Ningaloo Marine Park Symposium
July 2007

Hosted by:
Department of Environment and Conservation
CSIRO Wealth from Oceans Flagship
Murdoch University
Western Australian Marine Science Institution

Ningaloo Marine Park Symposium
24-25 July 2007

Venue: Kim E. Beazley Lecture Theatre
Murdoch University
South Street
MURDOCH WA 6150

Sponsored by:

Department of Environment and Conservation

Ningaloo Collaboration Cluster

Western Australian Marine Science Institution

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INTRODUCTION

The Ningaloo Marine Park (NMP) was established in 1987 and the first ten-year management plan was approved in 1989. The process to review and update the 1989 -1999 management plan began in 1999. In January 2005, the WA State Government approved an updated plan for the management of the NMP for the period 2005-2015. Two contentious issues arose during the planning process: (i) the potential impact of increased recreational use and tourism development on the marine park and (ii) the increase in sanctuary zones (i.e. no take zones). The debate surrounding these issues highlighted the deficiencies in the knowledge base needed to specifically address these issues and, more generally, to manage the marine park effectively into the future. In response, the State Government announced that it would provide $5 M over four years for a program of marine research and additional on-going funding to the WA Department of Environment and Conservation (DEC) and the WA Department of Fisheries (DoF) for the management of the marine park.

A Ningaloo Research Program (NRP) was developed, through consultation with the marine science community and relevant state government departments, to ensure that future decisions by government regarding the conservation and management of NMP were based on better scientific information. This program focuses on providing a better understanding of the marine park, its ecological resources and the effectiveness of management strategies to preserve these values.

In 2006, the WA Marine Science Institution (WAMSI) was formed as a collaborative venture of government, research, university and industry partners to engage in and facilitate research that will underpin the conservation and sustainable management of WAs marine environment and resources. The biodiversity conservation research stream (Node 3) is led by the DEC and comprises the Ningaloo Research Program.

Additionally, in mid-2005, CSIRO launched the Flagship Collaboration Fund which has since funded a study of the habitats, biodiversity, reef-use, socio-economics and modelling of the Ningaloo Marine Park, affiliated with the CSIRO Wealth from Oceans Flagship. Research in this study, the Ningaloo Cluster Project, commenced in January 2007 and will continue until 2010. In addition to these research initiatives, DEC, the Department of Fisheries, the Australian Institute of Marine Science, local and interstate universities and the mining and exploration industries have or support on-going marine research programs in the region.

The purpose of this Symposium is to bring together the broad spectrum of researchers from these and other programs working in the NMP and promote integration, linkages and opportunities between individuals, research projects and institutions. The objectives are to:

- Provide a forum for discussions among all researchers working at Ningaloo – including WAMSI Node 3, CSIRO Ningaloo Cluster, AIMS core activities and other researchers not affiliated with these programs;
- Identify the scope of the research at Ningaloo and who is doing what research;
- Enhance collaboration and integration across research projects;
- Seek ideas for developing the most effective ways of providing information, coordinating activities and liaising between researchers in the Ningaloo region;

- Highlight the importance, to researchers, of ensuring the science ultimately informs management decisions; and

- Promote ongoing liaison/ coordination/ communication between researchers after the symposium.

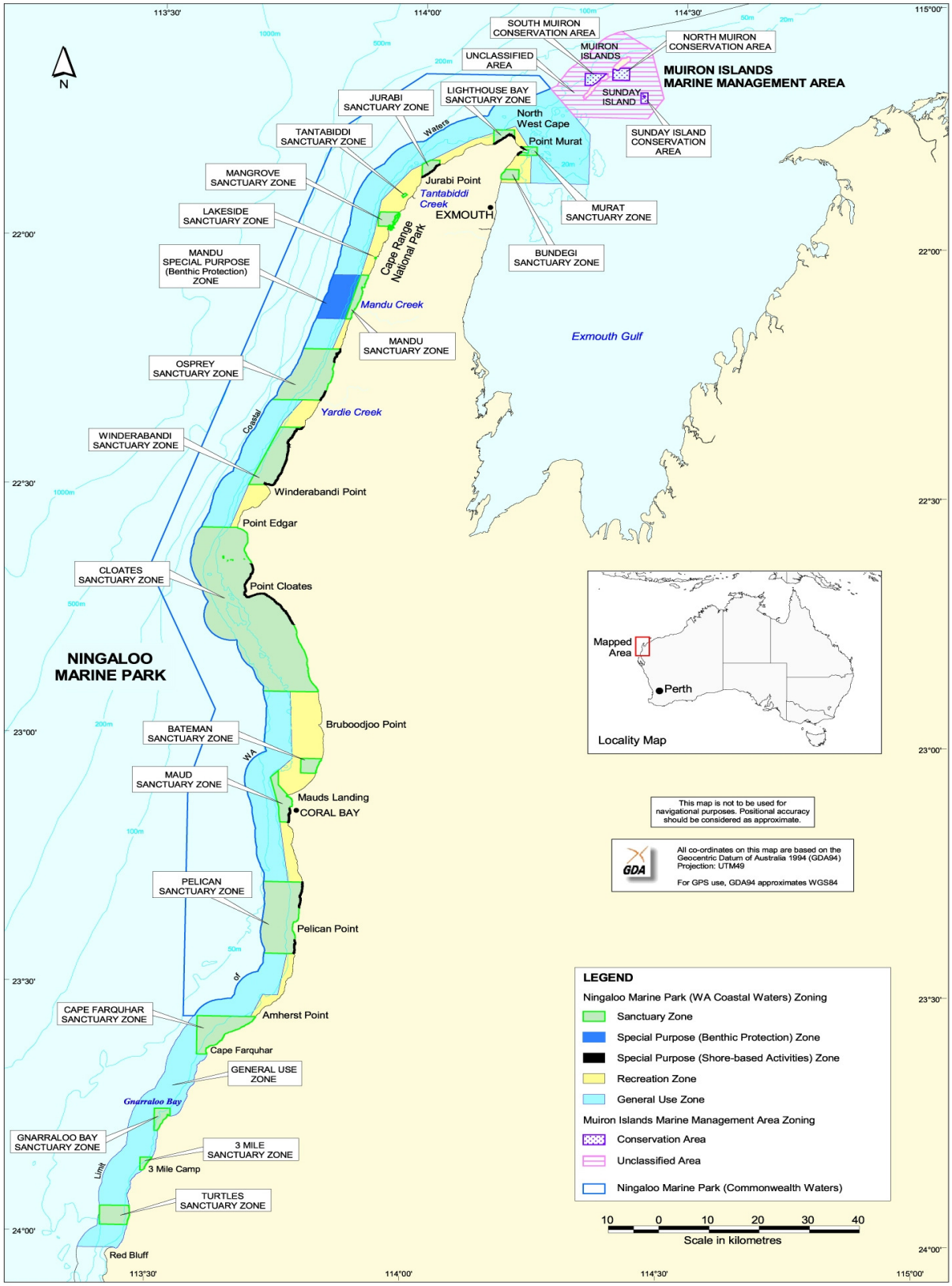
We wish you all an enjoyable and productive symposium.

Neil Loneragan, Irene McKissock (Murdoch University, Ningaloo Cluster)

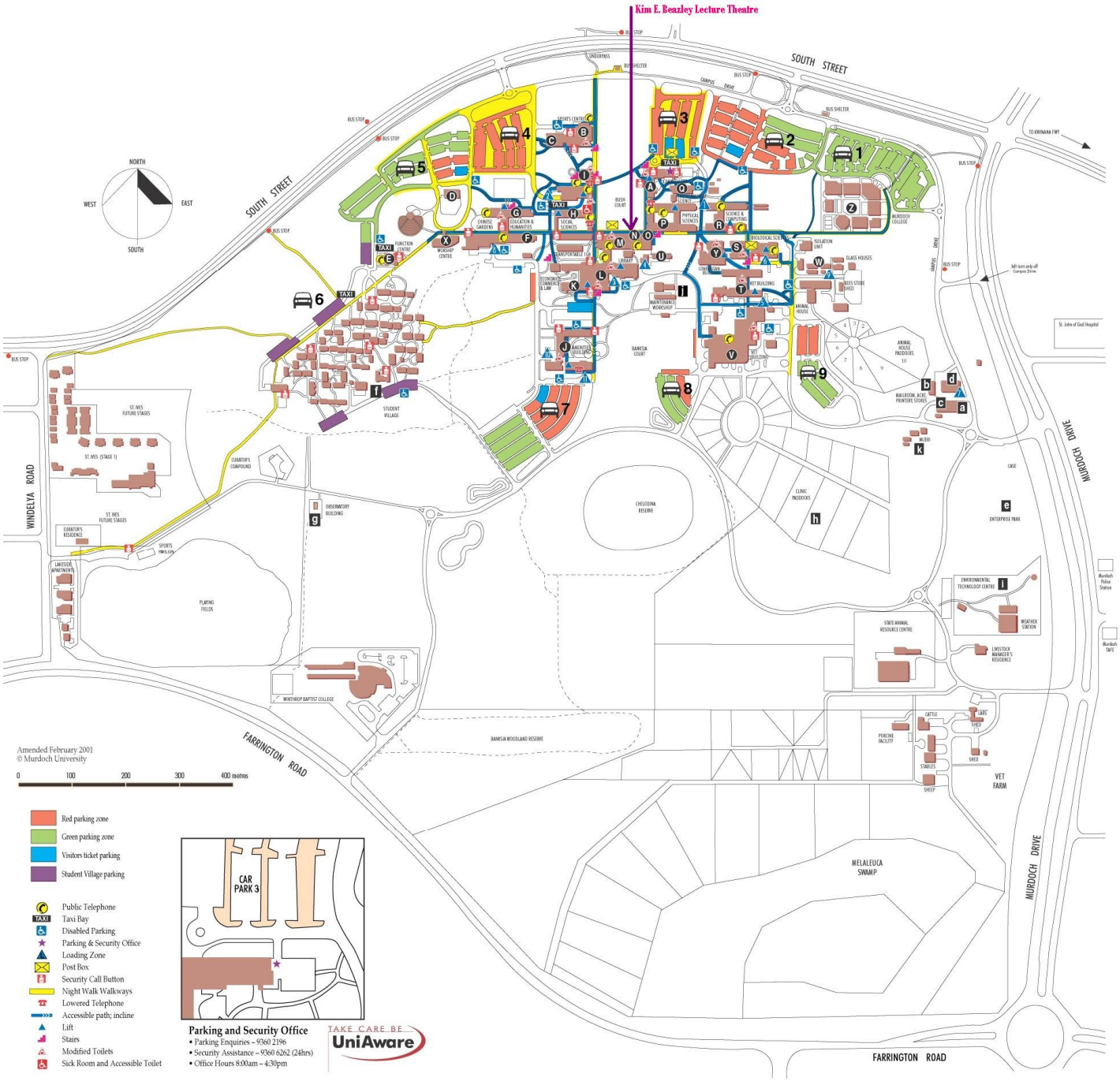
Kate Wilson (CSIRO Wealth from Oceans)

Kelly Waples, Chris Simpson (Department of Environment and Conservation, WAMSI, Node 3 research)

MAP OF THE MANAGEMENT ZONES FOR NINGALOO MARINE PARK



MAP OF MURDOCH UNIVERSITY



PROGRAM

Ningaloo Marine Park Symposium
24 and 25 July 2007
Kim Beazley Lecture Theatre, Murdoch University

Registration/coffee: From 8.30 fill in participants list and name tag, collect proceedings.

Time	Presentation	Speaker
9:00	Introduction and Welcome	Kelly Waples (DEC)
Research overviews for NMP – Chair: Kelly Waples		
9:10	Wealth From Oceans- Ningaloo Cluster	Neil Loneragan (Murdoch)
9:25	Science for Management: Ningaloo research by WAMSI Node 3 and the DEC	Chris Simpson (DEC)
9:40	AIMS research at Ningaloo: • Methods of monitoring the health of benthic communities at Ningaloo Reef. • Stock assessment of target invertebrates at Ningaloo reef. • Enhancing the big picture with corporate sponsorship • Ningaloo Reef Marine Park Deeper Waters Biodiversity	Andrew Heyward (AIMS)
Physical Environment – Chair: Kelly Waples		
10:10	The biological oceanography of Ningaloo Reef	Anya Waite (UWA)
10:25	Hydrodynamic modelling of Ningaloo Reef	Ryan Lowe (UWA)
10:40	***Morning Tea***	
Biodiversity – Chair: Chris Simpson		
11:00	The distribution and biodiversity of deepwater benthic fishes on the Ningaloo reef.	Euan Harvey (UWA)
11:15	Ningaloo HyMap processing-bathymetry	Wojciech Klonowski (Curtin)
11:30	Mapping habitats and biodiversity of Ningaloo reef lagoon using hyperspectral remote sensing data	Nicole Pinnel (Murdoch)
11:45	1 The Coral Bay Research Station 2 Biodiversity studies as part of the CSIRO Wealth from Oceans Collaborative Cluster programme	Mike van Keulen (Murdoch)
12:00	The Significance of Historical Collections: Ningaloo	Jane Fromont (WA Museum)
12:15	Aggregations of the commercial sea cucumber *Holothuria whitmaei* on Ningaloo Reef, Western Australia	Glenn Shiell (Oceania)
12:30	Gene flow, recruitment and disturbance in two coral species on coastal and offshore reefs of north-west Australia	Jim Underwood UWA, AIMS)
12:45	The role of herbivores verses nutrients on macroalgae and consequences for coral settlement and survival	Fiona Webster (Murdoch)

13:00	***Lunch***	
Data and Information Sharing - Chair: Steve Blake Purpose: to discuss data management and means of sharing information between projects to avoid repetition of data collection and enhance project outcomes		
13:45	WAMSI data management protocols	Steve Blake (WAMSI)
14:00	Ningaloo Wiki	Brendon Ward (CSIRO)
14:15	DIVE: visualising multidisciplinary, multidimensional data	Gary Carrol (CSIRO)
14:30	Bluenet	Luke Edwards (Bluenet)
	Open Discussion	
15:30	***Afternoon Tea***	
Megafauna – Chair: Kelly Waples		
15:45	Whalesharks	Brad Norman (Ecoceans)
16:00	Population biology of Whalesharks at Ningaloo Reef: current and future research	Mark Meekan (AIMS)
16:15	Temperature profiles of sea turtle nesting beaches along the Ningaloo coast	Gerald Kuchling (UWA)
16:30	Distribution and Abundance of dugongs in NMP and Exmouth Gulf	Amanda Hodgson (James Cook University)
16:45	Migratory Patterns in Distribution, Abundance and Behaviour of Humpback Whales (*Megaptera novaeangliae*) at North West Cape, Western Australia	Curt Jenner (Centre for Whale Research)
17:00	The Trophic ecology of the Manta Ray (*Manta birostris*) within lagoonal systems of Ningaloo Reef.	Frazer McGregor (Murdoch)
17:15	**Summing up**	**Neil Loneragan**
17:30-18:30 Drinks and Nibblies		

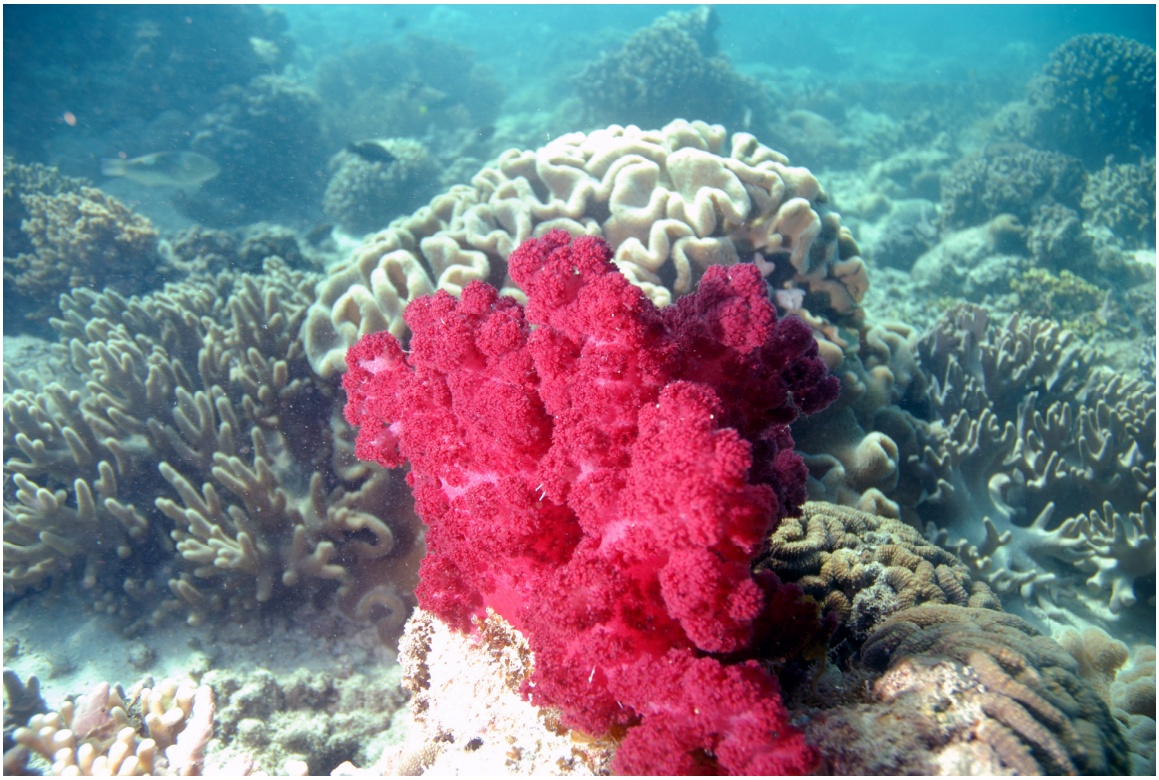
Wednesday, 25 July		
Time	**Presentation**	**Speaker**
Tourism and Modelling – Chair: Prof David Wood		
9:00	Social and economic assessment of tourism along the Ningaloo Coast: a dynamic modelling approach (Socio-economics of tourism)	Tod Jones (Curtin)
9:15	Estimation and integration of socio economic values of human use of Ningaloo in the MSE model structure.	Michael Burton (UWA)
9:30	The Policy Relevance of Choice Modelling: An application to Ningaloo Marine Park	Abbie McCartney (UWA)
9:45	Socioeconomic values/Indigenous values	Benedict Scambary(CSIRO)
10:00	Community perceptions of the socio-economic impacts of protected area management on local communities: A case study of the Ningaloo coast.	Colin Ingram (DEC)
10:15	Qualitative Modelling of Sustainable Tourism Development in Ningaloo Coast Region	Jeff Dambacher (CSIRO)
10:30	***Morning Tea***	
Management Strategy Evaluation Modelling – Chair: Bill de la Mare		
10:50	ElfSIM	Richard Little(CSIRO)
11:05	Management strategy evaluation using InVitro (Cluster Project 5)	Randall Gray (CSIRO)
11:20	A Sneak Preview of the MacVitro Prototype	Fabio Boschetti (CSIRO)
Marine Park Management and Fisheries Management – Chair: Neil Loneragan		
11:35	High resolution mapping of reef utilisation by humans in Ningaloo Marine Park	Lynnath Beckley (Murdoch)
11:50	Ecosystems and Fisheries Effects of Zoning	Russ Babcock (CSIRO)
12:05	Research for Integrated Fisheries Management of Gascoyne Demersal Scalefish	Ross Marriott (DoF)
12:20	WAMSI node 4	Daniel Gaughan (DoF)
12:35	Spatial and temporal variations in *Drupella cornus* populations and live hard coral cover over a fourteen year period at Ningaloo Marine Park, Western Australia	Shannon Armstrong (DEC)
12:50	Disturbance and recovery of reefs in Coral Bay over a 17-year period	Suzanne Long (DEC)
13:05	***Lunch***	
Technology and Biodiversity – Chair: Neil Loneragan		
13:45	The Australian Acoustic Telemetry and Monitoring System	Mark Meekan (AIMS)
14:00	The use of underwater acoustics in studies about Ningaloo	Rob McCauley (Curtin)

14:15	Autonomous Underwater Vehicle Surveys off Ningaloo Reef	Stefan Williams (AIMS)
14:30	***Afternoon Tea***	
Discussion session - Research coordination and management – Chair: Chris Simpson Purpose – to identify and discuss issues relevant for all researchers where collaboration and information sharing will enhance research efficiency and outcomes		
14:50	DEC regional operational activities and resource limitations Compliance Facilitating public involvement and interest **Open Discussion**	Roland Mau (DEC) Laurie Caporn (DoF)
16:15	**Summing up**	**Chris Simpson (DEC)**
16:30	***Symposium End***	

ADDITIONAL ABSTRACTS

Title	Principal Author
Physical	
Downscaling ocean climate into the Ningaloo Reef Tract	Richard Brinkman (CSIRO)
Ecological effects of climate change on regional diversity patterns of WA coral reefs	John Pandolfi (UQ)
Geomorphology, sediments and habitats of Ningaloo Reef, Western Australia	Emily Twiggs (Curtin)
Trophic ecology of coral reefs: the role of oceanographic-to-organism scale processes in trophodynamics and benthic-pelagic coupling	Alex Wyatt (UWA)
Biodiversity	
Intertidal Invertebrates Survey	Bob Black (UWA)
NCRIS	Julian Caley (AIMS)
The spatial and temporal distribution of demersal reef fish in Northern Ningaloo Marine Park	Ben Fitzpatrick (UWA)
Dynamics of arid zone mangrove ecosystems and their contributions to coastal productivity	Cath Lovelock (UQ)
Overview of CSIRO biodiversity survey of the Ningaloo Commonwealth MPA collected in 2005	Alan Williams (CSIRO)
Megafauna	
Diversity, abundance and habitat utilisation of sharks and rays	John D. Stevens (CSIRO)
Range and habitats of whale sharks in the Eastern Indian Ocean	Brent Stewart (Hubbs Seaworld)
Tourism and modelling	
Economic valuation of biodiversity conservation: Citizens' non-use value of Ningaloo Reef	Flavio Gazzani (Murdoch)
Socio-economic impacts of sanctuary zone changes in Ningaloo Marine Park	Jeremy Northcote (ECU)
Ningaloo research project client outreach	Geoff Syme (CSIRO)
Marine Park and Fisheries Management	
Low temperatures cause coral bleaching at Ningaloo Reef, Western Australia	Shannon Armstrong (DEC)
Ecological interactions in Ningaloo Marine Park	Glen Hyndes (ECU)

ABSTRACTS FOR ORAL PRESENTATIONS



Reef use, biodiversity and socio-economics for integrated management strategy evaluation of Ningaloo

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The Ningaloo Cluster Project is a major research endeavour to be undertaken by a group of eight research partners as part of the CSIRO Flagships Collaboration Fund. The project uses a multi-disciplinary approach to provide knowledge and develop models to assess the mutual dependency between the Ningaloo Reef system, human use of the reef and adjacent areas and the influence of zoning regulations on human activities. Research in the cluster will provide high resolution spatial data on the habitats (remote sensing using hyperspectral data), biodiversity (field studies), and reef use (aerial flights, interviews and observations from shore), and information on the economics of tourism (surveys) and reasons for choice of activities in the region (random utility modelling, destination modelling). These data and the models developed will contribute directly to the models for Management Strategy Evaluation being developed by CSIRO and will significantly enhance the information on human activities and socio-economic values in the region. This research will bring together researchers from a wide range of disciplines (e.g. remote sensing, marine ecology, sustainable tourism, socio-economic modelling and management strategy evaluation) from six universities (Murdoch University, Curtin University of Technology, The University of Western Australia, Edith Cowan University, The University of Queensland and the Australian National University), one CRC (Sustainable Tourism) and CSIRO Wealth from Oceans Flagship. Combined with research on management strategy evaluation for the multiple-use of marine ecosystems in the Wealth from Oceans Flagship, it will provide the basis for much more effectively evaluating different management and development scenarios in the region e.g. the potential conflict between growth in eco-tourism and the infrastructure to support this growth and the biodiversity values of the reef that are fundamental for the success of the ecotourism industry.

Science for Management

Chris Simpson

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The Ningaloo Marine Park (NMP) was established in 1987 and the first ten-year management plan was approved in 1989. In January 2005, the WA State Government approved an updated plan for the management of the NMP for the period 2005-2015. Two particularly contentious issues arose during the planning process: (i) the potential impact of increased recreational use and tourism development on the marine park and (ii) the increase in sanctuary zones (i.e. no take zones). The debate surrounding these issues highlighted the deficiencies in the knowledge base needed to specifically address these issues and, more generally, to manage the marine park effectively into the future. In response, the State Government announced that it would provide $5 M over four years for a program of marine research and additional on-going funding to the WA Department of Environment and Conservation (DEC) and the WA Department of Fisheries for the management of the marine park.

The Ningaloo Research Program (NRP), now part of Node 3 of the WA Marine Science Institution, was established specifically to ensure that future decisions by government regarding the conservation and management of NMP were based on better scientific information. Co-investment in the NRP by AIMS, CSIRO and local universities, combined with other Ningaloo research programs such as the Ningaloo Cluster Project, core research by AIMS and local and interstate universities as well as Government and industry-supported research now exceed $20M over the next four years. Integration of this research effort, knowledge transfer to support better management decisions and data management are now the major challenges to be faced over the next four years.

Methods of monitoring the health of benthic communities at Ningaloo Reef.

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This is a WAMSI Node 3 project lead by AIMS to provide baseline data on coral and fish recruitment along Ningaloo Reef and allow comparison of various survey approaches that will enable selection of meaningful and cost effective recruitment monitoring protocols.

The project is at the planning phase, with consideration given to methodology and design parameters for utility in any long term monitoring program for corals and fish. The project will:

1) Apply the most commonly used methods of quantifying changes in benthic communities (e.g. coral, algae) from digital imaging, and fish communities using visual censuses. These methods will be applied to determine the levels of spatial (number of sites/reefs) and temporal (number of surveys) replication necessary for detecting predetermined changes in community structures.

2) Quantify rates of coral and fish recruitment, which are important parameters underlying changes in the abundances of adult communities. Rates of recruitment of corals and fish will be quantified at different sites and reefs along Ningaloo, to determine the appropriate scales of assessment, background variation, and to identify the likely 'sinks' and 'sources' of recruits, based on variation in community structures and associated physical parameters.

3) Changes in the size-frequency of key groups of corals and fish will be combined with information about adult abundances and recruitment rates in an attempt to follow cohorts and infer the effects of significant events on the current and future health of the communities.

Commencement is anticipated in late 2007 –early 2008. It is expected that close communication and potential field collaboration will occur between AIMS, DEC and WAF The desired outcome is enhanced management effectiveness in planning spatial management controls using reef connectivity between monitoring locations and management zones.

Stock assessment of target invertebrates at Ningaloo Reef

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A WAMSI Node 3 Project, lead by AIMS, to assess the distribution and abundance of key invertebrates likely to be subject to significant harvesting pressure. In particular we shall focus on stock surveys for rock lobster and octopus. An additional component may be a subset of surveys to characterize the abundance and distribution of selected ornamental shells.

The research will be mostly sub-tidal and sample both within and outside existing lagoonal sanctuary zones. Study sites will be selected to spatially augment lobster surveys being led by CSIRO in the Effects of Fishing program and intertidal surveys of various invertebrates being undertaken by UWA.

A diverse set of links and collaborations will enhance this project. Octopus are a know collection target , mainly as bait, by recreational fishers. Close liaison is envisaged with the Wealth from Oceans Cluster fishing surveys led by Murdoch University, to identify areas with various levels of fishing pressure and water access along Ningaloo. Similarly new habitat maps to be derived from the WfO Cluster hyperspectral project will be evaluated for utility in mapping potential hotspots of crayfish and octopus distributions.

It is likely that a number of octopus species are utilized, so collaboration with the Ningaloo Census of Marine life project to establish a list of key octopus species and their favoured habitats. The project will include development and comparison of various sampling techniques, including application of novel commercial octopus traps used in central and southern WA fisheries, to evaluate their potential at Ningaloo as a cost-effective monitoring tool. The project is in the planning stage and field surveys are expected to commence in 2008.

Ningaloo – enhancing the big picture with corporate sponsorship

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Australian Institute of Marine Science, Botany Biology Bldg (M096) UWA Crawley WA 6009

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BHP Billiton Petroleum Pty Ltd is funding a variety of research projects to promote knowledge and awareness of the Exmouth region and Ningaloo Marine Park. The company continues to support a diverse portfolio of science projects in the region, including monitoring studies on whales and support for whale shark research.

In addition, a collaboration over four years until 2009 with AIMS exists to support research which is complimentary to various government initiatives at Ningaloo, such as those linking to WAMSI initiatives. .Each year a variety of projects are coordinated by AIMS to utilize the corporate funding support. In 2006 the Ningaloo hyper-spectral survey, which has captured probably the worlds most definitive coral reef survey using this technology, was completed and AIMS has provided the enabling data set for the Wealth from Oceans Cluster projects on habitat and bathymetric mapping of the entire marine park. In 2007 funds have supported cutting edge technology demonstrations at Ningaloo, with the major effort utilizing the Sydney University AUV Sirius, to undertake additional benthic mapping to depths of 200m off northern Ningaloo. Additional work on characterizing Ningaloo and past climates is planned for 2008, focusing on finding and coring ancient corals for use in climate studies. In 2009 a symposium or benchmark book is planned. Funds will be utilized to draw together a synthesis, at the mid- to final stage point of many current projects, of current knowledge about Ningaloo and publish it in a popular format aimed at a broad readership. This publication expects to draw significantly on the participants of this symposium and the knowledge they have available a couple of years hence.

Ningaloo Reef Marine Park deeper waters biodiversity

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The project is a WAMSI Node 3 collaboration of WA-based researchers, lead by the Australian Institute of Marine Science and involving AIMS, WA Museum, Curtin University, UWA and CMRA. It comprises four annual seasons of ship-based field work and seeks to contribute significantly to habitat mapping of the deepwater component of NMP (offshore of the fringing reef). Field work commenced in April 2006 and should be concluded in 2008-9. The research has a high element of discovery and will seek to characterise the diversity and abundance of benthic communities, associated fauna and geomorphology in NMP, especially in the waters below typical scientific diving limits (30m+). A key objective is to characterise the biodiversity values associated with the existing deeper water sanctuary zones to permit assessment of the current zoning using CAR principles. Reporting is annual and progressive, with the initial year's summary complete (Colquhoun et al, 2007).

In 2006 field work focused on sites between North West Cape and Pt Cloates. Towed video systems, stereo baited underwater video systems (stereo-BRUVs) and a benthic sled were used to survey and sample the biodiversity. Single and multibeam acoustics and sediment grabs were used to investigate and sample surficial sediments and seabed geomorphology. In 2007, with the exception of multi-beam methods, these surveys were extended throughout the southern half of the marine park, as far south as Cape Farquhar

Preliminary results north of Pt Cloates show a clear zonation of habitats across the shelf. Where hard substrate is available the dominance of hard corals begins to decline at around 40m depth, gradually replaced by a mixed benthic community dominated by sponges, crinoids, turf algae and *Halimeda*, with some soft corals (gorgonians, sea whips), ascidians and sea pens. There is an extensive middle shelf sand plain, where sediment thickness is variable, overlying limestone pavement and low relief consolidated systems. Here communities of sponges, crinoids, sea pens, sea whips and hydroids are patchy, with higher abundance associated with hard substrates. Bioturbation was evident from echinoderm feeding traces, polychaetes and burrowing fish and a diverse infauna have reworked the sediments to build mounds and burrows. Large ridges have been identified at various depths with an extensive system on the outer shelf (75-125 m).

The project has discovered patchy but diverse sponge and soft coral communities in the deeper waters of the State Marine Park (50-110 m), with potentially high and unique biodiversity values. Significant components of these communities are represented both within and outside declared deeper water sanctuary zones. Two large ridge systems parallel to the coastline support a vast array of sessile benthic species with diverse piscatorial associations. Hard corals were generally not dominant beyond 40-50 m. Extensive areas of sand and rhodolith habitats were also evident. A final season of benthic survey is planned for early 2008, followed by a broadscale resurvey of fish communities throughout the entire Marine Park.

Biological Oceanography of Ningaloo Reef

Anya M. Waite[1], Ryan Lowe[1], Alex S.J. Wyatt[1*], Stuart Humpries[2]

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Our initiative attempts to understand Ningaloo Reef as a unified ocean-reef system, in which pelagic production and benthic production are mechanistically linked. We present an overview of the aims and discuss the implications of this approach, and show new data from our first field season at the reef in May 2007 indicating the potential scale and impact of possible chemical and ecological benthic-pelagic interactions linking field work to hydrodynamic and biogeochemical modelling will be a key component of this work.

Hydrodynamic modelling of Ningaloo Reef

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We are developing a circulation model of Ningaloo Reef as part of WAMSI Node 3, Project 5. The circulation of Ningaloo is known to be a complex function of its bathymetry and the meteorological and oceanic forcing conditions present. A three-dimensional circulation model iteratively-coupled to a numerical wave model will be used to predict how waves, tides, winds and buoyancy effects control the circulation and distribution of wave energy on Ningaloo Reef. Initially, we will apply the model to a test section of reef surrounding Sandy Bay, using field data collected during a April-May 2006 experiment to validate its performance. By running simulations in parallel, we will eventually expand the model domain to incorporate large expanses of the reef system. This working circulation model will provide insight into how various ecological processes operating on Ningaloo Reef are coupled to its circulation (e.g. recruitment patterns, nutrient dynamics, etc.), and will provide a foundation for conducting a risk analysis of processes that may threaten its integrity (e.g. contaminant spills).

The distribution, biodiversity of deepwater benthic fishes on the Ningaloo Reef.

Euan Harvey

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The proposed research aims to characterise the deepwater fish assemblages (greater than 10 m) outside the crest of the Ningaloo reef and provide spatially explicit baseline data. Sampling will be stratified by depth and habitat in different areas of the Ningaloo Marine Park to encompass and describe spatial variation across the length and breadth of the park at selected locations.

The survey design will be planned using hydroacoustic data (multibeam, single beam and sidescan sonar) which has been verified with towed video. This work is being undertaken by AIMS.

Fish data will be collected within discrete habitats using baited remote stereo-video point counts and drift stereo-video transects. Baited cameras have been shown to be a very effective non-destructive technique for sampling a wide range of species. Drift stereo-video furthers the concept of Underwater Visual Census by Scuba Divers to deeper water. The use of stereo-video technology makes both of these powerful quantitative techniques as you can define the sampling area and assess relative abundance rather than just absence and presence and can obtain very accurate measures of the length of individual fish. In addition acoustic positioning allows for accurate positioning of the towed body within a specific habitat and data to be recorded from transects of a known length. A pilot study for this work was undertaken in the northern Ningaloo region in April 2006 as a collaboration between UWA and AIMS.

The proposed research is scheduled for 2009 and 2010. We plan to submit an ARC Linkage Grant in 2008. Partners in this research are Dr. Euan Harvey (UWA) and Andrew Heyward (AIMS). Additional collaborators that will be incorporated into the ARC Linkage Grant are Professor Howard Choat (JCU), Professor Marti Anderson (Auckland University) and Dr. Stephen Newman (DoF).

Ningaloo HyMap Processing – Bathymetry

Wojciech Klonowski, Prof. Mervyn Lynch and Dr. Peter Fearns

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In April 2006, Australia's largest hyperspectral aerial survey was conducted over the Ningaloo Marine Park. The HyMap (HyVista Corp.) imaging system was used, capturing spectral signatures of the marine park at a ground resolution of 3.5m. Curtin has undertaken the task of processing the image data to yield atmospherically corrected reflectance, bathymetry and benthic cover maps. The approach utilises a shallow water reflectance model which accounts for the absorption and backscattering properties of the water, the water depth and the substrate reflectance. A Levenburg-Marquardt optimization technique is used to retrieve the model parameters for individual pixels which are used to produce high quality bathymetry and benthic cover maps. The validation conducted so far suggests that the shallow water bathymetry maps are very accurate, with a typical normalised RMS error of less than 10% for depths ranging from 0.5 – 12m.

Mapping habitats and biodiversity of Ningaloo Reef lagoon using hyperspectral remote sensing data

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This project is focusing on the mapping of habitats and biodiversity of the Ningaloo Marine Park. This will be achieved through a combination of state-of-the-art hyperspectral remote sensing techniques, coupled with biodiversity field surveys of the area.

Airborne hyperspectral data were collected by HyVista in April 2006 over 3500 km^2 covering the whole Ningaloo Marine Park. This is the largest hyperspectral coral reef survey to date in the world and provides images in 3.5 m spatial resolution for a 1km wide terrestrial coastal strip and out to 20m depth over lagoon areas. Hyperspectral remote sensing data are corrected for atmospheric, air water interface and water column effects. This, physics-based approach, promotes automatisation and the removal of subjectivity from the classification process, allowing improved transferability to additional sampling locations and extension of the monitoring to other seasons.

Field work was carried out to support the airborne data acquisition in 2006 and 2007 collecting underwater field spectra, echo-sounding data and underwater photographs to allow for accurate validation and interpretation of hyperspectral data. Field spectra from various habitats are used to characterise their spectral features enabling differentiation and classification of various bottom cover types. Transects across coastal vegetation were also conducted to identify the vegetation types and key landforms contributing to the variability in the images along the coast.

Over the next three years, this project will use the hyperspectral data to develop a high-resolution characterisation of the reef, shallow water habitats and terrestrial vegetation of the coastal strip in order to support sound conservation and management of the Ningaloo Marine Park.

Coral Bay Research Station

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Murdoch University and the North West Research Association are pleased to announce the availability of the Coral Bay Research Station for researchers wishing to study the Ningaloo Reef in Western Australia. The research station is conveniently located in the town of Coral Bay on Ningaloo Reef, providing easy access to a wide variety of reef and lagoon habitats.

The station currently comprises a single building containing two bedrooms with comfortable accommodation for up to eight, with full kitchen and bathroom. A separate laboratory contains basic sample processing and laboratory facilities. Equipment includes two new Olympus microscopes with digital camera/video capabilities, digital camera with underwater housing, centrifuge, small drying oven, balance, freezer, etc. Office facilities include a computer with Internet access, printing facilities and telephone. A reference library is being compiled by the Murdoch University Library and is located at the Research Station.

Transport options include: a 4 m aluminium dinghy; a 5.5 m aluminium side-console work boat; and a 4WD for boat launching. Field equipment includes several complete sets of dive equipment with additional tanks and weight belts; GPS plotter/sounder; diving first aid kit and emergency oxygen equipment.

Biodiversity studies as part of the CSIRO Wealth from Oceans Collaborative Cluster programme

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Node 1 of the Ningaloo Cluster study addresses habitats and biodiversity. Key habitat types will be identified using aerial photography and will be used to develop a stratified sampling approach. Two focal areas have been selected, based on sanctuary zones within the Ningaloo Marine Park (NMP): Osprey in the northern part of the NMP and Maud in the south. A nested sampling programme will be initiated within each of these locations, consisting of surveying transects at different spatial scales: cross-reef transects (shore to reef edge) to identify major habitat types and changes; and finer-scale habitat surveys of biodiversity and abundance of different major groups of organisms. The focus of the finer-scale surveys will be on non-scleractinian cnidarians, macroalgae, sponges, echinoderms and molluscs. A field trip in September/October 2007 will provide field validation of the initial site selection and will commence the sampling programme.

Field trips in April 2006 and April 2007, while ostensibly to obtain spectral signatures to add to the spectral library for use in interpreting the hyperspectral imagery, were also an opportunity to test sampling techniques and identify key study locations.

The Significance of Historical Collections: Ningaloo

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Collections of marine organisms have been undertaken by Western Australian Museum staff in the Ningaloo region from the 1960s. However, inadequate resources (staff time and funds) have prevented the complete databasing of these historical collections, particularly the invertebrates. With the current strong research focus on the Ningaloo Marine Park and bioregion, we could see the value of databasing the marine invertebrate collections from this region, and successfully applied for DEWR funding to do this. These collections are derived from fieldwork undertaken between the 1960s to the late 1980s at Ningaloo, North West Cape and Exmouth Gulf. These collections are particularly valuable because they predate the *Drupella* outbreaks and coral spawning deaths at Bill's Bay, and the effects of the more recent cyclones.

The aim of the project is to database the common marine invertebrates from Ningaloo. This includes the scleractinian corals, the echinoderms, various crustacean groups including the shrimps, lobsters, and crabs, and certain molluscan families including the giant clams, oysters and volute gastropods.

Databasing of the scleractinian corals is completed with 220 species found in the region and 706 specimens databased. The echinoderm databasing is also completed with 72 species of brittle-stars (232 specimens), 35 species of crinoids (140 specimens), 43 species of echinoids (182 specimens), 68 species of seastars (343 specimens) and 35 species of holothurians (65 specimens) databased. Work on crustacean species is presently underway.

We believe that the databasing of these collections will provide valuable baseline data for fieldwork in the region. This work will produce a consolidated database of invertebrate species recorded from the area, with associated location, depth, date of collection and habitat data. The work will identify geographical gaps (areas where few specimens have been collected), and taxonomic gaps (where particular taxa have not been collected) in the region.

Aggregations of the commercial sea cucumber *Holothuria whitmaei* on Ningaloo Reef, Western Australia

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Despite the ecological significance of aspidochirote sea cucumbers, wild populations are subjected currently to unprecedented levels of commercial exploitation. Consequently, sound management requires knowledge of natural population densities prior to fishing. However, gathering density data is rarely straightforward as the distribution of sea cucumber is often heterogeneous, leading to significant errors when censuses are conducted over inappropriate scales. To demonstrate this notion, manta tow surveys utilised Global Positioning System (GPS) to determine the relative distribution of the sea cucumber *Holothuria whitmaei* over approximately 750 ha of coral reef habitat near Coral Bay, Western Australia. The spatial distribution of the *H. whitmaei* was typical of that reported in the literature, with specimens having a preference for outer reef habitats, including the outer reef-flat and reef-slope. Nevertheless, the distribution of specimens within these habitats was distinctly heterogeneous, with the majority of specimens being clustered at the leading edge of the reef flat (particularly perpendicular to the prevailing current) in relatively high densities ~78-123 ind. ha^{-1}. Utilisation of Geographic Information Software (GIS) determined that the aggregations were spatially significant (Moran's I; p=0.01), with ~40% of specimens being clustered within ~14.7% of the habitat surveyed. Subsequent estimation of the population density based on habitats containing 100% of the sample population (including outliers), yielded estimates of ~11-18 ind. ha^{-1}, results slightly lower than those reported from Marine Protected Areas (MPAs) on the Great Barrier Reef, Queensland. Given that Ningaloo Reef sea cucumber populations are currently precluded from commercial fishing, it is suggested that 11 to 18 ind. ha^{-1} may represent densities expected of natural *H. whitmaei* populations.

Genetic connectivity among populations of a broadcast spawning coral at Ningaloo and other reefs off northwest Australia.

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The degree of demographic connection among populations has profound influences on the ecology and evolution of species; from the short-term regulation and survival of communities, to the intermediate-term maintenance of genetic diversity among populations, to the long-term processes of speciation. However, the free-living larval stage of many marine species poses unique challenges to our attempts to understand and manage marine systems, and patterns of larval dispersal are currently poorly understood. Here, we use microsatellite DNA markers to quantify the genetic structure and infer the ecologically and evolutionarily relevant scales of dispersal of an abundant reef-building coral (*Acropora tenuis)* at Ningaloo and other coral systems off northwest Australia. Genetic structure over broad geographic scales shows a major divergence between the offshore zone (comprised of Scott Reef and Rowley Shoals), and the coastal zone (comprised of Ningaloo and Dampier), indicating that these regions have been reproductively isolated over evolutionary time frames. At the intermediate scale, genetic differentiation between systems within zones indicates that long-distance migrants occasionally move over distances of a few hundred kilometres, but systems are demographically independent. Further, significant subdivision was also detected within each system over the reef scale. At Ningaloo, sites clustered into three regions, with significant differentiation between groups of sites in the south, centre and north of the marine park. These results indicate that larvae disperse regularly over distances up to 50 kilometres within the three regions, but dispersal of large numbers of larvae between regions is rare. Variation in local hydrodynamics, coupled with local extinction and colonisation events, are the most plausible explanations of these patterns of genetic connectivity. The primary management implication is that viable *A. tenuis* communities should be able to regularly augment local recruitment in disturbed communities up to 50 kilometres away within these regions.

The role of herbivores verses nutrients on macroalgae and consequences for coral settlement and survival.

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The Ningaloo Reef provides a unique opportunity to investigate different components of a coral reef ecosystem without the confounding effects of poor water quality and severe overfishing, which is prevalent on many reefs throughout the world. This research examined the roles of herbivores and nutrients on macroalgal growth and consequences for coral settlement, survival and growth of coral recruits. Herbivores had a major influence on macoralgal growth, where as nutrients had little effect. The most important herbivores for controlling macroalgal abundance were large parrot fish, in particular *Scarus sordidus* and *S. schlegeli.* Small parrot fish whilst more abundant had little effect on macroalgae probably due to their small bite size. The dominant urchin *Echinometra mathei* was found to have no impact on macroalgae and is unlikely to be involved in trophic cascades on the Ningaloo Reef. Manipulative field studies using caged and uncaged treatments identified for the first time that macroalgae can affect both pre-and post- settlement components of the coral recruitment process. Successful coral recruitment is critical for long term coral population viability. This research further emphasizes the importance of maintaining herbivorous fish stocks, in particular scarids for long term coral reef resilience.

Ningaloo Wiki

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Wiki is the Hawaiin word for quick. A Wiki website is constructed using software that allows multiple users to create and edit the content of the Wiki online. The Ningaloo wiki aims to provide a collaborative tool to create, share and store information about Ningaloo. It is hoped the Ningaloo wiki will foster a community of researches and interested stakeholders and give them a resource to communicate their research. A brief demonstration of the functionality provided by the Ningaloo wiki will be given followed by a discussion.

DIVE: visualising multidisciplinary, multidimensional data

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DIVE is a project-level data-visualisation and data-storage tool. It was developed specifically for viewing and comparing multidisciplinary spatial and temporal data (in up to 4 dimensions) from sources including models, vessels, divers, moorings and satellites. The DIVE application was written as part of the SRFME (Strategic Research Fund for the Marine Environment) partnership between the WA Government and CSIRO, to provide both scientists and state environmental managers with access to project-wide data.

Development of DIVE is ongoing as part of WAMSI.

DIVE is most at ease with regularly-spaced data, for example from models or time-series moorings. We are still seeking advice on how to display most informatively the sparse data that are often a feature, for example, of ecological field programs.

BlueNet - Helping marine researchers find data

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BlueNet MEST (Metadata Entry and Search Tool)

Researchers at universities spend a great deal of effort collecting information about the marine environment. However, other researchers can find it difficult to locate and access this information, which leads to duplication and lost opportunities. BlueNet, a federally funded project and an extension of the Australian Ocean Data Centre Joint Facility (AODC-JF), aims to address this issue of marine data discovery and access. BlueNet will help marine researchers by providing the tools and resources to help them index and if appropriate, archive their data into secure, professionally managed repositories.

One of these tools is the MEST (Metadata Entry and Search Tool). It is an online tool that will allow researchers to easily and quickly create metadata (descriptive information about data) for their marine data. An index or database of marine data will result from this which will ultimately allow researchers to discover, access and integrate multi-disciplinary marine science data for the benefit of all marine researchers.

Luke Edwards is the Marine Data Facilitator for BlueNet based at UWA. He will demonstrate the MEST and answer researcher's questions.

Multi-level research approach to assist whale shark conservation

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Murdoch University and Ecocean Inc. are combining to undertake a broad study on the whale sharks on Ningaloo Marine Park (NMP) in an effort to better understand several aspects of whale shark biology and ecology to assist with the long-term conservation of this threatened species.

The method used to identify whale sharks using natural markings on the skin of each whale shark was developed from research undertaken at NMP between 1995-2007. The resultant ECOCEAN Whale Shark Photo-identification Library has become the global sightings database for this species, with entries logged from 37 countries (to date) and a total of 833 whale sharks identified. The computer-aided system used to test for 'matches' of individuals was adapted from an algorithm used by Hubble space telescope scientists to 'map' stars in the night sky. Population monitoring is employed to determine the status of whale sharks at NMP, updated on an annual basis with input of images collected by researchers, industry videographers, tourists and volunteers.

A stereo-camera system, developed in association with the University of WA, was tested at NMP in 2007 with the view to expanding this program in 2008 and beyond to determine an accurate mean length of whale sharks visiting NMP. When used in combination with the ECOCEAN Library, it will provide the first data on growth rate for this species in the wild.

In association with researchers at the University of Swansea, specially developed data-logging tags were successfully tested on whale sharks at NMP in 2007 and will be deployed in a broader study in 2008 to enable a better understanding of whale shark behaviour and assist in the development of refined guidelines to minimize impacts on whale shark sharks resulting from ecotourism pressure at NMP.

In collaboration with Curtin University, a survey regime incorporating data on visitor satisfaction and visitor expenditure will continue in 2008 and beyond and provide data to assist stakeholders to further refine the service provided to tourists at NMP and to assist in targeting their promotion to the public.

Public education of participants in whale shark ecotourism is a major focus of this broad program to assist the long-term conservation of whale sharks at NMP and abroad.

Population Biology of whale sharks at Ningaloo Reef: current and future research

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The past 15 years has seen rapid development of our understanding of the ecology and biology of whale sharks that aggregate seasonally at Ningaloo Reef, Australia. Monitoring fine-scale (metres to km) movement patterns suggests that whale sharks migrate to the reef to feed on seasonal aggregations of baitfishes and euphausiids. Satellite tagging has shown that sharks departing Ningaloo make frequent dives in excess of 980 m and migrate generally toward the northeast, often into Indonesian waters. Photo-identification (based on spot and stripe patterns) has confirmed that many sharks return to the reef, with some individuals resighted at intervals of more than a decade and a large number of individuals making frequent inter-annual visits. Photo-identification resightings have generated mark-recapture databases for estimation of population size and demographic parameters. Photograph matching has now been automated using open-access software (I^3S) and match parsimony ranking, permitting faster and more reliable matching success than manual comparisons. Most sharks (74 %) individually identified in the Ningaloo aggregation from 1992-2006 have been male. Jolly-Seber open-population models suggest that sharks sighted at the reef are drawn from a super-population of 300-500 animals and Cormack-Jolly-Seber survival models demonstrate size-influenced apparent survival probability ranging from 0.59 (5-m shark) to 0.81 (9-m sharks) per year. Declines in relative abundance of up to 40 % were also evident in a 10-year sightings-per-unit-effort dataset collected by tour operators. There was also a continuous decrease in the average size of whale sharks from 7 m in 1994 to 5 m in 2004. Current and future studies of this aggregation include quantification of mortality sources and the development of microsatellite genetic tags for individual identification and validation of photo-identification, and an assessment of ocean-scale gene flow.

Temperature profiles of sea turtle nesting beaches along the Ningaloo coast.

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Sea turtles have temperature dependent sex determination, with warmer egg incubation temperatures producing females and cooler temperatures males. Sex ratios of nests are influenced by climatic conditions of nesting beaches and may show seasonal variations. As part of a larger study of temperature profiles of sea turtle nesting beaches in Western Australia I also monitor since September 2004 sand temperatures at standardised nest depth at four locations along the length of the Ningaloo coast: Red Bluff, Bateman Beach, Janes Bay, and 5Mile Beach. The temperature monitoring at Red Bluff finished in 2006, but it will continue at the other three sites to provide long-term records.

Thermochron iButtons logging temperatures in four hour intervals are deployed at 50 cm depth just above the high water line where the lowest turtle nests are found and at 50 cm and 10 cm depth near the highest nests at the dune crests. Southern beaches are generally cooler than beaches further north. Sand temperatures increase during the start of the peak nesting season and highest sand temperatures (> 30°C) are generally measured in February and March. Among year variability includes the passage of cyclones. No major cyclone passed through the study area in 2004/05, but several were in the vicinity in 2005/06 and 2006/07. During and after cyclones or cyclonic rains sand temperatures drop down significantly.

This study will provide an overview of temperature variations at the sea turtle nesting beaches at Ningaloo and will only allow rough estimates of sex ratio variations according to published male and female producing temperatures for the different species. The data will indicate potential geographic, seasonal and among year differences in the production of male and female hatchlings at nesting beaches and provide a baseline for more targeted research into hatchling sex ratios at particular beaches.

Distribution and Abundance of dugongs in NMP and Exmouth Gulf

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Exmouth Gulf and Ningaloo Reef support a significant dugong population that is likely interconnected with the globally significant dugong population in Shark Bay. The Management Plan for the *Ningaloo Marine Park and Muiron Islands Marine Management Area (2005-2015)* identifies, as a medium priority, the need to undertake research to better understand dugong population, distribution and habitat requirements in the reserves and the adjacent areas of the Exmouth Gulf and determine the current status of the dugong population in relation to historical levels. This aerial survey was the forth comprehensive survey of dugong abundance and distribution in Shark Bay, Ningaloo and Exmouth Gulf. The most recent survey covering both regions was conducted in 1999, and showed a shift in dugong distribution between the two areas. The population estimate for dugongs in Shark Bay was higher, while Exmouth/Ningaloo was lower, than the previous two surveys. This was suggested to be a result of the effects of a cyclone in early 1999, which likely reduced the available dugong forage in Exmouth/Ningaloo and caused a large number of dugongs to migrate south to Shark Bay. The current survey results will be presented and discussed in relation to understanding the nature of the interconnectivity between the Shark Bay, Ningaloo and Exmouth Gulf populations. These results will also provide a focus for recommendations on managing human impacts on the dugongs and their habitat.

Migratory Patterns in Distribution, Abundance and Behavior of Humpback Whales (*Megaptera novaeangliae*) at North West Cape, Western Australia.

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Behavioural patterns and migratory timing of Group IV humpback whales (*Megaptera novaeangliae*) were described during their entire migratory cycle past North West Cape, Western Australia between 2000-2001, and 2003. In 46 aerial/boat surveys, 2045 humpback whales in 1455 pods were sighted. Whales were observed migrating north during June-July, both south and north during a transitions period in August, and south during September-November. Northerly migrating pods mainly occurred in waters shallower than 300m. Peak numbers occurred during the transition period, which was associated with the broadest distribution across bathymetric contours (high densities up to 600 m). Southerly migrating adult-calf pods traveled more slowly than northerly migrating pods, and were mainly observed within waters shallower than 100m. Dive times were longest for adult-only pods, while short dive times and long surface intervals were associated with adult-calf pods. During this study, migratory timing was highly consistent with those documented a decade and half century ago despite significant changes in population parameters and environmental conditions over that period. We suggest that factors such as sex, reproductive condition, high latitude origin, and polar conditions affect migratory timing on a fine scale, while a more consistent stimulus such as change in diurnal period determines migratory timing on a broad scale.

The Trophic ecology of the Manta Ray (*Manta birostris*) within lagoonal systems of Ningaloo Reef.

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Ningaloo Marine Park (NMP) plays host to numerous charismatic mega fauna, including the graceful manta ray (listed on the IUCN red list as Vulnerable). Manta rays can be seen year round within the NMP, and form the basis for a growing marine tourism industry. In terms of people numbers this has the potential exceed that involving the seasonal whale shark. Unfortunately unlike the latter, there has been no concurrent research into the population status of manta rays within NMP, and no understanding of how they utilise certain habitats within Ningaloo reef for food and shelter.

This project aims to address this paucity of knowledge by investigating the trophic links between manta rays and the Ningaloo reef. Combined with mark-recapture studies from photo id data, this will help determine the degree of dependence by manta rays on lagoonal areas where tourism pressures are greatest.

A seasonal overview of primary production is being linked to zooplankton composition and abundance, to explain the reasons for the year round aggregations of manta rays within lagoonal areas. To date collections have highlighted manta rays as selective foragers, targeting specific assemblages of Calanoid copepod. Stable isotope analysis is being used to determine where manta rays are sourcing there nutrients from and whether indeed all prey items are accounted for in analysis.

The population assessment which has to date identified over 200 individuals, suggests a largely transient population of immature individuals and mature males. There are however a number of 'semi- resident' mature females which appear to utilise the same areas for much of the year.

If the lagoonal areas prove to be an important source of prey items rather than simply a trap for oceanic sources then closer management of those areas is required to ensure that manta rays have ongoing passage to potentially critical habitats.

Ningaloo Collaboration Cluster Project 3: a Tourism Destination Model for the Ningaloo Coast

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According to the 2006 *Gascoyne Economic Perspective*, Tourism is the largest industry in the Gascoyne region with, according to Tourism Research Australia statistics, visitor numbers to the Ningaloo coast (Carnarvon and Exmouth shires) approaching 200,000 people annually. Carlsen and Wood (2004) measured visitor expenditure to the Ningaloo coast to be over $130 million in 2003. Given that the total population of this region is approximately 8,500 and the fragile characteristics of the natural environment, the tourism industry has major economic, social and environmental implications for the region. Tourism development planning will have a large influence over the future viability of the tourism industry and human activities along the Ningaloo reef.

Ningaloo Collaboration Cluster Project 3 will deliver a dynamic model of Ningaloo incorporating socio-economic, and load implications of tourism that is integrated with an ecological model of the region. The Ningaloo Destination Model (NDM) project draws from research expertise in three universities plus research partners through the Sustainable Tourism Cooperative Research Centre. The project is co-funded by the CSIRO Wealth from Oceans Flagship and the Sustainable Tourism CRC. Following a systems modelling methodology, the NDM project will collaborate with stakeholders and other research projects in the region to develop a scenario planning tool for tourism development in the region that captures the complex relationships and feedbacks within the tourism system.

In this presentation, we will provide an overview of the Ningaloo Destination Modeling Project and a summary of progress to date. We will: 1) present a brief history of the project and its methodological basis, 2) demonstrate an environmental load prototype model, 3) present a summary of the outcomes of the first destination modeling workshop held in Exmouth in June and 4) detail future plans for data collection and planned project outcomes.

Estimation and integration of socio economic values of human use of Ningaloo in the MSE model structure.

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This project has two components:

1) Estimating economic values associated with recreational fishing and marine recreation in the Ningaloo marine park. The methodology is based on estimating the surplus values associated with recreational site/activity choices within the park (and substitute sites outside of the park). Using data derived from surveys of site choice, and information on expectations about levels of experience at those and alternative sites, Random Utility Models of choices can be estimated that explain observed choices in terms of expected trip outcomes. Having estimated such models one can then identify the economic value (in $ terms) placed upon changes in expected experience (e.g. in terms of expected catch, viewing experience, congestion etc) or in changes in available sites (either closing or increasing access to sites). The models will also estimate shifts in activity amongst available choices as attributes or availability changes. The intention is to estimate models that can inform an understanding of decisions at the regional and local scale.

2) Incorporating 'economic agents" into an agent based management strategy evaluation model. As the RUMs are based on individuals behavioral decisions they can be used as the basis for simulated economic agents within a larger simulation model of the ningaloo ecosystem. These agents are then free to interact with the environment and make choices about activity levels, leading to feedback responses from the environment to behavior, and then through ecological modeling back onto the environment. Because the models will be based on the theoretical decision framework, they will allow surplus value measures to be derived from changing management conditions in the park.

The project is a part of the CSIRO Flagship Collaborative Research Fund, Ningaloo Cluster project.

The project team includes Michael Burton, Atakelty hailu, Ben White, Jananee Raguragavan (UWA) and Tom Kompas (ANU).

The Policy Relevance of Choice Modelling: An application to Ningaloo Marine Park

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The Ningaloo Marine Park is a unique public good, rich in many aspects from its commercial and recreational uses to its conservation values. This research is aimed at using the Ningaloo Marine Park as a case study to explore the policy relevance of Choice Modelling (CM) – a technique used to value public goods that don't belong to any particular market. The technique is hypothetical in nature, and so is often questioned as to its relevance in informing policy decisions. However, it has the advantage that it can isolate the non-use (e.g. conservation) values of the good in question, and in the case of Ningaloo these values are likely to be substantial given its high levels of unique biodiversity. The valuation of Ningaloo will attempt to investigate the suitability of CM as a tool for valuing marine parks and coral reef systems, with a specific interest in isolating non-use values, as well as provide a potential input towards guiding future management of the marine park by determining public preferences of different management options. Furthermore, it will address specific questions of the relevance of CM by comparing the values of Ningaloo held by public and expert samples to determine if public and expert groups share similar preferences for complex public goods or if those preferences diverge, and to examine the role of information in any observed divergence. Implications for divergence on valuation studies and public policy will also be considered. A second marine park of similar ecological importance to Ningaloo, but not as highly publicized, will also be valued using CM to compare preferential differences. Support for the study is provided by an UPA and a WAMSI PhD top-up scholarship.

Ningaloo Research Cluster—project Five – Indigenous livelihoods

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Increasingly Australian and international research is recognising the inter relationships of Indigenous livelihood practices to the maintenance of biodiversity and natural resource management in the coastal zone. This is reflected in emerging policy and management arrangements in Victoria, SA, NT and Qld, and internationally through the IUCN category of 'community managed areas'. Like much of the Australian coastline the Ningaloo Marine Park and NW Cape are entirely encompassed by a Native Title Claim.

Broadly, livelihoods refer to the diverse activities in which Indigenous people engage to sustain themselves. Livelihoods include tangible economic activities associated with the cash economy; and access to resources from the customary sector derived from activities such as hunting, fishing and gathering. Indigenous livelihoods are embedded in a corpus of Indigenous law and custom that define a complex of obligations and relationships between people and country. In this sense livelihoods are not only economic but incorporate intangible aspects of social life that are reliant on symbolic resources associated with use, knowledge and relatedness to country.

This research project will investigate ethnographically a range of inter-related Indigenous livelihood practices and aspirations pertaining to the Ningaloo Reef area including: resource use (fishing, hunting and gathering); resource management; residence; maintenance of sacred sites and cultural heritage; maintenance of traditional law and custom; commercial activities such as tourism and pastoralism. A key outcome of the research will be the identification of a range of Indigenous values, rules, and norms that determine Indigenous use and access to the Ningaloo Reef.

Within the broader Ningaloo cluster this research will usefully inform and be informed by Cluster project three, and will supplement the Management Strategy Evaluation of cluster project five. It is anticipated that the research will identify a range of Indigenous social and economic aspirations in the context of increasing development pressure in the region. The research will be innovative by incorporating Indigenous values, rules and norms in modelling outcomes that will assist Indigenous stakeholders in both post-scenario evaluation and goal setting in the context of the broader research project.

Community perceptions of the socio-economic impacts of protected area management on local communities: A case study of the Ningaloo coast.

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Attaining the 'appropriate' balance between human use of national parks and their protection is a topic of considerable public, academic and business interest and is an important focus for research. An increasingly affluent western society with a desire for travel has made tourism the world's largest industry; an industry with a significant reliance on protected areas and wildlife.

Regional communities have benefited from protected areas through tourism expenditure and the political recognition of the economic and social values realised from protected areas. High levels of visitation, and the management of human use require firm management. Tensions arise when park managers invoke policies and management prescriptions to mitigate human use. These actions and the way they are implemented can have an adverse impact on local communities, particularly those with a direct business dependency on park tourism.

This research explores the notion that truly sustainable management of national parks can only be achieved if park managers and communities living adjacent to park work deliberately and cooperatively together to meet each other's needs and through this process foster long-term, environmental, social and economic benefits derived from these parks. The research attempts to understand how local communities perceive park managers and the impact that park management has on local communities. Derived from this understanding are the opportunities for park managers and communities to improve the way they view each other and the skills, attitudes and approaches necessary to create the environment for a sustainable relationship and achieve sustainable outcomes.

The Ningaloo coast community's perception of park management has been diminished by a recent (2004) management planning process for Ningaloo Marine Park that culminated in significant constraints being placed on recreational fishing access. Both the planning process and the decision have worn the brunt of community anger. The levels of trust and respect within the community for the park agency and its management performance are low. Key findings include park management conformity with cultural and institutional norms, perceptions of inadequate communication planning, communications systems, processes and skills, ineffectual leadership and governance systems, local apathy to involvement in park planning, lack of community education and promotion of park programs and activities. This paper concludes that the preparation of a sustainable tourism development plan for the Ningaloo coast, involving the park agency, the community and the local government authority and which applies the principles of Ecologically Sustainable Development (ESD) offers an avenue for achieving mutual objectives and through this improved community support, sense of ownership and participation in park management.

Qualitative Modelling of Sustainable Tourism Development in Ningaloo Coast Region

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This project is a subcomponent of a Wealth from Oceans Cluster Project that will deliver integration across various aspects of a the Cluster Project, focusing on multiple-use-management and tourism development of Ningaloo Reef in north west Australia. It will employ qualitative modelling as a means to 1) develop alternative constructs of socio-economic and ecological system based on patterns, processes and responses determined from the Cluster Projects; 2) explore the consequences of model structure to system dynamics; 3) develop a management strategy evaluation that is based on uncertainty and error in model structure; and 4) facilitate stakeholder involvement in process of model building for socio-economic and ecological systems of Ningaloo coast. This project will provide a conceptual and integrative framework for analyses of alternative model structures and complementary modelling approaches. These analyses will be used to inform construction and development of quantitative and simulation based models, and also to develop robust management strategies for support sustainable tourism development in the Ningaloo Region.

Qualitative modelling can be used to address uncertainty in how socio-economic and ecological systems are structured, and explore different hypotheses about key processes and interactions among system variables. Qualitative models focus on the sign (positive, negative or zero) of the interaction between variables, and largely ignore the strength or magnitude of interactions. Based on system structure, and employing rigorous mathematics, qualitative models can provide predictions about system stability , and how system variables will respond (increase, decrease, or no change) to a sustained, or "press", perturbation. By ignoring the strength of interactions analyses can instead focus on structural uncertainty in a system and rapidly explore the consequence of different model structures.

The ELFSim software

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ELFSim is a decision support tool designed to evaluate options for conservation and harvest management. It includes a number of key components:

- a (meta) population dynamics model of the target species that captures its full life history (including larval dispersal, reproduction, development, and habits).
- A spatial effort allocation model that captures the exploitation pattern due to fishing behaviour.
- The ability to account for harvest by multiple sectors.
- A management model that simulates the implementation of management strategies.
- Output visualisation and run management, for easy scenario testing and interpretation of results.

ELFSim is suited to addressing the "Integration for Management of Ningaloo's Marine Environmental Resources" because it incorporates the following features.

- It can be used to evaluate the effect of different zone closures on both the stock and the harvest.
- It can model both sedentary and mobile target species.
- It can model different levels of larval settlement/transport, depending on the target species and, consequently, can account for the potential benefit of specific area closures.
- It can extrapolate fish stock dynamics into the future, subject to simulated fishing pressure which depends on imposed management measures.
- It allows the user to evaluate the consequences of various management options by examining biological and economic performance indicators that are generated from the model.
- It allows the user to specify area closures, gear selectivity and minimum catch size. The user is also able to specify an annual amount of effort to be allocated over the area.

The biological component permits several local populations of the same species. Each is associated with a single reef and has a specified age, sex, and size-structure, which may be linked to other reefs through larval dispersal. The number of animals settling each year is determined by the annual egg production, the assumed larval distribution pattern and density-dependence in first-year survival. The biological model also allows for variability in natural mortality and larval survival among different reefs and at different times, as well as monthly variation in the relationship between fishing effort and fishing mortality. Larval dispersal is controlled by reef-to-reef migration data, and a self-seeding parameter that specifies the proportion of larvae spawned on a reef that settles on it.

The spatial allocation of fishing effort in the projection period is modelled by a fishing component, which spatially allocates fishing effort to reefs at each monthly time step. The duration of the projection period will be determined by the consultative committee and stakeholders in discussion with program scientists. Effort allocation is determined by ranking reefs according to historical catch-per-unit effort (CPUE) and assigning to the highest ranked reef, the average amount of effort expended in it historically. This is repeated in descending reef rank order until the total amount of allocatable effort is expended. The fishing component also allows for both infringement into closed areas and displacement of effort away from them. This is done by assigning to closed areas a proportion of effort that would have been allocated to it had it been open, and the remaining effort is re-assigned to reefs with lower ranked CPUE. The proportion of effort allocated to closed reefs is set as a base level of infringement, which is then modified to account for spatial and temporal variability. This variability, which can be specified by the ELFSim user, is a feature that allows effort to infringe at the edges of closed areas, and increase with the amount of time an area is closed.

ELFSim operates at a monthly time scale and each simulation consists of two parts. In the first, the biological component uses information from the physical characteristics of individual reefs to determine the population size (and its age-, sex- and size-structure) on each reef given the documented amount of past fishing. In the second part, which projects the reef populations forward in time, the biological component is subjected to simulated fishing pressure, which is in turn subject to management measures imposed by the user. The user is then able to evaluate various management options by examining biological and economic performance indicators that are output from the model.

Regional MUMSE Model: a sneak preview of the MacVitro prototype

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Due to the multispecies and community level aims of the regional scale study integrated methods (spanning multiple sectors, as well as the biophysical system) needs to supplement targeted single sector tools to ensure indirect and cumulative effects and tradeoffs are recognised. Management strategy evaluation has successfully reconciled fisheries and conservation concerns in the past, as well as multiple use objectives on the North West Shelf. Building on past success the method is being implemented to consider the multiple-use management of the entire regional ecosystem of the Ningaloo-Exmouth region. This implementation will use a number of modelling approaches to guide its structure, but will ultimately employ an agent-based whole-of-system simulation model (InVitro). This modelling framework allows for a mix of many model types, so that the most effective representation (regarding resolution and formulation) of the system can be built – including the links between the ecosystem functioning and the cumulative impacts and interactions of the major human activities in the region. This framework also means that the bodies of research within the individual sectors (e.g. tourism and fisheries) that are already taking place in the area can feed directly into the MSE model's final formulation. Most importantly, uncertainty in system behaviour, developmental trajectories and management decisions will be considered explicitly, as will the behaviour of system components that may cause a divergence between management intentions and realised responses.

High resolution mapping of reef utilisation by humans in Ningaloo Marine Park

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This project forms part of the Wealth from Oceans Flagship Ningaloo Collaboration Cluster. The main objectives are (1) to determine the spatial and temporal distribution of recreational activities (e.g., fishing, diving, snorkelling, kayaking, surfing etc) within the reef lagoon system at Ningaloo Marine Park (NMP) and (2) to relate distribution patterns to factors such as biodiversity, physical conditions, park zoning, access roads and accommodation nodes.

During 2007, the project is in an intensive field work stage with aerial and coastal surveys being conducted throughout the year. Aerial and coastal surveys cover the entire 300 km length of the NMP and type and location of all shore-based recreational activities and boating activity in the lagoon are recorded in a geo-referenced format for input into a Geographical Information System. For logistical reasons, land-based coastal surveys, conducted using a four wheel drive vehicle, are split into three areas: Exmouth to Yardie Creek, Yardie Creek to Coral Bay and Coral Bay to Red Bluff. These land-based surveys also provide the opportunity for researchers to interview people engaged in recreational activities in the NMP in order to obtain information on demographics (e.g., tourist/local), trip duration, travel and site-specific usage patterns, other activities conducted in the NMP, catch and effort by recreational fishers (to supplement the Department of Fisheries Gascoyne creel survey), preferred launching sites etc.

The results of the project will contribute directly to the integrated ecosystem and socio-economic model being developed for the Ningaloo region through the Collaboration Cluster. It is expected that the quantitative information from the human use mapping project will have the required spatial and temporal resolution to assist local managers with predicting the likely consequences of future coastal development and changes in management regimes in the region.

Fisheries and Ecosystem Effects of Zoning

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This project consists of several subprojects that will undertake research and monitoring to assess the ecosystem effects of recreational fishing on key fish and invertebrate species, and to provide advice on the adequacy of zoning as well as future monitoring priorities. Partners in the work include scientists from CSIRO, University of Western Australia and Edith Cowan University. The project will include detailed work on the species composition, diversity, and abundance of fish and invertebrate species, particularly those that have been targeted by recreational fishing, and how this varies among management zones. The nature of any indirect effects of human activities on the structure of the Ningaloo fringing reef ecosystem will also be assessed through both observation and experiments. Furthermore it will provide detailed information on the movement patterns and habitat use of key fish species using acoustic tracking in order to provide assessments and predictions of the consequences of zoning for fish populations and as well as for fishers. In this way the project will enable the effectiveness and appropriateness of current management for comprehensiveness, adequacy and representativeness of park zoning to be assessed. Sites studied include locations throughout the length of the park in order to give a comprehensive baseline for future work, and include both large and small zones as well as a full range of different management zoning types. Preliminary results have highlighted trends in the abundance of key species in different regions of the park, but also the high level of variability in the abundance of these organisms. Nevertheless promising trends are evident in sanctuary zones. These are subtle however and do not seem to have resulted in large scale indirect changes in reef community structure between no-take and other areas.

Demersal scalefish in the Gascoyne

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The Department of Fisheries WA is currently undertaking research on commercial and recreational fishing of scalefish within the Ningaloo Marine Park and broader Gascoyne region for allocating fish resources between these sectors through the Integrated Fisheries Management (IFM) initiative within the broad context of Ecological Sustainable Development (ESD). Research projects are collecting information on current levels of fishing, catches, and the biology of key species caught in the Gascoyne Coast Bioregion (GCB), which includes the coastal and offshore waters of Shark Bay to Exmouth Gulf. The four IFM indicator species of primary focus in the GCB are: spangled emperor (*Lethrinus nebulosus*), Spanish mackerel (*Scomberomorus commerson*), pink snapper (*Pagrus auratus*) and goldband snapper (*Pristipomoides multidens*).

New research on spangled emperor will be focusing on filling gaps in existing knowledge about its biology and to understand fishing impacts on its populations. The timing and duration of spawning seasons, average size and age at maturity for males and females, average size and age at sex change and growth rates will be investigated. The biology of northern and southern populations of the GCB will also be compared. These data will be used to undertake a stock assessment for this species.

Other relevant projects in the Ningaloo Marine Park include: analysis of Spanish mackerel spawning and the length- and age-structure of Spanish mackerel caught (following on from previous work done), preliminary stock assessment of goldband snapper, implementing new logbooks for recording better high resolution commercial catch and effort data, voluntary Research Angler Program (RAP) logbooks and a Recreational Fishing Survey (RFS). The RFS repeats work first carried out in 1998/99 and involves researchers regularly visiting boat ramps and shore based fishing locations to collect information on numbers of persons fishing, number and size of fish kept, number of fish released, time spent fishing and where fishers live. Data collected will be used to provide an estimate of recreational catch and the current level of fishing for comparison with 1998/99 estimates.

Project Title: Ecosystem Based Fisheries Management

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The management of fishing in Western Australia must be undertaken within the context of managing the ecosystems that support the exploited fish stocks, and hence the fishery, a need consistent with the principles of Ecologically Sustainable Development (ESD). Implementing ESD principles in a practical manner for fisheries has involved the development of a new management approach which is termed Ecosystem-Based Fisheries Management (EBFM, one of several possible names). The WA Department of Fisheries (DoF) recognizes the inherent complexity in attempting to develop EBFM systems, including the need to consider a much wider range of processes, issues and data than was the case with singe-stock management. This project consists of a DoF initiative to begin developing an EBFM system. Currently the main component of the initiative is funded by the WA Marine Science Institution (WAMSI). The WAMSI project aims to (1) develop a means (mechanisms and processes) of integrating EBFM into "mainstream" fisheries management, including the WA Government's Integrated Fisheries Management (IFM) initiative, and (2) to source, identify and integrate appropriate supporting research. It is expected that EBFM will eventually subsume both traditional fisheries management and IFM. Ultimately, this project will provide stakeholders, including the broader WA community, with a much improved understanding of what EBFM means and how it could be achieved in WA, which will engender within the WA community a greater understanding of sustainable management of marine ecosystems and thus enhance the take-up of the project results. This talk provides an overview of how DoF and partners are progressing the implementation of EBFM in WA.

Spatial and temporal variations in *Drupella cornus* populations and live hard coral cover over a fourteen year period at Ningaloo Marine Park, Western Australia

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Density of the corallivorous gastropod, *Drupella cornus,* and live hard coral cover was studied over a fourteen-year period at thirteen sites at Ningaloo Reef, Western Australia. The peak density of *D. cornus*, the spatial and temporal extent of these peak densities, and the area and severity of *Drupella*-caused coral damage recorded throughout the duration of this study, was on a greater scale than reported elsewhere in the world to date. *D. cornus* were in outbreak densities at Ningaloo Reef from the mid 1980's to the early 1990's, peaking at 18.8 m^{-2} in 1991. They caused considerable loss to Ningaloo Reef coral communities during this period. It is unclear what caused the outbreak or why Ningaloo Reef generally supports a much higher density of *D. cornus* relative to other reefs elsewhere in the world. Since 1991, *D. cornus* densities decreased at the majority of survey sites and by 2005 live hard coral cover was equal to or greater than levels observed prior to the outbreak. One of the main factors that appeared to influence differences in *D. cornus* density between sites was plate *Acropora* coral cover, with 40% of changes in total counts of adult *D. cornus* explained by changes in plate *Acropora* cover. However, sites with a similar coral cover did not necessarily support similar densities of *Drupella*, suggesting that factors controlling *D. cornus* population dynamics are highly site specific. Furthermore, the capacity of any given reef to support a particular intensity of *Drupella* activity may be highly variable. Thus, any distinction between 'normal' and 'outbreak' densities of *Drupella* spp. becomes quite arbitrary unless defined on a site specific basis.

Stability, disturbance and recovery of reefs in Bill's Bay over a 17-year period

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Understanding of the conditions that promote recovery and resilience is essential for future effective management of the world's increasingly disturbed coral reefs, and this understanding requires long-term studies of reef responses to disturbance. We compiled survey data collected by both DEC and AIMS to describe the responses of reefs in Bill's Bay (Ningaloo Reef, Western Australia) to acute non-destructive disturbances over a 17-year period.

Reefs in inner Bill's Bay were completely killed by a dystrophic crisis in 1989. Despite very low rates of juvenile recruitment, recovery of pre-disturbance levels of coral cover from this zero baseline occurred within 10 years, and recovery of pre-disturbance type acroporid-dominated coral communities was achieved at one site within 17 years. In stark contrast to most Indian Ocean reefs, those in the outer zone of Bill's Bay appear to have been remarkably stable over time in terms of coral cover, high-level coral community composition, and density and taxonomic makeup of small (=recruited) coral colonies. If they continue to be relatively unimpacted by and resilient to environmental disturbances and human activities, these stable outer zone reefs at Ningaloo, and others like them in Western Australia, may be able to serve a critical function as coral reef refugia and reference sites of local, regional and potentially global significance.

The Australian Acoustic Telemetry and Monitoring System

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AATAMS, the Australian Acoustic Telemetry and Monitoring System received $1.74M from the Federal Government under the DEST-NCRIS program to increase the acoustic telemetry infrastructure available to scientists in Australia. Several acoustic arrays and curtains consisting of combinations of VR2W and VR3 (Vemco™) receivers will be deployed around the Australian coast. One of Australia's permanent acoustic instalments will be established on Ningaloo Reef – the Ningaloo Reef Ecosystem Tracking Array (NRETA). Ningaloo Reef within the Ningaloo Marine Park in Western Australia is an ideal location to undertake this initial research, as it abuts the narrowest part of Australia's continental shelf, presents a variety of habitats with high biodiversity, and experiences seasonal pulses in productivity. The aims of this project are to (1) establish the NRETA and data-handling protocols in collaboration with the international partner organisations; (2) establish the trophic linkages within the Ningaloo Marine Park and the spatial and temporal habitat usage of pelagic keystone predators and their prey; (3) determine the spatial and temporal habitat use and movement of snappers as important reef predators and the importance to the trophic structure of reefs; and (4) determine the spatial and temporal habitat use and movement of important commercial species at the Ningaloo Marine Park. This project will help answer fundamental questions regarding the trophic structure, function and management of this ecosystem, especially in terms of movement and migration patterns of key organisms. Obtaining such information is critical for management of MPAs, sustainable fisheries and development of appropriate ecotourism policies.

The use of underwater acoustics in studies about Ningaloo

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The Centre of Marine Science and Technology currently has two areas of interest for the Ningaloo region: 1) using sonar for seabed habitat classification and in water biomass assessment; and 2) the use of passive acoustics for studying great whales and fish. In conjunction with AIMS, single and multibeam data sets for selected areas from the reef seaward have been collected. For single beam habitat classification, bathymetry and indexes of seabed characteristics derived from the sonar backscattered signal, along the vessels track and averaged over the sonar footprint, are obtained. These are used to classify seabed communities along the vessel track and this interpolated between survey lines. One set of multibeam data was obtained in 2006 for a comparatively small area. While this data was obtained with settings optimised for bathymetry it can be processed for seabed backscatter with some limitations. The multibeam backscatter and bathymetry combined offer a powerful seabed habitat classification capability, although so far only across a limited area of Ningaloo. In-water backscatter targets from fish and zooplankton can be analysed for relative abundance. Without target identification and appropriate target-strength information this data cannot be converted to absolute abundance. At the least the in-water echo-sounder data highlights productive / barren areas for fish and zooplankton and can be used for relative monitoring through time.

Historical passive sea noise data sets have been collected from the Monte Bello Islands to Ningaloo back to 1996. This data has provided high resolution information on the passage of humpback, pygmy blue and dwarf minke whales through the region, enabled inshore – offshore comparisons of vocalizing humpbacks and has provided data on inshore and offshore vocalizing fish and fish choruses. Currently this work is not supported in the Ningaloo region.

Autonomous Underwater Vehicle Surveys off Ningaloo Reef

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Marine scientists and engineers recently deployed an Autonomous Underwater Vehicle (AUV) called *Sirius* to explore the ocean floor at Ningaloo in WA. The joint expedition between scientists from the Australian Institute of Marine Science (AIMS) and the University of Sydney's Australian Centre for Field Robotics (ACFR) was designed to explore the suitability of AUVs for environmental monitoring. BHP Billiton is providing AIMS with research funds to enhance marine knowledge of the North West Cape and Ningaloo Reef and it is this corporate support for science that is largely responsible for bringing the AUV to Ningaloo.

Sirius was designed for detailed surveys of underwater environments in depths of up to 700 metres. It uses an onboard computer system and an array of instruments to navigate just metres above the seabed. The vehicle scans the seafloor creating bathymetric sonar maps while collecting thousands of high-resolution digital images per hour. It is programmed prior to deployment to follow a survey pattern while its progress can be monitored on the surface via an underwater acoustic modem, in this case from the AIMS Research Vessel *Cape Ferguson*.

In all, half a million images were collected on 20 dives, with the vehicle operating on the continental shelf in depths of 40-100m and within upper canyon areas in depths of up to 250m. The individual stereo images, which are captured directly onto onboard computers, can be used to measure features of the seabed with unmatched clarity and detail. These images are being assembled together with sonar bathymetry into mosaics that enable larger scale patterns in the data to be observed. Stitched together the digital photos will effectively provide photographic maps of the seabed, giving an idea of the distribution of benthos in the survey areas.

For AIMS, this expedition has played a critical role in exploring the use of robots in underwater research. Robotic technology is a very effective way to run controlled surveys of steep walled canyons and other complex terrain. The vehicle uses a variety of sensors to navigate and to follow its planned mission. The data collected can then be geo-referenced to allow scientists to assess how deep sea communities are distributed as a function of depth or seabed composition.

The next step in this research is to look at repeating surveys to assess changes in these habitats over time. Given the current deployments, the vehicle can return to have another look in six months or a year. To observe really fine scale change will require that the robots have the ability to recognise parts of its survey when it returns. Parallel research into data management and artificial intelligence are also part of the R & D program. Work is underway examining automated methods to deal efficiently with the massive volume of data being collected. This is important to allow the data to be quickly assessed and to show the scientists the most interesting images or seafloor structures in the areas we have surveyed. It also raises the possibility of allowing the vehicle to decide during its

mission when it is seeing something of particular interest. It might then be instructed to go in and have a closer look when it sees something out of the ordinary.

Ningaloo Marine Park- DEC

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The Exmouth District Office of the Department of Environment and Conservation has been involved with a range of research and monitoring projects primarily related to whale sharks, marine turtles, coral reef and human usage monitoring. Since 1995, the Department has been monitoring whale shark industry activity and interactions through industry log books. DEC has been participating in whale shark tagging, tissue sampling and photo-identification projects with a range of researchers both in Australia and overseas providing essential data to unravel whale shark ecology. DEC has established the Ningaloo Turtle Program, a collaboration between the Department, Cape Conservation group and Worldwide Fund for Nature (WWF). This program has identified new significant mainland loggerhead turtle rookeries, breeding areas, and quantified nesting activity along the Ningaloo coast and some North-west islands. A number of research projects related to establishing turtle nest success, nesting beach temperature profiles and baseline toxicology have been linked to this program. *Drupella* spp surveys were conducted along Ningaloo reef as well as monitoring of coral recovery in Bills Bay (at Coral Bay) after three large coral mortality events since 1989. Visitation to Ningaloo Reef has been steadily increasing and aerial coastal camping surveys have been conducted at peak periods since about 1996. These were expanded recently and a more comprehensive human usage monitoring program has been established throughout the marine park. This data also provides details about Sanctuary Zone compliance as a function of patrol effort. Community stewardship of Ningaloo Marine Park is essential for long term conservation and to this end DEC has been scoping community involvement through a Marine Community Monitoring Program.

ADDITIONAL ABSTRACTS

Downscaling ocean climate into the Ningaloo Reef Tract.

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Downscaling ocean climate into the Ningaloo Reef Tract is a WAMSI and AIMS funded project concerned with investigating impacts of projected climate change scenarios to spatial scales relevant to the Ningaloo Reef ecosystems. The project forms part of WAMSI Node 2, "Climate Processes, Predictability and Impacts in a warming Indian Ocean" and is linked to WAMSI Node 3, which has a geographical focus predominately on the Ningaloo Reef System.

Circulation within the Ningaloo Reef Tract (NRT) is significantly influenced by large scale processes operating in the Indian Ocean via the Leeuwin and Ningaloo Current systems. The extent to which variability of this offshore forcing controls cross-shelf exchange and circulation within the reef systems of Ningaloo is not well described. This research aims to develop a system wide understanding of circulation in the NRT and it's response to variability of the Leeuwin Current system through the development of a numerical coastal circulation model nested within a larger scale data assimilating ocean model. The modeling approach provides a technique by which to downscale the impacts of projected climate changes from ocean-basin to spatial scales relevant to reef ecosystems. This project builds on the numerical model under development by UWA (Dr Ryan Lowe) through Node 3, Project 5, and links to basin-scale modelling of the response of the Leeuwin Current to climate change scenarios undertaken by CSIRO (Node 2, Project 2, Dr Ming Feng). The project utilises oceanographic data collected by AIMS, CSIRO-CMAR and UWA and makes use of the high resolution, reef-wide bathymetric information generated from the AIMS/BHPP airborne hyperspectral survey.

The project aims to deliver benefit to Western Australia through developing the best possible "look into the future" for the impacts of climate change upon key values of an environmental asset with significant and growing financial return to WA.

Coralline algae in space and time. Integrating ecological, genetic, morphological and palaeontological data to gain a perspective on climate change

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There is currently great interest in predicting how populations and ecosystems will change under different climate change scenarios. The most common response shown by species to past large-scale climatic warming trends during the Pleistocene and early Holocene is a shift in their range towards the poles or higher altitudes. But gaining a perspective on how climatic change is likely to impact populations and ecosystems is complicated by the lack of integration of ecological, genetic, morphological and palaeontological data.
Coral reef environments are one of the richest ecosystems of the world, providing habitat to over one million species. Coralline algae are an important component to reef environments; they are considered the glue that keeps the reef components together and are known to provide chemical clues for the larvae of many reef organisms to settle including reef building corals. Coralline algae are also a major component of fossil reefs and identifiable both in the fossil record and in extant populations to species level.

The coast of Western Australia (WA) is considered a stable continental margin where the records of marine events of the late Neogene-Pleistocene have been preserved. A collection of fossilised coral reefs occurs at 2-3m above present day sea level over a latitudinal gradient. These fossilised reefs have been dated to 129 ± 1 to 119 ± 1 ka (thousand years ago) and developed under sea surface temperatures at least 2-3°C higher than present day. Along this same coastline are also found several extant fringing coral reef systems, from the Dampier Archipelago at 20°S to Rottnest Island at 32°S.

Coralline algae in the WA coast are ideal target species to look for biotic responses to climate change since they are present in both the fossil and extant reefs. Two species, *Porolithon onkodes* and *Titanoderma* sp, found on this coast have been linked to the settlement of invertebrate larvae and reef-binding. The overall goal of this project is to determine whether populations of these algae show differences in genotype and morphotype over a latitudinal gradient that can be related to range expansion or contraction due to climate change since the late Pleistocene.
The specific aims are:

1. To characterise the genotypic diversity in extant populations of *Porolithon onkodes* and *Titanoderma* sp over a 12° latitudinal gradient along the WA coastline.
2. To characterise the morphological diversity in extant and fossil populations of *Porolithon onkodes* and *Titanoderma* sp over the same latitudinal gradient.
3. To determine whether climatic change over the late Pleistocene has affected the morphological patterns of these species over the latitudinal gradient.
4. To investigate the possibility that populations that shifted as a result of climate change are genetically distinct from those that didn't.

Physical

Geomorphology, sediments and habitats of Ningaloo Reef, Western Australia WAMSI Node 3, Project 3.4

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The characterisation and conservation of benthic habitats and communities based on physical factors is central in the selection and ongoing monitoring and management of the Ningaloo Marine Park (NMP). Physical factors including; geomorphology, sediment composition, mobility of the substrate, bathymetry, the hardness and roughness texture of the seabed and water depth, are significant in describing the distribution of benthic biota and habitat types over this broad geographic region.

This GIS-based study comprises a number of techniques to characterise and map the reef and seabed geomorphology, substrates, sediments and communities using a hierarchical classification scheme to describe benthic habitats in selected areas of the NMP. In the clear lagoonal waters and reef crest zone, aerial photography and hyperspectral satellite imagery will be used to determine preliminary geomorphic and biological cover boundaries. For the offshore areas seaward of the reef crest, acoustic remote sensing techniques (singlebeam, multibeam and sidescan sonar) will provide physical data on seabed bathymetry and geomorphology, and bottom textures in terms of roughness and hardness. Finescale ground-truthing both within offshore and inshore areas includes towed-video and GPS controlled scuba and snorkeling transects. This data is supplemented by sediment grabs to provide detailed information about the physical and biological nature of the seabed.

Multivariate statistical analysis and GIS modeling will be undertaken to establish trends and similarities across the Ningaloo Reef. Known relationships between physical and biotic values may identify factors that are reliable indicators or 'surrogates' of specific habitats and be used to inform our understanding of benthic habitat variability across the whole Marine Park. These will be extrapolated to the broader area to aid in the production of broadscale habitat maps of the Ningaloo Marine Park (NMP).

The degree to which fluctuating sea-levels and ancestral reef morphology, linked to earlier events of reef growth, provide controls on present day habitats and patterns of reef development is likely to be significant, and this will be fully evaluated.

This PhD research forms part of the objectives for WAMSI Project 3.4 Characterisation of geomorphology and surface sediments. There are also strong collaborative linkages to WAMSI Project 3.1.1 Habitat mapping and biodiversity assessment of the offshore component of the Ningaloo Reef system, and CSIRO Cluster Project 1 Habitats and biodiversity in the reef lagoon.

Trophic ecology of coral reefs: the role of oceanographic-to-organism scale processes in trophodynamics and benthic-pelagic coupling

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This study aims to quantify the importance of pelagic sources of nutrition and links to the surrounding ocean for a coral reef for the first time, combing the disciplines of benthic ecology and biological oceanography. Trophic links will be examined at the fringing Ningaloo Reef, Western Australia using biomarkers across a range of spatial and temporal scales in four related studies: (1) a regional assessment of benthic-pelagic coupling in deep water habitats (30 – 100 m) of the Ningaloo Marine Park and is relation to biodiversity and localised oceanographic processes; (2) a reef section scale food web study, quantifying the incorporation of various sources of nutrition by the benthos using dual-isotope and fatty acid biomarkers, in addition to a typical control volume analysis of particle depletion; (3) species-specific examinations of temporal and spatial variation in nutritional sources and condition in situ; and (4) laboratory studies of variations in stable isotopes and nutritional condition in response to changing diet and light availability. In 1930 Sir Maurice Yonge wrote "Few subjects of such obvious zoological importance are so obscure as the nutrition of corals and the significance of their zooxanthellae. Until these problems are fully elucidated, knowledge of the fundamental conditions controlling the formation of coral reefs must remain imperfect" [1]. Although understanding of coral nutrition and the role of the zooxanthellae have increase greatly since this time, there are still fundamental gaps in knowledge that prevent a full understanding of coral reef function, and by association the response of coral reefs to change, anthropogenically-induced and otherwise. This study aims to redress the lack of knowledge regarding the role of pelagic sources of nutrition in the benthic structure and function of coral reefs.

[1] C. M. Yonge, in Scientific Reports of the British Museum (British Museum, London, 1930), Vol.1, pp.13-57

Physical

Intertidal invertebrate surveys

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We have planned our initial field trip with Dr Alan Kendrick, who has advised us on accessibility of locations and is organizing personnel and vehicles to assist the work on our first field trip, 26 July to 7 August during a period of exceptionally low spring tides which will give us access to intertidal shores for one or two sessions per day. Our basic plan is to conduct surveys of intertidal, rocky platforms at matched paired sites inside and outside existing or planned sanctuary zones in four regions centered on 1) Bundegi on the northern gulf, 2) northern cape, 3) Coral Bay, and 4) Gnarloo. We are examining aerial photos to help select potential sites, but will use our existing knowledge and experience, and that of Dr. Kendrick, to make the final selections during our first field trip. Our first work will focus on 1) locating suitable sites which we will use in subsequent years in order to establish the nature and extent of temporal variation, 2) estimating spatial variation within and between sites which will allow us to establish the amount of sampling necessary to detect the influences of sanctuary zones, 3) quantifying the abundances of sought-after and harvested species of invertebrates on the intertidal platforms, and 4) establishing an efficient method that detects rare species that are not adequately sampled in our other quantitative sampling methods.

The CReefs Project at Ningaloo Reef

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The CReefs project is an international field project focused on filling gaps in taxonomic information about what species live on coral reefs. It is one of 14 projects within the Census of Marine Life; a 10-year project (2000-2010) designed to census what lives in the oceans. The CReefs project began in 2005. Hence, the field program is just beginning. In Australia, we are planning 3 field expeditions to each of 3 sites, Ningaloo Reef, Heron Island and Lizard Island, over the next 4 years. The first of these Australian expeditions is planned for Ningaloo before the end of 2007. The field collecting and taxonomy will be undertaken by a consortium of Australian and international taxonomic experts using a diverse array of sampling methods in a wide range of habitats. Because this project is designed to fill taxonomic gaps, its focus will be primarily on non-coral and non-fish species. Through the Census of Marine Life, CReefs is associated with the Bar Code of Life initiative and we will be supplying tissues from these samples for genetic bar-coding. A further goal of the CReefs project is to make data on coral reef biodiversity available by facilitating the serving of coral reef data sets via the Ocean Biogeographic Information System.

The spatial and temporal distribution of demersal reef fish in Northern Ningaloo Marine Park.

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This initial work aims at defining the spatial and temporal distribution of reef fish assemblages across the Ningaloo continental shelf. To date, fish assemblages have been sampled within discrete depth and habitat combinations typical of the Northern Ningaloo Marine Park providing a spatial representation of species distributions. We have sampled shallow lagoon habitats including nearshore subtidal reef platforms, porite bommies, branching and tabulate acroporas, the reef flat and reef passes. We have also sampled offshore habitats, to the seaward side of the reef crest, including the reef slope, rodolith beds, various soft substrates, and sponge and soft coral dominated reefs to water depths up to 100m. These habitats have been sampled using up to six replicate baited remote stereo video drops. Drops have been made within four representative areas and additional offshore sampling has included waters adjacent Point Cloates Sanctuary Zone. Subsequently we have analysed video of fish that represent all of these cross-shelf habitats. A total of 400 stereo videos have been analysed and counts of the number of fish species, their relative abundance and their sizes have been made. A highly diverse and abundant fish fauna including 400+ species of fish from 60+ families have been found to inhabit the lagoon and offshore habitat. The same habitats from adjacent areas support the same, predictable reef fish assemblages. These assemblages include trevally, snapper, cod, parrot fish, wrasse, sharks and rays. The size of many fish is correlated to the cross-shelf distribution of habitat. Species exhibiting this include many species commonly targeted by anglers such as spangled emperor (Lethrinus nebulosus), red emperor (Lutjanus sebae), red throat emperor (Lethrinus miniatus) and goldband snapper (Pristipomoides multidens). Juvenile L. nebulosus for instance are found in nearshore coral lagoon habitats dominated by branching acropora, while adults are found using most habitats defined by this study. Coronation trout, (Variola louti) was found to be the most dominant piscivorous territorial reef fish in contrast to reefs south and north of Ningaloo which are dominated by other coral trout species. Additionally, a number of butterfly fish (chaetodontidae), parrot fish (scaridae) and wrasse (labridae) were found in depths of up to 100m. These fish are typically associated with shallow phototrophic coral and algae dominated reef habitats. These spatially explicit data will be analysed using multivariate statistics and provide the basis of a number of scientific publications. Additional datasets are being derived to capture temporal variation in the fish assemblages of the lagoon.

Dynamics of arid zone mangrove ecosystems and their contributions to coastal productivity.

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Mangrove forests of Mangrove Bay and other small stands of mangroves on the Ningaloo coast enhance diversity of the region, enhance connectivity between terrestrial and marine ecosystems and may make significant contributions of nutrients and carbon to the adjacent marine communities. Although they are small in area compared to the extensive mangrove forests in the Exmouth Gulf, they are communities that can give insights into the factors constraining mangrove productivity in the arid zone. Since 2003 20% of the forest in Mangrove Bay has died. Dispersal of propagules into dead patches is occurring but currently recruitment is poor. There is evidence of previous periods of forest contraction and expansion, suggesting conditions that favour growth of mangroves are episodic and could be linked to climatic fluctuations.

In addition to examining the role of climate in determining the extent of mangrove forests, current investigations of 1) the factors limiting mangrove and cyanobacterial mat productivity, 2) the patterns of faunal use of mangrove and cyanobacterial mats and 3) nutrient and carbon fluxes from mangroves and cyanobacterial mats in both Mangrove Bay and in the Exmouth Gulf are aimed at understanding the contributions of these intertidal ecosystems to coastal productivity in the arid zone.

Overview of CSIRO biodiversity survey of the Ningaloo Commonwealth MPA collected in 2005

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In 2005 CSIRO Marine and Atmospheric Research collected samples, imagery and mapping data within the Commonwealth Ningaloo MPA during a pair of surveys by the RV Southern Surveyor (SS07/2005 & SS10/2005). Detailed voyage summaries and sampling tracks can be viewed at http://www.marine.csiro.au/nationalfacility/voyages. Samples were targeted at depths of 100, 200, 400, 800 and 1000 metres.

Multibeam mapping: A region was mapped towards the northern end of the Commonwealth MPA; coverage was between State waters and ~1000-1500m depth (i.e. beyond the outer MPA boundary). A study area was defined within this region.

Photographic data: Ten successful photographic transects were done within the Commonwealth MPA, (and 3 additional transects seaward of the Commonwealth MPA). Data taken on each transect includes high resolution video footage from paired (stereo) digital video cameras, and high resolution still images from a digital camera.

Faunal data: Eighteen sled/beam trawl transects were done within the Commonwealth MPA, (and a 6 additional transects seaward of the Commonwealth MPA). Fauna captured by these gears are primarily emergent macro-epifauna (eg. sponges and corals), near-surface macro-infauna (eg. polychaetes, molluscs) and a variety of mobile benthic and near-bottom macroinvertebrates and fishes. Taxonomic identification of the high priority taxa (sponges, molluscs, echinoderms, crustaceans, ascidians and corals) has been conducted by experts from Australia's museums (WAM, MV, AM, MAGNT, QM).

Sediment data; Smith-MacIntyre grab samples were also collected. The faunal components are being curated by Museum Victoria, while grain-size and other analyses are being conducted by Geoscience Australia. Sub-samples of sediments were collected for stable isotope analysis. CTD casts were made for water chemistry and nutrient data and pico-plankton analysis and LADCP casts for water column and near-bed currents were also made.

These Ningaloo data are part of a larger biodiversity project which sampled from Albany to Dampier to support regional marine planning and to assist in the management of Commonwealth MPAs.

Diversity, abundance and habitat utilisation of sharks and rays

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Ningaloo Marine Park (NMP) has possibly the largest and most diverse shark and ray fauna found anywhere on the Australian coastline but the habitat requirements and distributions of most of these species are poorly known. Some of the megafauna (i.e. whale sharks and manta rays) are already economically important to a seasonal ecotourism industry at Ningaloo. This research will characterise the diversity, abundance and spatial dynamics of sharks and rays within different habitats and zones in the NMP to provide a baseline for developing management strategies and assessing ecotourism potential for these species.

This research will be conducted over 2 years and will include summer and winter surveys using a range of census techniques that are appropriate for the different habitats including visual census, baited underwater video, tagging. Longline surveys will also be undertaken and genetic samples (e.g. fin clips) may be taken for ongoing molecular studies.

Critical to the question of the adequacy of reserves is whether they are large enough to contain the activity space of mobile predators. Movements and space requirements of key shark and ray species will be addressed using a variety of tagging and tracking techniques. Conventional tagging (using dart and fin tags) of some species will be carried out to determine movements and obtain population estimates. Acoustic tracking studies will focus in one region where an array of acoustic receivers will be located.

The NMP supports a very important marine ecotourism industry for Western Australia but its economic potential is limited by the narrow time frame when whale sharks can be viewed. However, given the richness and abundance of the megafauna, there is a major opportunity to raise its ecotourism profile and expand the industry across the whole year by incorporating other charismatic species. Candidate species and ideal observation sites will be identified from the habitat studies.

Range and habitats of whale sharks in the eastern Indian Ocean

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Whale sharks (*Rhincodon typus*) aggregate to forage along Ningaloo Reef off Western Australia from March through June each year. Though a few sharks may occur there at other seasons, the whereabouts and habitats of most have been unknown from austral winter through autumn. In 2002/03 Hubbs-SeaWorld Research Institute (Stewart & Wilson) initiated a collaborative research project with the U.S. NOAA Fisheries (Polovina), the Australian Institute of Marine Sciences (Meekan), and CSIRO Marine and Atmospheric Research (Stevens) to document the seasonal movements and habitat use of whale sharks that appear at Ningaloo Reef from March through June. We attached satellite-linked radio transmitters to 43 whale sharks at Ningaloo Reef (near Norwegian Bay) from 2003 through 2006 and documented their geographic and vertical movements, ranges and habitat use for up to nine months each year. Virtually all sharks moved northward soon after tagging, some dispersing to the northeast whereas others dispersed northwest toward the central Indian Ocean. The tracks of some sharks suggested that they returned to Ningaloo Reef the year after tagging whereas tracks of others were equivocal, suggesting that they may have continued moving west in the northern Indian Ocean. Sharks spent most of the time close to the surface (i.e., <100 m deep) where sea water was correlatively warm (i.e., > 25°C), though they did dive deeper (deepest ca = 1000 m) and into colder water (i.e., minima of 5 to 10°C) on occasion. Our findings indicate that these marine mega vertebrates are generally far ranging in a variety of neritic, epipelagic, and mesopelagic habitats in the Indian Ocean, consistent with population genetic analyses that have argued for a relatively large mobile global population. The motivation for these movements and the extent to which they are passive or active is still a mystery. Regional marine biological productivity appears to be an aggregating factor and spatial gradients may be a directional cue in some cases. Attraction toward habitats suitable for giving birth and mating likely explain the movements in other cases and further tracking studies may reveal where those breeding areas are. The transjurisdictional movements of whale sharks through the territorial waters of a large number of coastal states, through international waters, across and perhaps between ocean basins presents substantial challenges for their management and conservation. Temporal and geographic variability in oceanographic conditions that influence whale shark movements may confound assessments of patterns in their local and regional abundance. Coordinated, systematic, long-term monitoring (i.e., over a decade or longer) of local seasonal abundance of this apparently long-lived animal will be needed to assess regional and global population trends. Distinguishing among migratory, transient, and resident elements of populations or subpopulations will be a key element for these assessments. This collaborative project may extend through the 2008 season at Ningaloo Reef.

Economic Valuation of Biodiversity Conservation. Citizens' Non-use Value for Ningaloo Reef

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Considered one of the healthiest reef environments in the world, Ningaloo sits in a special bio-geographic zone where the distributions of tropical and temperate marine and terrestrial organisms overlap. Currently, this fringing barrier reef system and its coasts are subject to significant human pressure due to its unique proximity to the coast and commercial and recreational fishing have the potential for major negative impacts on the marine life of Ningaloo Reef waters. This project aims to assist policy makers in formulating efficient, effective and sustainable coral reef conservation and management policies by providing them with the results and information of a valuation study using the Ningaloo Reef in Western Australia as a case study.

Choice Modelling, an economic valuation technique is employed to estimate the benefits of the non-use values of the Ningaloo Reef and how their choices may be related to certain socio-economic characteristics. Application of the technique involved surveys of coral reef protection and conservation in the region of Ningaloo coast. Choice Modelling is found to provide a flexible and cost-effective method for estimating non-use value, particularly when different alternative proposal need to be considered. This project can aid in the design of socially optimal policies for conservation and sustainable management of the Ningaloo Reef, with implications for other coral reef regions in the rest of Australia.

Socio-economic impacts of sanctuary zone changes in Ningaloo Marine Park: A preliminary investigation of effects on visitation patterns and human usage.

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This project was commissioned by the Sustainable Tourism CRC to gather baseline data on human usage and tourism patterns to assess potential socio-economic impacts from the expansion of sanctuary zones in Ningaloo Marine Park on visitors and residents. In September/October 2005, 135 Shire of Exmouth residents were surveyed about their views on the sanctuary zones and the extent to which the changes might impact on their activities. In July 2006 a survey was carried out with 358 wilderness campers along the Ningaloo coast (ten months after legislation enforcing the sanctuary zones had been introduced). Additionally, a range of data from two 2002 visitor surveys of wilderness campers were re-analysed and reconstituted as baseline data. Finally, a range of visitor data - including vehicle counts to the National Park, camping revenue, Visitor Centre door entry counts and aerial surveys of pastoral station camps - was collated and analysed using time series analysis in order to detect changes to visitation levels. A theory referred to as the 'threshold of tolerability' is proposed that states that the more destination conditions change in ways that are contrary to visitor expectations, the more visitors will seek out alternative destinations (first locally, second regionally) or, alternatively, refrain from the activity altogether. In the case of Ningaloo, wilderness campers seem to have undergone the first stage of local redistribution but not the second of regional dislocation, indicating that the magnitude of the sanctuary zone changes are, for the time being at least, within their threshold of tolerability. This is partly attributed to the wide range of activities that wilderness campers engage in as part of the 'Ningaloo experience', even though recreational fishing is for many a key component of their visit to the Marine Park. A key finding of the project is that the Ningaloo visitor experience is related to a general 'wilderness experience' in which recreational fishing is one of a constellation of activities that contribute to visitors' enjoyment of their holiday. The full report will be available shortly.

Ningaloo Research Project Client Outreach

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This project is yet to begin and will be designed to support uptake and adoption by the operational management agencies in Western Australia of results from major research initiatives in the Ningaloo region. It will both support the use of outputs of the research and help inform the design and form of the research outputs. The main task of the project is to identify and implement the most effective strategies for providing support to operational management agencies in the successful use of the information and management tools provided by the study. These strategies could take the form of reciprocal secondment of staff, targeted use of contractors to produce particular products/data, facilitated meetings/workshops, or building custom decision support tools. Clients in the context of this project include state and commonwealth departments and agencies, local councils, industry groups, conservation groups, indigenous interests and local community groups. The proposed outcome of the project is substantially improved management of the Ningaloo region through effective uptake and adoption of outputs from the *Ningaloo Cluster* projects and Western Australia's *Ningaloo Research Program*. It will provide a collaborative planning approach to science and science impact planning.

Low temperatures cause coral bleaching at Ningaloo Reef, Western Australia

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Mass coral bleaching triggered by anomalously high seawater temperatures has been reported with growing frequency over the past two decades. However, the impacts of low temperature coral bleaching on reefs are less well known.

During mid July 2006 at Ningaloo Reef, Western Australia, the combination of unusually cold air temperatures and aerial exposure of corals due to a low spring tide and a high pressure system appeared to cause bleaching of shallow-water corals. Observations made during an aerial survey indicated that bleaching had occurred along the entire length of the Ningaloo Reef. The most severe bleaching was recorded at Pelican Point where approximately 83% of live hard coral was bleached. Bleaching was mainly restricted to shallow-water corals of back-reef and patch reef environments which were dominated by plate and corymbose acroporids. To investigate the recovery of bleached corals two surveys were undertaken at Coral Bay and Pelican Point. At Coral Bay 95% of coral had recovered by 14 weeks after the event and 100% of coral had recovered at Pelican Point 30 weeks after the event.

This is the first major temperature related coral bleaching event to be recorded at Ningaloo Reef. To date, Ningaloo Reef is only the third location where coral bleaching resulting from low temperature anomalies has been recorded. The research has also provided one of only two documented reports on the recovery of corals after a low temperature bleaching event.

Bleaching of corals during winter months may be a natural occurrence for high-latitude coral reefs. Climate change, however, may also lead to local decreases in seawater temperature or to greater variability in seasonal conditions. The potential coupling of both winter and summer bleaching occurring in one year at the same reef could result in an increased threat to corals and should be considered among the climate change projections for coral reefs at some locations.

Ecological interactions in Ningaloo Marine Park

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This project will examine the trophic interactions among invertebrates and fish in a range of habitats in the Ningaloo Marine Park, in order to better understand ecological processes that have the potential to impact on the system through human disturbance, e.g. overfishing. Data collected will have relevance to assessing the adequacy of reserves, in relation to the habitat composition and size of those reserves. This will be achieved through a range of approaches, including: experimental manipulations to examine potential top-down and bottom-up processes; biomarker analyses, particularly stable isotopes, to examine food sources and trophic links in the food web; and acoustic tagging to examine the scale of movement of key organisms within and among habitats. The proposed work will be undertaken in collaboration with Drs Russ Babcock and Mat Vanderklift at CSIRO under WAMSI Project 3.2. While the broad aspects of the project have been planned, specific details of approaches are to be determined when funding in finalised. Pilot work has begun through the collection of some samples for stable isotope analyses.

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