures and for determining the adequacy of existing knowledge is outlined in detail below (see Sections 4.1, 4.2 and 4.3). Once this task has been undertaken, research and monitoring priorities can be developed using the following formulae:

Fundamental research (FR) priorities can be determined according to the equation:

$$\mathbf{FR = [V * (12 - K)]}$$

Applied research (AR) priorities can be determined according to the equation:

$$\mathbf{AR = [V * P * (12 - K)]}$$

Monitoring (M) priorities can be determined according to the equation:

$$\mathbf{M = V*P}$$

In the absence of available quantitative data on V, P and K, accurate scoring for each criterion is dependent on the expertise, knowledge and experience of the people involved in the assessment process. This will be robust if a sufficiently large group with a broad range of expertise and knowledge of the area is used. This approach with all its inherent imperfections provides, at the very least, a transparent expression of the logic and a record of the outcomes of the prioritisation process. As such, the outcomes can be revised and improved as new information comes to light.

4.1 Values/Attributes

This section provides a rationale to rank the values/attributes of the Property. The values of the Property reflect both the implicit ecological characteristics and the explicit 'social' attributes of the Property. In this context, the values are defined in terms of **ecological** (i.e. physical, chemical, geological and biological) and **'social'** significance. The 'social' attributes relate to the economic, aesthetic, spiritual, cultural and scientific uses of the Property. As many human uses depend on the maintenance of healthy ecosystems and not vice versa, the ecological values are, intrinsically, of greater importance than 'social' values and this natural hierarchy should be reflected in research and monitoring priorities.

Scoring for each criterion is based on a relative assessment of each value/attribute (i.e. down columns). A *High* score =3, a *Medium* score = 2 and a *Low* score = 1.

Ecological significance

Trophic status ***(E1):*** low trophic level biotic attributes (i.e. primary producers) such as seagrass meadows, coral reefs and mangals will score high against this criterion. Higher trophic level (e.g. consumers) biota such as fish, birds and mammals will score low against this criterion.

Areal extent/biomass ***(E2)***: attributes of the property that are widespread/abundant in their distribution, such as seagrass meadows/dugong, will score high against this criterion. Those with relatively localised distribution (e.g. coral reefs) will score low.

Vulnerability ***(E3)***: attributes that are highly susceptible to degradation by natural events and/or human pressures will score high against this criterion and vice versa.

Recovery potential ***(E4)***: recovery potential can be measured in terms of *resilience* (measured as the maximum stress from which a value can recover) and *stability* (measured as the rate of recovery from a stress). Attributes with a low recovery potential will score high for this criterion and vice versa.

Biodiversity significance

Biodiversity significance relates to the uniqueness of biotic components over various spatial scales. For instance, the coral reefs of Shark Bay are important at a local level, but have limited significance at regional, national and global levels. Conversely, the dugong population is significant at all levels, particularly nationally and globally given that it is one of the largest known remaining undisturbed populations in the world and is considered integral to the survival of the species globally.

Locally significant ***(B1)***
Regionally significant ***(B2)***
Nationally significant ***(B3)***
Globally significant ***(B4)***

Social significance

Cultural ***(C1)***: attributes with existing or potential importance to the local, regional, national or international communities because of their heritage, historical, traditional, aesthetic and educational qualities will score high against this criterion.

Economic ***(C2)***: attributes that have existing or potential economic importance will score high against this criterion. Examples would be any values that support or contribute to important commercial activities such as fisheries, aquaculture and nature-based tourism, are a food source and/or a source of income for indigenous communities, or function as nursery areas or replenishment areas for economically important species.

Scientific ***(C3)***: attributes that have particular significance for scientific study at local, regional, national and international scales (e.g. the stromatolites in Hamelin Bay or the Hamelin Pool *Coquina* deposits) will score high against this criterion.

Recreational ***(C4)***: attributes that have existing or potential importance as resources for recreational activities (e.g. the recreational snapper fishery and the coral communities on the east coast of Dirk Hartog Island) will score high against this criterion.

A ranking matrix for various values/attributes is illustrated in Table 1. Overall ranking of values is determined through a summation of unweighted criteria scores. As mentioned above many human uses depend on the maintenance of healthy ecosystems and not vice versa, the above ecological criteria are

therefore, intrinsically, of greater importance than social criteria. This functional dependency could be acknowledged by applying 'weighting' to the ecological criteria (i.e. E1-E4, B1-B4) in Table 1.

Table 1: Example of the Value/Attribute Ranking Matrix

Value/Attribute	E1	E2	E3	E4	B1	B2	B3	B4	C1	C2	C3	C4	V=Σ(E+B+C)	Rank
Seagrass	3	3	3	3	3	3	2	3	1	1	3	1	29	1
Mangrove	3	2	1	1	3	2	1	1	1	1	2	1	19	3
Coral reef	3	1	1	1	2	1	1	1	2	1	1	2	17	6
Dugong	1	2	3	3	3	3	3	3	2	1	3	1	28	2
'Soft'sediment communities	3	3	2	1	2	1	1	1	1	1	2	1	19	3
Seabirds	2	1	1	1	1	1	1	1	1	1	1	1	13	7
Coral trout	2	1	2	2	2	1	1	1	1	1	1	2	17	5

Key: Ecological significance, E1=trophic status, E2=areal extent, E3=vulnerability, E4=recovery potential; Biodiversity significance B1=local, B2=regional, B3=national, B4=global; Social significance, C1=cultural, C2=economic, C3=scientific, C4=recreational.
Scoring: 3=High, 2=Medium , 1=Low.

4.2 Pressures

Pressures are those processes that threaten some or all of the values/attributes outlined above. These can be natural physical and biological processes or those associated with human activities. For the purposes of this paper *pressures* are defined as human activities that impact on a regional-scale or less (i.e. management has some degree of control) and have, or potentially have, an undesirable impact on one or more of the attributes outlined above. Examples of pressures include nutrient enrichment, oil or waste material discharge and anchor or diver damage to sensitive habitats.

Broadscale natural events, such as damage to coral reefs by physical processes like cyclonic waves, or by biological processes like Crown-of-Thorns starfish predation, are considered natural cyclic events and are, therefore, not considered here to be a 'pressure'. Similarly, human processes operating at greater than regional scales, such as the so-called 'Greenhouse Effect', are not considered to be 'pressures', for the purposes of this paper, as 'management' of this type of 'pressure' requires co-ordinated global-scale action to be effective. These types of broadscale 'pressures' can, however, greatly affect ecosystems and observations of resultant changes to ecosystems should be routinely monitored (see *Surveillance Monitoring* section), thereby allowing management action to consider and, if appropriate, respond to the changes caused by these processes and events.

A comprehensive database of human usage and a conceptual understanding, at the very least, of the links between usage and the deleterious effects on one or more value/s, are required to identify and rank existing and potential pressures. Without this information, an assessment of pressures is largely subjective.

Ranking of pressures can be undertaken by determining the relative likelihood and consequences of different pressures using the following criteria:

Biological intensity ***(P1)***: this criterion relates to the trophic level of the community/biota impacted by the pressure. Pressures impacting on lower trophic levels (e.g. primary producers) score high and vice versa for this criterion.

Spatial scale ***(P2)***: this criterion acknowledges that, in general, the greater the spatial extent of the pressure the greater the management concern (i.e. widespread impacts versus localised impacts). Larger scale will score high and small scale pressures will score low for this criterion.

Temporal scale ***(P3)***: this criterion acknowledges that pressures that are on-going (i.e. chronic) are generally of greater management concern than pressures that are short-lived. Chronic or high frequency pressures will score high whereas low frequency pressures will score low for this criterion.

Consequence (P4): this criterion acknowledges that different pressures have different social and political consequences. A high socio-economic/political consequence will score high and vice versa for this criterion.

Probability (P5): this criterion addresses the probability of a pressure occurring within the timeframe of the management plan. Existing pressures or a high probability of a pressure occurring will score high and a low probability of a pressure occurring will score low.

A ranking matrix for pressures is illustrated in Table 2. As outlined above, limited biological information, the absence of a quantitative human usage database and an inadequate understanding of the oceanography for the Property preclude a comprehensive assessment of the existing and potential pressures. However, a collective assessment by key scientists and managers with experience of the Shark Bay area can, to some degree, overcome these constraints.

Table 2: Example of a Pressure Ranking Matrix

Pressure - value	p1	p2	p3	p4	p5	P =(Σp1-4) *p5	Rank
Anchor damage-coral reefs	3	1	1	1	3	18	3
Eutrophication - seagrass	3	3	3	3	1	12	5
Oil spill- seabirds	2	3	1	2	2	16	4
Oil spill - mangroves	3	2	1	3	1	9	6
Recreational fishing – fish populations	1	3	3	2	3	27	2
Oil exploration – dugong	1	1	1	3	1	6	7
Trawling – 'soft' sediment communities	2	3	3	3	3	33	1

Key: p1= biological intensity; p2= spatial scale; p3= temporal scale; ; p4= consequences p5= probability.
Scoring: 3=High, 2 =Medium , 1=Low.

4.3 Adequacy of Existing Knowledge

An assessment of the adequacy or otherwise of the existing knowledge base for management in relation to key values and/or pressures is an essential element in developing a cost-effective research and monitoring program. Too much research on a particular topic is as inappropriate, in a management context, as too little because this prevents research in other areas from being undertaken. Assessing the level of knowledge would be a relatively simple process if a comprehensive relational database of past and current research and monitoring programs existed. Although several bibliographies of scientific work in the Shark Bay area exist, none are easily used for the aforementioned purpose. The establishment of a research and monitoring database should, therefore, be a high priority if optimal use of research funding is to be achieved.

In deciding tactical or applied research priorities for management purposes it is also critical to develop and apply research 'stopping rules'. A practical approach for managers to this difficult issue is to ensure all tactical research is directly linked to the achievement of management objectives. Once the fundamental requirements for the formulation of monitoring programs of a particular value are met, the research program should cease as the knowledge base is, for management purposes at least, considered to be 'adequate'. These requirements include inventories, baselines and the identification of key monitoring parameters and sufficient predictive capacity to set management 'triggers' and targets (only needed if the target is some acceptable departure from the 'natural' state).

Using the above approach, the adequacy of existing information can be assessed using the following criteria:

Inventory (K1): This criterion assesses the existing level of resource information on the value (e.g. seagrass biomass distribution). Scores are high if a complete, verified inventory is available and low if only limited data exists.

Baseline data (K2): This criterion assesses whether adequate quantitative baselines exist to determine the spatial and temporal extent and cause/s of natural variation for the value in question. This information is critical to establishing a quantitative expression of the 'natural' state. These data are needed to distinguish between natural variability and human change. Adequacy of baseline data in this context is measured in both temporal and spatial terms.

Long-term, spatially representative, baseline datasets would score high for this criterion and short-term, localised data sets would score low.

Monitoring parameters (K3): This criterion assesses whether adequate information exists to identify monitoring parameters. This information flows from process studies that provide an adequate understanding of key maintenance processes (e.g. growth and reproduction) of major structural components of the ecology. And from studies that link natural or human 'forcing factors' with changes in the ecology or human use of an area; the ultimate aim being the identification of clear cause-effect links. Monitoring parameters may be direct measures of a value such as population estimates or 'surrogate' measures such as changes in phytoplankton biomass as a measure of potential impacts of nutrient enrichment on seagrasses. If current knowledge allows appropriate monitoring parameters to be readily identified a high score would be recorded.

Management targets (K4): This criterion assesses whether the level of knowledge is adequate to formulate appropriate management 'triggers' and targets.

Targets will be either the 'natural' state or some acceptable departure from the 'natural' state (i.e. Limits of Acceptable Change (LAC) approach). If the target is the 'natural' state or within the limits of natural variability this criterion would be scored high. The score will decline as the departure from the 'natural' state widens or as the level of understanding of the cause-effect pathways decreases (i.e. declining level of confidence in being able to set an 'acceptable' level of change).

Table 3 provides an example of using the above criteria to assess the adequacy of the existing knowledge about selected ecological values. As outlined above, the absence of a research and monitoring database precludes a comprehensive assessment. However, a collective subjective assessment by key scientists and managers with knowledge of historical and current research in the Shark Bay area can, to some degree, overcome these constraints. All else being equal, research priorities should focus on areas where the existing knowledge base is lowest (i.e. where (12-K) is highest)

Table 3: Example of a Knowledge Ranking Matrix

Value/Attribute	k1	k2	k3	k4	K = Σk	(12-K)	Rank
Seagrass	2	1	3	3	9	3	5
'Soft' sediment communities	2	1	1	1	5	7	1
Coral reef	1	1	3	3	8	4	3
Mangrove	2	1	3	3	9	3	5
Recreational fish spp.	1	1	2	1	5	7	1
Seabird	1	1	3	3	8	4	3
Dugong	3	2	3	3	11	1	7

Key: k1= inventory, k2= baselines, k3= monitoring parameters, k4= management targets.
Scoring: 3 = High, 2 = Medium, 1 = Low.

5. RESEARCH AND MONITORING PRIORITIES FOR THE SHARK BAY WORLD HERITAGE PROPERTY

5.1 Generic Research Priorities

The framework for setting research and monitoring priorities, as outlined in Section 4, uses a combination of the relative significance of the ecosystem values/attributes (V), pressures (P) [on these attributes] and the adequacy of existing knowledge (K). As such, the development of research and monitoring priorities for the Property depends largely on the following primary datasets being available. These are:

- A comprehensive inventory of the key ecological values;
- a comprehensive inventory of the relative level of anthropogenic pressure/s (as defined) on the values (i.e. from the nature, patterns and implications of human activities);
- an adequate understanding of key physical processes;
- an understanding of the outcomes of historical ecological and social research; and

- a knowledge of the extent and cause/s of natural variability of key ecosystem values (i.e. natural 'pressures').

The critical importance of these datasets indicates that the acquisition of these data should be given the highest priority.

5.2 Specific Research and Monitoring Priorities

In the absence of the information outlined in section 5.1, it is difficult to objectively develop specific research and monitoring priorities. However, as outlined earlier, it is possible to use an 'expert group' approach to overcome this problem, to some extent, and develop specific research and monitoring priorities. However, this should only ever be seen as an interim approach. In May 1999, the Shark Bay World Heritage Property Scientific Advisory Committee convened a meeting of marine scientists, managers and decision-makers to undertake an 'expert group' approach to this issue using the framework outlined in Section 4.

The workshop outputs have been used to help construct Tables 4–6. These tables show the priorities for fundamental and applied research and monitoring. Appendix I outlines what the funding priority of past Property projects would have been if submitted and assessed under the proposed framework using the priorities outlined in Tables 4-6.

6. ASSESSMENT AND RANKING OF MARINE PROJECT PROPOSALS

At present, there is no formalised framework underpinning the allocation of World Heritage funding for marine research and monitoring of the Property. The setting of research and monitoring priorities is an inherently difficult, and often contentious, task as it involves making subjective assessments often with very limited information.

At the beginning of each funding round a decision should be made as to the relative proportion of the total funds available to be allocated to the marine and terrestrial components of the Property. All marine projects should then be screened for compliance with the 'pragmatic' criteria outlined in Appendix II. Project proponents should be required to provide a response to these criteria as part of their project application. Projects unable to meet these criteria should not be included in the assessment process.

Broadly speaking, projects seeking funding fall into three distinct categories: fundamental research, applied research and monitoring. An *a priori* decision should be made as to the proportion of funding to be allocated to each category as it is extremely difficult to objectively prioritise projects across these three categories. Projects can then be prioritised separately in each category.

As outlined above, the approach proposed here uses a combination of relative value (V), pressure (P) [on the ecosystem attributes] and knowledge (K) as a basis for setting fundamental and applied marine research and monitoring priorities. Each criterion for V, P and K is scored, tabulated and the overall scores determined from the formulae outlined in Section 4 and ranked accordingly to determine priorities. Tables 4-6 are examples out outputs from this process.

The scores for V, P and K would require updating regularly to incorporate newly gained knowledge, emerging issues and changing management priorities as a result of the success or otherwise of threat abatement strategies.

Table 4: Fundamental Research Priorities

Value/Attribute*	E1	E2	E3	E4	B1	B2	B3	B4	C1	C2	C3	C4	V	k1	k2	k3	k4	K	12-K	V*(12-K)	RANK#	FUNDING PRIORITY
Hydrological cycle	3	3	3	1	3	3	3	3	3	3	3	3	**34**	2	1	1	1	5	**7**	238	***1***	**H**
Genetic diversity	2	3	3	2	1	1	3	3	2	1	3	2	**26**	1	1	1	1	4	**8**	208	***2***	**H**
Soft sediment communities	2	3	2	1	3	3	2	1	1	1	3	1	**23**	1	1	1	1	4	**8**	184	***3***	**H**
Supratidal flats	3	3	1	1	3	3	1	1	1	1	2	1	**21**	1	1	1	2	5	**7**	147	***4***	**H**
Microbial mats	3	2	2	1	3	3	2	1	1	1	1	1	**21**	1	1	1	2	5	**7**	147	***4***	**H**
Bivalve diversity	2	2	2	1	3	3	1	1	2	2	2	1	**22**	3	2	1	1	7	**5**	110	***6***	**H**
Wilderness	1	1	1	1	1	1	1	1	3	2	1	3	**17**	2	1	1	2	6	**6**	102	***7***	**H/M**
Coral reefs	3	1	3	1	2	1	1	1	2	1	1	3	**20**	1	1	2	3	7	**5**	100	***8***	**H/M**
Halodule seagrass	3	3	3	3	3	3	3	3	1	1	3	1	**30**	1	2	3	3	9	**3**	90	***9***	**M**
Fisheries production	1	3	2	2	3	3	3	1	3	3	3	3	**30**	2	2	3	2	9	**3**	90	***9***	**M**
Mangroves	3	2	2	2	3	2	1	1	1	2	2	1	**22**	1	1	3	3	8	**4**	88	***11***	**M**
Dolphins	1	2	1	1	3	3	1	1	2	1	3	1	**20**	1	1	3	3	8	**4**	80	***12***	**M**
Seascapes	1	1	1	1	1	1	1	1	3	2	1	3	**17**	2	3	1	3	9	**3**	51	***13***	**M**
Turtles	1	1	2	1	3	3	3	3	1	1	2	2	**23**	2	2	3	3	10	**2**	46	***14***	**M**
Seabirds	1	1	1	2	1	1	1	1	1	1	1	1	**13**	2	1	3	3	9	**3**	39	***15***	**M/L**
Holocene deposits	3	3	3	1	3	3	3	3	3	3	3	3	**34**	3	3	3	2	11	**1**	34	***16***	**M/L**
Amphibolis seagrass	3	3	3	3	3	3	3	3	1	2	3	1	**31**	3	2	3	3	11	**1**	31	***17***	**L**
Dugong	1	3	3	3	3	3	3	3	3	1	3	1	**30**	3	2	3	3	11	**1**	30	***18***	**L**
Stromatolites	3	1	2	3	3	3	3	3	1	1	3	1	**27**	2	3	3	3	11	**1**	27	***19***	**L**
Monkey Mia dolphins	1	1	3	3	3	1	1	1	3	3	3	3	**26**	3	2	3	3	11	**1**	26	***20***	**L**
Fragum	1	3	2	1	3	3	3	3	1	2	2	1	**25**	3	3	3	2	11	**1**	25	***21***	**L**
Humpback whales	1	2	1	2	3	3	1	1	1	1	1	1	**18**	3	2	3	3	11	**1**	18	***22***	**L**

Key: V= Sum (E1-4 + B1-4+C1-4);
K=Sum (k1-4);
* = list compiled at WHPSAC/CALM workshop;
# = pragmatic criteria have not been considered

Table 5: Applied Research Priorities

Value/Pressure*	E1	E2	E3	E4	B1	B2	B3	B4	C1	C2	C3	C4	V	p1	p2	p3	p4	p5	P	k1	k2	k3	k4	K	12-K	V*P*(12-K)	RANK#	FUNDING PRIORITY
Soft sediment communities - trawling	2	3	2	2	3	3	2	1	1	1	3	1	**24**	2	3	3	3	3	**33**	1	1	1	1	**4**	**8**	6336	***1***	**H**
Amphibolis seagrass - land-based sources of pollution	3	3	3	3	3	3	3	3	1	1	3	1	**30**	3	1	2	1	2	**14**	1	1	2	1	**5**	**7**	2940	***2***	**H**
Target fish spp - recreational fishing	2	2	2	1	3	3	2	2	3	2	2	3	**27**	1	2	2	2	3	**21**	2	1	3	1	**7**	**5**	2835	***3***	**H**
Biodiversity (excl. above) - introduced marine pests	2	3	3	3	3	3	2	1	1	1	3	1	**26**	3	1	1	3	1	**8**	1	1	1	1	**4**	**8**	1664	***4***	**H**
Coral reefs - anchor damage	3	1	3	1	2	1	1	1	2	1	1	3	**20**	3	1	1	1	2	**12**	1	1	2	3	**7**	**5**	1200	***5***	**H**
Dugong - oil exploration (seismic)	1	3	3	3	3	3	3	3	2	2	3	2	**31**	1	1	1	3	1	**6**	2	2	1	1	**6**	**6**	1116	***6***	**H**
Dugong - indigeneous harvesting	1	3	3	3	3	3	3	3	2	2	3	2	**31**	1	1	2	1	1	**5**	1	1	3	1	**6**	**6**	930	***7***	**H**
Monkey Mia dolphins - habitat loss (pollution, aquaculture)	1	1	3	3	3	3	3	3	3	3	3	2	**31**	1	1	2	3	2	**14**	3	3	2	2	**10**	**2**	868	***8***	**H/M**
Dugong - disturbance (tourism)	1	3	3	3	3	3	3	3	2	2	3	2	**31**	1	1	1	1	1	**4**	2	1	1	2	**6**	**6**	744	***9***	**H/M**
Halodule seagrass - catchment impacts	3	3	3	3	3	3	3	3	1	1	3	1	**30**	3	2	1	2	1	**8**	1	2	3	3	**9**	**3**	720	***10***	**M**
Supratidal flats - catchment impacts	3	3	1	1	1	2	1	1	1	1	2	1	**18**	1	2	1	1	1	**5**	1	1	1	2	**5**	**7**	630	***11***	**M**
Microbial mats - catchment impacts	3	3	1	1	1	2	1	1	1	1	2	1	**18**	1	1	1	1	1	**4**	1	1	1	2	**5**	**7**	504	***12***	**M**
Mangroves - catchment impacts	2	2	2	2	2	2	1	1	1	1	2	1	**19**	3	1	1	1	1	**6**	1	1	3	3	**8**	**4**	456	***13***	**M**
Turtles - trawling (by-catch)	1	2	3	3	2	2	1	1	1	1	1	1	**19**	1	2	2	1	1	**6**	1	1	3	3	**8**	**4**	456	***13***	**M**
Monkey Mia dolphins - human disturbance (tourism, recreation)	1	1	3	3	3	3	3	3	3	3	3	2	**31**	1	1	2	3	2	**14**	3	3	2	3	**11**	**1**	434	***15***	**M**
Coral reefs - litter	3	1	3	1	2	1	1	1	2	1	1	3	**20**	3	1	1	1	1	**6**	1	2	3	3	**9**	**3**	360	***16***	**M/L**
Humpback whales - oil exploration (seismic)	1	1	1	3	1	1	1	1	1	1	1	3	**16**	1	1	1	1	1	**4**	3	2	1	1	**7**	**5**	320	***17***	**M/L**
Fragum - mining	1	3	2	1	3	3	3	3	1	2	2	1	**25**	1	1	2	2	2	**12**	3	3	3	2	**11**	**1**	300	***18***	**L**
Amphibolis seagrass - nutrient enrichment (aquaculture)	3	3	3	3	3	3	3	3	1	1	3	1	**30**	3	1	2	3	1	**9**	3	2	3	3	**11**	**1**	270	***19***	**L**
Mangroves - coastal development	2	2	2	2	2	2	1	1	1	1	2	1	**19**	3	1	1	1	1	**6**	1	3	3	3	**10**	**2**	228	***20***	**L**
Seabirds - human disturbance	1	1	1	2	1	1	1	1	1	1	1	1	**13**	1	1	1	1	1	**4**	2	1	3	3	**9**	**3**	156	***21***	**L**
Marine wildlife - catastrophic oil spills (shipping)	1	2	3	3	3	3	3	3	2	2	3	2	**30**	1	1	1	1	1	**4**	3	2	3	3	**11**	**1**	120	***22***	**L**
Primary producers - catastrophic oil spills (shipping)	3	3	3	3	3	3	3	3	1	1	3	1	**30**	1	1	1	1	1	**4**	3	2	3	3	**11**	**1**	120	***22***	**L**
Stromatolites - trampling	3	1	2	3	3	3	3	3	2	2	3	2	**30**	1	1	1	1	1	**4**	2	3	3	3	**11**	**1**	120	***22***	**L**

Key: V= Sum (E1-4 + B1-4+C1-4);
P=Sum (p1-4) * p5;
K=Sum (k1-4);
* = list compiled at WHPSAC/CALM workshop;
# = pragmatic criteria have not been considered.

Table 6: Monitoring Priorities

Value-Pressure*	E1	E2	E3	E4	B1	B2	B3	B4	C1	C2	C3	C4	V	p1	p2	p3	p4	p5	P	V*P	RANK#	FUNDING PRIORITY
Soft sediment communities - trawling	2	3	2	2	3	3	2	1	1	1	3	1	**24**	2	3	3	3	3	**33**	792	***1***	**H**
Target fish spp - recreational fishing	2	2	2	1	3	3	2	2	3	2	2	3	**27**	1	2	2	2	3	**21**	567	***2***	**H**
Monkey Mia dolphins - habitat loss (pollution, aquaculture)	1	1	3	3	3	3	3	3	3	3	3	2	**31**	1	1	2	3	2	**14**	434	***3***	**H**
Monkey Mia dolphins - human disturbance (tourism, recreation)	1	1	3	3	3	3	3	3	3	3	3	2	**31**	1	1	2	3	2	**14**	434	***3***	**H**
Amphibolis seagrass - land-based sources of pollution	3	3	3	3	3	3	3	3	1	1	3	1	**30**	3	1	2	1	2	**14**	420	***5***	**H**
Coral reefs - anchor damage	3	1	3	1	2	1	1	1	2	1	1	3	**20**	3	1	1	1	3	**18**	360	***6***	**H**
Fragum - mining	1	3	2	1	3	3	3	3	1	2	2	1	**25**	1	1	2	2	2	**12**	300	***7***	**H**
Amphibolis seagrass - nutrient enrichment (aquaculture)	3	3	3	3	3	3	3	3	1	1	3	1	**30**	3	1	2	3	1	**9**	270	***8***	**H/M**
Halodule seagrass - catchment impacts	3	3	3	3	3	3	3	3	1	1	3	1	**30**	3	2	1	2	1	**8**	240	***9***	**H/M**
Biodiversity (excl. above) - introduced marine pests	2	3	3	3	3	3	2	1	1	1	3	1	**26**	3	1	1	3	1	**8**	208	***10***	**M**
Dugong - oil exploration (seismic)	1	3	3	3	3	3	3	3	2	2	3	2	**31**	1	1	1	3	1	**6**	186	***11***	**M**
Dugong - indigeneous harvesting	1	3	3	3	3	3	3	3	2	2	3	2	**31**	1	1	2	1	1	**5**	155	***12***	**M**
Dugong - disturbance (tourism)	1	3	3	3	3	3	3	3	2	2	3	2	**31**	1	1	1	1	1	**4**	124	***13***	**M**
Stromatolites - trampling	3	1	2	3	3	3	3	3	2	2	3	2	**30**	1	1	1	1	1	**4**	120	***14***	**M**
Marine wildlife - catastrophic oil spills (shipping)	1	2	3	3	3	3	3	3	2	2	3	2	**30**	1	1	1	1	1	**4**	120	***14***	**M**
Primary producers - catastrophic oil spills (shipping)	3	3	3	3	3	3	3	3	1	1	3	1	**30**	1	1	1	1	1	**4**	120	***14***	**M**
Coral reefs - litter	3	1	3	1	2	1	1	1	2	1	1	3	**20**	3	1	1	1	1	**6**	120	***14***	**M/L**
Mangroves - catchment impacts	2	2	2	2	2	2	1	1	1	1	2	1	**19**	3	1	1	1	1	**6**	114	***18***	**M/L**
Mangroves - coastal development	2	2	2	2	2	2	1	1	1	1	2	1	**19**	3	1	1	1	1	**6**	114	***18***	**L**
Turtles - trawling (by-catch)	1	2	3	3	2	2	1	1	1	1	1	1	**19**	1	2	2	1	1	**6**	114	***18***	**L**
Supratidal flats - catchment impacts	3	3	1	1	1	2	1	1	1	1	2	1	**18**	1	2	1	1	1	**5**	90	***21***	**L**
Microbial mats - catchment impacts	3	3	1	1	1	2	1	1	1	1	2	1	**18**	1	1	1	1	1	**4**	72	***22***	**L**
Humpback whales - oil exploration (seismic)	1	1	1	3	1	1	1	1	1	1	1	3	**16**	1	1	1	1	1	**4**	64	***23***	**L**
Seabirds - human disturbance	1	1	1	2	1	1	1	1	1	1	1	1	**13**	1	1	1	1	1	**4**	52	***24***	**L**

Key: V= Sum (E1-4 + B1-4+C1-4);
P=Sum(p1-4) * p5;
* = list compiled at WHPSAC/CALM workshop;
# = pragmatic criteria have not been considered.

In summary, the prioritisation of marine project proposals for the Property involves the following steps:

Step 1: Decide on the proportion of total funding available to the marine and terrestrial components of the Property.

Step 2: Assess each project proponent's response to the pragmatic criteria (merit, ethics, and feasibility) outlined in Appendix II. Projects that clearly do not provide a satisfactory response to these criteria should be excluded from the assessment process.

Step 3: List the proposals and separate into categories of fundamental research, applied research and monitoring.

Step 4: Decide on the level of 'marine' funding available for each of fundamental research, applied research and monitoring projects.

Step 5: Fundamental Research: Identify the ranking and priority of each project using Table 4.

Step 6: Applied Research: Identify the ranking and priority of each project using Table 5.

Step 7: Monitoring: Identify the ranking and priority of each project using Table 6.

Step 8: Apply available funding in each category according to rankings.

7. CONCLUSIONS

This report outlines a framework for identifying marine research and monitoring priorities for the conservation and management of the Property. A methodology to assess and rank research and monitoring projects seeking World Heritage funding is also outlined. The framework provides clear direction to potential applicants for funding regarding both research and monitoring priorities and the process by which projects are assessed by the Department of Conservation and Land Management (the Department) and the Shark Bay World Heritage Property committees. Significant aspects of this framework are derived from the outcomes of a workshop on this issue held in Perth in February 1998 and attended by members of the Shark Bay World Heritage Property Scientific Advisory Committee and over thirty scientists and managers.

Of highest priority are the development of Property-wide primary physical, biological and social datasets and a comprehensive database of past and current research. This information provides the basis for a risk assessment framework from which research and monitoring priorities are derived. These datasets include an adequate understanding of the physical environment (e.g. water circulation and transport), comprehensive marine resource inventories (e.g. habitats, marine wildlife seasonal movements etc) and human usage patterns, trends and implications of this use on the ecology. An understanding of the nature and extent of current scientific knowledge is also essential. Without this basic information it is difficult to develop meaningful research and monitoring programs. As such, the acquisition of these primary datasets should be the highest priority for funding.

Fundamental research priorities should be based on the relative conservation and socio-economic significance of the values of the Property and on an assessment of the adequacy of existing information, with the most significant values that are least understood being the highest priority for funding. Applied research priorities should be determined on the basis of the relative conservation and socio-economic significance of the values, the level of human pressure on these values and an assessment of the adequacy of the existing information base to manage these pressures. In this case, the most significant and most threatened values that are least understood should be the highest priority for funding.

It is critical to apply research 'stopping rules' as too much research is as inappropriate as too little because other important areas of research are deprived of funds. A practical approach for managers to this difficult issue is to ensure all research contributes, in some way, to the formulation of monitoring programs. Once the fundamental requirements for the formulation of monitoring programs of a particular value are met, the research program should cease as the knowledge base is, for management

purposes at least, considered to be 'adequate'. These requirements include inventories, baselines and the identification of key monitoring parameters and sufficient predictive capacity to set management 'triggers' and targets.

Monitoring priorities should be determined on the basis of the relative conservation and socio-economic significance of the values and the relative level of human pressure on these values.

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APPENDIX I

APPENDIX I: PRIORITISATION OF PAST WHP FUNDED MARINE PROPOSALS IF SUBMITTED UNDER THE PROPOSED FRAMEWORK

No.	Project Title	Year	Type	Ranking	Priority for Funding*
1	**FRAGUM**				
	• *Fragum* ecology survey	92/93/94	F	21	L
	• *Fragum* deposition rate	92/93/94	F	21	L
	• Continuing research on the ecology of *Fragum*	94/95	F	21	L
2	**TURTLE**				
	• Turtle nesting – Dirk Hartog Is	92/93/94	F	14	M
	• Loggerhead turtle tagging – Dirk Hartog Is	95/96	F	14	M
	• Loggerhead turtle tagging – Dirk Hartog Is	96/97	F	14	M
	• Loggerhead turtle tagging – Dirk Hartog Is	97/98	F	14	M
	• Loggerhead turtle tagging – Dirk Hartog Is	98/99	F	14	M
3	**DUGONG**				
	• Dugong survey	92/93/94	F	18	L
	• Dugong conservation – behavioural, etc	96/97	F	18	L
	• Population census and winter distribution of dugongs	98/99	F	18	L
	• Satellite tracking of dugongs	99/2000	F	18	L
4	**SEABIRDS**				
	• Census of seabirds	95/96	F	15	M/L
5	**OCEANOGRAPHY**				
	• Monkey Mia Lagoon flushing (spring)	95/96	F	1	H
	• Monkey Mia Lagoon flushing (autumn)	96/97	F	1	H
6	**WATER QUALITY**				
	• Baseline study along Peron Peninsula	96/97	A	8	H/M
7	**INTRODUCED MARINE PESTS**				
	• Risk management and investigation for IMP	98/99	A	4	H
8	**FISH**				
	• Measuring recreational fish catch	99/2000	A	3	H

* = pragmatic criteria not considered

APPENDIX II

PRAGMATIC CRITERIA FOR ASSESSING RESEARCH AND MONITORING PROJECT PROPOSALS

MERIT

The key criterion for evaluating the merit of a proposal is whether the outcomes will provide or contribute to the scientific/technical foundation from which to manage activity in the Property so that the values are not unacceptably compromised by usage. In essence, will the project outcomes ensure that usage is maintained, through appropriate management strategies, at ecologically sustainable levels? Criteria against which to assess the merit of a proposal include:

Eligibility: Are the project objectives consistent with the generic priorities identified in section 5? Are the project outcomes consistent with the management goals for the Property? Will the project lead to long term improvements to management strategies?

Appropriateness: Are there alternative sources of funding for the project? Would the project be more appropriately funded from elsewhere?

Scientific/technical validity: Is the project based on sound scientific principles and methodology? Has the proposal been reviewed at an appropriate level?

Application: Is the project innovative and does it have a broad application? What is the time-frame for delivery of effective returns to the management process?

Compatability: Is the project complementary to other existing and/or proposed projects? Is there sufficient integration or is it a duplication of other projects?

Social significance: Does the project involve key stakeholders? What is the educational significance of the project?

Reporting: How effectively will the results/outcomes of the project be disseminated? How will specimens and data collected be managed, archived and maintained?

ETHICS

The ethical criteria detailed below have been adapted from a number of sources, including terms of reference for the Great Barrier Reef Marine Park Authority Research Ethics Advisory Committee (GBRMPA, 1997) and the Australian Science, Technology and Engineering Council guidelines for the ethical conduct of research in environmentally sensitive areas (ASTEC, 1998).

Best practice: Does the project represent best practice? Can the project outcomes be obtained using alternative and less intrusive or destructive techniques or by using a different sampling design? Does the experimental design address the objectives with minimal disturbance?

Impacts: Will the project have any direct, indirect or cumulative impacts? What, if any, remediation will be required after the project is complete? Do the potential benefits of the project warrant the extent of likely impacts?

Risk: Does the project involve endangered, vulnerable, threatened or commercially important species or communities? Can the project be carried out in less sensitive areas? Does the project involve the introduction or relocation of any biological material (including genetically modified organisms)? Are toxic/radioactive/cumulative or persistent chemicals likely to be released into the marine environment?

Acceptability: Does the project involve any manipulative/intrusive techniques? Is the work likely to be controversial or sensitive (culturally) or could it be seen as cruel or unnecessary? Will the research take place in a highly protected area such as a sanctuary zone of a marine park, or a marine nature reserve?

Equity: Does the project involve the infringement of privacy and property rights? What are the potential benefits for resource conflict resolution between different users?

Commercial gain: Will the research, including the availability of results, be likely to lead to direct or indirect commercial gain which may compromise the project.

FEASIBILITY

Achievability: Does the proponent have the technical expertise and proven capability/track record to successfully undertake the project? Is the project likely to achieve the proposed outcomes?

Resources: Does the proponent have access to sufficient resources to conduct the work?

Cost-effectiveness: Is the budget appropriate for the work to be done? Are the costs for technical/scientific support and implementation actions and materials realistic and reasonable?

Quality control: What measures are proposed to ensure that the research is conducted as proposed?

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