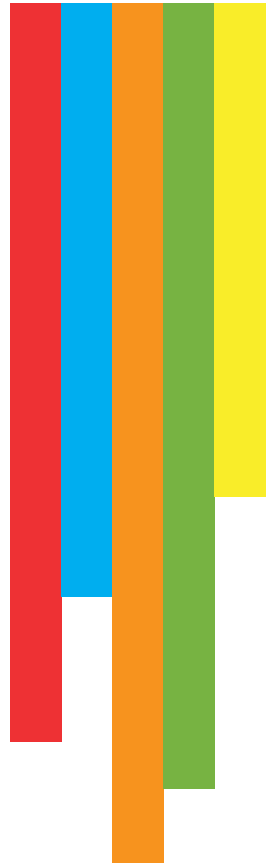




Australian Government



**AUSTRALIAN INSTITUTE
OF MARINE SCIENCE**



Research Plan **2007-2011**

The research described herein is based on early analyses of complex datasets and should not be considered definitive in all cases. Institutions or individuals interested in all consequences or applications of AIMS research are invited to contact the CEO at the Townsville address given below. Those wishing to discuss matters relating specifically to the material outlined in this publication should contact the AIMS Research Office by telephone on 07 4753 4444 or reception@aims.gov.au

The Research Plan is reviewed during the course of the funding cycle to ensure that our efforts and resources are effectively targeted toward high quality outcomes for stakeholders. Please check on-line for any recent updates to this document, along with a range of other information about the Institute, at www.aims.gov.au

For additional copies of this Research Plan, please telephone the Institute on 07 4753 4444, write to us at our Townsville address or email bookshop@aims.gov.au.

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Images:

p 10 Diverse coral assemblages in south Scott Reef Lagoon, Northwest Shelf. Photo: James Colquhoun; **p 13** Scientists from AIMS use underwater visual census and digital video to monitor fish and benthic communities on the reef. Photo: AIMS Long-Term Monitoring Team; **p 16** Developing hatchery technology for the tropical rock lobster will ensure a sustainable supply of this high value crustacean to meet future global demand. Photo: Carsten Wolff. **p 18** *Coscinoderma matthewsi* on the reef slope at Yorke Island, Torres Strait. Photo: Alan Duckworth; **p 22** High tech equipment designed and built at AIMS allows researchers to measure the respiration rate of corals in their natural environment. Photo: Ray Berkelmans; **p 24** A river plume from the Daintree River around Snapper Island. Photo: GBRMPA; **p 28** Slice from coral colony collected from Kent Island in the Wet Tropics region of the northern GBR under UV light. The bright luminescent lines record river runoff events. (the bright line in the middle is 1991 flood event; the dark line not far from the outer surface is a growth hiatus associated with the 1998 bleaching event. Photo: Eric Matson; **p 30** Sea surface temperature image captured by the MODIS sensor on board the NASA "Aqua" satellite; **p 32** Two *Acropora millepora* colonies side by side had different bleaching responses during the 2006 bleaching event in the southern GBR. Unlocking the complex interactions of environment and biology is the key to understanding the impacts of climate change. Photo: Ray Berkelmans; **p 33** AIMS automated weather station at Myrmidon Reef. Photo: Ray Berkelmans; **p 39** Fluorescence image of cultured symbiont of the sponge *Ircinia ramosa*. Photo: Cathy Liptrot; **p 41** Diverse community of planktonic bacteria from a water sample. Reproduced from Giovannoni, S. J., E. F. DeLong, T. M. Schmidt, and N. R. Pace. 1990. Tangential flow filtration and preliminary phylogenetic analysis of marine picoplankton. *Appl. Environ. Microbiol.* 56:2572-2575; **p 45** The AIMS Cape Ferguson site. Photo: Aerial Impressions; **p 47** The RV *Solander*, named on October 8th in Fremantle by the Australian Government Minister for Science, Education and Training, the Hon. Julie Bishop. Photo: Paul Rumens Photo-Graphic Co.

Foreword

With more than seventy percent of our territory under water, Australia is largely a marine nation. Australia's coast and oceans contribute enormously to our identity as Australians. Our expansive ocean territory houses much of Australia's biodiversity and hosts some of the most iconic marine life and marine habitats on earth. With stewardship of these environments, which are a rich source of enjoyment, knowledge and wealth for all Australians, comes both responsibility and opportunity. What we do over the next decade will be crucial to ensuring the wellbeing of these magnificent national assets.

From the Great Barrier Reef to the Ningaloo Reef system and the oceanic shoals of the Timor Sea, Australia's tropical marine waters hold important biological, cultural and economic resources. The region supports key marine industries such as offshore petroleum and gas, tourism, and fisheries, accounting for around half of the estimated \$52 billion¹ in wealth generated from Australia's oceans each year. While current marine industries generate substantial revenue, their continued rapid growth and increased economic potential from emerging industries such as marine biotechnology and aquaculture are likely to be realised with further research. In addition to the need for research to support sustainable marine industries, environmental threats to Australia's oceans are compelling and require major scientific contributions supported by world-class scientific research infrastructure, inter-agency collaboration and global engagement.

Internationally significant marine ecosystems and well-established marine science capability provide the ingredients for Australia's continued position as the world leader in tropical marine science. Established in 1972, the Australian Institute of Marine Science (AIMS) was one of the first marine science agencies to study the Great Barrier Reef and now possesses the longest and richest records of changes in this complex ecosystem. AIMS scientists now apply their research across tropical Australia and, where appropriate, internationally.

¹ CSIRO (2005). Wealth from Oceans Flagship.
<http://www.csiro.au/org/ps2a.html> 2 December 2005

AIMS is Australia's tropical marine research agency and one of the world's most productive and innovative marine research agencies. The Institute is known for its unique capacity to investigate topics ranging from macroecology and climatology to microbiology and molecular structures. Highly specialised facilities, world-class staff and well-developed partnerships have secured the Institute's position as a global leader in tropical marine science.

This Research Plan explains how AIMS, in collaboration with its partners, will support the National Research Priorities and enhance Australia's reputation as a world leader in tropical marine science.

By 2011, we will:

- deliver the outcomes promised in this Research Plan including major new initiatives in North Western Australia;
- maintain our ranking in the top 1% of research institutions in the world in the fields of Environment and Ecology, and Plant and Animal Science;
- implement Australia's first tropical ocean observing system on the Great Barrier Reef (GBROOS) and start the roll-out to other tropical shelf areas;
- become an international leader in the development of smart environmental sensors using wireless technology;
- establish ourselves as a centre of excellence for tropical marine microbiology with a growing international reputation;
- establish the AIMS Data and Knowledge Centre as a leading provider of coral reef data and information including GBR risk, vulnerability assessments and forecasts;
- enhance Australia's sea-going research capability with the launch of our new 34.9 metre vessel, *RV Solander*;
- enhance the training of future marine scientists through an active post-doctoral program; and
- continue to provide high quality, independent marine science to support management and policy-making processes and sustainable industry development.

If you would like more information on any of the research areas outlined in this plan, please do not hesitate to contact us for a full briefing.



Dr Ian Poiner, CEO

Contents

About AIMS	1
Strategic Directions underlying this Research Plan	3
Supporting the National Research Priority Goals	7
Key Result Areas to be delivered through the <i>Assessing and Using Marine Biodiversity</i> Team	9
Key Result Areas to be delivered through the <i>Measuring Water Quality and Ecosystem Health</i> Team	21
Key Result Areas to be delivered through the <i>Responding to Climate Change</i> Team	27
Key Result Areas to be delivered through the <i>Understanding Marine Microbes and Symbioses</i> Team	37
Operating Strategy	43
Appendix 1: National Research Priorities	51



Photo: Ray Berkelmans.

About AIMS

The Australian Institute of Marine Science (AIMS) is Australia's tropical marine research agency. The Institute was established by the Australian Government under the *Australian Institute of Marine Science Act 1972* in recognition of the importance of marine assets, especially the Great Barrier Reef, to Australia. Today AIMS is recognised worldwide for the quality of its research into marine environments and their resources.

AIMS mission is to generate and transfer the knowledge to support the sustainable use and protection of the marine environment through innovative, world-class scientific and technological research.

To do this, AIMS surveys and documents marine life from the microbes to whole-of-ecosystems, and the processes that sustain them; monitors changes and identifies trends in the marine environment; and develops enabling molecular tools and ocean technologies.

The products of our research include improved understanding of tropical marine ecosystems, improved forecasting of the effects of global climate change and information to guide the sustainable development of tropical marine-based industries.

OUR PEOPLE

AIMS is home to a dynamic team of 126 science staff working across four research teams plus 65 support staff who provide specialised skills in the areas of data management, information technology, engineering, field operations, information services, science communication and corporate services. Many of our scientists are world authorities in their field and have achieved international acclaim for their research.

OUR RESEARCH

The Institute's expertise in tropical marine ecosystems, combined with a multidisciplinary capability, makes possible the full spectrum of scientific investigation from the seafloor to the lab bench.

National and international research partnerships and collaborations enhance AIMS capacity to improve our understanding of complex marine ecosystems. AIMS research is applied from whole ecosystems down to the molecular level and is focussed in the broad areas of marine biodiversity, impacts and adaptation to climate change, water quality and ecosystem health, tropical aquaculture and the emerging area of marine microbiology.

OUR LOCATION

The Institute's expertise is engaged throughout Australia's ocean territory and in tropical waters worldwide. AIMS headquarters is ideally located on a 207 ha coastal site 50 km from Townsville, Queensland, in a scientific zone surrounded by National Park and Marine Reserve. The location was selected because of its proximity to the geographical centre of the Great Barrier Reef and access to clean seawater. This strategic position provides a fast transition from the sea to the lab, a key advantage in marine science. Two smaller laboratories (in Perth, Western Australia and Darwin, Northern Territory) provide direct links for research partners and clients in these regions.

OUR FACILITIES

AIMS Townsville headquarters, which acts as the operational hub for work on the Great Barrier Reef, features modern research laboratories, a state-of-the-art biomolecular analysis facility, a bioresource library, an aquaculture centre, seawater aquaria and controlled environment rooms, and engineering workshops for the development of instrumentation required for research activities. In 2006, after 12 years working from laboratories located in Dampier and Fremantle, AIMS transferred its Western Australian base of operations to the campus of the University of Western Australia in Perth. This site provides the office, laboratory and workshop space required to support our WA-focused activities and facilitates access to collaborators and industry partners. AIMS research in northern Australia is undertaken from a base located at the Arafura Timor Research Facility (ATRF) – an unincorporated joint venture between AIMS and the Australian National University (ANU) – in Darwin. These laboratories provide support for a range of marine research activities and are equipped with analytical equipment including a Stable Isotope Ratio Mass Spectrometer and a molecular research facility.

A research fleet comprising two ships, the RV *Solander* and the RV *Cape Ferguson*, and several smaller boats, provides both access to all Australian tropical marine environments and the capacity for *in situ* oceanographic, reef and coastal studies. During 2006–2007, our ships spent a total of 556 days at sea and travelled 32,228 nautical miles to support 49 different research expeditions.

Strategic Directions underlying this Research Plan

AIMS provides world-leading tropical marine science in areas of high priority for Australia and for our stakeholders. Our research supports marine policy and management processes and contributes to industry development by providing independent advice and essential knowledge about the status and functioning of ecosystems from Australia's tropical oceans, seas, and coasts. We work closely with stakeholders to understand their needs in order to deliver the most relevant research outcomes.

AIMS is funded on a multi-year basis by the Australian Government to allow financial stability and forward planning at the Institute. For the first time in our history, the forward commitment in the federal budget has changed from a three-year cycle to a four-year period (a quadrennium), from July 2007 to June 2011.

Our new Research Plan was formulated following a searching review and update of our research portfolio done in consultation with our stakeholders. The process included five external peer reviews of the quality and impact of our past research (following the Research Performance Assessment framework agreed with government), and a review of our strategic directions based upon feedback from the users of our research. The result is a new Research Plan that delivers to the National Research Priorities by merging ongoing and new elements into a plan that maximises returns from our available resources as measured by indicators of science quality and impact.

Three broad strategic research directions now represent our future performance focus:

- understanding tropical marine ecosystems and processes;
- understanding the responses of tropical marine systems to global changes; and
- supporting the sustainable development of tropical marine-based industries.

In addition, AIMS research will be characterised by technological as well as scientific innovation.

DELIVERING OUR VISION

Our research portfolio for the next four years will be structured around the following twelve Key Result Areas (KRAs) designed to support our Strategic Directions:

- ▣ Assessments of tropical marine biodiversity;
- ▣ Accurate and timely information on issues and threats to coral reefs;
- ▣ Sustainable tropical aquaculture;
- ▣ Sustainable supply of bioresources;
- ▣ Human impacts on tropical water quality and ecosystem health;
- ▣ Tropical marine ecosystem processes and land-sea interactions;
- ▣ Marine climate history of northern Australia;
- ▣ Resilience and risk mapping in space and time;
- ▣ Ecological responses to climate change;
- ▣ Ocean Observing Systems to monitor the physical environment;
- ▣ Understand and predict the responses of reef symbioses to environmental change; and
- ▣ Understand the role of microbes in the functioning of healthy and stressed reefs.

The outputs from these KRAs will be delivered through the efforts of four Research Teams:

- ▣ Assessing and Using Marine Biodiversity;
- ▣ Measuring Water Quality and Ecosystem Health;
- ▣ Responding to Climate Change; and
- ▣ Understanding Marine Microbes and Symbioses.

The first three teams are enduring themes from the last triennium, albeit with updated goals. As such, they have built strong co-investment portfolios, reflecting the relevance of our research to science users.

The fourth team, Understanding Marine Microbes and Symbioses, is a new theme that recognises the importance of microbial systems to ecosystem processes such as nutrient cycling and ecosystem health; recognises that these systems will respond rapidly to climate change; and recognises how little we know about such systems. This is a new direction for AIMS that is as significant as our previous introduction of biotechnology into an Institute founded upon field ecological studies. As with any new direction, it will require some capacity building and new investment with our aspiration being to build a centre of excellence in tropical marine microbiology within five years.

The goals identified for each of the KRAs will be the focus of our performance reporting systems. The relationships between our philosophical underpinnings (Strategic Directions), our science deliverables (KRAs) and our science management arrangements (Research Teams) are illustrated in the following table:

	Strategic Direction 1	Strategic Direction 2	Strategic Direction 3		
Key Result Area	<i>Understanding tropical marine ecosystems and processes</i>	<i>Understanding the effects of global environmental changes upon tropical marine systems</i>	<i>Supporting the sustainable development of tropical marine based industries</i>	<i>Technology Innovation</i>	Team delivering research outcomes
1.1 Assessments of tropical marine biodiversity	✓		✓	✓	Assessing and Using Marine Biodiversity
1.2 Accurate and timely information on issues and threats to coral reefs	✓	✓	✓		
1.3 Sustainable tropical aquaculture			✓	✓	
1.4 Sustainable supply of bioresources	✓		✓	✓	
2.1 Human impacts on tropical water quality and ecosystem health	✓		✓	✓	Measuring Water Quality and Ecosystem Health
2.2 Tropical marine ecosystem processes and land-sea interactions	✓	✓		✓	
3.1 Marine climate history of northern Australia	✓	✓		✓	Responding to Climate Change
3.2 Resilience and risk mapping in space and time	✓	✓	✓		
3.3 Ecological responses to climate change	✓	✓	✓		
3.4 Ocean observing systems to monitor the physical environment	✓	✓	✓	✓	
4.1 Understand and predict the responses of reef symbioses to environmental change	✓	✓		✓	Understanding Marine Microbes and Symbioses
4.2 Understand the role of microbes in the functioning of healthy and stressed reefs	✓	✓		✓	



Photo: Ray Berkelmans.

Supporting the National Research Priority goals

AIMS mission aligns strongly with the National Research Priorities (see Appendix 1) with the majority of our science effort being dedicated to research supporting the National Priorities of achieving 'An Environmentally Sustainable Australia' and developing 'Frontier Technologies for Building and Transforming Australian Industries'. The relationship between the Institute's research activities and the National Research Priorities is illustrated in the table below, with the strength of the match shown as highly relevant (■), very relevant (■) or relevant (■).

National Priority	An Environmentally Sustainable Australia				Frontier Technologies for Building and Transforming Australian Industries		
Priority Goal	A1 — Water a critical resource	A2 — Transforming existing industries	A5 — Sustainable use of Australia's biodiversity	A7 — Responding to climate change and variability	C1 — Breakthrough Science	C2 — Frontier technologies	C4 — Smart information use
Assessments of tropical marine biodiversity							
Accurate and timely information on issues and threats to coral reefs							
Sustainable tropical aquaculture							
Sustainable supply of bioresources							
Human impacts on tropical water quality and ecosystem health							
Tropical marine ecosystem processes and land-sea interactions							
Marine climate history of northern Australia							
Resilience and risk mapping in space and time							
Ecological responses to climate change							
Ocean observing systems to monitor the physical environment							
Understand and predict the responses of reef symbioses to environmental change							
Understand the role of microbes in the functioning of healthy and stressed reefs							

Key Result Areas to be delivered through the *Assessing and Using Marine Biodiversity* Team

- ▣ **1.1 Assessments of tropical marine biodiversity**
- ▣ **1.2 Accurate and timely information on issues and threats to coral reefs**
- ▣ **1.3 Sustainable tropical aquaculture**
- ▣ **1.4 Sustainable supply of bioresources**

INTRODUCTION

Biodiversity has intrinsic environmental, economic and social values. Activities to realise these values can sometimes conflict; usually where actions that enhance short-term economic gain lower the capacity of the environment to sustain resource exploitation in the longer term, or compromise environmental resilience in response to other impacts. Such pressures can lead to loss of ecosystem services including social amenity values.

Humans today have considerable power to impact the structure and function of natural ecosystems. In order to manage natural resources for sustainability in the face of competing economic and social drivers, environmental managers require knowledge of the natural variability of the ecosystem and human effects on ecosystems, and need to be in a position to make robust forecasts about the ecological responses (of species and assemblages of species) to be expected under alternative management scenarios.

While the end goals are clear, considerable gaps remain in our fundamental knowledge of tropical marine biodiversity and the ecological processes that generate and maintain it. During the next quadrennium, we are committed to research that will help fill these gaps (Key Result Area 1.1).

Although substantial knowledge gaps exist, some systems have been well characterised. For example, AIMS has accumulated a large store of knowledge about the Great Barrier Reef over the last two decades. These data sets will underpin the development of a new generation of models to advance understanding of the processes that generate and maintain biodiversity, leading to the

development of decision support tools for conservation, management and industry development (Key Result Area 1.2).

In this quadrennium, we expect our continued voyages of discovery and ecological syntheses to contribute to the profitable expansion of marine-based tourism across northern Australia, and to the expansion of the offshore oil and gas industry in north Western Australia. Our new vessel, the 34.9m RV *Solander*, will be a key asset allowing AIMS scientists and collaborators to reach remote locations. A new partnership with Geoscience Australia will enhance the geophysical capacity of the vessel to sample deeper habitats.

In addition to generating knowledge about the environment that will assist natural resource managers and marine-based industries to achieve their goals of sustainable use with conservation, AIMS will continue to play a role in the development of other marine industries, such as aquaculture (Key Result Area 1.3) and finding novel uses for Australia's marine biodiversity (Key Result Area 1.4).

Key Result Area 1.1: ASSESSMENTS OF TROPICAL MARINE BIODIVERSITY



Description

Although AIMS has accumulated unique data sets about the distribution and abundance of biodiversity in the Great Barrier Reef and elsewhere during the last two decades, we recognise that there are important gaps in our knowledge of tropical marine systems.

The least well-known of Australia's shallow tropical seas is a broad expanse of the continental shelf starting from just below the latitude of Broome in Western Australia and continuing eastwards across the top of northern Australia to the border between the Northern Territory and Queensland. This area covers 650,000 km². Because of its vast size, we must prioritise our investments in researching this area. In the next three years, we will survey the little studied Kimberley Coast and offshore reef provinces in a north-western arc from Broome to Darwin as this area is currently the focus of much offshore exploration by energy companies. These expeditions will combine local assessments to build regional models of biodiversity, oceanography and ocean productivity. Our eventual goal is to construct models of ecosystem structure and functioning for this large marine domain. As this goal is approached, we will shift focus to the area east of Darwin.

There are relatively few places where we have information about habitats and communities in waters deeper than those reached safely by SCUBA divers. The exception is the Great Barrier Reef. In the last funding period, AIMS collaborated with three other research agencies (CSIRO, QDPI&F, and the Queensland Museum) to complete the Great Barrier Reef Seabed Biodiversity Project. This resulted in comprehensive surveys of non-reef habitats down to 100 metres from an area covering approximately 210,000 km². Information from this project will now be used to evaluate the performance of the GBR Zoning Plan (2003) against the CAR (comprehensive, adequate and representative) principles for the design of marine protected areas. We will also form new partnerships in Western Australia to extend similar research to the Ningaloo Marine Park for similar outcomes.

There are few places where our ecological knowledge of reef communities goes much beyond the dominant corals and bony fishes. In the quadrennium, we will extend our knowledge to the other species living on coral reefs via the CReefs Project, which is affiliated with the global Census of Marine Life. This will be the first project in AIMS history to receive significant sponsorship from the corporate sector delivered through the philanthropic Great Barrier Reef Foundation, which has secured support of more than \$3 million from BHP Billiton for the CReefs Project. The Project will involve collaborative work with marine taxonomists from Australian and international museums and international organisations, including Scripps Institution of Oceanography and NOAA, to significantly extend knowledge of the species associated with coral reefs and how they vary over natural and human impact gradients.

Another stream of work will be focused on the cartilaginous fishes, particularly sharks. The biology of sharks makes them vulnerable to over-fishing and we intend to understand the ecological consequences of removing these apex predators from reef communities. Initially, however, our focus will be to assess the distribution, abundance and ranging behaviour of a selection of tropical sharks.

Planned Outcomes

- ▣ Reduced business risk through better characterisation of diversity patterns and natural variability in ecosystems;
- ▣ More effective environmental management through objective characterisation of tropical marine biodiversity and performance assessment of management plans; and
- ▣ Better management of tropical sharks through improved understanding of their ecology and the impacts on ecosystem function of their removal from reef communities.

Key Stakeholders²

Australian Museum, Australian National University, Australian Research Council, BHP Billiton, BHP Billiton Petroleum, CERF Hub for Marine Biodiversity Research, Commonwealth Environment Research Facility, CSIRO, Curtin University, Environmental Protection Authority of Western Australia, Fisheries Research and Development Corporation, Geoscience Australia, Great Barrier Reef Foundation, Great Barrier Reef Marine Park Authority, INPEX Browse, Integrated Marine Observing System, Murdoch University, Museum of Victoria, Northern Territory Department of Natural Resources, Environment and the Arts, Northern Territory Department of Primary Industries, Fisheries and Mines, Queensland Museum, Sloan Foundation (Census of Marine Life), University of Tasmania, University of Western Australia, WA Department of Environment and Conservation, Western Australian Marine Science Institution, Western Australian Museum, Woodside Energy.

Initial Focus of Plan

- ▣ Complete surveys in deeper areas of Ningaloo Reef Marine Park;
- ▣ Collaborate with the WA Department of Environment and Conservation to design a long-term monitoring program for Ningaloo Marine Park;
- ▣ Collaborate with museum partners to sample non-coral invertebrate communities of the GBR and Ningaloo Reef;
- ▣ Develop spatial models of biodiversity with particular emphasis on species turnover and environmental drivers;
- ▣ Collaborate with other AIMS teams to model changes in biodiversity on the GBR under climate change and water quality scenarios;
- ▣ Model community structure and trophic interactions using the model ECOSIM to make predictions about the long term response of coral reef ecosystems to shark removal; and
- ▣ Establish acoustic listening stations at Ningaloo Reef to track the movements of sharks and rays.

Performance Measures

- ▣ Maps of habitat and biodiversity for deeper parts of Ningaloo Marine Park;
- ▣ Improved resolution of bathymetric charts for areas seaward of Ningaloo Reef;
- ▣ Long-term monitoring of Ningaloo Marine Park implemented by DEC staff;
- ▣ Substantial discovery of new species of invertebrates from the GBR and Ningaloo Reef;
- ▣ Predictions of biodiversity responses to water quality, fishing, and climate changes; and
- ▣ Integrated Marine Observing System (IMOS) acoustic tracking array at Ningaloo Reef operational and utilised by others.

² Key Stakeholders are defined as people and/or organisations that affect what we do, have interest in what we do, or are impacted by what we do. It therefore includes clients, all forms of collaborators, and funding sources.

Key Result Area 1.2:
ACCURATE AND TIMELY INFORMATION
REGARDING ISSUES AND THREATS TO CORAL REEFS



Description

Coral reefs provide a range of ecosystem services. The Great Barrier Reef contributes more than \$5 billion³ annually to the Australian economy from industries based around fishing and marine tourism. Since both industries rely on healthy and productive ecosystems to deliver this value, the Great Barrier Reef Marine Park Authority has one of its key performance indicators (KPIs) as:

‘The relative numbers of reefs that are ‘healthy’ compared to ‘not healthy’ as assessed by the AIMS Long-term Monitoring Program’

For 15 years, AIMS has maintained a monitoring team to provide the Authority with the primary information to be able to report against this KPI as well as providing situational awareness on pest outbreaks and coral disease. Over time, this team has recorded the natural variability of coral and fish populations and documented their resilience to disturbances like cyclones, crown of thorns starfish outbreaks, and coral bleaching. The monitoring data are made available online from the AIMS website within six weeks of collection, summarised in annual status reports, and finally published in peer review science journals.

³ Insight Economics Pty Ltd (2006). Marine Imprint: the crucial impact of 33 years of AIMS research in the public interest. Melbourne: Insight Economics Pty Ltd http://www.aims.gov.au/pages/about/communications/issues/aims_impact.pdf

On 1 July 2004, the GBR Zoning Plan (2003) came into effect and resulted in a large expansion (from 4.5% to 33.3%) of the area protected within the Marine Park. As this is the single most significant change to the zoning since the inception of the Park, GBRMPA expressed a strong need to know the impact of changed zoning upon reef biodiversity. In 2005–2006, AIMS started a new bi-annual monitoring design aimed at assessing the impacts of the Zoning Plan upon reef biodiversity on mid-shelf reefs from Cairns to Gladstone. This new program will be interlaced throughout the quadrennium with the traditional GBR broad-scale monitoring (see above).

The new zoning plan extended protection to the full range of habitats in the GBRMP. Consequently, we will also monitor fish populations on deep shoals in the GBR Lagoon with planned outcomes similar to those from the monitoring of coral reefs.

In Western Australia, AIMS has been monitoring fish and coral communities on Scott Reef since 1994 to understand natural variability on a very isolated oceanic reef. AIMS decadal observations provided crucial information in 2007 when the WA Environment Protection Agency gave the offshore oil and gas industry conditional approval to develop the gas reservoirs of the Browse Basin below Scott Reef. Further development will trigger more extensive study of the region and its reef ecosystems. AIMS will deliver much of this research with full cost recovery from industry.

While AIMS reef monitoring has provided valuable information to managers, regulators and industry, natural resource managers are asking for a theoretical framework that defines 'reef health' with indicators and thresholds of concern that would trigger management action. Preliminary work on this issue in 2006–2007 showed that this is a challenging proposition. Further work to satisfy the need will be done during the quadrennium.

Reef health is just one example of our goal to elevate reef assessment and monitoring to a more quantitative framework based upon models that can simulate and forecast the responses of coral reef ecosystems to natural and anthropogenic pressures. In this quadrennium, we will advance this goal by investing additional resources into analysis and synthesis of the large-scale and long-term data sets collected during the history of AIMS. The aim of this strategy is to place more knowledge and effective tools for risk analysis and management strategy evaluation into the hands of the natural resource managers who are charged with the protection of coral reef ecosystems in Australia.

Planned Outcomes

- GBRMPA will be provided with performance assessment of the GBR Zoning Plan (2003) on reef biodiversity on coral reefs and submerged shoals;
- Reduced business risk through better characterisation of diversity patterns and understanding of ecosystem processes and responses; and
- Improved management of reef resources through:
 - intelligence about status and trends gathered by monitoring programs
 - quantitative models and indicators of reef health
 - robust models of risk-mapping and resilience
 - robust models of reef processes with reliable forecasts of ecosystem responses to alternative management scenarios.

Key Stakeholders

Australian Research Council, Commonwealth Environment Research Facility, Environmental Protection Authority of Western Australia, Great Barrier Reef Foundation, Great Barrier Reef Marine Park Authority, WA Department of Environment and Conservation, Offshore Oil and Gas Industry.

Initial Focus of Plan

- ▣ Survey reefs and shoals to assess the performance of GBR Zoning Plan (2003);
- ▣ Collaborate with GBRMPA to develop a quantitative framework for reporting reef health in their first Outlook Report;
- ▣ Host an international workshop of experts to progress indicators of reef health and thresholds of concern;
- ▣ Invest effort and resources in a risk and resilience atlas for the GBR; and
- ▣ Collaborate with Woodside Energy to design and implement a three-year program of research for Scott Reef.

Performance Measures

- ▣ Peer-reviewed publications on the performance of the GBR Zoning Plan (2003) on reef biodiversity;
- ▣ Inclusion of AIMS data in the GBRMPA Outlook Report due 2009;
- ▣ Peer-reviewed publications on indicators of reef health and thresholds of concern; and.
- ▣ Scott Reef research program endorsed by regulators and industry.

Key Result Area 1.3:
SUSTAINABLE TROPICAL AQUACULTURE



Description

Tropical aquaculture research effort at AIMS is aimed at overcoming technological barriers to the expansion of aquaculture industries in northern Australia with community benefits expected from wealth creation, employment growth, and improved sustainability for natural stocks.

AIMS research concentrates on two high value tropical crustaceans: black tiger prawns (*Penaeus monodon*) and tropical rock lobsters (*Panulirus ornatus*). The two targets are in different stages of industry development. The Queensland prawn aquaculture industry was founded more than 20 years ago. Despite this history and the existence of many profitable prawn farms, the sector is still largely reliant on wild spawners to stock each generation of prawns into land-based ponds. This raises issues of sustainability because the dominant prawn in the aquaculture industry (black tiger) is one of the least abundant prawns in Queensland. During the last five years, AIMS has been a partner in a national consortium of research providers (including CSIRO and QDPI&F) led by the Australian Prawn Farmers Association to domesticate this species. The consortium has now raised five generations of prawns from domesticated stocks and the Institute has played a key role in selective breeding of fast-growing germ lines within these domesticated stocks. With many of the technical barriers, including diseases, largely solved during the last 15 years, AIMS plans to finalise the transfer of knowledge to industry and withdraw from this research during the quadrennium.

Resources from prawn research will then be redirected to tropical rock lobsters, which currently have a limited industry base. Wild caught lobsters provide a valuable export industry from Torres Strait and Great Barrier Reef, and the very high prices for live lobsters supplied to Asia provide the incentive for attempting to domesticate this species. The technological barrier to land-based aquaculture of lobsters is their very long and complex larval life (up to eight months and 11 moult stages) and their high mortality in hatcheries. In the last three years, AIMS has made continuous improvements in larval survival by better control of microbial diseases and improved diet. These themes will continue to be the focus for the next four years.

At the opposite end of the technology spectrum to the indoor culture of lobsters, the team has also promoted low technology aquaculture in sea ranching operations based upon animals with low maintenance and no artificial feeding needs. The current focus is on bath sponges for which there is an established international market and a diminishing supply from traditional sources. In the last Triennium, AIMS established demonstration projects for sponge farming in the Torres Strait and the Palm Islands. This is a first for Australia and both ventures are moving towards commercial start-ups involving local indigenous communities. AIMS will withdraw from this area with the handover to the communities within the next few years.

Planned Outcomes

- ▣ Improved domesticated stocks, which offer more stable supplies of larvae and faster growth in ponds allowing more competitive and profitable prawn farming;
- ▣ Improved sustainability of wild stocks of black tiger prawns (taken by the East Coast Otter Trawl Fishery), by reducing competition from the aquaculture sector for gravid females;
- ▣ Lower the technological barriers to larval rearing of tropical rock lobsters until the stage where new commercial enterprises are feasible; and
- ▣ At least one commercial sponge farm operational by 2010.

Key Stakeholders

Australian Prawn Farmers Association, Commonwealth Environment Research Facility, Coolgaree Community Development and Employment Program, CSIRO, Fisheries Research and Development Corporation, Gold Coast Marine, Great Barrier Reef Marine Park Authority, McCloy Industries, MG Kailis, Queensland Department of Primary Industries & Fisheries, Queensland Department of Tourism, Regional Development and Industry, Seafarm, Tasmanian Aquaculture and Fisheries Institute, Torres Strait Regional Authority.

Initial Focus of Plan

- ▣ Improve fertility of domesticated prawns by studying effects of nutrition and microbial pathogens on male reproductive system health;
- ▣ Develop manufactured feeds for lobster larvae based on understanding digestive mechanisms for Stage V–VI phyllosoma;
- ▣ Develop probiotic treatments, and better diagnostic tools for health, to improve the survival of phyllosoma by reducing microbial infections;
- ▣ Complete demographic and genetic assessments of Torres Strait sponges;
- ▣ Complete sponge growth experiments in the Torres Strait and Palm Islands; and
- ▣ Host a stakeholder workshop in 2008 with indigenous collaborators and relevant agencies on sponge farm technology transfer and environmental audit.

Performance Measures

- Benefits from the five-year Prawn Domestication Project transferred to one or more commercial operations through their peak body (APFA);
- Continuous improvement in the survival and/or growth of larval lobsters attributable to improved diets;
- Continuous improvement in the survival and/or growth of larval lobsters attributable to improved microbial health;
- Peer-reviewed publications on sponge ecology; and
- Agreement reached between communities and regulators about commercial sponge farms.

Key Result Area 1.4:

SUSTAINABLE SUPPLY OF BIORESOURCES



Description

Australia's vast marine territories, which encompass shallow and deep habitats from the Tropics to the Antarctic, are an enormous repository of unique biodiversity. For more than a decade, AIMS has been sampling shallow water biodiversity from Australia and its adjoining seas to increase knowledge about distribution and abundance patterns of species but also to create a curated collection that is useful for biodiscovery. Currently, the AIMS collections include almost 20,000 entities with just over half representing microbial isolates.

The Research Performance Assessment (RPA) review of Biomolecular Sciences in 2006 recommended that the Institute move to a partnered biodiscovery model. This means that AIMS will provide fractionated extracts from marine invertebrates and microbial sources to one or more external partners with access to high throughput screening facilities (such as the proposed Queensland Compound Library). Follow-up chemistry on any active compounds detected in the screens will be done through separate commercial partnerships. Even without the latter, AIMS will continue to link the screening results with the source data in an increasingly sophisticated bioinformatics database that will allow desktop searches for therapeutic targets and reliable recollection, where this is desirable. In addition, the bioinformatics capability will be cross-linked into KRA 1.1 for taxonomic and biogeographic syntheses.

A development coincident with this Research Plan is that AIMS has been asked to lead the biotechnology node in the new Western Australian Marine Science Institution (WAMSI), where the first challenge is to persuade the Government of Western Australia to legislate for appropriate access and benefit sharing agreements to marine bioresources. This is an area where AIMS has been influential in the past, with the first success being legislation passed by the Queensland Parliament (Queensland's Biodiscovery Act 2004). In the international area, AIMS has taken a leading role in discussions about access and benefit sharing from marine resources under the auspices of the UN Convention on Biological Diversity, which has led to legislation by the Australian Government to cover Commonwealth waters. More recently, the Northern Territory has drawn up its own legislation. When similar legislation is enacted in WA, AIMS will scale back its effort in this area consistent with our focus on Australia's tropical environments.

Planned Outcomes

- ▣ Maximum use of AIMS Bioresources Library by national screening networks to enhance the likelihood of finding valuable bioactive leads for industry development;
- ▣ Value-adding to the Bioresources Library through a proprietary bioinformatics system that will permit desktop biodiscovery tailored for clients or therapeutic targets; and
- ▣ Creation of a Perth-based marine biotechnology program to exploit Western Australia's marine biodiversity.

Key Stakeholders

BioScience North Australia, Griffith University, National Cancer Institute, Queensland Department of State Development and Innovation, Western Australian Institute of Medical Research, Western Australian Marine Science Institution.

Initial Focus of Plan

- ▣ Renew collecting permits for all jurisdictions;
- ▣ Collect novel biodiversity from new areas as piggyback operations on selected AIMS voyages;
- ▣ Conclude partnership negotiations with the Queensland Compound Library and make AIMS existing collections available for high throughput screening by the QCL and others;
- ▣ Upgrade the Bioresources Library information base with enhanced bioinformatics capability; and
- ▣ Work through WAMSI to facilitate action by the WA government on legislation for access and benefit sharing to WA marine bioresources.

Performance Measures

- ▣ 200–300 new entities added to the Bioresources Library;
- ▣ Participatory membership of the QCL;
- ▣ A more effective Bioinformatics database; and
- ▣ Progress towards an access and benefit sharing agreement for Western Australian bioresources.



Photo: Ray Berkelmans.

Key Result Areas to be delivered through the *Measuring Water Quality and Ecosystem Health* Team

- 2.1 Human impacts on tropical water quality and ecosystem health
- 2.2 Tropical marine ecosystem processes and land-sea interactions

INTRODUCTION

The health of coral reefs and other tropical marine ecosystems depends on the quality of the water in which they live. Sedimentation and turbidity regimes, nutrient availability, the amount and type of organic matter, presence of contaminants, salinity, temperature and alkalinity can all strongly influence the productivity, resilience and function of these ecosystems.

The primary causes of observed declines in coastal water quality and ecosystem health are increasing human populations, intensifying land use and development in coastal regions and river catchments. We study human impacts upon water quality, and the movement of water, nutrients and sediment. We monitor reef health in relation to these changes and we develop novel indicators and bioassays for reef organism health, and for application in environmental impact assessments of the coral reefs of the world, aquaculture and other coastal industries (Key Result Area 2.1).

This team does research to inform and enable natural resources managers to manage the conservation of biodiversity alongside the sustainable use of marine, coastal and catchment resources. Consequently, the central goal of the Team is to understand spatial and temporal issues of water quality in tropical marine waters and to know and to forecast the responses of key organisms, communities, and ecosystems to changing water quality. This aspiration implies more knowledge than we currently possess, which means that we do research to address the critical gaps in our understanding (Key Result Area 2.2).

The nature of the problem demands multidisciplinary research from ecology to oceanography to molecular and genetic disciplines, all

integrated by spatial and process modelling. Since no team can possess all of these skills, we will have strong links with all three of the other research teams in this Plan.

The geographic focus of the Team's research will be tropical Northern Australia with particular emphasis on the Great Barrier Reef because of the strong population growth being experienced along the Queensland east coast adjacent to the Great Barrier Reef Marine Park with its World Heritage values. Population growth is the same reason why we expect to expand our work around Darwin Harbour, but the Northern Territory also offers opportunities to work with a growing minerals mining sector that exports its products by sea and not road. We expect to continue our research in Gove Harbour and to expand it to other areas of potential interest to the mining industry. Some of our work will be done in developing countries when it is appropriate to study extreme pressure states on the environment beyond those currently existing in Australia.

Key Result Area 2.1:

HUMAN IMPACTS ON TROPICAL WATER QUALITY AND ECOSYSTEM HEALTH



Description

The impact of human activity on coastal ecosystem health and functioning is a universal challenge for countries with a maritime border. Human activities on the land have increased the runoff of nutrients, sediments, and contaminants to rivers and hence to the oceans.

Agricultural impacts on land-use have been detected in the inner Great Barrier Reef. The oldest clue is increased levels of barium deposited in the skeletons of near shore corals from the 1870s, which indicate increased sediment discharge shortly after the introduction of cloven-hooved animals to grazing catchments. The most recent clue is the appearance of modern synthetic pesticides in coastal ecosystems. The current consensus is that recent changes to coastal water quality have reduced ecosystem health and resilience in some inshore parts of the Great Barrier Reef.

The Reef Water Quality Partnership is a coalition of federal, state and local organisations that seeks to halt and reverse the decline in water quality entering the World Heritage Area. AIMS is the major provider of marine monitoring to this partnership through projects measuring sediment and nutrient loads at the ends of catchments, and field surveys

monitoring the condition and trends of inshore coral reefs. All parties recognise that this will be a long-term commitment. The status of marine water quality elsewhere in tropical Australia and its impacts upon local ecosystems is less well understood than for the Great Barrier Reef because of the absence of baseline data and monitoring. Thus this Key Research Area will also cover ecosystem health monitoring in the Northern Territory and fundamental research into biological indicators of ecosystem health seeking simple measures with universal application.

While most of our past work has concerned potential impacts from agriculture and minerals processing, we have anticipated the need to inform the debate in northern Australia about the potential impacts of aquaculture. While land-based operations concentrate upon zero discharge operations, there may be a legitimate role for sea cage aquaculture, which does not have this option. Since 2005, we have been measuring the impacts of sea cage operations in Indonesia with an immediate aim of enhancing marine planning guidelines in that Country but in the longer-term to return this knowledge to local industry and management.

Planned Outcomes

- ▣ Collection of baseline data and long-term monitoring to contribute to stabilisation or improvement in the quality of terrestrial runoff entering the Great Barrier Reef;
- ▣ Clear evidence and understanding of the linkages between coastal water quality and the health and resilience of near shore coral reef ecosystems;
- ▣ The development of effective bio-indicators for measuring and monitoring sub-lethal stress in tropical marine organisms arising from poor water quality; and
- ▣ Increased public awareness about the environmental impacts of catchment and coastal developments, including new industries such as sea cage aquaculture.

Key Stakeholders

Alcan Gove, Australian Centre for International Agricultural Research, Bluewater Barramundi, Charles Darwin University, Commonwealth Department of Environment and Water Resources, Commonwealth Environment Research Facility, Great Barrier Reef Marine Park Authority, Northern Territory Department of Natural Resources, Environment and the Arts, Queensland Environmental Protection Agency, Queensland NRM Boards.

Initial Focus of Plan

- ▣ Continue monitoring of coastal water quality and near shore coral reefs as agreed in the annual work plan of the Reef Water Quality Partnership (subject to funding);
- ▣ Install sensors for underway monitoring of water quality by AIMS research vessels as part of the Integrated Marine Observing System (Ships Of Opportunity Program);
- ▣ Refine indicators for water quality status based on biofilm communities and corals;
- ▣ Determine responses of key organisms to changing water quality (sediments, nutrients, metals, pesticides, light) in experiments crossed with changing climate (temperature, pH);
- ▣ Continue studies into the marine health of Melville Bay in the Northern Territory through partnership with Charles Darwin University and Alcan Gove; and
- ▣ Develop a generic model to predict environmental carrying capacity for sea cage aquaculture at the scale of embayments.

Performance Measures

- ▣ Continued acceptance and endorsement of status and trend reports by regulatory authorities
- ▣ Data from underway sensors installed on AIMS research vessels posted on public websites as required by the IMOS-SOOP business plan
- ▣ Peer-reviewed publications on bio-indicators and physical indicators of water quality status
- ▣ Timely delivery of client reports to the Melville Bay Marine Health Monitoring Program
- ▣ Application of guidelines to at least one embayment containing sea cages for fin fish aquaculture

Key Result Area 2.2:

TROPICAL MARINE ECOSYSTEM PROCESSES AND LAND-SEA INTERACTIONS



Description

Coastal seas are complex mixing zones between the land and the ocean. On narrow continental shelves, much of the terrestrial materials exported by rivers can pass straight to sinks in the deep ocean. On broad continental shelves as occurs in most of tropical Australia, this material is more often trapped and recycled near the source. In either case, additional nutrients can also be imported onto the outer shelf from oceanic sources by upwelling at the shelf break. Ultimately, the productivity of benthic and pelagic ecosystems on the continental shelf depends upon the biogeochemical cycling of nutrients from these two sources (land and ocean), which has many dimensions including temperature and the reprocessing of materials by the poorly known but crucial microbial world.

Since 2000, we have been working towards completion of a shelf-scale budget for nutrients entering the Great Barrier Reef from terrestrial and oceanic sources to inform the Reef Water Quality Protection Plan. The Plan seeks to determine appropriate targets for end-of-river monitoring based upon the predicted impacts of additional nutrients discharged into the inner GBR. While we have reasonable numbers on many of the key inputs and processes required for a gross budget, there are key gaps in our understanding including: the contribution of inorganic nutrients (especially nitrogen and phosphorus) from the deep sea by upwelling processes at the shelf break; the roles of nitrogen-fixing cyanobacteria (*Trichodesmium* species); and the role of suspended organic matter as food web drivers in tropical waters.

This research goal will build upon decades of AIMS research and will use a multidisciplinary approach to synthesise long-term measurements of oceanography and biogeochemical processes into a complete understanding of nutrient inputs and cycling at the scale of the Great Barrier Reef.

Planned Outcomes

- ▣ Knowledge of the net flux of nutrients from the Coral Sea to the GBR shelf;
- ▣ Knowledge of the balance between nitrogen fixation by pelagic *Trichodesmium* and benthic bacteria and denitrifying processes in the water column and sediments; and
- ▣ A robust shelf-scale nutrient budget for the Great Barrier Reef ecosystem.

Key Stakeholders

Commonwealth Department of Environment and Water Resources, Commonwealth Environment Research Facility, Great Barrier Reef Marine Park Authority, Queensland Environmental Protection Agency, Queensland NRM Boards.

Initial Focus of Plan

- ▣ Review and synthesise existing data to identify data and knowledge gaps preventing the delivery of an accurate shelf-scale nutrient budget for the GBR;
- ▣ Complete the next upgrade of technology for the assessment of *Trichodesmium* abundance in the water column;
- ▣ Deploy oceanographic instrument arrays off the Burdekin and Tully Rivers to trace fine suspended sediments entering the marine environment during flood events; and
- ▣ Complete inspections of catchments on the north and south coasts of Timor Leste at the invitation of that Government.

Performance Measures

- ▣ Peer-reviewed synthesis of available data on GBR shelf-scale nutrient processes;
- ▣ Peer-reviewed publication on a regional nutrient budget for the northern GBR;
- ▣ The assessment of *Trichodesmium* abundance at large spatial scales;
- ▣ A shelf-scale budget for the whole GBR shelf; and
- ▣ A report to the Government of Timor Leste with recommendations for catchment management to improve coastal water quality.



Photo: Ray Berkelmans.

Key Result Areas to be delivered through the *Responding to Climate Change* Team

- **3.1 Marine climate history of northern Australia**
- **3.2 Resilience and risk mapping in space and time**
- **3.3 Ecological responses to climate change**
- **3.4 Ocean observing systems to monitor the physical environment**

INTRODUCTION

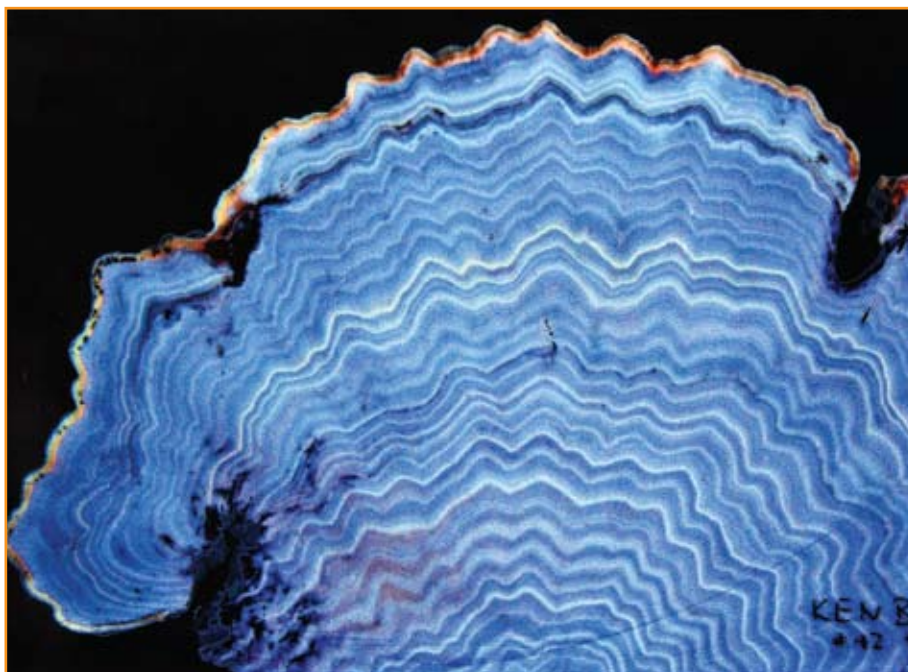
Australia's tropical marine ecosystems are already reflecting the regional consequences of global climate change caused by enhanced greenhouse gas emissions with a 1.4°C rise in sea temperature over the last 100 years. Even if nations adopt mitigation strategies that stabilise and reverse atmospheric greenhouse gas concentrations by the middle of this century and keep average global warming below 2.5°C by 2100, tropical marine climates will continue to experience rapid and significant changes that will result in organism and ecosystem responses. A key issue for tropical marine ecosystems is that it is not simply a change to a new climate regime to which the ecosystems have to adapt but that, for the foreseeable future, climate will be continuously changing and it may be hundreds of years before a new, stable climate regime is reached. Furthermore, so far as we know, the rate of change is unprecedented; this raises questions about the ability of some species and systems to adapt in time.

Changes of the physical environment include: continued warming of ocean temperatures (with mass coral bleaching responses already observed); gradual acidification of the ocean (likely to reduce the ability of various marine calcifying organisms to form their skeletons and shells, with impacts on coral growth already measured by AIMS); increased intensity of tropical cyclones (causing local physical destruction); more extreme rainfall events (with increased amounts of freshwater and sediment extending further out from the coast); gradual sea-level rise (affecting coastal erosion, storm surges and the area available for shallow-water marine organisms); and changes in ocean circulation and upwelling patterns (presently ill-defined but fundamental to many ecological processes).

Informed management strategies, against this backdrop of rapid environmental change, require clear identification of the magnitude and spatial and temporal dimensions of physical and chemical changes and ecological responses. This team will provide this type of information by placing current changes in an historical context (Key Result Area 3.1), downscaling large-scale climate scenarios to space scales relevant to coral reef processes and providing a risk and resilience framework for assessing the impacts of various future changes and management actions (Key Result Area 3.2), assessing the ecological responses of coral reefs and associated organisms (Key Result Area 3.3) and monitoring trends in the physical environment through a new GBR Ocean Observing System (Key Result Area 3.4).

Key Result Area 3.1:

MARINE CLIMATE HISTORY OF NORTHERN AUSTRALIA



Description

To assess the significance and magnitude of the currently changing climate requires placing recent observations of changes in a historical context. Of particular importance is identifying when current climate trends (for both mean climate and its extremes) exceed those of the recent past several centuries – climates to which present-day tropical marine ecosystems have adapted. The available instrumental records give us a historical context that is barely 100 years long which, although useful, means that we can only say that an observed event exceeds the known variability in that parameter observed in the recent past. This is where natural proxies for climate (e.g. corals, tree-rings, ice-cores) that go back

hundreds and thousands of years become immensely valuable to climatologists. The skeletons of massive corals, particularly the genus *Porites*, contain a rich archive of annually-resolved proxy climate and environmental information for northern Australia extending back over 1000 years in the case of the oldest living colonies. The coral skeleton contains evidence of coral growth responses to environmental and climate changes and extremes; allowing us to test hypotheses about the frequency of events like floods and coral bleaching events as well as to measure the more gradual drift in average conditions of key variables like temperature and pH.

AIMS houses the world's best archive of long coral cores and colonies, based mainly on corals collected from the Great Barrier Reef. Over the last 10 years, these collections have been used to demonstrate that the skeletal records can provide reliable paleoclimatic reconstructions of past river flow and rainfall. Through strategic collaborations involving geochemical analyses of coral skeletons, we have provided new insights into past temperature, salinity, sediment flux and oceanic pH. We are now at the stage of combining all of this information into a detailed model of *Porites* growth that will reveal the resilience of this species to changes in its physical environment.

While most of our past work has concentrated on the GBR, our plan for the quadrennium is to extend this knowledge to the whole of northern Australia. Starting from below the Tropic of Capricorn in Western Australia (Ningaloo Reef), we will collect long-coral cores from massive *Porites* to cover the north-west and begin to build a climatology for the Indian Ocean to contrast with our understanding of contemporaneous climate on the Pacific coast. In subsequent years, we will fill in the gap across northern Australia adjacent to the Arafura Sea with the eventual aim of producing a marine climate history across tropical Australia.

Planned Outcomes

- A comprehensive model of the growth responses of the massive coral, *Porites*, in relation to environmental gradients (including temperature) and bleaching shocks;
- A reconstruction of sea temperatures across northern Australia for the last 200–300 years based upon historical records of *Porites* growth;
- A reconstruction of relative rainfall across northern Australia for the last 200–300 years based upon floods recorded in the skeletons of *Porites* growing near key rivers; and
- A baseline with historical perspective for calcification rates in *Porites* in order to monitor future changes due to ocean acidification.

Key Stakeholders

Australian Greenhouse Office, Australian National University, Australian Research Council, BHP Billiton Petroleum, Commonwealth Department of Environment and Water Resources, Great Barrier Reef Marine Park Authority, Western Australian Marine Science Institution.

Initial Focus of Plan

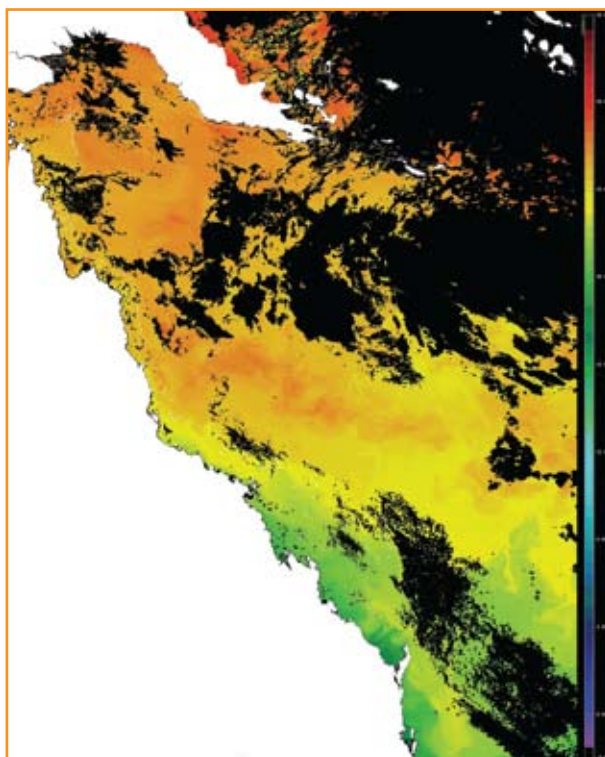
- Collect long coral cores from Ningaloo Reef, WA;
- Collect long coral cores from Whitsunday Islands, GBR;
- Identify geochemical indicators in coral skeletons that can be used as robust proxies for water quality; and
- Determine spatial patterns of stable isotopes (Oxygen-18, Carbon-13) for GBR corals over the recent past.

Performance Measures

- Add coral cores representing at least 1,000 years of annual coral growth to the AIMS coral records collection;
- Peer-reviewed scientific publications on the geochemical investigations; and
- Progressive delivery of the climate history of tropical Australia on AIMS web site.

Key Result Area 3.2:

RESILIENCE AND RISK MAPPING IN SPACE AND TIME



Description

Climate change is already impacting tropical marine ecosystems, for example, an increased frequency of temperature variations sufficient to trigger mass coral bleaching events. It is clear, however, that ecosystem responses to thermal stress vary at a range of space scales and that some locations appear to exhibit greater resilience to climate change.

Identification of the spatial patterns of resilience to and risk from climate change is a key to informed and focussed management strategies. This requires integration of information from many sources to make explicit the risks faced and how they vary in space and time. A critical step is the development of spatially explicit, sub-regional scale information (hazards, interactions with other stressors, exposure and vulnerability) about the risks

posed by climate change and variability. Once these risks are understood, management tools can be built that identify areas worth the highest level of protection from other pressures because of their potential to provide resilient sources of biodiversity. As part of this objective it is essential to determine what set of biological and environmental attributes confer resilience and where such attributes are most likely to be found.

Climate risk mapping for coral reef ecosystems requires knowledge of oceanography from basin scales to local processes. Physical climate change scenarios will be downscaled to reef scale for the Ningaloo Reef in Western Australia and for the Great Barrier Reef.

Planned Outcomes

- ▣ An atlas of climate change risk and resilience for the Great Barrier Reef;
- ▣ Decision support tools identifying potential marine protected areas based on coral resilience; and
- ▣ Downscaled ocean circulation models for key locations on the Indian and Pacific Ocean coasts that translate climate change scenarios to spatial scales relevant to coral reef processes.

Key Stakeholders

Australian Greenhouse Office, Commonwealth Department of Environment and Water Resources, Commonwealth Environment Research Facility, CSIRO, Great Barrier Reef Marine Park Authority, Western Australian Marine Science Institution.

Initial Focus of Plan

- ▣ Generate a new bathymetry model of the southern GBR;
- ▣ Collaborate with CSIRO BlueLink to build nested models for downscaling climate change scenarios to regional-scale coral bleaching threat; and
- ▣ Develop decision support system based on coral resilience for inshore reefs of the GBR.

Performance Measures

- ▣ New bathymetry for southern GBR integrated into downscaling model;
- ▣ Future climate scenarios for Ningaloo Reef considered in marine planning by the WA Department of Environment and Conservation; and
- ▣ Peer-reviewed scientific publications.

Key Result Area 3.3: **ECOLOGICAL RESPONSES TO CLIMATE CHANGE**



Description

The occurrence, intensity and recovery from mass coral bleaching events varies between coral species and places. Although sea temperature is the prime stressor, there are clear indications of interactions with other environmental variables such as mesoscale ocean circulation patterns. This project aims to improve early warning of thermal stress conducive to coral bleaching for the GBR and to determine the role of ocean dynamics in making some locations more or less susceptible to bleaching conditions.

Following major bleaching events in 1998 and 2002, there are tentative indications that the thermal tolerances of some coral populations have shifted upwards. There are a variety of mechanisms that could explain this, including selective mortality of more temperature sensitive symbioses. The project will concentrate on what makes some reefs more thermally tolerant than others and how these features change over time. This will involve research on at least four levels (community composition, population structure, coral physiology, and molecular genetics) across pairs of reefs known to have contrasting sensitivity to temperature stress. This research will provide new insights into mechanisms of, and scope for, reef corals to adapt to a warming ocean.

We will also develop a research response to the challenge presented by ocean acidification as a significant fraction of the excess atmospheric carbon dioxide arising from the burning of fossil fuels is absorbed by the oceans.

Planned Outcomes

- Near real-time coral bleaching warning system for the Great Barrier Reef;
- More certain knowledge about the potential for and the limits on rapid adaptation of reef corals to rising sea temperatures; and
- Ocean acidification research strategy for tropical marine ecosystems.

Key Stakeholders

Australian Greenhouse Office, Australian Research Council, Commonwealth Department of Environment and Water Resources, Commonwealth Environment Research Facility, Great Barrier Reef Marine Park Authority, National Oceanic and Atmospheric Administration.

Initial Focus of Plan

- ▣ Reactive surveys after any future incidences of widespread bleaching on the GBR;
- ▣ Identify areas on the GBR at risk from frequent coral bleaching;
- ▣ Comparative research between matched pairs of reefs with different thermal tolerances; and
- ▣ Host international workshop on ocean acidification research strategy.

Performance Measures

- ▣ Rapid response to another bleaching season;
- ▣ Peer-reviewed scientific publications; and
- ▣ A research strategy for ocean acidification with a 5 and 10 year outlook.

Key Result Area 3.4:

OCEAN OBSERVING SYSTEMS TO MONITOR THE PHYSICAL ENVIRONMENT



Description

The motion of water over the continental shelf and its contents (heat, nutrients, sediments, etc.) are the strongest natural drivers of ecosystem structure and function. On the outer shelf, where land-based influences are low, the productivity of the water column is a major control on the productivity of benthic invertebrates and demersal fishes. The combined motion of currents and tides transports nutrients to reefs and exports propagules from them. In other words, it is impossible to understand reef productivity and population dynamics without knowing about their physical, chemical and biological oceanographic settings.

For almost 20 years, AIMS has observed oceanic influences on shelf processes by maintaining a long-term instrument array on the continental slope about 120 km northeast of Townsville. This array records the pulsing southward flow of an oceanic boundary current through the Townsville Trough on its way to become the East Australian Current which influences marine climate and ecosystem performance down the eastern seaboard of Australia as far south as Tasmania. Inter-annual variations in this flow have been linked to the difference in sea-levels between Noumea and Townsville ports, which can in turn be linked to large-scale atmospheric pressure systems and long-term term cycles like El Niño. In recent years, the point measurements of currents have been supplemented by synoptic views of the sea surface available from satellite remote sensing, which show that the heat-laden flows of water across the Coral Sea and along the continental margins are complex and turbulent.

From 2007–2008, AIMS will lead the implementation of the Great Barrier Reef Ocean Observing System (GBROOS) as part of the most exciting development for ocean observations to occur in Australia since the launch of earth observing satellites by other nations. The Australian Government has provided \$50 million to create an Integrated Marine Observing System (<http://www.imos.org.au/>) comprising bluewater and coastal observation networks around Australia. With initial funding of \$17.4 million (\$9.4 million cash from IMOS and the Queensland Government, \$8 million from providers), we will establish the Great Barrier Reef Ocean Observing System (GBROOS).

GBROOS will be a regional observation network for the western Coral Sea, which is the least intensively studied regional sea in the Australian Marine Jurisdiction because of its challenging bathymetry and complex flows. The network will be a partnership between AIMS, the Tropical Marine Network representing the four island research stations: Heron (University of Queensland), Lizard (Australian Museum), Orpheus (James Cook University) and One Tree (University of Sydney), the Queensland Cyber-Infrastructure Foundation (UQ) and the ARC Research Network for Intelligent Sensors, Sensor Networks and Information Processing (University of Melbourne). Its purpose will be to document variability in the western Coral Sea, particularly along the continental margin, and to provide observing infrastructure that will allow researchers to determine the influence of variations in the oceanic boundaries currents upon the performance of outer-shelf ecosystems.

GBROOS will collect measurements from ship-borne sensors, oceanographic instruments moored on and off the shelf at four latitudes, upgraded remote sensing facilities in Townsville covering both sea surface temperature and ocean colour as far east as Fiji, and a unique network of environmental sensors using wireless technology that will be installed at the four island research stations. The latter will deliver real-time measurements of local marine climate and will be a plug-and-play technology that allows other researchers to add specialised sensors to the network to collect spatially dense, continuous measurements in real-time from two-thirds of the GBR at the same time. This infrastructure will allow researchers to study the links between marine climate and ecosystem performance with experiments never previously possible. The wireless network (Facility for Automated Intelligent Monitoring of Marine Systems, FAIMMS) will also become part of international networks concerned with long-term ecological monitoring of sensitive sites (ILTER) and/or the application of wireless sensor networks to environmental monitoring, which is cutting-edge science.

Planned Outcomes

- ▣ A robust observation system for long-term continuous monitoring of the marine climate and key ecosystem parameters in the western Coral Sea and outer-shelf of the Great Barrier Reef reported publicly in the manner of weather forecasts; and
- ▣ Open access infrastructure at the island research stations that allow scientists and student researchers to experiment with next generation tools for environmental monitoring.

Key Stakeholders

Association of Marine Parks Tourism Operators, Australian Greenhouse Office, Australian Museum, Australian Research Council, Bureau of Meteorology, Great Barrier Reef Marine Park Authority, Integrated Marine Observing System, James Cook University, National Aeronautical and Space Agency, National Oceanic and Atmospheric Administration, University of Melbourne, University of Queensland, University of Sydney, University of Tasmania.

Initial Focus of Plan

- ▣ Purchase, build and deploy four long-term GBR instrument moorings;
- ▣ Design, build and deploy wireless sensor networks in the southern GBR;
- ▣ Purchase, install and commission an X/L band satellite receiving station at AIMS;
- ▣ Purchase and install underway sensors on two AIMS research vessels and two tourist ferries;
- ▣ Develop and implement QA/QC system for Automatic Weather Station data; and
- ▣ Build web-based GBROOS data and knowledge delivery systems.

Performance Measures

- ▣ Data from oceanographic moorings available on-line within three months of retrieval of instruments;
- ▣ Data from underway sensors on AIMS research vessels available on-line within two weeks of each voyage;
- ▣ Operational high-speed communications between four island research stations and AARNET;
- ▣ Satellite data from the Townsville receiving station(s) being assimilated on a daily basis by the Bureau of Meteorology; and
- ▣ Annual Reports and Business Plans from the GBROOS Node approved by the IMOS Board.



Photo: Ray Berkelmans.

Key Result Areas to be delivered through the *Understanding Marine Microbes and Symbioses* Team

- 4.1 Understand and predict the responses of reef symbioses to environmental change
- 4.2 Understand the role of microbes in the functioning of healthy and stressed reefs

INTRODUCTION

Marine microbes encompass all microscopic organisms found in the sea including viruses, bacteria, and micro-algae; groups that differ considerably in their biological characteristics. Although unseen, microbes constitute the vast majority of marine biomass. They are the oldest life forms, the primary catalysts of energy transformation, and fundamental to the biogeochemical cycles that shape our oceans. They were the only kinds of life on Earth for approximately 80% of the planet's history and all multicellular life depends upon microbial processes.

The global oceans have been estimated to contain 3.6×10^{29} bacterial cells, 1.3×10^{28} archaeal cells and 4×10^{30} viruses. Current estimates of marine bacterial diversity range from thousands to millions of distinct taxa. Recent applications of shotgun sequencing techniques that recover unique DNA sequences from bulk water samples and the use of 454 DNA tag sequencing indicate that marine microbial diversity may be some 10 to 100 times more than expected, and the vast majority are previously unknown, low-abundance organisms that are likely to play an important role in the marine environment as part of a 'rare biosphere'. Only 0.1–1.0% of marine microbes present in seawater can be cultured using conventional approaches, which is indicative of the state of our knowledge of this unseen world. Despite that, we know that microbial communities are the most significant decomposers and recyclers of nutrients in the oceans: hence an essential element in global cycles and among the most serious of information gaps when we try to forecast how ecosystems will respond to change.

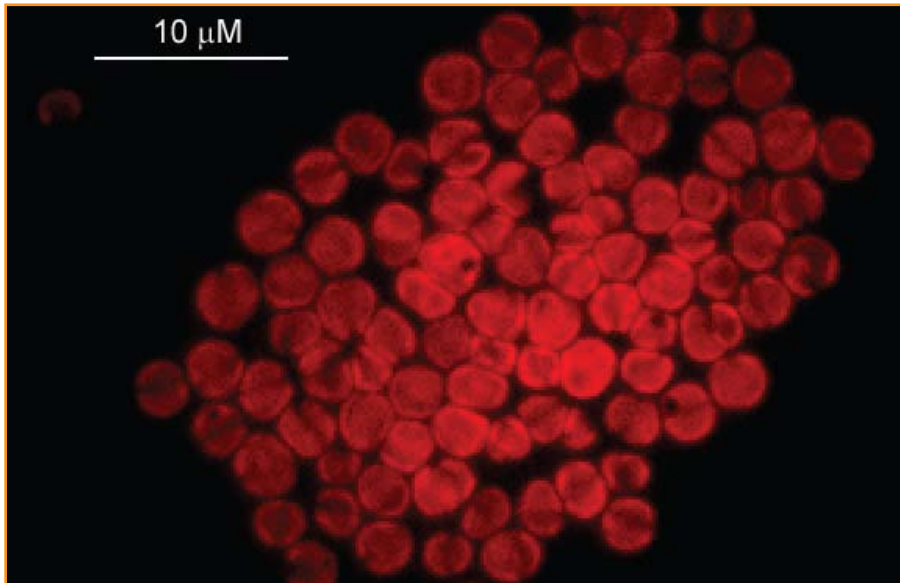
Marine science cannot continue to overlook the unseen world of microbes and Australia must build capacity in this area. This is a

medium-term challenge and direction for the Institute. Over the quadrennium, we will build our capacity by focusing on two areas where microbial processes are clearly central to issues of immediate concern to the world's coral reefs.

'Coral symbiosis' is a mutually beneficial association between organisms of different species and is fundamental to the performance of reef building corals and hence the existence of coral reefs. The combination of the coral animal host and its intracellular zooxanthellae, which are non-motile dinoflagellates capable of photosynthesis, captures more energy for growth by the coral than is available to the animal when relying on heterotrophic nutrition alone. The coral-algal symbiosis is a delicate partnership, however, that is disrupted by the combination of high temperature and strong light – the classic summer conditions leading to coral bleaching, especially when temperatures are elevated for sustained periods. Until recently, coral bleaching looked like a simple mismatch between the needs of two mutualists but the coral 'holobiont' is now known to include the coral, multiple genetic clades of zooxanthellae, fungi, endolithic algae, and more than 30 species of bacteria. The interactions within this complex community will form the basis of a three-year project to understand the biochemical and molecular mechanisms behind coral bleaching in order to improve our fundamental understanding of the coral-algal symbiosis and to help predict the stability and adaptability of this symbiosis to changing external conditions.

Marine microbes (prokaryotic, eukaryotic and viral) are also involved in a variety of important symbiotic relationships with other marine invertebrates including sponges, cnidarians, molluscs, echinoderms and nematodes. Potential synergies in these relationships include enhancement of nutrition (as with corals), enhancement of thermal tolerance, assistance with reproduction, contribution to structural rigidity, waste reduction and the production of secondary metabolites used in defence, immune competence and other functions that promote the survival of multicellular organisms in complex, hostile and changing environments. We propose to enter this area by studying the symbioses of micro-organisms known to occur within sponges and to test these relationships by experiments mimicking expected climate change (experiments with crossed treatments of temperature, pH and nutrients).

Not all associations between multicellular organisms and microbes are symbiotic. Many are pathogenic and the Team will also investigate coral diseases with a particular interest in the mechanisms that may explain the increased incidence of coral disease throughout the GBR that was observed by the AIMS long-term monitoring team after the last episode of coral bleaching. This study will start with observations on the bacterial assemblages found in coral mucus under normal conditions and by manipulating the internal and external nutrient environments. This research will contribute to the MWQEH Team's research to develop bacterial coats (biofilms) as novel indicators of changes in water quality (see page 23).

Key Result Area 4.1:**UNDERSTAND AND PREDICT THE RESPONSES
OF REEF SYMBIOSES TO ENVIRONMENTAL CHANGE****Description**

A multidisciplinary research effort will describe the key biochemical and genetic mechanisms that buffer tropical reef symbioses against external stresses. As well as insights into the fundamental functioning of these important coral reef associations, the research will describe the tolerance limits and predict when these symbioses will be unstable and why. This molecular understanding will complement the investigations of individuals and populations being done by the climate team (Key Result Area 3.3).

The project will have four elements. Firstly, development of a genetic technique to quantify bleaching resistance in corals based on sequence analysis of a set of neutral and functional genes. Once developed, this technique will be used to assess the vulnerability of corals to climate change which will contribute to climate impact risk and vulnerability assessments for the GBR (Key Result Area 3.2).

Secondly, determination of the resilience of coral populations to bleaching conditions based on estimates of genetic connectivity among GBR populations of coral and their algal endosymbionts. This will show the potential for replenishment of populations from other sources following mortality caused by rising sea temperatures.

Thirdly, an integrated biochemical and genomic approach will be applied to determine the molecular and physiological triggers causing coral bleaching in response to environmental change. The research will focus on host-symbiont signalling interactions and be measured

by shared metabolic responses to oxidative stress. These results will feed into models of the potential for corals to evolve greater bleaching resistance in response to climate change.

Finally, we will conduct experiments that place corals under stress to probe biochemical mechanisms (such as cell-cell communication) and genetic processes (including gene exchange and genetic drift) that underpin the evolution of symbiotic relationships in a changing environment. We will elucidate shared metabolic pathways, and the role of secondary metabolites, in maintaining symbiotic relationships. The metabolic function of symbioses will be examined with a primary focus on their chemical ecology. Gene exchange (among host species as well as between host and viral symbionts) will be investigated as this can lead to novel function as well as increased genetic diversity and therefore scope for adaptation to climate change.

Planned Outcomes

- Genetic tools to quantify bleaching resistance in corals that will contribute to risk maps and vulnerability assessments with universal application;
- Theoretical model that predicts the speed of bleaching resistance in GBR coral populations;
- Understand the functioning and limitations of biochemical mechanisms to cope with oxidative stress in coral-algal symbioses; and
- Understand the role of secondary metabolites from symbioses in facilitating or limiting evolutionary adaptation to climate change,

Key Stakeholders

Association of Marine Parks Tourism Operators, Australian Research Council, Commonwealth Environment Research Facility, Great Barrier Reef Foundation, Great Barrier Reef Marine Park Authority, Netherlands Foundation for Tropical Research, Swedish Research Council, United States National Science Foundation.

Initial Focus of Plan

- Test competing models of genotypic vs phenotypic stress tolerance through aquarium experiments in controlled environments using colonies with known genotypes at functional loci;
- Genotype populations of Acroporid corals and their Symbiodinium populations (using microsatellite loci) to understand potential for reseeded after bleaching from exogenous sources;
- Culture a genotyped zooxanthella population and run pilot experiments examining the effects of trace metal limitation on oxidative stress in bleaching corals to understand the role of Coenzyme Q and the plastoquinone redox balance as a measure of oxidative stress in bleaching corals; and
- Determine the role of secondary metabolites and their biosynthetic origins (host/microbial) to understand the potential of biochemical mechanisms allowing adaptation to environmental change.

Performance Measures

- Peer-reviewed scientific publications; and
- The responses of reef symbioses to environmental change included in risk and vulnerability assessments for the GBR.

Key Result Area 4.2:**UNDERSTAND THE ROLE OF MICROBES IN THE FUNCTIONING OF HEALTHY AND STRESSED REEFS****Description**

This research will explore key features of microbial disease in tropical waters and reef communities. To achieve this, we must enhance our understanding of the impact of environmental change on corals and sponges and their microbial partners.

The research will provide valuable baseline data on disease aetiology and the potential impacts of environmental change on invertebrate-microbe relationships. The goal is a diagnostic tool for the assessment of reef health. Specifically, the project will examine the impact of changing water quality (potential nutrient stress) and increased temperature upon microbial biofilms including those coexistent with corals. Ultimately we plan to build a genetic microarray based on microbial sequences that will be useful for rapid assessment and monitoring.

The project will have three key elements. Firstly, monitoring the incidence of coral disease on the Great Barrier Reef to connect disease outbreaks with environmental variables (e.g. temperature) and to assess the impact of disease on coral reef populations. From this we should learn whether some coral-algal symbioses are more vulnerable to disease than others.

Secondly, we will study the response of bacterial symbionts to pathogenic attack and other stresses through controlled experiments designed to identify vulnerability thresholds.

Finally, we will build our capacity with marine viruses through collaboration with the Menzies School of Medical Research to study some recent hotspots of marine viral activity in the Northern Territory resulting in necrotising infections in humans.

The overall objective of this project is to increase knowledge about microbial community ecology and pathogen virulence against a backdrop of imminent environmental change.

Planned Outcomes

- ▣ A diagnostic tool for the assessment of reef health;
- ▣ A spatial risk assessment for coral reef disease in the Great Barrier Reef; and
- ▣ Increased capacity to study marine viruses.

Key Stakeholders

Association of Marine Parks Tourism Operators, BioScience North Australia, Charles Darwin University, Commonwealth Environment Research Facility, Great Barrier Reef Marine Park Authority, MacArthur River Mines, Menzies School of Medical Research, World Bank.

Initial Focus of Plan

- ▣ Conduct temperature stress experiments on symbiont profiles within sponges and corals to assess vulnerability thresholds;
- ▣ Conduct experiments on diseased corals and sponges to discover the responses of symbionts to pathogenic attack; and
- ▣ Characterise *Vibrio* isolates from hotspots in the Northern Territory to determine normal and abnormal bacterial/viral loadings.

Performance Measures

- ▣ Peer-reviewed scientific publications; and
- ▣ Coral reef disease risk included in risk and vulnerability assessments for the GBR.

Operating Strategy

AIMS employs an integrated and multidisciplinary approach to marine science. It has the expertise and capability to explore and examine the marine environment through studies ranging from regional ship based investigations to state-of-the-art microbial and molecular analysis. In support of its research objectives, AIMS has adopted an operating strategy focused on the continual improvement of its three foundational pillars of people and process, scientific capital and relationships.

RESPONDING TO CHANGE

Responding to change is both an organisational and scientific necessity for AIMS. AIMS has established a research plan based on achieving its strategic science objectives. These objectives have been established in consultation with key stakeholders, however it is a continual process identifying issues and user needs, reviewing our capabilities (people, infrastructure and resources) and refocusing our efforts. AIMS requires the ability to respond to these challenges. Nowhere is this emphasised more clearly than with the increasing need to understand the impact of climate change on the marine environment and its ability to adapt. This is driving AIMS to not only focus increased resources in this area but to also develop capabilities in new scientific areas such as microbiology. Similarly with the need to support the conservation and management of marine natural resources in Western Australia, AIMS requires the ability to refocus its resources into this area.

AIMS organisational structure is centred around four science teams; these are assisted by support staff that provide specialist services to these teams. This structure enables AIMS to quickly adjust its science focus with minimum disruption and maximum effectiveness. Funding and cost savings achieved in 2006–2007 have further added to AIMS flexibility by enabling a significant increase in post-doctoral fellows and enhanced capability in the development and application of novel marine technology.

FOUNDATION 1: PEOPLE AND PROCESS

AIMS employs approximately 191 staff and has a significant relationship with a further 50 researchers located at and supported by AIMS, comprising visiting scientists, PhD students and post-doctoral fellows. AIMS indirectly employs the equivalent of a further 20 persons via major outsourcing contracts. This combination of people represents AIMS most valuable asset, and they are the single most crucial component to achieving the stretch targets contained within research goals. AIMS continually strives to create an environment where the full capabilities of its people are realised and during the quadrennium the focus will be on three key areas:

Culture

AIMS values people and a key strength is the innovation, commitment and scientific excellence it displayed by its workforce. This is reflected in the broad-spectrum recognition at a national and international level of scientists and support personnel. It has adopted effective and efficient management practices that recognise and reward achievement. AIMS desires to build on this base and create a world-class high performing culture based around the principles of continuous improvement, values and behaviours, leadership, performance management and the celebrating of success. Over the quadrennium these principles will be the focus of several improvement programs including:

- ▣ Continuous improvement as a formal process;
- ▣ Leadership development; and
- ▣ Alignment of values and behaviours.

Science Capability

AIMS has core scientific capabilities in three disciplinary areas: marine ecology, oceanography and biotechnology. The Institute also has great support for marine technology and an emphasis will be placed on technological innovation to ensure that we are working smarter not harder in the new quadrennium.

As in our past, we acknowledge that one of the most effective ways to work smarter is to collaborate with others and the AIMS science core is now widely leveraged by collaborations with domestic and international partnerships. The latter range from informal peer networks created among scientists to formal MoUs for collaboration with foreign agencies such as the United States National Oceanic and Atmospheric Administration, which covers joint work on climate change. New developments in this area will include the integration of our ocean observing activities (enhanced by AIMS leadership of Australia's Integrated Marine Observing System (IMOS), and the Great Barrier Reef Ocean Observing System (GBROOS)) into international networks like CREON, GOOS, and ILTER. On the domestic front, we have negotiated a MoU with Geoscience Australia for closer collaboration on seabed habitat mapping and will continue to support strategic Joint Ventures including AIMS@JCU, WAMSI in Perth and the Arafura-Timor Research Facility in Darwin. Benefits from these collaborations include access to a broader skill and infrastructure base, more cost-effective utilisation of infrastructure, and improved training opportunities for research students and early career scientists.

Above all, we recognise that people are the most important ingredient in successful science delivery and we have committed substantial resources to identify current capabilities and future needs. This includes building the cadre of early career marine

scientists who can take advantage of the extensive infrastructure that AIMS operates for the national benefit before moving into professional careers in Australian universities, research and management agencies, and industries. Our aim is to reward our experienced scientists, those that attract top quality post-doctoral fellows, and to recruit at least 15% of our scientific workforce from internationally-competitive AIMS post-doctoral fellows by the end of the quadrennium. This will enhance existing capabilities and allow us to establish new skill sets to complement those of our current research leaders.

Processes and Systems

AIMS has a good foundation of processes and systems established to support its research objectives along with expanding stakeholder expectations. These processes and systems are enabling AIMS to achieve its high levels of science output and further demonstrate the qualities of innovation and creativity within AIMS. Complementing our science review and taking the opportunity to improve process and system efficiencies, AIMS will undertake a major review of its core processes and supporting corporate systems over the next two years to improve overall efficiencies, reduce the exposure of scientists to non-science tasks, and improve the information available to support the science operations.

FOUNDATION 2: SCIENTIFIC CAPITAL

AIMS has world class significant scientific capital contained within its infrastructure, innovative technology, science collections and databases and knowledge.

Our Infrastructure

AIMS is located in Townsville, Perth and Darwin. The Perth and Darwin sites are located on the campuses of local universities. AIMS WA is housed with WAMSI on the campus of the University of Western Australia. AIMS NT is part of the ATRF site on the Australian National University's Darwin campus which adjoins Charles Darwin University. Our headquarters are at Cape Ferguson near Townsville in a 12,500m² complex established on a 207 ha beachfront site surrounded by Marine Reserve and National Park (in a scientific research zone), with a high level of natural biosecurity. Located on the coast at the geographical



centre of the coastal edge of the Great Barrier Reef, this site enables a fast transition from the sea to the laboratory, as well as access to high-quality coastal water. Alternatively, with the use of our ships we can take the laboratory to the reef. The complex contains scientific, engineering, vessel operations and science data and sample management, along with corporate and administrative facilities.

- Laboratory capabilities include an integrated high-tech research facility for identification of marine molecules and advanced biosecure laboratories with a PC2 facility. These are further supplemented by a suite of analytical chemistry and microbiology laboratories.
- AIMS has been steadily developing its seawater precinct and now delivers up to 700,000 litres of treated seawater per day into a range of aquaria, aquaculture facilities and controlled environment seawater rooms. Over the quadrennium this capability will be further expanded with additional water treatment capability and the Centre for Marine Microbiology and Genetics (CMMG) will provide PC2-compliant flow-through aquarium rooms and laboratory facilities. The CMMG will deliver marine microbial and genetic research leading to an understanding of tropical reef processes and advancing applications to conserve and sustainably utilise the marine genetic resources of tropical Queensland. The CMMG has been financed partly by the Queensland Government Smart State Fund.
- Field Operations controls the logistics of all AIMS vessels and provides berthing facilities for research vessels up to 34.9 m.
- Data (information) management and knowledge delivery is a crucial capability underpinning research, particularly with the advent of computerised modelling and the move to real-time monitoring. AIMS now has a high capacity data management centre, supplemented through a fibre optic high bandwidth link into the AARNET system. Throughout the quadrennium this team will be focused on further developing capabilities to maximise the data management effectiveness along with improving the availability of information and knowledge products to scientists both at AIMS and to collaborating organisations.

Two large purpose-built scientific research vessels, the RV *Cape Ferguson* and RV *Solander*, support access to the tropical waters off Queensland, the Northern Territory and Western Australia. The RV *Cape Ferguson* is 24 m in length with 14m² of dry laboratory space and 10 m² of wet space, and accommodates 9 researchers. The RV *Solander* is 34.9 m in length with 20.6 m² of dry laboratory space and 12.5 m² of wet laboratory space, and will accommodate 18 crew and researchers. The RV *Cape Ferguson* will focus on supporting research on the Great Barrier Reef, while the RV *Solander*, with its larger size and greater oceanographic capabilities (including a moon pool), is better suited to supporting the increasing volume and range of work being undertaken in the open waters off Western Australia. These vessels are supported by 3 smaller trailer-mounted aluminium vessels between 6 m and 8.5 m in length.

Our Technology

Innovative marine research requires innovative technology and many of AIMS field and laboratory studies are achieved with specialised equipment developed and/or adapted in-house by our scientists and technologists working together with our integrated Engineering Facility. In the rapidly evolving field of biotechnology, we are constantly updating our equipment as well as our skills in the molecular sciences to apply cutting-edge science to the challenge of observing our marine environment.



In the next quadrennium, AIMS will invest in:

- ▣ Real-time ocean measurements linking biological and physical processes;
- ▣ In-sea visualisation and automated intelligent monitoring of marine systems; and
- ▣ Biotechnological tools for monitoring ecosystem processes.

Over the last 10 years AIMS has been developing technologies to augment the observations collected by divers. This is essential for surveying habitats deeper than 20–30 m but can also be a more cost-effective replacement for some types of monitoring in shallow water. Ultimately, new observation technologies including remote sensing will reduce the need for physical site inspections, which is essential as we seek to know the status and trends of marine ecosystems across all of northern Australia.

In the next four years, we will build and implement a real-time remote sensor network in key areas of the GBR. This will be a significant collaboration between AIMS and the network of island research stations, with other technology partners. Along with providing the research community with continuous monitoring of the marine climate at these locations, the communications backbone of the network will allow researchers with local platforms access to collecting intensive real-time data for specialised applications via plug-and-play wireless environmental sensor network technology. This will revolutionise monitoring of the GBR at a time when there is a great need to understand how reef ecosystems will respond to changing conditions in the oceans caused by climate change.

Our Collections, Data and Knowledge

AIMS possesses collections, observations and measurements containing extensive information about Australia's tropical marine ecosystems extending from the Great Barrier Reef to those off north-western Australia, and these nationally valuable assets continue to grow. They include:

- ▣ Two decades of water quality measurements from the Great Barrier Reef;
- ▣ Fifteen years of field measurements on coral reef health from the Great Barrier Reef;
- ▣ Over a decade of measurements of biodiversity, ecological change and oceanography at Scott Reef off north-west Australia;
- ▣ Two decades of biodiversity sampling from around the continent for biodiscovery;
- ▣ Coral cores that record environmental conditions ranging up to 1,000 years from the Great Barrier Reef; and
- ▣ Integrated oceanographic models of processes ranging in scale from single reefs to the entire ecosystems such as the Great Barrier Reef.

Sophisticated mathematics and modelling can integrate this information and enable the investigation of previously unanswerable questions about how tropical marine ecosystems function and respond to change. Revealing these previously hidden patterns will allow us to more fully understand the past and project forward into the future. The most powerful knowledge is that which can be widely understood. Modern visualisation and communication tools will be used to convey the knowledge gleaned from AIMS information base to enable resource managers, decision-makers and planners to make the wisest judgements.

FOUNDATION 3: RELATIONSHIPS

AIMS implements a strongly collaborative approach to its research. Scientists work in partnership with other research institutions, managers and key stakeholders to deliver high quality research to improve understanding of the complex processes sustaining tropical marine ecosystems. The transfer of knowledge and technologies generated from the Institute's research supports the sustainable use and protection of the marine environment and is the fundamental purpose of AIMS. To this end, AIMS uses a variety of targeted mechanisms to transfer research outputs to all users (e.g. scientific publications, presentations, user group forums, direct linkages to users, media and the internet).

Leveraging Investment and Building Critical Mass

AIMS adds value to the government's investment by successful implementation of a collaborative approach and through co-investment with industry, other research providers, and users of marine science. AIMS research collaborations and strategic alliances enhance its capacity to address complex marine science questions by building critical mass, linking to specialist science skills, and gaining access to data and research infrastructure – leveraging investment by the government in AIMS.

In addition to strong researcher networks which underpin the high level of collaborative research undertaken at AIMS, the Institute has also established strategic organisational links through joint ventures and alliances. Current examples include AIMS@JCU, the Arafura-Timor Sea Research Facility, the Census of Marine Life CReefs Project, the Integrated Marine Observing System, the Marine and Tropical Sciences Research Facility, the Western Australian Marine Science Institution and the research alliance with the United

States National Oceanic and Atmospheric Administration, Great Barrier Reef Marine Park Authority and Queensland University. AIMS has an ongoing commitment to these arrangements and over the next four years will see expansion of relationships with Queensland agencies to deliver the Great Barrier Reef Ocean Observing System (as part of the Integrated Marine Observing System).

Stakeholder Relationships – a Key to Effective Delivery of Research Outputs

AIMS maintains strong links with users of its research to: ensure the ongoing relevance of its research; coordinate effort; and enhance the effectiveness of transfer of new knowledge to users. In addition to strong researcher networks which underpin the high level of collaborative research undertaken at AIMS, the Institute has also established strategic organisational links through joint ventures and alliances. The collaborative nature of AIMS co-investment in multi-agency research, as noted above, enhances the Institute's total investment in science and subsequent returns to Australia. Applying this collaborative approach and continuing to grow AIMS relationships with users of marine science will help us improve the transfer of research outputs to them. This will include further development of AIMS relationship with managers, regulators and key industries operating in north-west Australia, especially the offshore oil and gas industry.

Managing and Reporting Performance

AIMS provides leadership in tropical marine science and is committed to science quality and the effective transfer of research outputs to users to enhance the uptake of its research. Ongoing evaluation of performance is a critical component of maintaining the Institute's contribution to the national innovation system and AIMS has established systems for developing, managing and assessing the research portfolio.

Regular review of performance and capabilities is a critical component of planning and continuous improvement at AIMS. At the operational level, research teams are responsible for achieving research goals that have been identified and agreed with stakeholders as being valid contributions to achieving intended outcomes. Team activities to deliver these outcomes are described in implementation/operational plans against which teams prepare annual reports of progress and achievements. Assessment comprises regular monitoring and assessment of team performance against milestone based implementation plans within AIMS, and periodic external expert review.

The integration of regular reporting and evaluation into AIMS planning provides a mechanism for ongoing review of performance and effective allocation of resources. Taken together, AIMS performance management system allows monitoring and evaluation on the effectiveness of the Institute's research and performance in relation to quality, leadership, relevance, and efficiency. AIMS system of evaluation includes:

- Annual assessment and reporting of performance against performance indicators. AIMS reports against performance indicators that have been agreed between the Australian Government and the Institute as part of its Funding Agreement. Performance against these indicators is reported each year in AIMS Annual Report and demonstrates ongoing productivity and the relevance and impact of the Institute's research;
- The regular submission of research findings to external review by peers in science publications. AIMS continues to be recognised for its leadership and expertise in

tropical marine science and has been consistently ranked in the top 1% of research institutions in the world in the fields of Environment and Ecology, and Plant and Animal Science, based on journal citations;

- The annual cycle of staff performance appraisal. The annual performance agreement for staff provides a framework for effective performance management, through clear communication of work requirements, alignment of corporate and individual goals, and regular performance feedback; and
- External, expert review of research teams. Expert reviews provide independent, discipline-relevant assessment of AIMS research performance. The review provides assessment of science quality and user impact.

Appendix 1.

National Research Priorities

NATIONAL RESEARCH PRIORITY GOALS

A. An Environmentally Sustainable Australia

Transforming the way we utilise our land, water, mineral and energy resources through a better understanding of human and environmental systems and the use of new technologies.

1. Water – a critical resource
Sustainable ways of improving water productivity, using less water in agriculture and other industries, providing increased protection of rivers and groundwater and the re-use of urban and industrial waste waters.
2. Transforming existing industries
New technologies for resource-based industries to deliver substantial increases in national wealth while minimising environmental impacts on land and sea.
3. Overcoming soil loss, salinity and acidity
Identifying causes of and solutions to land degradation using a multidisciplinary approach to restore land surfaces.
4. Reducing and capturing emissions in transport and energy generation
Alternative transport technologies and clean combustion and efficient new power generation systems and capture and sequestration of carbon dioxide.
5. Sustainable use of Australia's biodiversity
Managing and protecting Australia's terrestrial and marine biodiversity both for its own value and to develop long-term use of ecosystem goods and services ranging from fisheries to ecotourism.
6. Developing deep earth resources
Smart high-technology exploration methodologies, including imaging and mapping the deep earth and ocean floors, and novel efficient ways of commodity extraction and processing (examples include minerals, oil and gas) while minimising negative ecological and social impacts.
7. Responding to climate change and variability
Increasing our understanding of the impact of climate change and variability at the regional level across Australia and addressing the consequences of these factors on the environment and on communities.

B. Promoting and Maintaining Good Health

Promoting good health and well being for all Australians

1. A healthy start to life
Counteracting the impact of genetic, social and environmental factors which predispose infants and children to ill health and reduce their well being and life potential.
2. Ageing well, ageing productively
Developing better social, medical and population health strategies to improve the mental and physical capacities of ageing people.
3. Preventive healthcare
New ethical, evidence-based strategies to promote health and prevent disease through the adoption of healthier lifestyles and diet, and the development of health-promoting products.
4. Strengthening Australia's social and economic fabric
Understanding and strengthening key elements of Australia's social and economic fabric to help families and individuals live healthy, productive and fulfilling lives.

C. Frontier Technologies for Building and Transforming Australian Industries

Stimulating the growth of world-class Australian industries using innovative technologies developed from cutting-edge research

1. Breakthrough science
Better understanding of the fundamental processes that will advance knowledge and facilitate the development of technological innovations.
2. Frontier technologies
Enhanced capacity in frontier technologies to power world-class industries of the future and build on Australia's strengths in research and innovation (examples include nanotechnology, biotechnology, ICT, photonics, genomics/phenomics, and complex systems).
3. Advanced materials
Advanced materials for applications in construction, communications, transport, agriculture and medicine (examples include ceramics, organics, biomaterials, smart material and fabrics, composites, polymers and light metals).
4. Smart information use
Improved data management for existing and new business applications and creative applications for digital technologies (examples include e-finance, interactive systems, multi-platform media, creative industries, digital media creative design, content generation and imaging).
5. Promoting an innovation culture and economy
Maximising Australia's creative and technological capability by understanding the factors conducive to innovation and its acceptance.

D. Safeguarding Australia

Safeguarding Australia from terrorism, crime, invasive diseases and pests, strengthening our understanding of Australia's place in the region and the world and securing our infrastructure, particularly with respect to our digital systems

1. Critical infrastructure
Protecting Australia's critical infrastructure including our financial, energy, communications and transport systems.
2. Understanding our region and the world
Enhancing Australia's capacity to interpret and engage with its regional and global environment through a greater understanding of languages, societies, politics and cultures.
3. Protecting Australia from invasive diseases and pests
Counteract the impact of invasive species through the application of new technologies and by integrating approaches across agencies and jurisdictions.
4. Protecting Australia from terrorism and crime
By promoting a healthy and diverse research and development (R&D) system that anticipates threats and supports core competencies in modern and rapid identification techniques.
5. Transformational defence technologies
Transform military operations for the defence of Australia by providing superior technologies, better information and improved ways of operation.

