

Autonomous Underwater Vehicle 2010-2013 IMOS EIF Facility Project Plan

Overview:

Proposed Infrastructure Investment:	AUV monitoring of benthic reference sites
IMOS Facility:	IMOS AUV Facility
Operating Institution:	Sydney Institute for Marine Science
Facility Leader (for this Proposal):	Dr. Stefan B. Williams Australian Centre for Field Robotics, University of Sydney Sydney Institute for Marine Science Ph: 02 9351 8152 / 0403 849 183 Email: stefanw@acfr.usyd.edu.au
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Collaborating Institutions:	CSIRO AIMS SIMS University of Sydney University of New South Wales University of Tasmania University of Western Australia Tasmanian Aquaculture and Fisheries institute Parks Victoria DECCW

Nature of Investment:

A nationally focused IMOS AUV facility to provide precisely navigated time series measurements of benthic imagery using Autonomous Underwater Vehicles (AUVs) at selected reference stations on Australia's shelf. The facility will incorporate a suite of observing programs that capitalize on the unique capabilities of AUVs into IMOS, and will provide a critical observational link between oceanographic and benthic processes. IMOS has, and will maintain, a strategic focus on the impact of major boundary currents on continental shelf environments, ecosystems and biodiversity. To support a more complete understanding of natural, climate change, and human-induced variability in shelf environments, the facility will generate physical and biological observations of benthic variables that cannot be cost-effectively obtained by other means.

Data streams to be produced will include precisely geo-referenced benthic imagery, multibeam swath bathymetry, Conductivity, Temperature, Depth (CTD) profiles and fluorometer data measuring chlorophyll-a and colored dissolved organic matter (CDOM), turbidity (scattering in red) and photosynthetically active radiation (PAR), at the benthic reference sites. This proposal

outlines the implementation strategy and funding requirements to support capital, salary and operating costs associated with generation of these data streams. A second element of enhancement of the IMOS AUV Facility sought support for the establishment of pelagic reference transects that would use a REMUS AUV to collect high-resolution Acoustic Doppler Current Profiling (ADCP), fluorometer and CTD observations at cross shelf transect locations. This element of the proposal was deemed outside of the current scope of IMOS investment and better suited to a future round of funding.

Investment in this facility will comprise

- Extension of the current funding that supports benthic imaging based surveys through on-going support to cover the logistical costs associated with transport, deployment and maintenance of the existing AUV system operated by the Facility.
- Enhancements to the AUV benthic imaging platform and vehicle subsystems to increase coverage by improving speed and reducing turnaround time on deck.
- Support personnel for operations, data processing and management, maintenance and training of end users.
- Mobilization costs of equipment and personnel

Co-investment in this facility has been committed by national research organizations, state government agencies and partner universities and will cover

- Ship time
- Insurance
- Vehicle acquisition
- Management of the facility and partial support for development and operations personnel.

Implementation Strategy:

- **Summary**

The facility will expand from one focused primarily on exploratory, benthic imaging missions to provide repeated, sustained observational programs at a number of reference sites around the country. IMOS nodes have defined the location, extent and frequency of surveying of benthic reference sites and cross-shelf transects to be visited by the Facility's AUVs. Observations will include detailed, high-resolution benthic imaging based surveys designed to support the monitoring of changes in benthic habitats over time.

- **Objectives**

The objectives of the IMOS AUV Facility are to deliver a set of observations suitable for studying spatial and temporal variability in benthic habitats around the country.

Observing program 1 (OP1): Sustained Observations at Benthic Reference Sites

The IMOS Five Year Strategy and the Node Scientific Plans recognize the importance of effectively linking physical and biological observations. This Facility program will provide data streams suitable for the assessment of the effects of climate change and climate variability on benthic communities on the continental shelf, with a particular focus on reef habitats. The strong focus on benthic reef systems is justified because:

- Reefs are among those ecological systems most sensitive to environmental change as they support sessile and sedentary individuals that are unable to relocate once established;
- Dominant species on reefs are largely long-lived species whose dynamics integrate ocean conditions over periods of time from several months to several years;
- They have a disproportionate contribution to marine economic activity in supporting key fisheries and offer potential for bioprospecting;
- Deep reefs in particular are understudied as a result of the difficulties inherent in accessing them and in obtaining highly resolved geo-referenced data beyond diving depths;

- Reefs have prominent physical features that make them ideal for precision monitoring using exactly matching image mosaics through time, as can be generated by state-of-the-art AUV technology demonstrated by the current IMOS AUV Facility.

The existing AUV facility has demonstrated the ability of benthic imaging AUVs to rapidly and cost-effectively deliver high resolution, accurately geo-referenced, and precisely targeted optical and acoustic imagery. This capability makes AUVs ideally suited to undertaking repeat surveys that will be necessary to monitor changes in the benthos, particularly beyond diver depths. Changes in community structure and benthic cover derived from precisely registered maps collected at regular intervals will provide researchers with the baseline ecological data necessary to make quantitative inferences about the long term effects of climate change and human activities on the benthos. In the short term, the facility will also provide stakeholders with data useful for the effective management of marine parks and fisheries where the benthos provides a food source or plays a role in the lifecycle of the target species.

AUVs have the potential to achieve unprecedented coverage of benthic ecosystems. For example the study of Dayton et al (1999) of long-term dynamics in the Californian kelp forests was a seminal work that spanned over 20 years. The actual area surveyed in this work was 1200 m², less than half the area covered annually by the AUV facility at a single Tasmanian site. There is an opportunity to develop a world-leading program of observations through this program.

Benthic observing programs have been designed for both temperate and tropical reef systems.

Observing Program 1.1 Temperate Reef Systems

A key aspect of the monitoring of temperate reef systems, particularly in Victoria and Tasmania but also in NSW, will be to determine rates of change of benthic habitat. Kelp forest habitats on these reefs are predicted to undergo significant change related to changes in boundary current characteristics, contracting at their northern end due to warming and thickening of mixed layer depth, and in the south through the formation of 'barrens habitat' as a result of overgrazing by the long-spined sea urchin, *Centrostephanus rodgersii*. The effects of climate change on the dynamics of the EAC have resulted in the incursion of *C. rodgersii* into eastern Tasmanian and eastern Victorian waters. In this region, the *C. rodgersii* poses a significant threat to the biodiversity, productivity and key fisheries associated with reefs over the depth range 10-40+ m. Long term monitoring of the dynamics of *C. rodgersii* populations and associated barrens habitat is a critical component of the climate change signal, and is necessary to assess responses to manage the *C. rodgersii* problem. Repeated and precisely registered AUV surveys at key sites will enable scientists to describe the extent of kelp habitats, from inshore to deep water areas, and determine changes within these habitats over time.

Observing Program 1.2 Tropical Reef Systems

In Australia's northwest the oceanography is complex and seabed monitoring of offshore and coastal habitats influenced by a mix of regional and local currents has been very limited. At Ningaloo Reef (21°50'S to 23°35'S), where the Leeuwin current is of particular note on the adjacent shelf, and at Scott reef (14°04'S), which is under the influence of the Indonesian throughflow, long term data exists in the respective shallow reef habitats, but until recently data has been virtually non-existent in the majority of waters (>30 m) because of constraints on scientific diving depths. Recent deeper-water seabed surveys at Ningaloo Marine Park and Scott Reef, including missions with the AUV Sirius in depths from 20-150m, have demonstrated that in both areas extensive and diverse benthic habitats exist that contribute significantly to the known biodiversity values of the system.

This plan builds on recent AUV surveys at both locations to implement a monitoring program of the diverse deeper areas of reef habitat at Scott Reef and filter feeding sponge gardens at Ningaloo Reef. The deeper water Scott Reef habitats provide an excellent, large-scale example of the mesophotic reef habitats, which occur throughout the Oceanic Shoals bioregion. They are associated with industry development down the track, but also provide an excellent global reference site to monitor the status of deeper water reef habitats over time in the face of large scale climate related change e.g., SST anomalies and more acute site specific pressures and disturbances such as fishing and cyclones

The deeper shelf areas of Ningaloo Marine Park have been revealed to contain highly diverse filter feeding communities located over relict geological features in depths from 30-90m. These sponge dominated habitats now provide an additional biodiversity attribute for the NMP, which will be factored into management of the park in the future and is to be considered for World Heritage listing (likely proposed Feb 2010). The growth, orientation and feeding of sponges in this region are likely closely coupled to coastal productivity and water movement, which is significantly modulated by the oceanography.

Relevance of Facility Objectives to the IMOS Five Year Strategy

The Facility objectives are closely aligned with the IMOS Five Year Strategy; in particular of the ten Strategic Priorities, this proposal addresses priorities:

2. Impact and delivery through improving model output. OP1 will provide a rich set of spatial and temporal observations that can support ecosystem models extending to the benthos.

5. Continuing to build institutional strengths into national capability. This proposal is carefully aligned with node science requirements and IMOS principles. It engages in an integrated way across several IMOS nodes by establishing a national-scale coastal benthic observing program directly linked to regional observations of the benthos. The AUV Facility will focus on sustained observation to support science that is long term in nature. This facility also has a strong educational component and we will continue to train tomorrow's experts in marine robotics.

6. Exploring the potential for whole-of-system approaches. OP1 brings IMOS to the shelf, generating co-registered multi-modal data suited to multidisciplinary investigations, integrating biology, ecology, physical oceanography and issues of climate change. OP1 offers direct, sustained observation of the benthos together with bathymetry and oceanographic variables at a range of depths and latitudes. The Nodes have selected sites such that prevailing conditions can be inferred from ocean models and observations from moorings. OP1 will also provide an ecological and biodiversity baseline from which to assess the impact of climate and anthropogenically-driven change on shelf communities.

7. Driving down the cost per observation. OP1 offers unmatched levels of spatial precision and repeatability at costs that compare favourably to traditional techniques. OP1 includes upgrades to improve ship time utilization and reduce turn around time of the benthic imaging platform.

9. Ensuring the data is used. The IMOS AUV Facility and the data it produces is being used by members of the Australian research community including UTas/CSIRO Quantitative Marine Science (QMS) Program, SIMS, AIMS@JCU, the UWA/AIMS and the CERF Biodiversity Hub. The current proposal reflects input from a broad range of science users requiring and expecting to use the data.

10. *Partnering for sustained ocean observing.* The IMOS AUV Facility will continue to attract high levels of co-investment. In reflecting the transition to sustained observations, co-investments in this proposal cover multi-year surveys of reference sites.

- **List of major activities** – including major party(s) involved, duration, start, finish

Major activities associated with this facility will include the establishment and repeated survey of benthic imaging reference sites around the country.

Activities OP1: Sustained Observations at Benthic Reference Sites

Figure 1 shows an overview of the proposed benthic reference sites to be visited as part of this program. It is anticipated that these sites will be revisited on an annual or semi-annual basis for the duration of the funding period to provide a sustained set of observations at these locations, including associated AUV-based geo-referenced imagery and bathymetry together with measurements of conductivity, temperature, depth, chlorophyll-a, CDOM, backscatter in red and PAR.

AUV dive sites have been selected to capture habitats at a variety of depths and latitudes along the East and West coasts. The general sampling methodology using the AUV is designed to monitor the fundamental reef processes that maintain reef biodiversity and resilience. The sampling design will be optimised using information from existing survey data to designate particular transect sites. The processes of interest occur at a number of spatial scales so a nested hierarchical sampling method will be adopted as appropriate to detect changes at these differing scales.

1. Broad transects will be used to monitor broad community structure and integrity, community boundaries and transitions.
2. Sparse grids are designed to i) collect meta-population measures for major benthic communities ii) estimate changes in three dimensional reef structure and ii) Estimate change in biomass of sessile benthic primary producers iii) Detect and monitor any signs of disease
3. Fine scale full cover grids will be used to i) facilitate highly accurate fine scale monitoring of reef structure ii) estimate recruitment of sessile organisms iii) monitor boundaries between major sessile benthic groups.

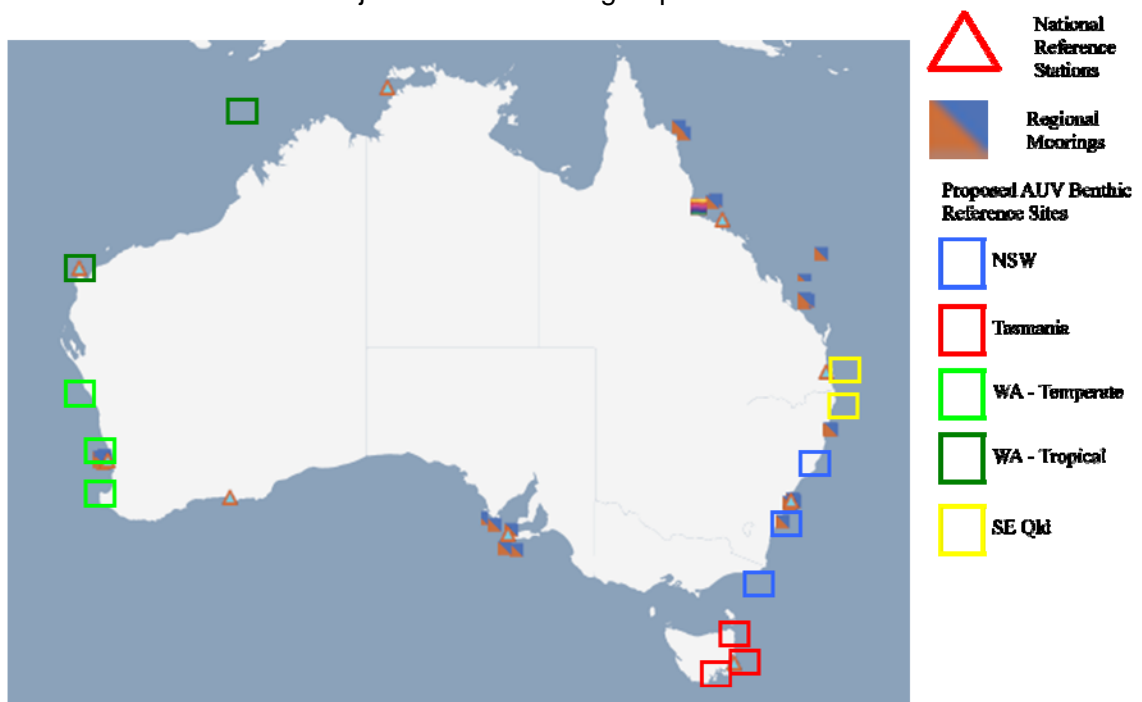


Figure 1 - Proposed benthic monitoring sites. The site markers are colour coded by the proposed deployments.

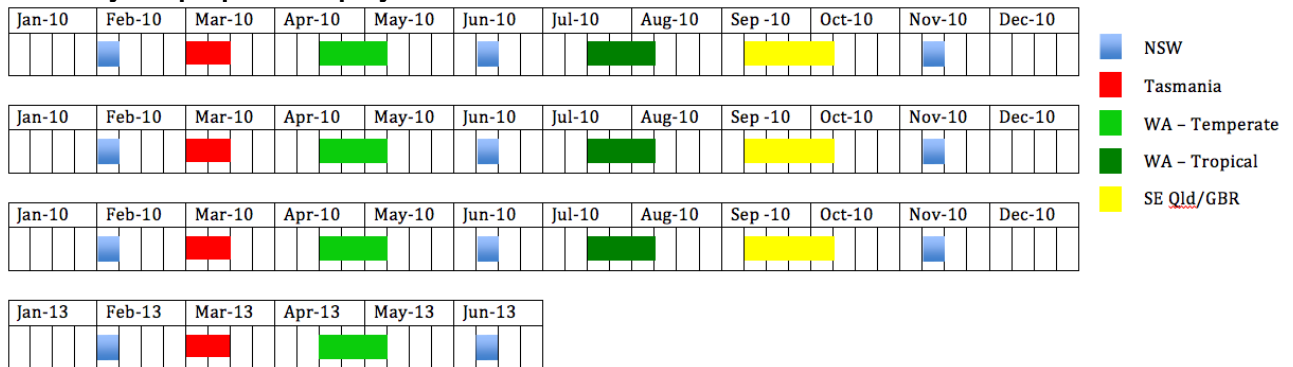


Figure 2 - Proposed Benthic Surveying schedule. The deployments are colour coded to match the markers in Figure 1, with each row corresponding to a year. Dates have been selected based on ship availability and to take advantage of the best weather windows at locations around the country. It is anticipated that between two and four weeks will be required to cover the sites at each location. One week is available either side of each cruise to allow for shipping with additional time provided in the schedule to account for managing data, vehicle maintenance and to allow for delays induced by weather or other unforeseen events.

This approach provides both fine scale, high-resolution surveys of selected areas as well as broader scale grids and transects along depth gradients designed to examine the correlations between populations and underlying bathymetric processes that help shape their distribution.

Because the areal coverage of any measurements will be small relative to areas of interest, we will employ standard ecological sampling designs using replicate stratified permanent transects. For the dense area surveys a fully overlapping survey pattern of 25mx25m and up to 50mx50m is well within the capabilities for repeated surveying of the benthic imaging AUV. These will be located in areas characterised by prior multibeam sonar mapping (to facilitate effective depth and habitat sampling design), and/or prior AUV surveys, and provide a contrast across a range of reef biotopes (e.g. communities with different dominants, reefs with different morphology and physical composition).

Wherever possible, sampling sites have been selected in proximity to mooring lines within each geographic region in order to provide the best possible linkage with medium scale biophysical processes and benthic dynamics. Additional sites focus on the expected limits of the distributions of interest in order to provide a more accurate picture of factors affecting actual changes in distributional range and are more relevant to longer term, potentially climate related processes. The combination of these two sites will therefore address questions at a range of scales relevant to understanding the linkages of the boundary currents with ecological processes. The close linkage and integration of these observations with IMOS node observations along the Australian east and west coasts will allow us to understand and observe processes at still larger scales.

A further element of the monitoring design associated with reefs in Tasmanian, SEQ and NSW is that sites will be chosen inside and outside of recently declared MPAs, where all forms of commercial and recreational fishing and harvesting are prohibited.

Activities OP1.1 Temperate Reef Systems

The latitudinal (N-S) bounds of the reefs to be examined are defined by the distribution of the kelp *Ecklonia radiata*, which is the dominant habitat-forming organism on shallow temperate hard-bottom systems from WA across southern Australia and up to SE Queensland. It is responsible for a large amount of the production of these systems, and is likely to be responsive to climate change. Cover and distribution of the kelp will be monitored on reefs 5-50+ m depth (5-10 m by divers; 10-50+ m by AUV) at key sites within the Leeuwin and EAC-driven systems in WA, Qld, NSW, Victoria and Tasmania. The depth range will include and extend beyond the lower limits of *E. radiata*. It is expected that in the medium – long term, Tasmanian reefs will demonstrate greatest change because significant exposure to EAC water is relatively recent, and because of high rates of endemism. Depth zonation, as well as the biogeographic distribution of kelp, is expected to reflect changes in ocean climate and wave fields. It is also expected that in the medium – long term kelp populations in SEQ, which are restricted to waters >15m, will be reduced dramatically as a result of both general warming trends but also due to deepening of the mixed layer that may inhibit the injection of cooler water across the shelf. Kelp habitats are therefore at risk at both ends of their range.

The EAC and Leeuwin are predicted to change at different rates and to different extents, providing a strong comparative aspect to these observations, as well as a truly national scope to the science questions being addressed. On the East coast, reefs will be monitored in SE Queensland, New South Wales, Victoria and Tasmania using AUV surveys. Major parties involved in this work include CSIRO, Sydney Institute of Marine Science (SIMS), Victoria Parks, the University of Tasmania and the Tasmanian Aquaculture and Fisheries Institute (TAFI). On the West coast, equivalent sampling at corresponding latitudes within the current latitudinal range of *E. radiata* will be conducted to allow comparisons of distributional changes on Western Australian reef communities influenced by the Leeuwin Current. Major parties involved in this work will be the University of Western Australia and CSIRO.

As proposed by the relevant IMOS Scientific Nodes, specific reference survey sites will be established at the following locations:

Eastern Australia and the East Australian Current

- NSW IMOS and Victoria

In order to assess changes in depth distribution, replicate ($n = 3$) cross-shelf transects will be conducted at each of 2 sites at 3 locations in NSW (Cape Byron Marine Park, Batemans Marine Park and Port Stephens Great Lakes Marine Park).

To assess latitudinal changes in *Ecklonia* distribution, four main sampling locations are proposed in NSW that overlap with the sites above. These locations are chosen to span areas close to the northernmost limit of *Ecklonia* kelp forest on the east coast (e.g. Byron Bay) to well within its southern distribution in NSW (Batemans Marine Park). The northernmost location is perhaps most important as it is where we expect to see early/existing changes in kelp distributions. Precise locations will be determined based on the results of preliminary bathymetry, habitat mapping and towed underwater video (DECCW). Where possible sampling will be done in $n = 3$ replicate sanctuary zones in each marine park. At each site we will sample two depth strata with the AUV (10-15m (scuba), 20-30m, and 40-80 m) with 5 replicate transects. Transects will be predominantly based on the fine scale grid surveys.

Parks Victoria will provide support for equivalent sampling in the Cape Howe Marine Park, extending the range of observations to the South.

- Tasmania

There are two elements to the activities in Tasmania

a) Impacts of climate change on key reef species

AUV surveys will enable assessing the abundance of *Ecklonia radiata*, other canopy forming seaweeds and sea urchins *Centrostephanus rodgersii* from stereophoto mosaics (each 25 x 50 m) obtained from the AUV at experimental sites and associated control areas in 15-35 m depth where there have been large scale translocations of rock lobsters (the key predator of *C. rodgersii* in Tasmanian waters) in the vicinity of St Helens (experimental site = Elephant Rock; control site = St Helens Island) and North Bay on the Tasman Peninsula (experimental = Southerly Bottom; control = Cape Paul Lemanon) (Figure 3). These sites are the subject of long term monitoring, and data obtainable through the AUV are far superior and more extensive than can be obtained by other means. Each site will be surveyed every two years over the period to 2013.

In addition, abundances of *E. radiata*, *C. rodgersii* and associated flora and fauna will be obtained from AUV stereophoto transects on rocky substrata ~15-60+ m depth on prominent headlands where incipient *C. rodgersii* barrens are already formed at Cape Tourville (Freycinet area), Mistaken Cape (Maria Island) and The Lanterns (Tasman Peninsula)(Figure 3). Note that for analysis, these data will be combined with information on *E. radiata* and *C. rodgersii* obtained from shallower reefs surveyed as part of the broader survey of reefs described below. Each of these sites will be surveyed every two years over the period to 2013.

b) Meso- and large-scale physics as drivers of reef community structure and dynamics

Four main sampling locations are proposed in the Tasmanian region.

1. On coastal reefs in NE Tasmania adjacent to Cape Barren Island, extending to the shelf break within the Flinders MPA;
2. On coastal reefs in eastern Tasmania adjacent to the Freycinet Peninsula, extending from The Nuggets into the Freycinet MPA;
3. Extending from coastal reefs at The Friars (SE Bruny Island) to the shelf break within the Huon MPA;
4. On coastal reefs extending offshore from Maatsuyker Island to the shelf break within the Tasman Fracture MPA (Figure 3).

At each of these major locations, replicate transects will encompass depth strata ranging from 10 m on the inshore reefs to 200 m on the shelf break, and encompass, with sufficient replication, depth strata planned to be surveyed in matching studies in other states. Prior surveys at depths from 20 m to 100 m within the eastern and SE locations have field-tested the proposed methodology and give confidence that this design will be successful. It is anticipated that 4-5 x 1.5 hour duration missions would be able to be completed each day, with approximately 16 stations at each location, providing four replicates within four depth strata. Shallower strata will be further sub-divided where necessary (e.g. 10-60 m could be encompassed in several locations and sub-divided into 10-20, 20-40, 40-60 etc).

Each of the four sites will be surveyed every two years, i.e. sampling will focus on two locations per year over the period to 2013. High resolution stereo-imagery, temperature, salinity, dissolved oxygen and light levels (PAR) measured by the AUV, hydrology samples for nitrate analysis, and fine-scale bathymetry from multibeam sonar conducted as part of work through the CERF Biodiversity Hub will enable the biological signal to be interpreted in the context of local environmental conditions.

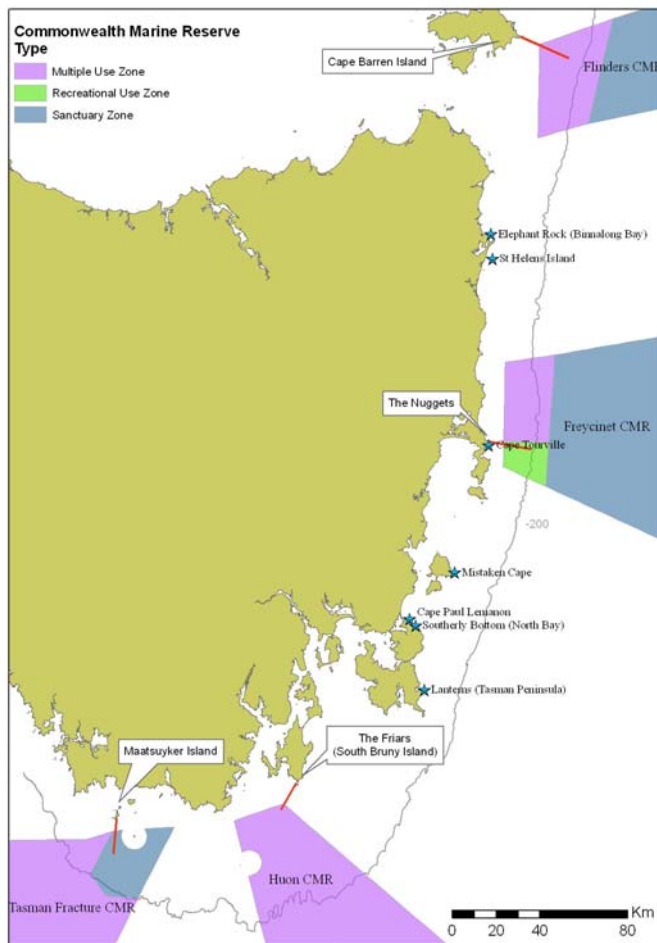


Figure 3 - Location of proposed AUV transects. Relatively short and shallow transects are marked by blue stars, while longer depth stratified transects are shown in red. Use zones of Commonwealth MPAs are shown.

- **SE Queensland (SEQ)**
 Two main sampling locations are proposed in the SEQ region. The first will be located on reefs adjacent to the IMOS mooring line (Figure 4) while the precise location of the second transect will be determined based on the results of exploratory surveys that will define the northernmost limit of *E. radiata* kelp forest on the east coast (believed to be somewhere north of Moreton Is). There will be three depth strata (10-15m, 20-30m, and 40-60m) at each location, with 5 transects within each depth stratum. The transects in this region will be based predominantly on the fine scale, full cover survey grids outlined earlier and targeted at particular reef sites to be identified using fine scale multibeam surveys to be conducted prior to the first deployment of the AUV.

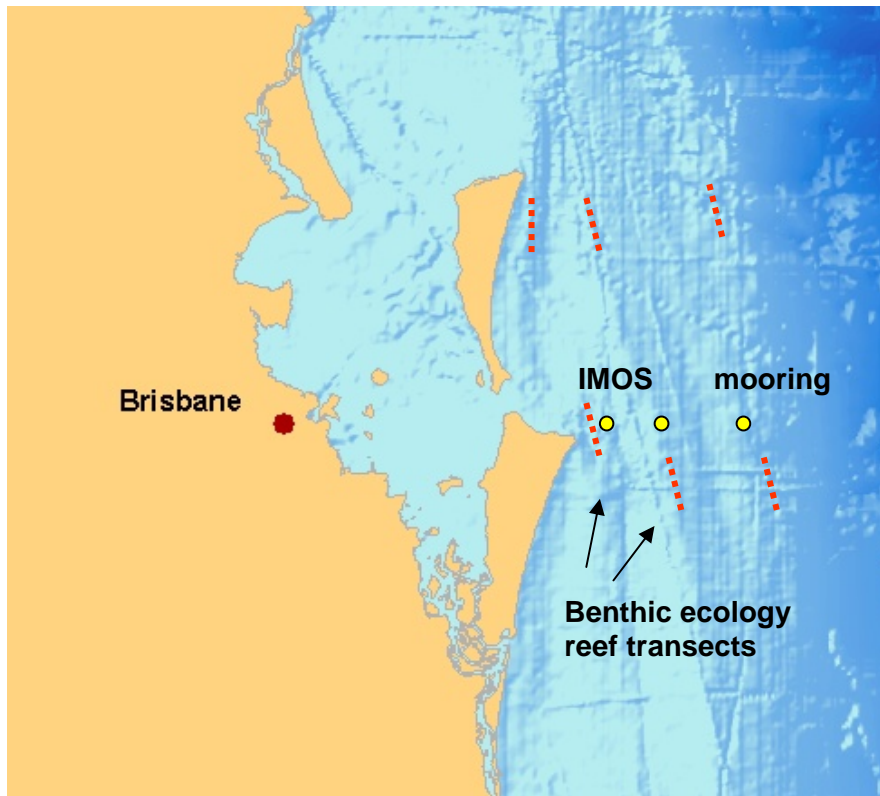


Figure 4 - Map of Moreton Bay and the Coral Sea showing the proposed configuration of benthic transects off southeast Qld. Red dashes indicate the likely location of depth-stratified permanent transects.

Western Australia and the Leeuwin Current

- Western Australia;
The AUV will be deployed in 2 depth zones: 20 – 40 m, 60 – 80 m, at Cape Naturaliste, Rottnest Island, Jurien Bay and Houtmans Abrolhos. These are existing Fisheries ecosystem based fishery management (EBFM) and Western Australian IMOS node (WAIMOS) sites, and represent a coordinated WA state government approach to monitoring for ecosystem change (human-induced and climate-change related).

Because benthic ecosystem dynamics vary as a function of water depth, and their responses likely integrate water column processes we propose making observations across a depth gradient at each of the main National Benthic network locations including the National reference station, Rottnest Island, Western Australia.

Activities OP 1.2 Tropical Reefs

Locations in the tropics have been selected to complement existing long term monitoring programs in shallow waters and to allow these to be extended to deeper water reef systems. The focus of this work will be on describing the distribution, variability and responses to changing oceanic conditions in coral habitats at Scott Reef, WA as well as sponge dominated habitats at Ningaloo, WA. This will build on recent AUV surveys at both locations to implement a monitoring program of the diverse deeper areas of reef habitat at Scott Reef and filter feeding sponge gardens at Ningaloo Reef. These sites will be visited on alternate years.

The deeper water Scott Reef habitats provide an excellent, large-scale example of the mesophotic reef habitats that occur throughout the Oceanic Shoals bioregion. They will provide an excellent global reference site to monitor the status of deeper water reef habitats

over time in the face of large scale climate related change e.g., SST anomalies and more acute site specific pressures and disturbances such as fishing and cyclones. AUV dive sites have been established at Scott Reef, where the Australian Institute of Marine Sciences (AIMS) currently have a long term monitoring program in shallow depths. These sites have been selected to allow the response of coral reefs to be monitored in light of changes in ocean temperature and acidification at a range of depths. Figure 5 illustrates the prior dives undertaken in July, 2009 around which the sustained observing program will be planned.

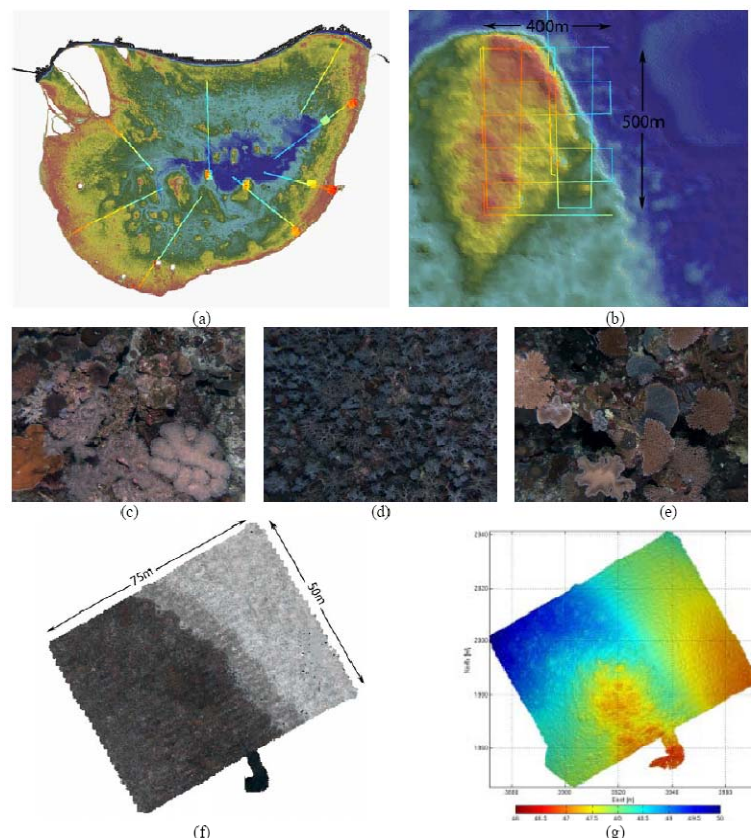


Figure 5 - (a) Scott Reef AUV dive tracks overlaid on the bathymetry. The dive profiles are coloured by inferring depth of seafloor to illustrate the extent of coverage and design of survey profiles. (b) Details of grid survey overlay on the detailed bathymetry. This method was targets a particular seafloor reef feature located near the centre of the lagoon. (c)-(e) Examples of the imagery collected from this illustrating the variety of coral communities imaged by the vehicle. (f) Reconstruction of seafloor at the edge of a coral reef community. The site was targeted as the interface between reef and sandy habitats. Revisiting sites such as these will allow monitor rates of change and turnover in these environments (g) Fine scale multi-beam bathymetry collected by the AUV in the sampling method multi-beam data is gridded at 10 cm resolution

In addition to sites at Scott Reef, benthic reference sites will be established at Ningaloo. The deeper shelf areas of Ningaloo Marine Park have been revealed to contain highly diverse filter feeding communities located over relict geological features in depths from 30-90m. The growth, orientation and feeding of sponges in this region are likely closely coupled to coastal productivity and water movement, which is significantly modulated by the oceanography. Sites to be surveyed at Ningaloo are shown in Figure 6 and have been selected to cover a broad range of habitats and depths over the length of the Marine Park.

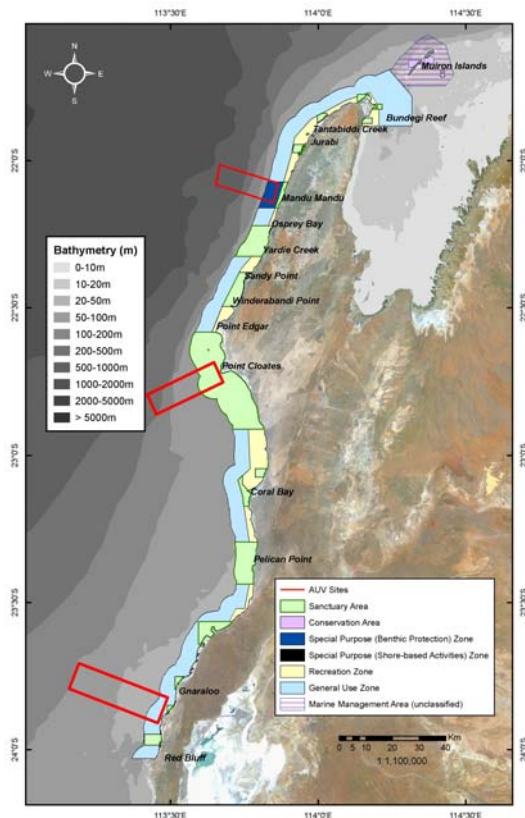


Figure 6 - Proposed cross-shelf benthic survey sites at Ningaloo Marine Park, Western Australia.

On the East coast, sea grass beds in the middle of the GBR lagoon will be established as benthic reference sites in order to understand how their abundance is affected by upwelling coming through the Magnetic and Palm Passages.

- **List of major equipment to be purchased / developed**

Major equipment to be purchased include AUV systems to support the cross shelf reference work as well as the upgrade of systems on the AUV Sirius to support more efficient and potentially more reliable survey operations.

AUV Sirius System Upgrades

The following equipment purchases are focused on improving operational aspects of vehicle deployment.

Imaging Upgrade

The volume of data being collected by the current system requires considerable time to transfer the imagery off the vehicle once the AUV is retrieved. This limits the number of dives that are achievable in a single day. We propose to upgrade the imaging system to facilitate a quicker turnaround between dives. Costs associated with this upgrade are shown in Table 1. We envisage a system that will consist of a pair of cameras permanently mounted in the vehicle with a housing for storage and control of the cameras (i.e. a data pod) that can be quickly swapped out of the vehicle. This design will allow the cameras, which must be calibrated on each cruise, to remain undisturbed while the hard drives are swapped between dives. The data transfer can then take place while the vehicle is underway. The cameras would also be upgraded to a Gigabit Ethernet (GigE) interface,

improving transfer speeds by a factor of 4-10. An additional benefit of this design is the redundancy provided by having multiple data pods. In case of failure of one of these modules, we could still operate with short surface intervals (compared to current ones), even if the unit cannot be repaired at sea. We envisage undertaking this upgrade in three phases over the 2010-2011 period. The first upgrade would involve converting the vehicle cabling and internal switches to GigE throughout. Following this, the new camera system would be commissioned. We would then build a second data pod once the system operation has been validated. This timeframe is reflected in the final budget.

Table 1 - IMOS AUV Facility Imaging Upgrade Budget

Imaging System	Unit Price	Qty	Cost \$k
GigE Vehicle Upgrade	\$7.5	1	\$7.5
GigE Cameras	\$5.0	3	\$15.0
Camera housings	\$2.5	3	\$7.5
Strobes	\$5.0	3	\$15.0
Strobe Housings	\$2.5	3	\$7.5
Computing + Storage	\$5.0	2	\$10.0
Computing Housing	\$2.5	2	\$5.0
		TOTAL	\$67.5

Another attractive feature of this design based on GigE will be the ability to add additional, remote cameras to the system. We have had a number of requests from scientists for periodic higher resolution stills or the ability to look around the vehicle, rather than simply straight down at the seafloor. This will allow for more taxonomic resolution or the assessment of fish assemblages in the survey areas. The current imaging package was not designed to be expanded in this manner and we have not been able to accommodate these requests to date. An additional, wide field of view camera and strobe mounted in the nose of the vehicle and connected to the camera storage unit will allow us to provide imagery around the vehicle while it is underway. This feature would also be added in the third phase of development.

Battery Systems

In addition to an upgrade to the imaging system, the batteries would also to be duplicated to allow these to be swapped at the same time as the imaging storage. These two components are the main sources of lag between dives. Another advantage of sparing these systems is the redundancy introduced. We will construct an additional pressure vessel to house a second battery system and purchase sufficient additional batteries to comprise a complete spare.

Improved Propulsion

Our current operating speed is 1 knot resulting in about 5-8 nautical miles of linear coverage on a typical day of operations. An increase of 50% to 100% of the operating speed would result in a commensurate increase in coverage for the same amount of ship time. The present propellers and gearbox used on the vehicle are optimized to run at 1 knot but there is excess power capacity to drive the vehicle faster. We are requesting funds to purchase a propeller and gearbox combination to increase operating speed. In addition to more efficient use of ship and AUV time, this would also extend our reach into high-current areas.

Photosynthetically Active Radiation (PAR)

Node plans have requested PAR observations in addition to existing measurements of Conductivity, Temperature and Depth as well as fluorometer based measurements of chlorophyll-a, CDOM, and scattering in red. We are requesting IMOS support for an AUV compatible Satlantic multispectral radiometer.

Vehicle

University of Sydney support will be provided to replace the AUV as it is now entering its fifth year of operations. The AUV *Sirius* was originally purchased using a funding provided by the University of Sydney through Sesqui Major Equipment. The vehicle was built at the Woods Hole Oceanographic Institution and we have subsequently equipped it with a comprehensive suite of oceanographic sensors. Its primary purpose is for near bottom, high-resolution benthic imaging. The vehicle was delivered in 2005 and we have operated it on cruises around the country, completing in excess of 100 dives over the past 4 years.

Although we undertake regular maintenance of the vehicle, it will have a finite life span and 6 to 10 years of operation is what might be expected for such a vehicle. We are therefore proposing to begin the process of replacing the vehicle during the course of this round of IMOS funding. With the increased commitment to survey time, the vehicle will be subject to more wear and we would like to begin this process in 2010/2011. Funds committed by the Deputy Vice Chancellor - Research to facilitate this process represent a substantial co-investment in this facility by the University of Sydney. In addition to addressing the issue of replacement, an additional vehicle may provide us with more flexibility in operation and some level of insurance against loss.

We estimate that replacement of the vehicle will require \$350,000 based on the cost of manufacturing and the suite of sensors on the vehicle. Refinement of the design, manufacture and commissioning of the vehicle will take on the order of one and a half years to complete given current commitments.

Access, pricing regimes:

- *How will data access be provided?*

Access to the data streams will be provided through the eMII Oceans Portal. We have established protocols for delivering data through the portal. In keeping with current practice, the data collected by the AUV is processed and geo-referenced onboard the ship. Scientists directly involved in cruises are given a copy of the data products on a hard disk on completion of the expedition. The finished data set is delivered to eMII via the Australian Research Collaboration Service (ARCS) Data Fabric.

As part of these activities, the facility will deliver the following data streams via eMII:

- Geo-referenced imagery
 - Bathymetric maps
 - CTD
 - Fluorometer
 - ADCP
 - PAR/Radiometer
- *How will data and products be managed?*
Data and data products are currently managed by the Facility. Data is downloaded and processed on the completion of each dive. After post-processing, the data products outlined above are generated and a report outlining the dive statistics is produced. The data is uploaded to eMII once the Facility team return from the field.
 - *What are the dependencies on external / other facilities (national and international)?*
Modelling of variability in benthic habitats will complement data being collected by other facilities, including the Moorings Network, coastal radar and gliders. While data collection by the AUV Facility does not depend directly on these other facilities, the scientific interpretation and modelling will be dependent on a comprehensive suite of data.

- *Collaborative structures for allocation of priorities*
An advisory committee will be responsible for allocation of priorities and have had considerable input into the selection of sites and determination of deployment schedules.

Governance

- *Performance indicators*
The performance of the IMOS AUV Facility will be measured against the proposed deployment schedules. An advisory committee will oversee that the data and sites are adequate to address node science requirements.
- *Describe key risks and risk management strategies*
The major risks associated with this facility arise from the possibility of loss of vehicle, departure of skilled and experienced personnel and potentially poor choice of reference sites. Our standard operating procedures mitigate to some extent against risk of loss of the vehicle and we carry a variety of safety systems to minimize the chance of loss. We are proposing to expand the number of qualified operators of AUV systems to reduce the impact on operations in case of the departure of existing personnel. The choice of reference sites has been made in close consultation with the relevant scientific nodes. These sites and transect designs will be refined once the outcomes of this funding process are known.
- Issues raised in the 2008 IMOS Review
 - ***27. The AUV to be funded at around \$400,000 for the balance of IMOS subject to details being provided as part of the 2009/10 business plan.***
A decision was made as part of the 2008 IMOS Review to extend further funding for the AUV Facility. The funding made available to the Facility after the mid-term review was equivalent to \$300,000 and was designed to support personnel and logistical costs associated with on-going work of this Facility.

This proposal outlines the funding required to support a program of sustained observations associated with this Facility.

- ***28. In future the IMOS Office should manage the call for proposals, and also work with the leader to outline a description of how the role of the AUV can be developed in the wider IMOS context***
Given the proposed changes to the nature of operation of the AUV Facility, we will no longer support an on-going call for proposals under the IMOS program. The AUV systems will be fully committed to the program of work outlined here. We anticipate that the IMOS Office will continue to provide us with guidance and feedback on the success of the observing program and its relationship to IMOS.
- ***29. The membership of the AUV advisory committee should be more nationally focused (currently very NSW centric) and promotion of availability to be a key driver***
The following people have been invited to be part of the IMOS AUV Facility advisory committee. They have played a substantial role in defining the scientific rationale for the establishment of the sustained observing programs.
 - Prof. Craig Johnson (U Tas)
 - Dr. Russ Babcock (CSIRO)
 - Prof. Peter Steinberg (SIMS)
 - Dr. Gary Kendrick (UWA)
 - Dr. Moninya Roughan (UNSW)
 - Dr. Andrew Heyward (AIMS)

This group represents a nationally focused membership.

- **30. Investigate ways to utilise the AUV engineering capability more widely in IMOS – there may be synergies for the ANFOG and ACORN capability required in NSWIMOS**

The engineering capability of the AUV Facility has been made available more widely in IMOS. In addition to the support provided through the AUV Facility to AUV deployments around the country, we have participated in all glider deployments and recoveries undertaken in NSW in the past year. While this has amounted largely to managing the deployment and not so much to engineering activities, we are willing to play a larger role in managing glider deployments and providing engineering support where appropriate.

Budget:

Detailed budget in 'Final IMOS EIF Project Plan' submitted to DIISR 26 February 2010

- EIF Funds
 - Extension of existing Facility
As outlined above, the extension to the facility will require on-going support to cover the logistical costs associated with transport, deployment and maintenance of the existing AUV system operated by the Facility
 - Expansion of existing Facility / New Facility
The expansion of the Facility will provide for an upgrade to the AUV Sirius.
- Co-investments – source and nature
 - Ship time
 - Ship time has been committed to support the activities outlined above
 - Academic participants time
 - The leaders of the AUV Facility will continue to invest substantial time and effort to the operation and support of this facility.
 - Technical Support
 - Technical support is available through SIMS and the resources available at the University of Sydney
 - University of Sydney cash (~\$700k)
 - The University of Sydney's DVC Research will make a substantial co-investment to help secure additional infrastructure to the activities proposed of the facility. Additional funds have also been committed by the Faculty of Engineering and the ARC Centre of Excellence for Autonomous Systems.
 - State Government Support
 - A number of state agencies have committed ship time and/or cash to support the activities of the IMOS AUV Facility
- Staffing details
 - Three Technical Officer positions will be supported by the Facility.
 - Software and data management
 - Field Operations benthic, Mechanical and electronics
 - Field operations and logistics for cross shelf transects
- Description of proposed new infrastructure for Nodes – please complete the Table on the next page, referring to Attachment 1 to the Guidelines for further information

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TABLE: Observations required by the Nodes in relation to this Facility

Facility	Observations required by the Node			
	NCRIS Funded (already allocated to Jun11) (see Appendix 1 of the Guidelines)	EIF first \$8M funded (already allocated to Jun10)	Extension of existing facility infrastructure out to 2013.	Enhancements of existing Facilities / new infrastructure required 2010-2013
Bluewater & Climate				
WAIMOS	Benthic observations		Benthic observations	Cross shelf current observations
GBROOS			Benthic observations	Cross shelf current observations
NSW-IMOS	Benthic observations		Benthic observations	Cross shelf current observations
SAIMOS	Benthic observations			
TASMOS			Benthic observations	Cross shelf current observations