WAMSI Biannual Progress Report to 30 June 2009 for

WAMSI Node 1 Project 2 (WAMSI Code 1.2):

Coastal ecosystem characterisation, benthic ecology, connectivity and client delivery modules

WAMSI Project Reference No: 1.2

Project title: Coastal ecosystem characterisation, benthic ecology, connectivity and client delivery modules

Node Leader: John Keesing

Project Leader: John Keesing

Project duration: 1 July 2006 to 30 June 2011

Due date for current milestone report: 30 June 2009

Project Objectives: To better characterise the south west Australian marine coastal and shelf ecosystem structure and function, and enhance our shared capacity to understand, predict and assess ecosystem response to anthropogenic and natural pressures by:

2.1. An assessment of the importance of physical forcing and ecological interactions among key functional groups in determining patterns of spatial mosaics in benthic habitats.
2.2. An assessment of ecosystem processes with particular relevance to contrasting fished and non-fished areas.
2.3. An assessment of likely dispersal patterns for marine organisms based on hydrodynamic and population genetic models.
2.4. Electronic delivery of data and models to management agencies, building on the development of the Data Interrogation and Visualisation Environment (DIVE) in SRFME.

WAMSI Node 1 Project 2 (WAMSI Code 1.2) Coastal ecosystem characterisation, benthic ecology, connectivity and client delivery modules

Executive Summary

2.1 An assessment of the importance of physical forcing and ecological interactions among key functional groups in determining patterns of spatial mosaics in benthic habitats.

The correlation between wave energy at the sea floor and gap size and frequency in kelp canopy habitats (larger and more frequent on the outer edge of the reefs than they are elsewhere) provides the potential to make predictions about how changing climate may impact on the structure and function of temperate reef ecosystems in south western Australia.

Since climate change will affect both wave- and temperature-regimes off the WA coast, understanding of gap formation processes is essential to predicting how this key primary producer will react, and assessing the resilience of WA coastal ecosystems.. While a limited number of studies have attempted to summarise recent trends in wave climate in south west WA, and to understand and predict changes in swell wave generation in the southern ocean, the likely future wave climate in WA under climate change is far from certain, and there is a lack of targeted information on this question for southwest WA.

Experimentally created gaps continue to be monitored in order to better parameterise models of gap formation and infilling. With more than one year elapsed since experimental gap clearance, all gaps a dominated by a similar assemblage of macroalgae and none have yet returned to kelp forest habitat.

Further progress has been made on the development of habitat models aimed at understanding and predicting system dynamics, including the production of a draft manuscript describing the cellular automaton model. The model will allow inter-comparison of both field and model investigations conducted at different resolution in time and space since it is able to account for how changes in the spatial resolution lead to different interpretation of spatial structure. In particular, as the resolution is reduced, that is, as spatial cells are aggregated, the apparent dominance of one habitat type over the other increases.

Specific milestones to be reported on in this period

Milestone 2.1.4 Comparison of model behaviour with reference to observed patterns of patch distribution and modelled wave climate. MS preparation

The findings are summarised above and in detail including with illustrations on page 17 of the full report. A manuscript has been prepared from this work: Craig, P.D.(2009): Imposed and inherent scales in cellular automata models of habitat (in internal review).

2.2 An assessment of ecosystem processes with particular relevance to contrasting fished and non-fished areas

Timely decision-making for ecologically sustainable management requires the ability to rapidly and cost-effectively address the condition of resources and the ecosystems that sustain them. Research in this component of WAMSI Node 1 Project 2 has been directed at assessing the patterns of abundances of key groups of species that are important commercially or ecologically, and at key ecosystem processes that influence, and are influenced by, these patterns. Because one likely important modifying process on the temperate west coast of Australia is fishing by humans, surveys have been structured in a way that uses management units that aim to provide spatial refuges from fishing (sanctuary zones in DEC and RIA managed marine parks).

Surveys of abundance have encompassed finfish, rock lobsters, and large invertebrates, and were conducted at 26 sites during 2007 and 2008. Where possible, surveys encompassed reef, and seagrass and bare sand habitats. In addition, surveys of rates of herbivory and rates of predation have been performed. Sites have included six sanctuaries, two each at Rottnest Island, Marmion Lagoon, and Jurien Bay – these sanctuaries include a range of sizes from ~1 ha to >1,300 ha, and a range of ages from 3 years to 20 years.

Analyses suggest that key targeted taxa (rock lobsters and finfish) are generally more abundant inside sanctuaries that in the same area of equivalent habitat in areas open to fishing. This was especially evident for rock lobsters (5 of 6 sanctuaries). Abundance of rock lobsters and targeted finfish was not simply related to the size and age of a sanctuary, but size and age together explain a statistically significant proportion of the variation in abundance. The greatest responses were in sanctuaries that were old (20 years) or large (>1,300 ha). The weakest responses were observed in small sanctuaries.

In addition, the effects are somewhat context-dependent, with variation in assemblage composition due to differences in habitat (seagrass vs reef) and geography (three different regions: Rottnest, Marmion, Jurien) influencing the results. The underlying processes are complex – for example the compositional differences in Marmion might reflect a greater intensity of fishing pressure over a sustained period rather than true geographical gradients.

The spatial patterns in abundance of targeted taxa were not reflected by the rates of predation on mussels. There was little difference in the rates of survival between sanctuary and fished areas. However, the was a very strong difference between caged and uncaged mussels - uncaged mussels showed very low survival (30%) while caged mussels showed high survival (93%). This result suggests that predation (at least on organisms such as mussels) is likely to be a ubiquitously important process, and is high even where abundances of some predators have been depleted.

Specific milestones to be reported on in this period

Milestone 2.2.3 Draft MS on indicators of resource condition for selected WA coastal benthic systems

Research conducted towards understanding spatial gradients in community composition related to marine park zoning is intended to provide insights into what might be the best indicators of resource condition. The coastal ecosystems of Western Australia provide many resources, but those most germane to our study relate to fish and invertebrate resources accessed by the commercial and recreational fishing and tourism sectors. Analyses of these data is ongoing, but results of analyses to date do indicate that simple indicators might be misleading. For example, spatial gradients in fishing are overlain on geographical gradients in community composition. In addition, indicators that are appropriate for one type of habitat are perhaps not appropriate for other habitats – for example, indicators that are appropriate for reef habitats are not likely to be appropriate for seagrass habitats. Some of these data are presented in the full report on page 33. Analyses of the data will further develop these context dependencies. A manuscript is in preparation that contains summary statistics and comparisons of a range of metrics that have been proposed as indicators of resource condition. This work is still in progress.

2.3 An assessment of likely dispersal patterns for marine organisms based on hydrodynamic and population genetic models.

Sea urchins were sampled between Jurien and Esperance for assessment of population structure using DNA sequence variation. This phylogeographic analysis will be coupled with hydrodynamic dispersal modelling to determine biological connectivity under the influence of the Leeuwin Current system.

We have now developed protocols for reliable DNA sequencing of the Cytochrome Oxidase I mitochondrial gene and four nuclear exon-primed intron crossing (EPIC) regions to assay phylogeographic structure in West Australian urchins. Potentially suitable DNA sequence variability exists across the full sampling range in two species *H. erythrogamma* and *P. irregularis* and these form the basis of the comparative study based on samples at four widely spaced sights (Jurien, Marmion, Albany and Esperance). Sequencing should be completed late in 2009.

To model the influence of hydrodynamic processes on urchin larval dispersal, a deterministic particle tracking model has now been implemented in Matlab for the BLUELink Re-analysis (BRAN) model outputs during 1997-2002. Particle tracking experiments have been carried out to quantify the fate of the Leeuwin Current waters and the modelled larval dispersal patterns among the four urchin sample sites.

Preliminary results show that a significant portion of the Leeuwin Current particles, representing more than one third of the Leeuwin Current southward volume transport, are advected around Cape Leeuwin and eastward into the Great Australian Bight. The rest of the particles are dispersed by the Leeuwin

Current eddies and interaction with the continental shelf. Particle dispersal from sampling sites was generally southward on the west coast and eastward on the south coast, however, substantial northward dispersal was also observed in summer from the west coast sites when the Leeuwin Current flow is weakest and eddy activity is greatest. Dispersal distances were greater in winter when Leeuwin Current activity is greatest. Areas of higher retention or lower flushing rates are visible at several points along the coast indicating potential for the accummulation of larvae. The ecological implications of this result invite further investigation.

Specific milestones to be reported on in this period

Milestone 2.3.5 Population genetic modelling of likely dispersal patterns and generation of null models for comparison with observed genetic structure patterns. Draft MS on observed patterns of genetic structure and what it reveals about potential versus realised dispersal.

With the hydrodynamic modelling now complete (milestone 2.3.2) parameterisation of the population modelling (degree of spatial structure, rates and direction of gene flow and larval migration) awaits completion of the spatial genetic sequencing in milestone 2.3.4. Sequencing of COI and ANT genes in all available specimens from the four sampling regions has been completed and a preliminary analysis of genetic connectivity in one species *H. erythrogamma* has been conducted. Lodgement of these data with GenBank is now possible but effort is currently focussed on completing sequencing at the other loci so that the full genetic analysis can be conducted.

Sequencing is still underway at the other nuclear loci and while this was expected to be completed by March 09, unforeseen delays resulting from reduced quality of PCR amplification and DNA have occurred. Efforts to identify the cause(s) included complete replacement of experimental reagents and repetition of the PCR amplification in another laboratory (courtesy of Murdoch University) and these appear to have succeeded. We now expect to be able to complete sequencing at ATPs alpha within weeks. Lodgement of sequences with GenBank and the full multilocus genetic analysis can then be conducted.

Once this work has been completed, the proposed comparison of hydrodynamic estimates of connectivity with spatial genetic patterns and modelling will then be made and written up. Milestone 2.3.5 is now not expected to be completed until the end of 2009.

2.4 Electronic delivery of data and models to management agencies, building on the development of the Data Interrogation and Visualisation Environment (DIVE) in SRFME.

Upgrades to DIVE in 2008/9 (updated from previous milestone report)

New features in DIVE since the June 2008 milestone report are as follows:

- The user can now select the time-zone in which the data are displayed.
- Data can be viewed in "single steps" through the time series or vertical layers.
- There have been many interface and consistency improvements:
  - A "busy indicator" shows users when DIVE is active but busy.
  - Improved display of data for multiple datasets and multiple variables, through the use of colour and line styles.
  - Hiding and display of data depending on the selected viewing time.
- Improved animation exporting:
  - more options on time-range to export.
  - export of AVI format as well as animated gif.
- Files in GeoTIFF format (e.g. navigation charts) can be used as backdrops.
- The user-preference system has been improved.
- The "lift-out" function has been improved .
- DIVE now has the ability to read multiple files in folder-based datasets as a single source.
- Ability to read ROMS (Regional Ocean Modeling System) output.
- The DIVE manual is updated.
- Improvements to facilitate improved display of biological and underway datasets including high-resolution glider data. For underway measurement, hovering the cursor over the vessel track will produce detail of the data

Modifications in progress include:

- An import facility for incorporation of non-continuous, non-contextual data (effectively by copy and paste from a spreadsheet).These data are insufficiently located, in time or space, in the data file, requiring additional user-input through the import facility.
- User-facility to create and edit symbols, and to add text to annotate DIVE output.

Scoping is currently underway for a "wizard tool" that will enable biological scientists to create relational database records from arbitrarily formatted data in documents such as Excel spreadsheets. DIVE will be able to display data from the relational database records so created.

DIVE will also be extended to use OGC (Open Geospatial Consortium) Catalogue Services standards to access data sets across the web. This capability will enable DIVE to access data sets archived by the Australian Oceanographic Data Network (AODN), and the Australian Integrated Marine Observation System (IMOS), which have both adopted OGC standards.

Specific milestones to be reported on in this period

There were no specific milestones related to this Output in this reporting period

Research Activity: Listed below by milestone within each project objective

2.1 An assessment of the importance of physical forcing and ecological interactions among key functional groups in determining patterns of spatial mosaics in benthic habitats.

Milestone 2.1.1: Development of cellular automaton gap model for investigation of habitat patch dynamics

Original Forecast Finish Date: 30/06/07

Revised Forecast Finish Date: 30/06/07

This section updated from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:
A working cellular automaton model has been developed. At present the model represents the reef as a gridded rectangle, with a specific habitat type at each grid point. It uses relatively simple succession rules. When a habitat at a particular location expires, according to a life-span specification, it is either replaced by a neighbour's habitat, or by the next type in the succession cycle. The model produces a graphical 2-d, time-varying depiction of the reef evolution, and summary time-series of patch sizes. Example model output is shown in Figure 1 below, for four macro-algae types (gap, red, green, brown) on a nominal 50 m x 40 m after 1000 years evolution from a random start. This component of the work is now complete and the model can be used in the next stages of the project (milestones for delivery in 2009 and 2010).

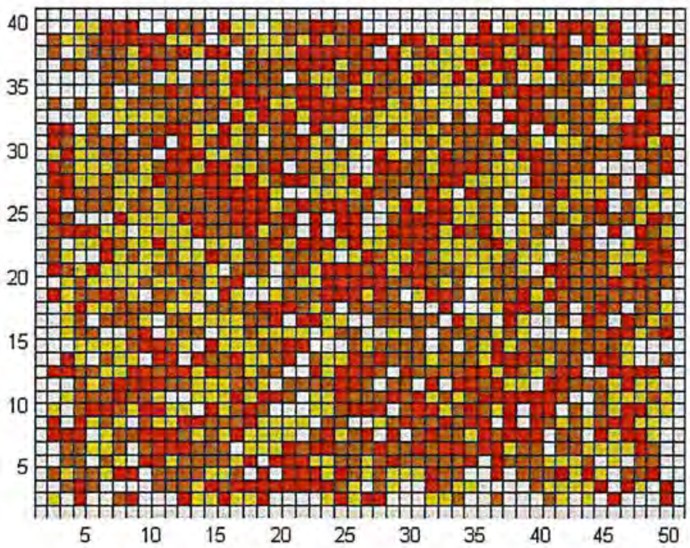


Figure 1. Example habitat model output.

Both observational and modelling studies of the natural environment are characterised by their 'grain' and 'extent', the smallest and largest scales resolved in time and space. These are imposed scales that should be chosen to ensure that the natural scales of the system are captured in the study. The simplest cellular automata models of habitat represent only the presence or absence of vegetation, with global and local interactions described by four empirical parameters. Such a model can be formulated as a nonlinear Markov equation for the habitat probability which produces inherent space- and time-scales that may be considered as recovery scales following disturbance. However, if the resolution of the model is changed, the empirical parameters must be changed to preserve the properties of the system. Further, changes in the spatial resolution lead to different interpretation of the spatial structure. In particular, as the resolution is reduced, that is, as spatial cells are aggregated, the apparent dominance of one habitat type over the other increases. Insights from the model have clear implication for inter-comparison of both field and model investigations conducted at different resolution in time and space.

Milestone 2.1.2: Scale and proportion of habitat patches across a coastal gradient quantified

Original Forecast Finish Date: 30/06/07

Revised Forecast Finish Date: 30/06/07

This section unchanged from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Sites for field work were identified across a coastal wave exposure gradient at Marmion lagoon. Sampling of large scale transects using towed video recordings was carried out in December for approximately half the sites, with the remainder completed in January -February of 2007. Characterisation by divers completed; canopy composition, substrate rugosity, and abundances of potentially important fauna quantified at 24 sites across the wave exposure gradient, consequently the field work for this project is ahead of schedule. The surveys have confirmed previous impressions that patch structure is an important and ubiquitous characteristic of Marmion Lagoon benthic communities, with strong implications for biodiversity and productivity.

Further, time series of wave parameters on a 30m grid over the Marmion Marine Park have been derived from 12 months of output from the wave model SWAN forced by the observed waves at the Rottnest Buoy. These data can be used to derive high resolution maps of wave exposure defined by wave statistics such as means or variances. The data are then compared with habitat maps to examine the distribution of the major habitat types (sand, seagrass, algae) as functions of wave exposure. Analysis of seagrass distribution in the Marmion Marine Park occurs in shallower, lower energy regions compared to macroalgae. This result is illustrated in Figure 2 below, where the root mean square bottom velocity has been used as a measure of wave exposure.

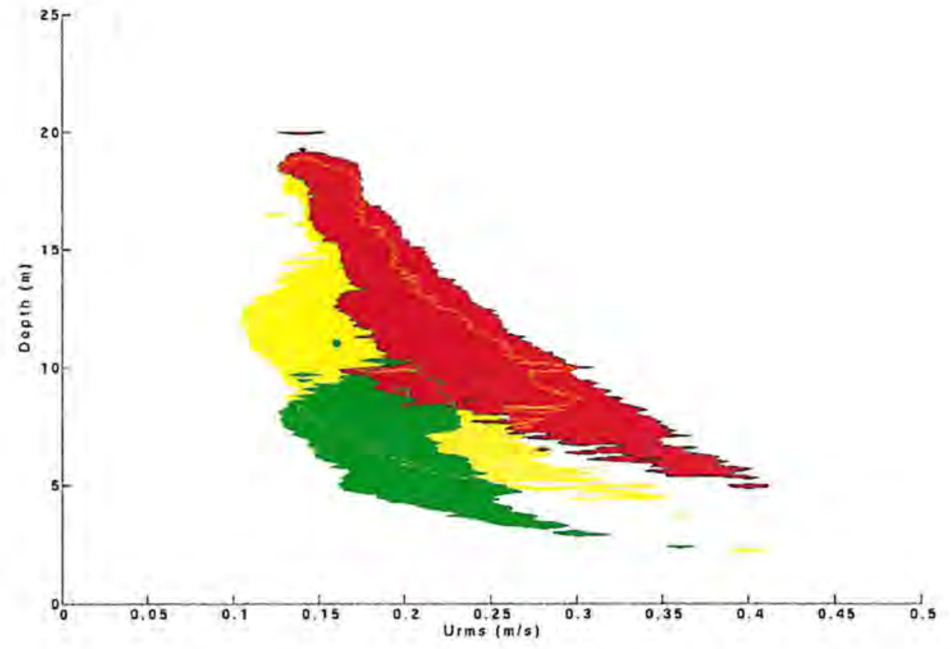


Figure 2. Distribution of sand (yellow), seagrass (green) and low relief algae dominated reef (red) as a function of wave induced root mean square bottom velocity (Urms) and water depth.

A shortcoming of this measure is the bottom velocity is a function of surface wave height, period and water depth. In particular, for a given wave height and period, the bottom velocity decreases with increasing depth which would account for some of the depth dependence seen in Figure 2. Kelp density measurements derived from diver surveys show density increases with increasing wave exposure and decreases with increasing depth. If time and resources allow this analysis may be extended to Jurien to see if the same functional relationship exists in a different geographic region. These components of the work are now complete and can be used in the next stages of the overall project (milestones for delivery in 2009 and 2010).

Milestone 2.1.3: Patch dynamics and invertebrate demography quantified.

Original Forecast Finish Date: 30/06/08

Revised Forecast Finish Date: 30/06/08

This section updated from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Surveys to obtain demographic data from massive sessile invertebrates have been completed at 24 sites along the Marmion reef tract (Figure 3). At each site the number and size of all sponges, hard corals, soft corals and ascidians have been recorded by divers along a 1m x 25m transect. Many of the sites surveyed have been found to consist of distinct patches, some dominated by the kelp *Ecklonia radiata* and others devoid of kelp. These 'bare' patches often feature an abundance of the three major sessile invertebrate groups;

sponges, hard corals and soft corals (Figure 4) In fact the distribution of all three invertebrate groups were strongly correlated with habitat type, with hard corals and soft corals four times more likely to be encountered within bare compared with kelp patches.The persistence of hard coral colonies within these patches provides some support to the theory that these patches persist for many years; and are thus functionally very important component of the system.

Work to obtain accurate demographic information for resident hard corals within these bare patches is well progressed At six offshore sites colonies of the hard coral genera *Plesiastrea* have been collected and have been prepared for x-ray and skeletal density analysis. To determine an accurate age for each colony sectioned slices have been x-rayed and the seasonal density bands analysed for small changes in skeletal density. Initial results suggest individual colonies may live for greater than 15 years with up to 18 seasonal density bands discernable within one x-ray image. Currently these seasonal density bands are being validated to confirm they are deposited annually, which once complete, will be combined with coral population structures collected in 2006-2007 enabling us to independently validate models of patch dynamics (including patch longevity) using estimated coral ages.

During November 2007 three study sites were established that will form the basis of repeated observations of natural temporal variability in habitat patch dynamics (Figure 5). The sites are located on reefs in the Marmion Marine Park with each site approximately 2500 m^2 in extent. The sites are comprised of a patchy mosaic of kelp forest, mixed algal canopy, and low foliose algal assemblages. Initial mapping at these sites took place in January 2008 using stereo video mosaic images produced by the Starbug AUV. The maps will allow us to monitor changes in patch sizes through time. There were three sites covered during the week. The total number of images collected was just over 8200, taken at approximately 2 second intervals at heights of 1m to 2m above the sea-floor. Review of the results suggests this frequency should be increased to images at 0.5-1 seconds to account for the excessive pitching caused by wave action. This equates to approximately 5700 square meters of coverage. There were some difficulties during testing resulting from hardware (GPS) failure and fouling of thrusters with seagrass whilst surface trimming requiring intervention and reducing mission time.

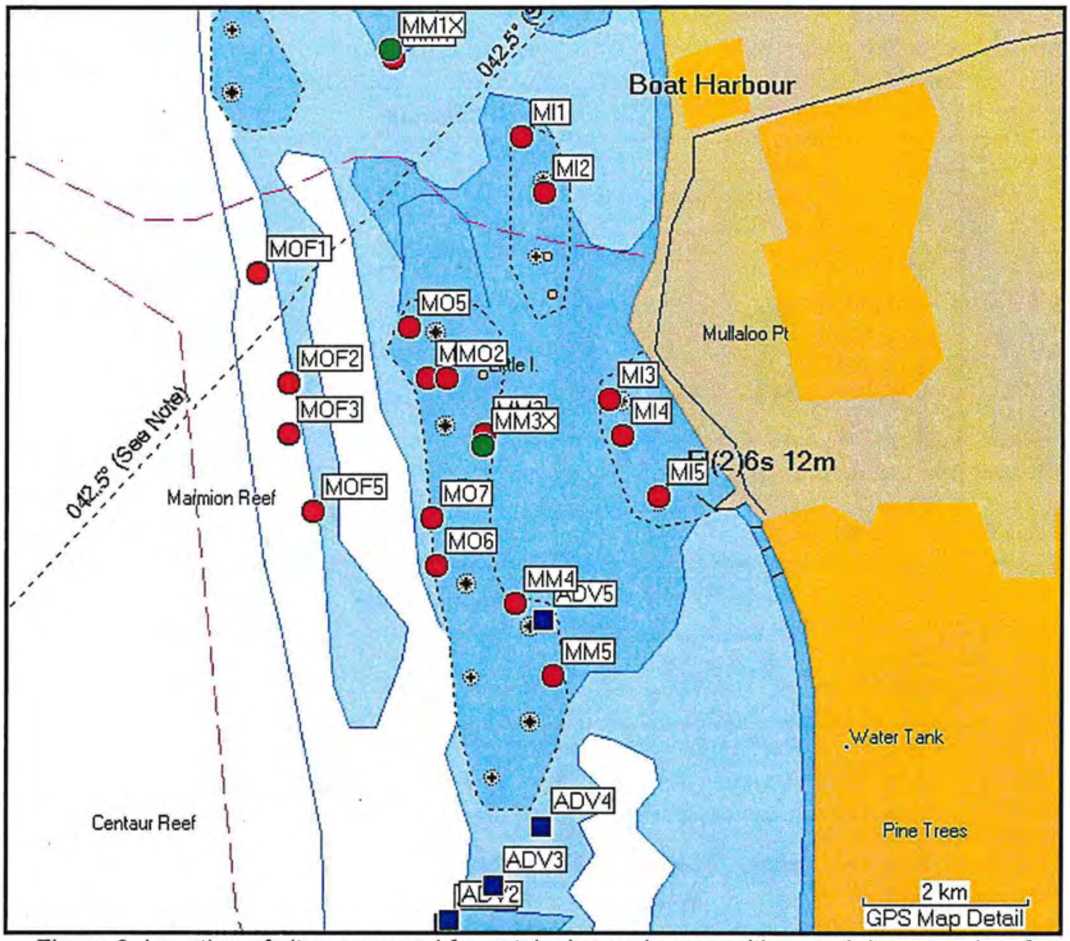


Figure 3. Location of sites surveyed for patch size and composition, and demography of sessile invertebrates

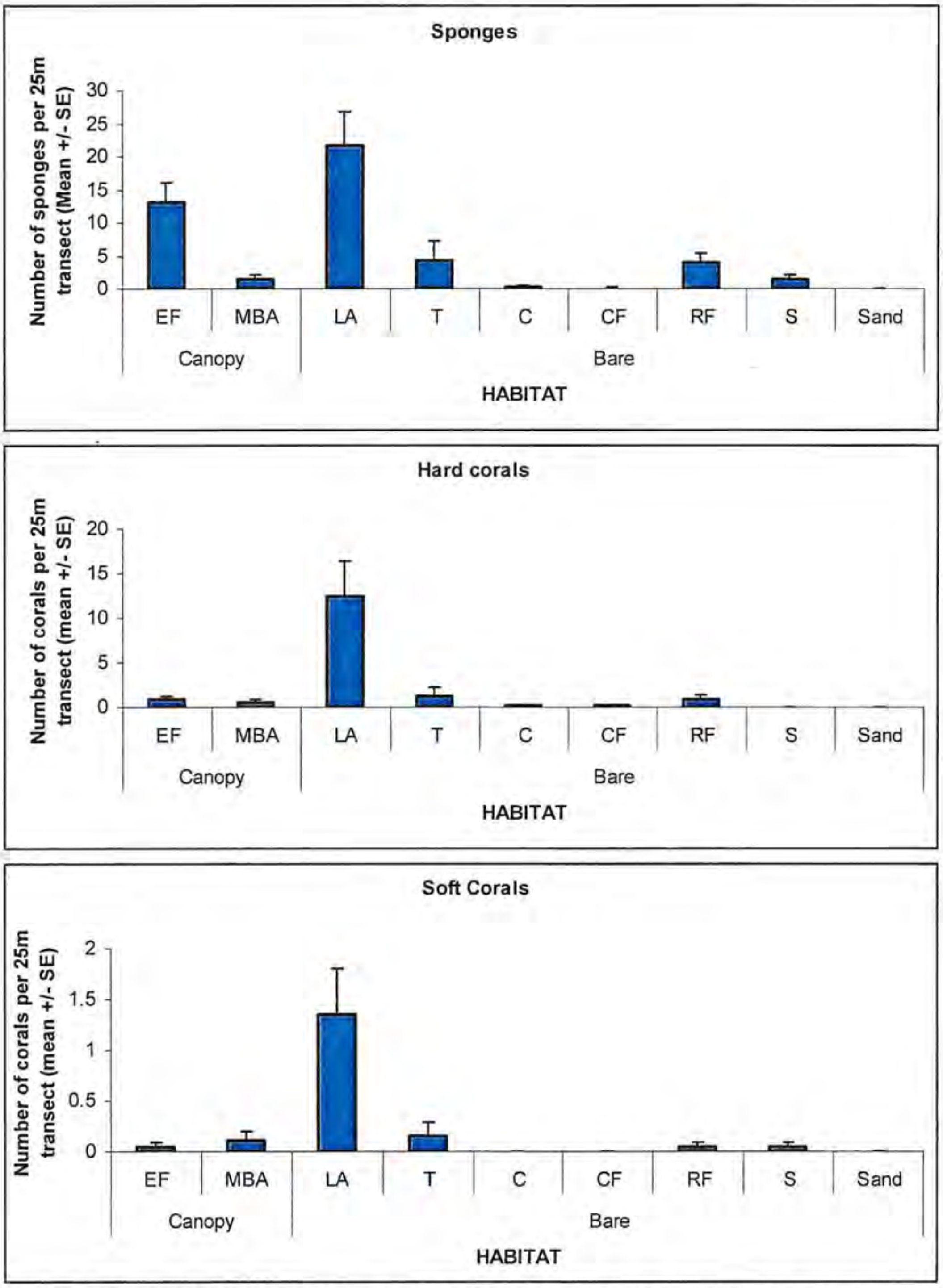


Figure 4. Abundances of sponges, hard corals and soft corals recorded along 1 x 25m transects within the two canopy habitat types (Ecklonia (EF), Mixed Brown Algae (MBA)) and seven bare habitat types (Low Algae (LA), Turf (T), Caulerpa (C), Coralline foliose (CF), Red Foliose (RF), Sargassum (S) and Sand).

Figure 5. Location of sites used for clearing experiments.

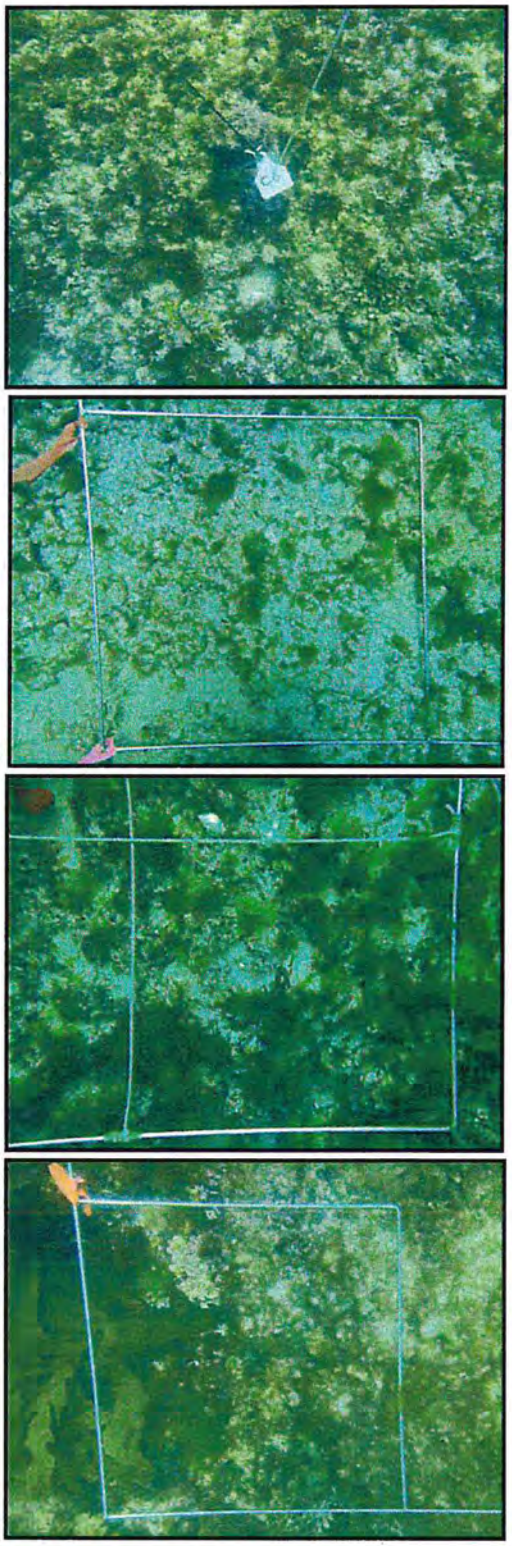
Post processing of the images into a coherent mosaic has posed a number of issues primarily due to excessive uncompensated pitching of the vehicle (+/- 20 degrees) as a result of wave surge. Standard Mosaic construction requires common features between co-located sections of the image. One problem over the kelp was that between image intervals (2s) the kelp movement can completely cover the scene. The more significant problem is vehicle pitching motion between images due to surge has meant that some images have no overlap at all which will result in some "holes" in the mosaic. The effect of vehicle trajectory drift due to the wave action has been researched and corrected to a reasonable bound of uncertainty for parts of the mission.

Follow-up mapping took place in April 2009, incorporating experience from the previous year and using higher sampling frequency at two meters above the substratum. Unfortunately a breakdown of the AUV meant that only one of the sites (ADV3) could be completed. Differences between the two sampling dates are still being quantified. Modifications of the rates of data collection and improved image processing to account for variation in pitch meant that the images were much better quality than those from 2008 and the ability to mosaic images was improved (Fig. 9).

The next phase of the work will be to complete the trajectory compensation for all sites and mission legs and continue with implementation of SIFT (Scale Invariant Feature Tracking) to mosaic images. The next field mission will repeat experiments whilst evaluating an improved AUV tracking system developed for another WfO project.

Clearance experiments were also conducted in January to look at mechanisms underlying maintenance of the different types of habitat patches; 3 replicate clearances were made in (a) kelp dominated habitats, (b) in kelp-free 'bare' patches, and (c) at borders between these two habitats, in addition to controls. These patches were re-surveyed in April and November of 2008 (Figure 6) and most recently in March 2009..

Towed video transects recorded in 2006-2007 have been extended with the inclusion of further tows undertaken in late 2007. Analysis of the video data showed statistically significant trends along a cross-shore gradient ($F_{3,18}$ = 4.29, $p<0.022$), with larger gaps in the canopy in the outer Marmion reef sites relative to sites offshore in slightly deeper water, or at sites in the middle of the lagoon (Figure 7). Gap habitats also comprised a significantly larger proportion of the total reef area at the outer reef sites ($F3,18 = 4.15$, $p<0.025$).



a)
b)
c)
d)

Figure 6.Example of experimentally-cleared patch within Gap habitat a) before clearance, b) after clearance 28/1/2008 c) succession after 3 months 2/5/2008 d) after 10 months 18.11.08.

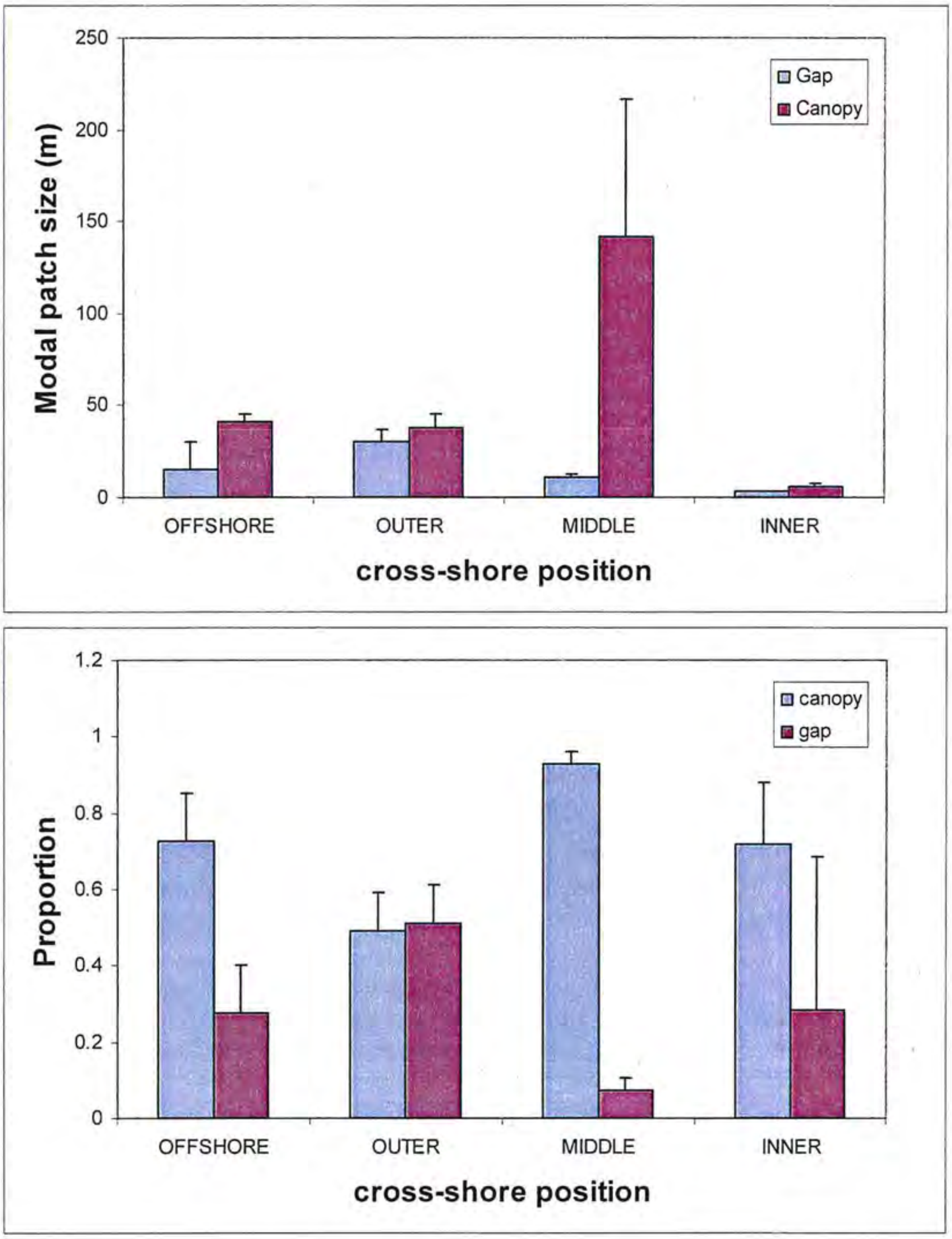


Figure 7. Patch composition of reefs along a cross-shore gradient at Marmion lagoon. Data are from video tow transects and algal assemblages are classified as either "canopy" (*Ecklonia* forest, mixed brown algae, fucoid, *Sargassum*) or gap (low algae, turf, *Caulerpa*).

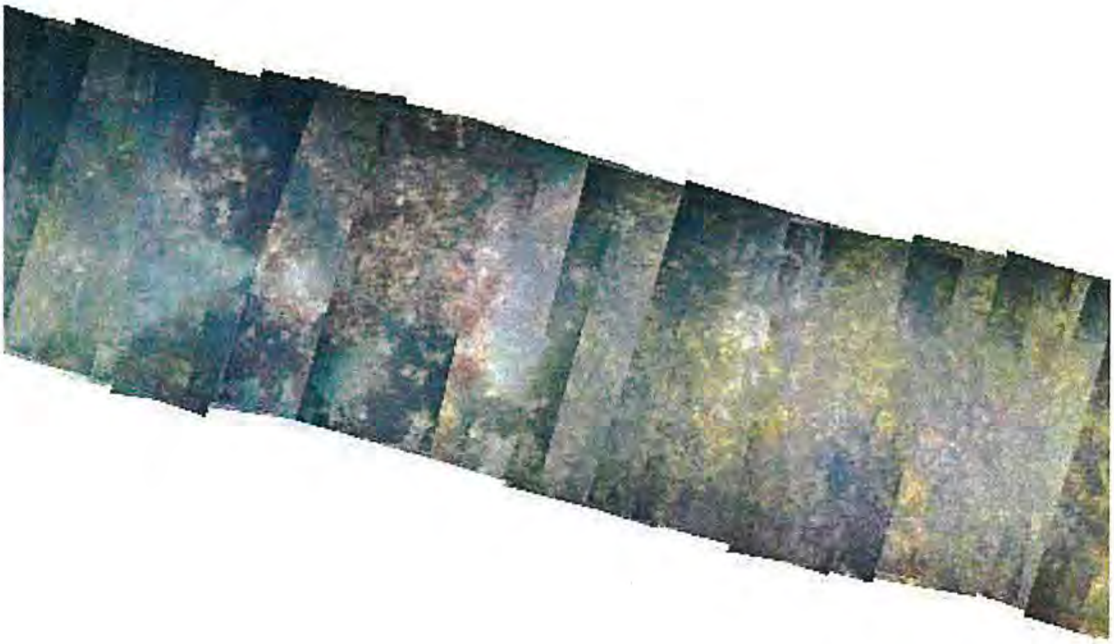


Figure 8 Portion of habitat photomosaic at Marmion Reef. The site (ADV3) was mapped using Starbug stereo photography in April 2009. the mosaic is of a small portion of reef approximately 5 m long.

Milestone 2.1.4: Comparison of model behaviour with reference to observed patterns of patch distribution and modelled wave climate. MS preparation

Original Forecast Finish Date: 30/06/09

Revised Forecast Finish Date: 30/06/09

This section updated from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

The wave climate experienced across the Marmion Lagoon areas being studied as part of the patch dynamics project has now been modelled based on historical wave height records using the SWAN model. Outputs from the model in the form of estimated mean annual water velocity (mean U_{rms}) and maximum annual water velocity (Max U_{rms})at the sea floor have been derived for all the study sites, averaging values along the length of transects (Figure 9). Mean and maximum values follow similar trends, with the highest values being found on the outer sites in shallow water on the exposed aspect of reefs. Values drop off in deeper offshore waters and in more protected sites within the lagoon. The differences between lagoon sites and offshore sites is greatest for the maximum values which would be experienced only during large storm or swell events.

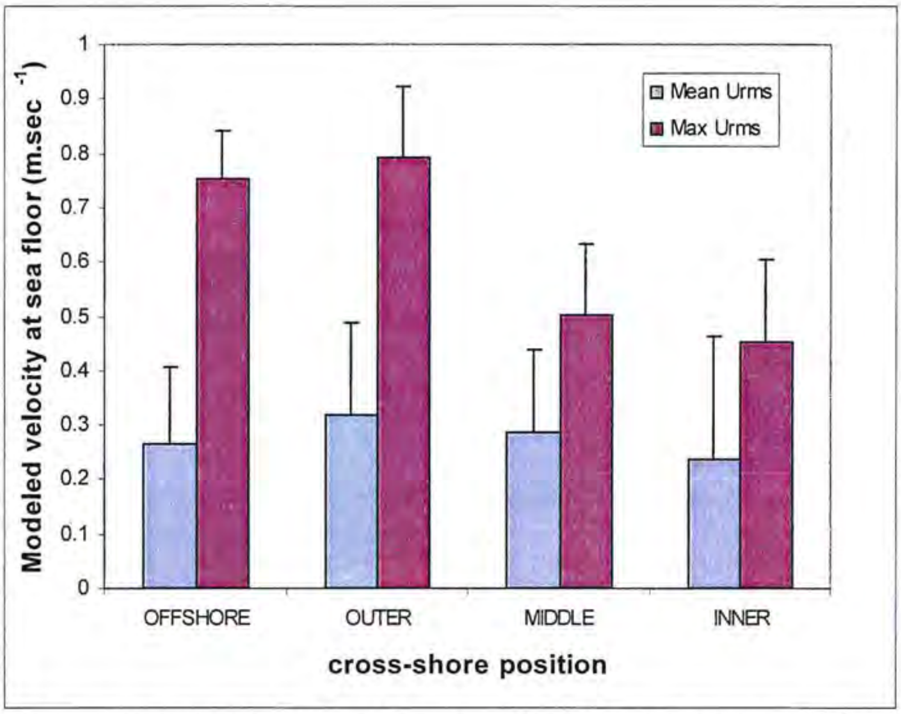


Figure 9. Predicted water velocities in Marmion lagoon. Data are averages experienced at the sea floor for reef areas where patch dynamics transects have been conducted.

A primary hypothesis for explaining the creation of gaps in the macroalgal canopy of kelp forests is damage by storm waves which generate high velocity currents at the sea bed. To test this idea we examined whether gap size or frequency was correlated with wave-generated water velocity at the sea floor, consistent with expectation.

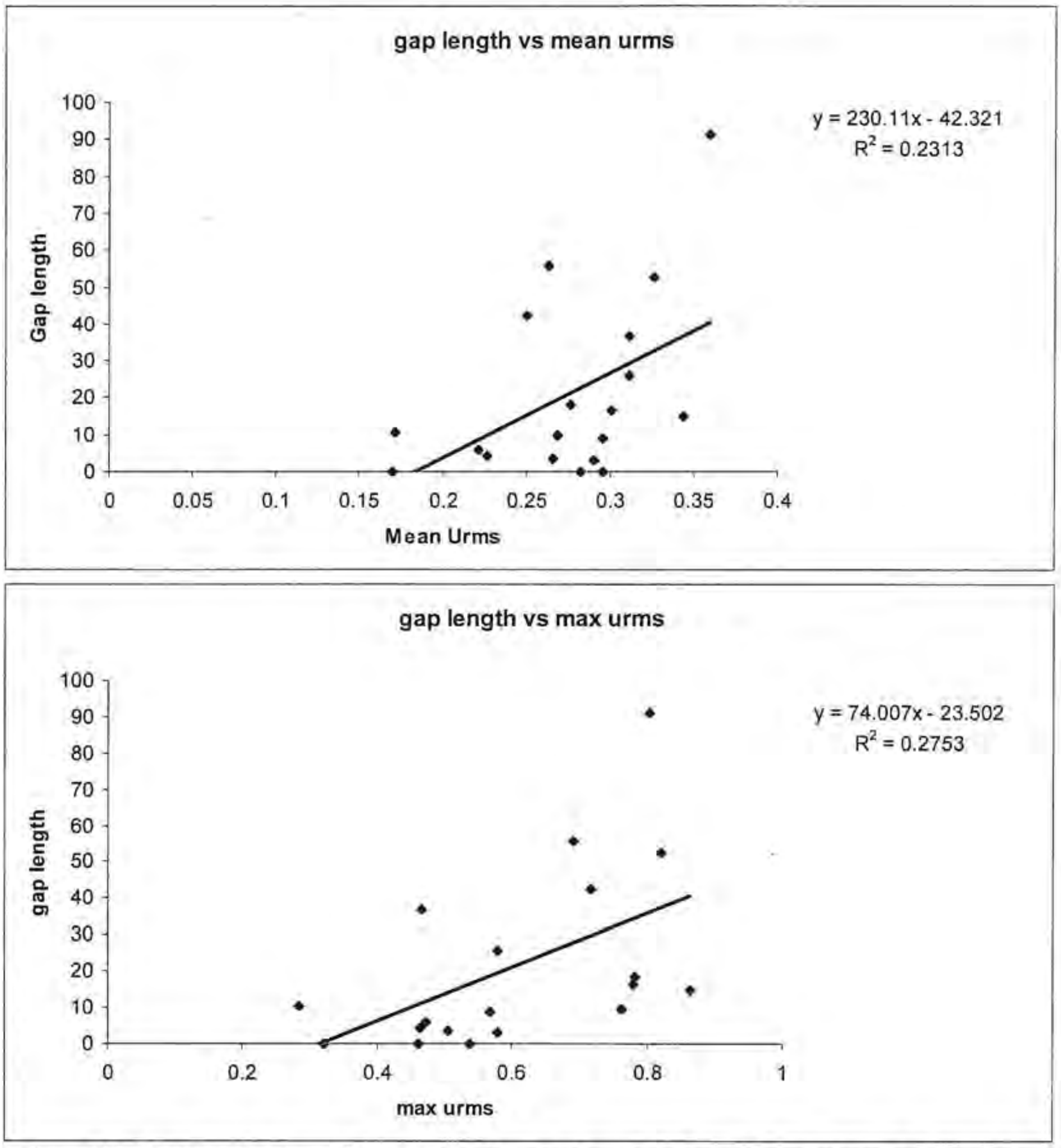


Figure 10. Gap size and sea bed water velocity. Gap sizes were from video tow transects. U_{rms} values obtained from SWAN model of the Marion Lagoon.

There were statistically significant positive correlations between both mean water velocity ($F_{1,18}$ = 5.12, p<0.034) and maximum water velocity ($F_{1,18}$ = 6.46, p<0.021), which is consistent with the role of wave disturbance in gap formation. The correlations did not explain a large proportion of the total variation however the R^2 values were higher (0.27) for maximum water velocity than for mean values (0.23) (Figure 10).

An alternative explanation for the creation and maintenance of the gaps is through the feeding of herbivorous invertebrates or fish. The data however are not consistent with this hypothesis, with no significant correlation between the total herbivore abundance and the proportion of gap habitat (Figure 11).

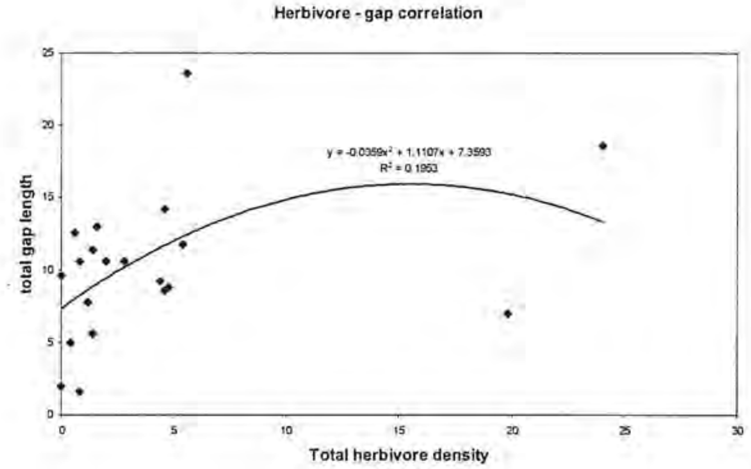


Figure 11. Proportion of gap habitat and herbivore density.

A manuscript has been prepared from this work: Craig, P.D.(2009): Imposed and inherent scales in cellular automata models of habitat (in internal review).

2. 2. An assessment of ecosystem processes with particular relevance to contrasting fished and non-fished areas.

Milestone 2.2.1: Field data collection completed at all sites

Original Forecast Finish Date: 30/06/07

Revised Forecast Finish Date: 30/06/07

This section unchanged from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Field data collection completed at inshore sites in Marmion, with abundance of consumers (predatory and herbivorous fish and invertebrates) obtained from reef, seagrass and sand habitats. Rates of growth and consumption of kelp also obtained from inshore reef habitats. Collections of selected invertebrate taxa were completed for stable isotope analyses that will elucidate important trophic pathways, and for obtaining biomass measurements that will be needed by ecological modelers. Fieldwork also completed at a number of sites at Rottnest Island, focusing on abundances of consumers and consumption of kelp on reef habitats. This work revealed useful insights into potentially important indicator characteristics of fish communities (see Figure 12) that reflect differing levels of exploitation. Differences in trophic structure such as those found at Rottnest Island may have important consequences for other ecosystem components at lower trophic levels.

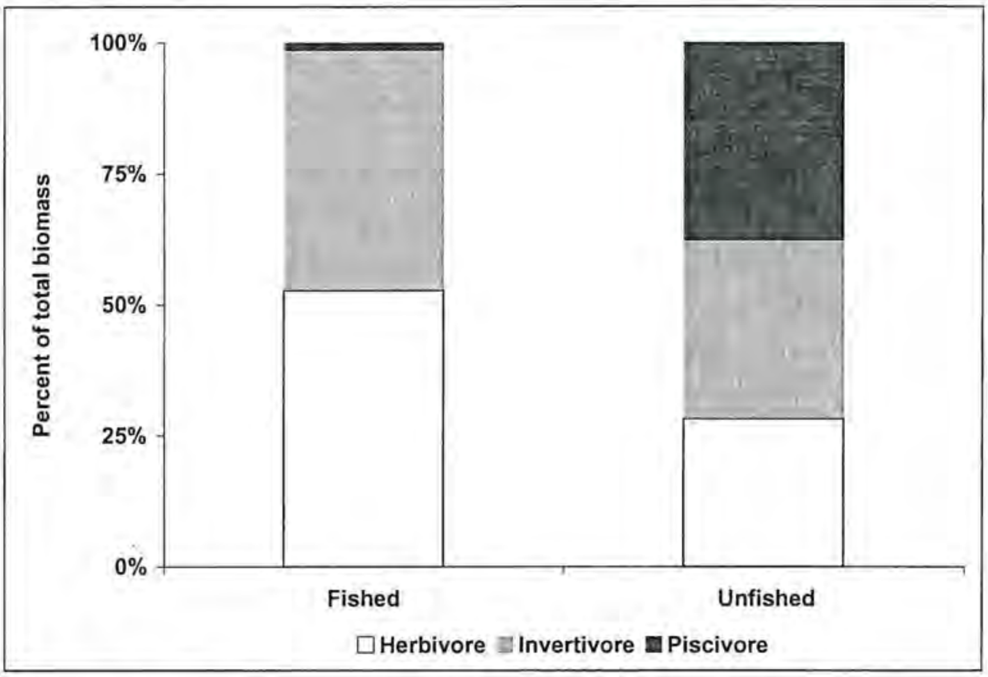


Figure 12. Biomass of different trophic categories of fish in fished and unfished areas.

The recent withdrawal of funding from NHT for complementary work in support of this objective has meant that the scope of the work originally proposed has been reduced to focus mainly on Marmion lagoon, and a limited set of sites at Rottnest, rather than the extended set of sites at Rottnest, Shoalwater Bay and Marmion. The work in this project will therefore focus more on variation in processes as indicators of ecosystem condition, rather than extensive quantification of fish community and population structure as previously envisaged.

Milestone 2.2.2: Field data collected at all sites. Draft MS on predator gradients in relation to spatial management regimes and size of management unit. Draft MS on variation in ecological processes in relation to spatial predator gradients.

Original Forecast Finish Date: 30/06/09

Revised Forecast Finish Date: 30/06/09

This section updated from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

In April 2008 field surveys were successfully completed at 12 sites in Jurien Bay, bringing the total number of sites surveyed across all three regions (Marmion Lagoon, Jurien Bay Rottnest Island,) to 28 (Figure 13, Figure 14 and Figure 15).

Of these, 13 were located within marine sanctuaries – 6 sanctuaries were surveyed (2 in each region). At each site surveys included abundance of rock lobsters (three transects of 30 m each on reef habitat), abundance of fish (three transects of 50 m each in reef and seagrass habitats), and abundance of large invertebrates (five transects of 5 m each in reef, seagrass and sand habitats). In addition, estimates of rates of grazing and predation have been conducted within each sanctuary area. Biomass production by *E. radiata* can be considerable (see report under Milestone 1.3.2), and these data show that little of this production is grazed directly. This implies considerable export of kelp production that probably sustains fauna in other habitats (seagrass, sand). These insights point to the importance of ungrazed production in coastal food webs at spatial scales far greater than the reefs themselves.

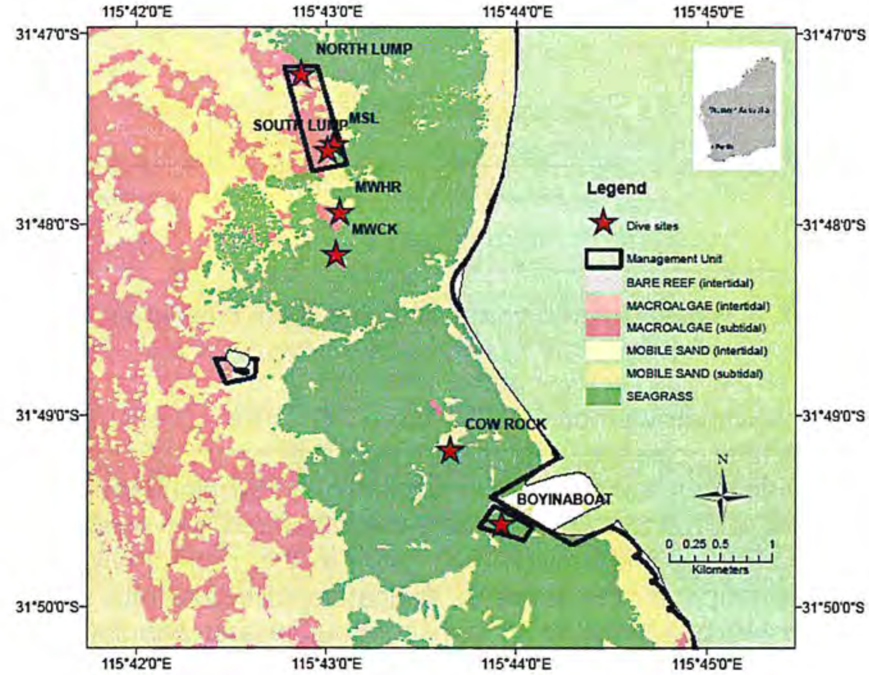


Figure 13. Sites surveyed in Marmion Lagoon.

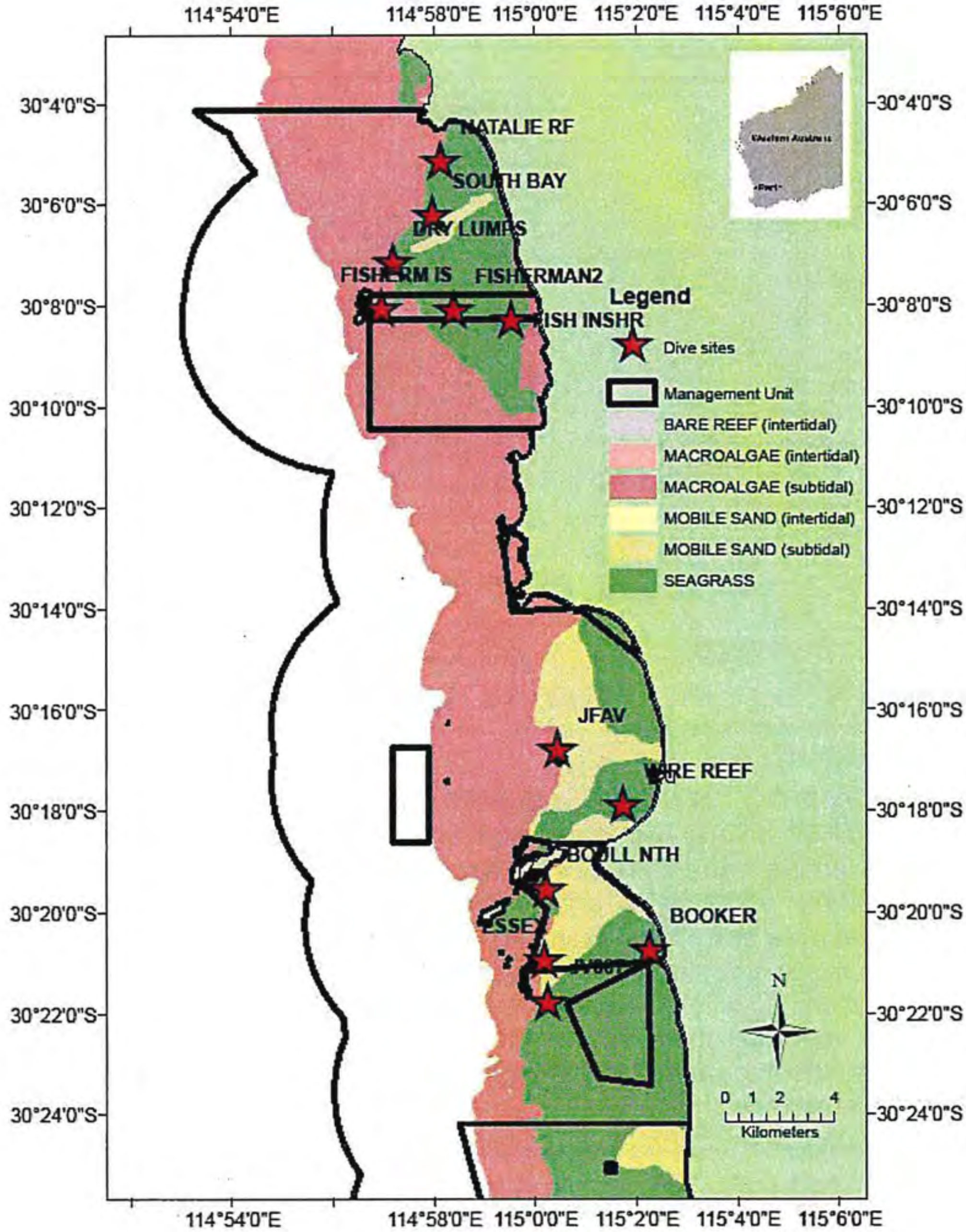


Figure 14. Sites surveyed in Jurien Bay.

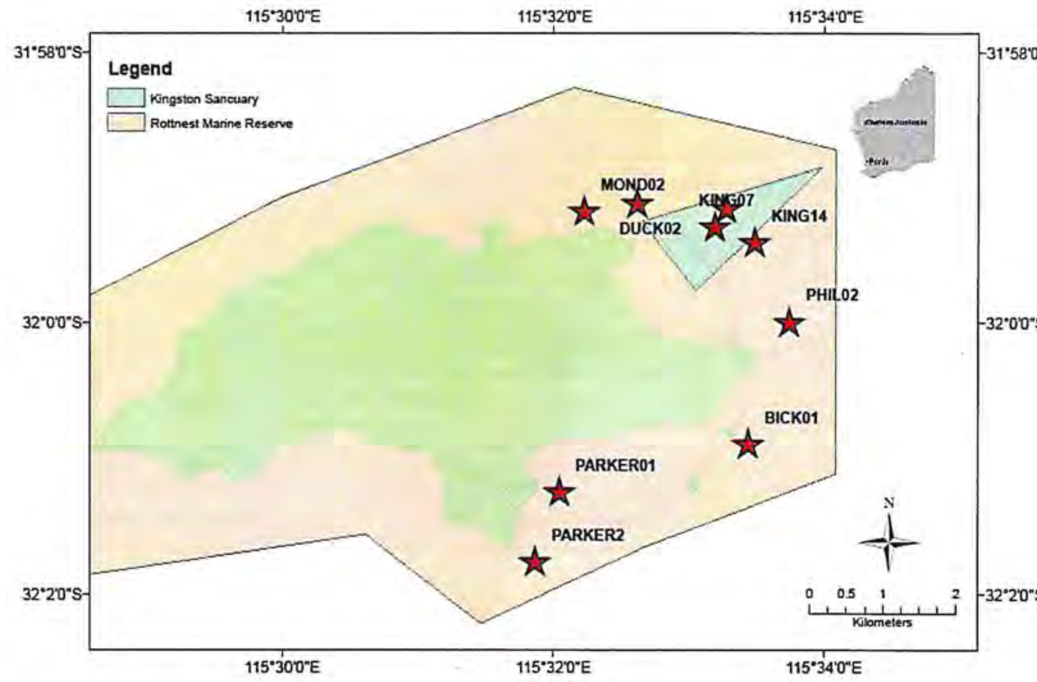


Figure 15. Sites surveyed at Rottnest Island.

Analyses of the data continue to yield , but have already yielded insights into the potential for differences in patterns among different spatial management units. For example, abundances of western rock lobsters in fished areas are comparable at Marmion and Rottnest, but abundances are far higher in an unfished area at Rottnest than in an unfished area at Marmion (Figure 16). Lobster abundance inside sanctuary areas does not show a simple relationship with size of sanctuary (Figure 17) or with age of sanctuary (Figure 18). However there appears to be a complex dependence on both size and age, with the ratio of lobster abundance in unfished versus fished areas being well-explained by a linear model that incorporates both size, age, and the interaction between them (adjusted $r^2 = 0.95$, $F_{3,2} = 34.8$, $p = 0.03$).

Similarly, the relative abundance of fish typically targeted by fishers does not show a simple relationship with size of sanctuary (Figure 19) or with age of sanctuary (Figure 20), but a multiple regression model containing both size and age explains much of the variation in relative abundance of targeted fishes (adjusted $r^2 = 0.69$, $F_{3,2} = 6.7$, $p = 0.07$). These preliminary results warrant deeper investigation, but perhaps suggest that we should not expect significant responses of heavily fished species in sanctuaries that are not large or old.

Rates of grazing on kelp *Ecklonia radiata* are higher at fished sites in Marmion Lagoon (due mainly to higher rates of grazing at a single site), but not at Rottnest Island (Figure 21). Grazing was mainly by large herbivorous fish (*Kyphosus*).

Mussels were deployed to determine whether gradients in predator abundance translated to spatial patterns in predation. Eight replicate groups of 12 mussels were deployed to all sites. Eight replicate groups of 12 mussels were deployed to all sites (except Kingston Rf03 where only three groups of caged mussels were deployed). Four of these groups were caged while four were uncaged. Data obtained from these groups were pooled for preliminary statistical analysis of the % survivorship of the mussels deployed by each method at Marmion, Jurien Bay and Rottnest Island. The groups were further broken down into the 48 mussels deployed by each method to each sampling site within these areas.

Overall mean survivorship for each group of caged mussels was 11.19 (95% CI= ±0.4) or 93.25% (± 3.33%) while the overall mean survivorship for each group of uncaged mussels was 3.69 (95% CI= ±1.19) or 30.75% (±9.92%) (Table 1).

Table 1. Overall mean and percentage survivorship of the twelve mussels deployed to each sample site.

Deployment method	*Mean Survivorship*	*%*
Caged	11.19 (±0.4)	93.25% (± 3.33%)
Uncaged	3.69 (±1.19)	30.75% (±9.92%).

Marmion had the lowest survivorship of uncaged mussels of the three areas (Figure 22). There was also a significant difference in the survivorship of mussels deployed in the cages compared to uncaged, suggesting that predation was generally high. When the survivorship of uncaged mussels within the all of the reserves was compared to those deployed outside the reserves the survivorship of uncaged mussels within the reserves was slightly higher than for the non-reserve mussels although the difference was not statistically significant (Figure 23).

The mean survivorship of each group of caged mussels at Marmion was 11.45 (±0.44) or 95.42% (±3.68%) while the mean survivorship of each group of uncaged mussels at Marmion was 0.85 (± 0.81) or 7.08% (± 6.73%). There was also a significant difference between the survivorship of caged and uncaged mussels at each site. Marmion had the largest difference between the uncaged and caged mussels at each site that is reflected in the comparison between the sites. There was no significant difference between the sampling sites for caged mussels or uncaged mussels.

The mean survivorship of each group of caged mussels at Jurien Bay was 11.35 (±0.38) or 94.58% (±3.17%) while the mean survivorship of each group of uncaged mussels at Jurien Bay was 6.2 (± 2.43) or 51.67% (±20.23%). Jurien Bay had increased variability for the caged mussels at each site compared to Marmion. Two sites (JV007 and Essex Rf JESS3) had significantly lower survivorship of uncaged mussels compared to the other sites and to the caged mussels at the same site. There was no statistically significant difference between uncaged or caged mussels at the other sites although in each site the survivorship of the uncaged mussels was lower.

The mean survivorship of each group of caged mussels at Rottnest Island was 10.83 (±1.01) or 90.25% (±8.39%) while the mean survivorship of each group of uncaged mussels at Rottnest Island was 4.00 (±2.12) or 33.33% (±17.69%). There was no significant difference between uncaged and caged mussels at Phillip Rf02, Kingston Rf03 and Pocillopora Rf although in each of these sites the survivorship of caged mussels was lower. There was a significant difference in the survivorship of uncaged mussels compared to caged mussels at Kingston Rf07, Bickley Rf and Parker Pt. However, there was a significant difference between the survivorship of caged mussels at Kingston Rf07 compared to Phillip Rf02, Parker Pt and Pocillopora Rf The survivorship of uncaged mussels also varied significantly between sites. Uncaged mussels at Phillip Rf02 and Kingston Rf03 had significantly higher survivorship compared to uncaged mussels at Kingston Rf07 and Bickley Rf.

This preliminary study suffered from a high amount of variability in mussel survivorship between the reserve and non-reserve sites. Uncaged mussels outside the reserves haad lower than survivorship than those inside the reserves but the analysis requires much better resolution to obtain a statistically significant result. Getting the required resolution may be difficult given the magnitude of the difference compared to the variability of the data (size of the 95% CI).

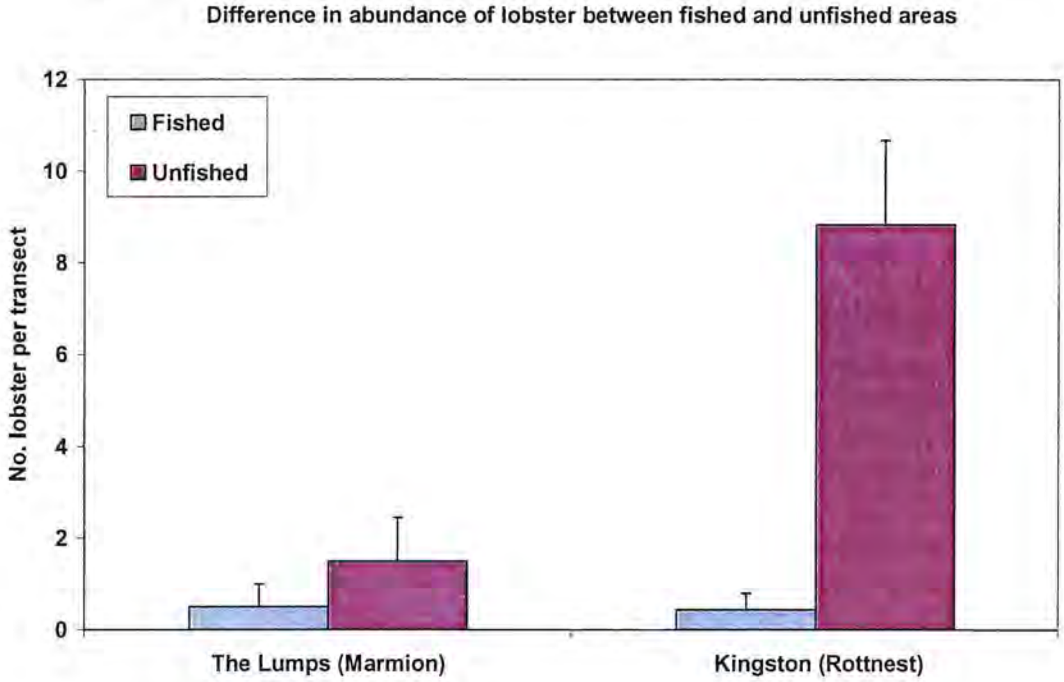


Figure 16. The abundances of western rock lobsters in unfished and fished areas of Marmion and Rottnest.

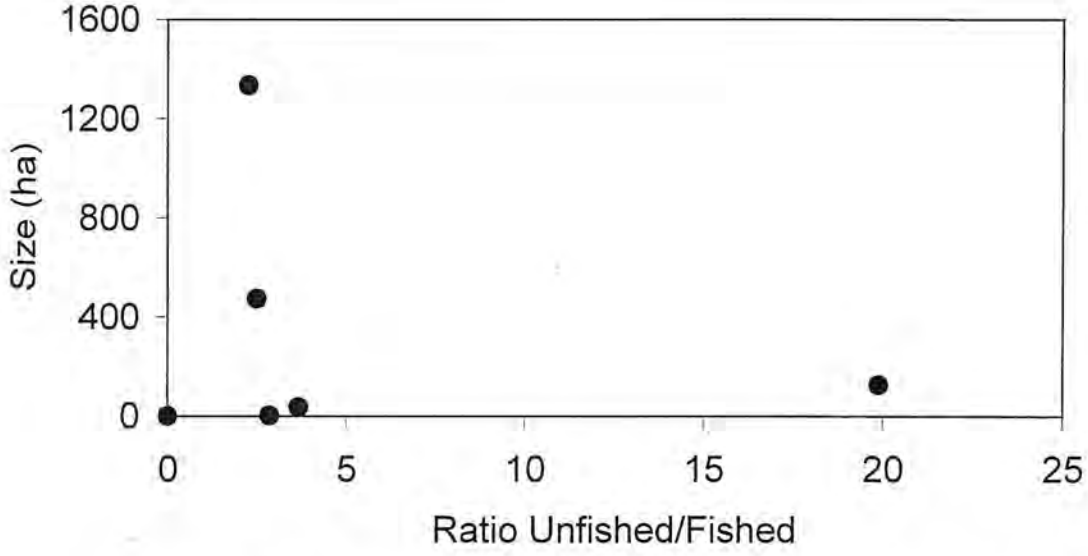


Figure 17. Ratio between sanctuary (unfished) and fished areas in abundance of rock lobsters, relative to size of sanctuary.

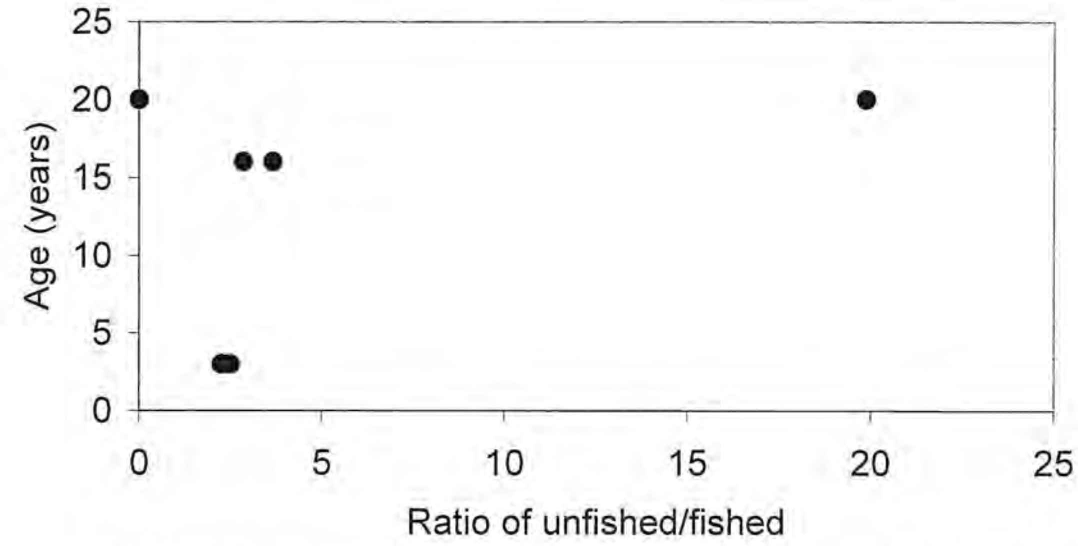


Figure 18. Ratio between sanctuary (unfished) and fished areas in abundance of rock lobsters, relative to age of sanctuary.

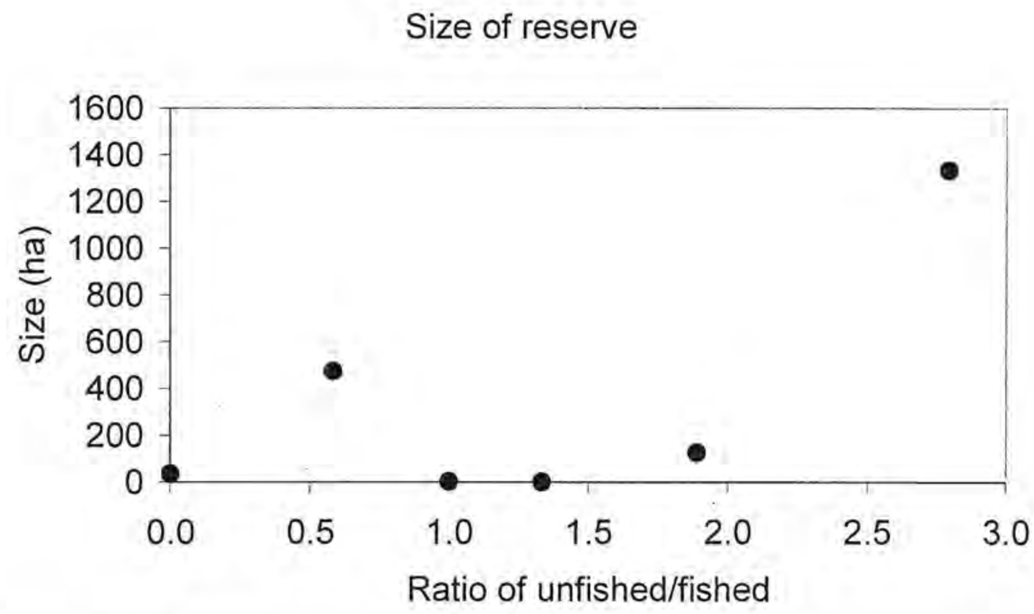


Figure 19. Ratio between sanctuary (unfished) and fished areas in abundance of targeted fish species, relative to size of sanctuary.

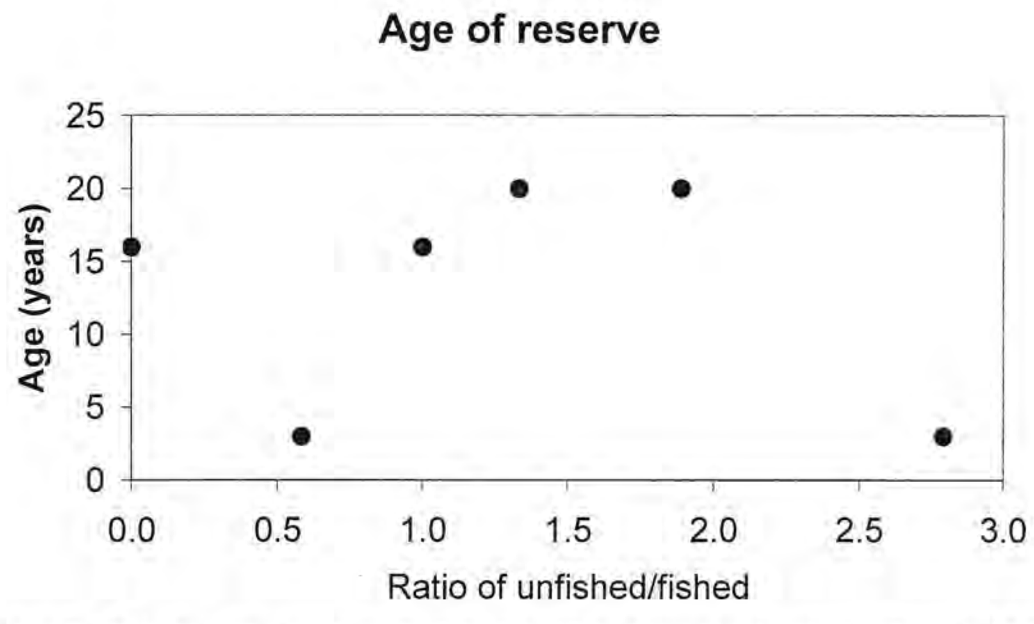


Figure 20. Ratio between sanctuary (unfished) and fished areas in abundance of targeted fish species, relative to age of sanctuary.

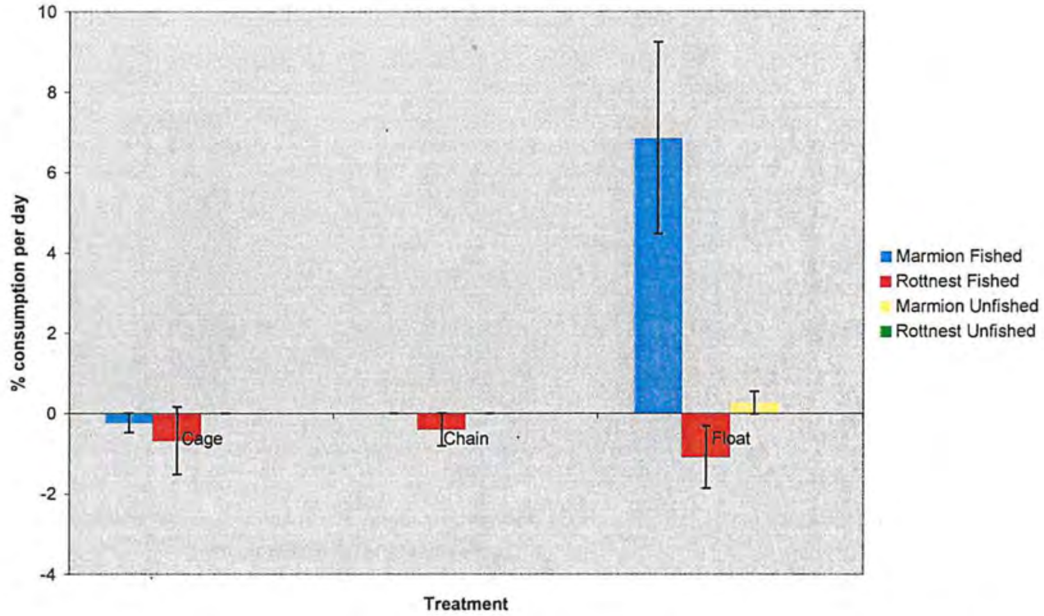


Figure 21. Rates of consumption of kelp *Ecklonia radiata* at fished and unfished sites in Marmion Lagoon and Rottnest Island.

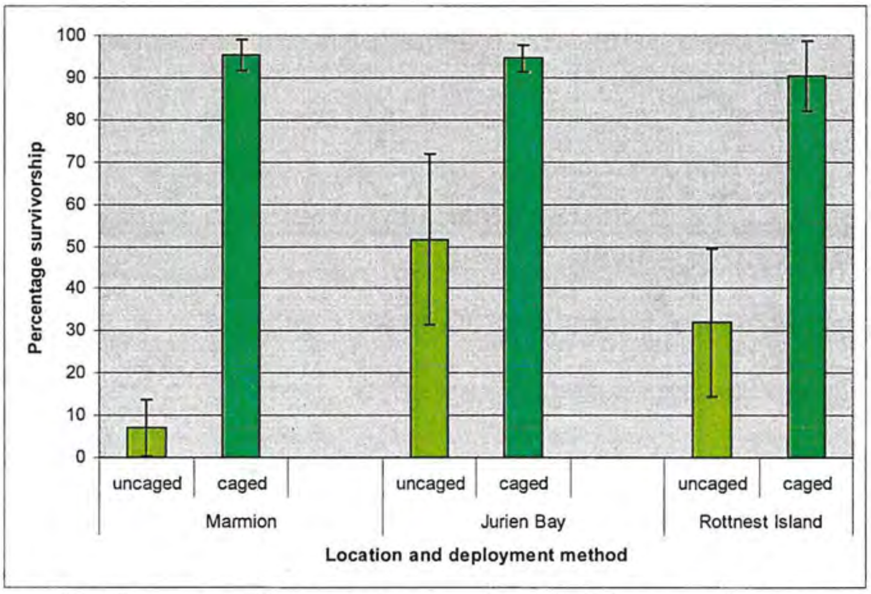


Figure 22. Summary of the percentage survivorship of the mussels compared to the deployment method for each of the field locations. The dark green bars represent the caged mussels while the light green bars represent uncaged mussels. Error bars represent a 95% confidence interval.

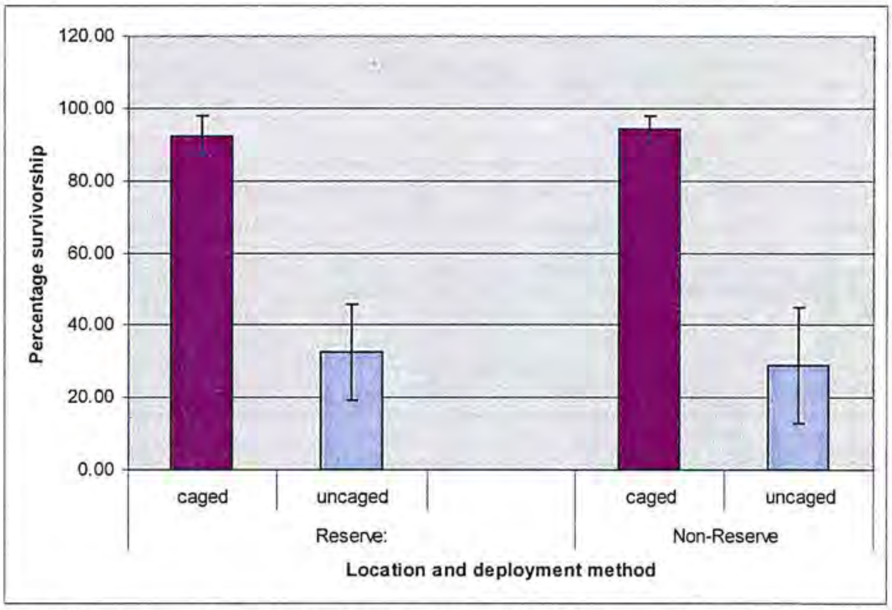


Figure 23. Summary of the percentage survivorship of the mussels with the deployment method for all of the reserve sites and non-reserve sites. The purple bars represent the caged mussels while the light blue bars represent uncaged mussels. Error bars represent a 95% confidence interval.

Data on gradients related to spatial management (i.e. marine park sanctuary zones) in predators and in ecological processes has been combined into a single draft manuscript. This draft currently contains summary statistics and is available on request.

Milestone 2.2.3: Draft MS on indicators of resource condition for selected WA coastal benthic systems

Original Forecast Finish Date: 30/06/09

Revised Forecast Finish Date: 31/12/09

This section updated from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Research conducted towards understanding spatial gradients in community composition related to marine park zoning (see milestone 2.2.2 above) is also intended to provide insights into what might be the best indicators of resource condition. The coastal ecosystems of Western Australia provide many resources, but those most germane to our study relate to fish and invertebrate resources accessed by the commercial and recreational fishing and tourism sectors. Analyses of these data is ongoing, but results of analyses to date do indicate that simple indicators might be misleading. For example, spatial gradients in fishing are overlain on geographical gradients in community composition (Figure 24). In addition, indicators that are appropriate for one type of habitat are perhaps not appropriate for other habitats – for example, indicators that are appropriate for reef habitats are not likely to be appropriate for seagrass habitats (Figure 25). Analyses of the data will further develop these context dependencies.

A manuscript is in preparation that contains summary statistics and comparisons of a range of metrics that have been proposed as indicators of resource condition. This work is still in progress.

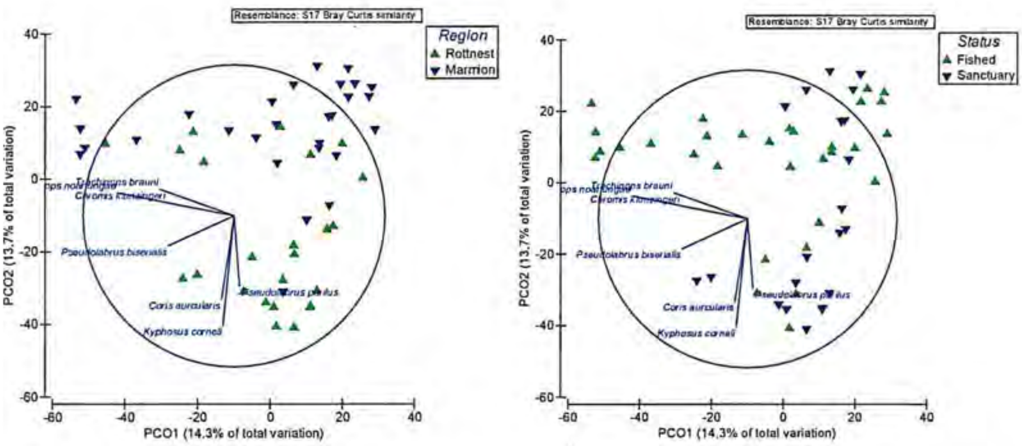


Figure 24: Principal component analysis of fish assemblages surveyed at Rottnest Island and Marmion Lagoon, showing gradients related to geography (left panel) and fishing pressure (right panel).

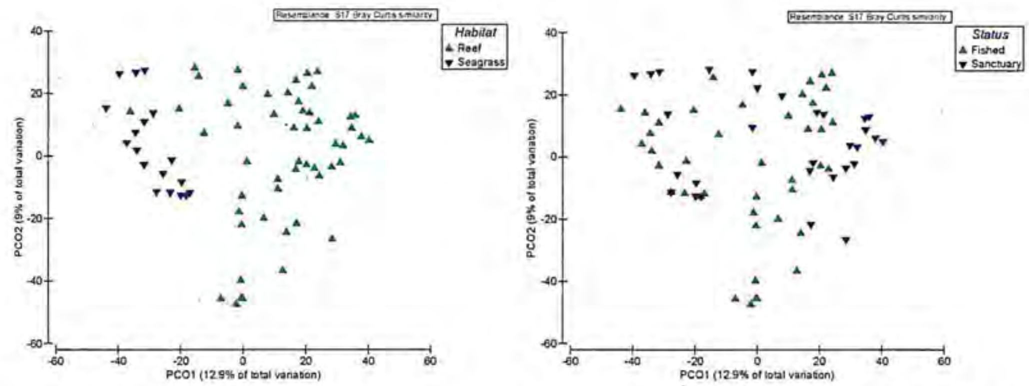


Figure 25: Principal component analysis of fish assemblages surveyed at Rottnest Island and Marmion Lagoon, showing gradients related to habitat (left panel) and fishing pressure (right panel).

2.3 An assessment of likely dispersal patterns for marine organisms based on hydrodynamic and population genetic models.

Milestone 2.3.1: Identification of genetic region with suitable resolution for detecting genetic structure at relevant spatial scales

Original Forecast Finish Date: 30/06/07

Revised Forecast Finish Date: 30/6/08

This section unchanged from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Urchins were initially collected from the west coast sites of Jurien and Marmion lagoon. This range was expanded in January 2008 to several south coast sites at Albany and Esperance in response to low sequence variation found in the west coast sites and recent scientific findings suggesting urchin populations structure was most likely to be observed across the geographical range spanning the southwestern Capes region.

MtDNA COI (cytochrome oxidase I gene) fragments of approximately 700 base pairs have been sequenced successfully in individuals of *Heliocidaris erythrogamma, Holopneustes porosissimus* and *Phyllocanthus irregularis* collected at Jurien, Marmion lagoon, Albany and Esperance. The following variation has been identified: *H.erythrogramma* (n=14, 3 haplotypes), *H.. porossisimus* (n=9, 3 haplotypes; N.B there are no samples from Albany), and *P.irregularis* (n=1, 2 haplotypes). Figure 26 summarises the phylogenetic relationships among species and haplotypes identified within species based on the COI gene fragment. COI clearly separates different species. *H. erythrogamma* shows distinct divergence at continental scales with Sydney,Tasmania and WA diverging with strong node support. Within the three species for which multiple sequences are available in WA, no geographic structure is yet evident at this locus. A common haplotype occurs in samples from the west and south coasts. Unique haplotypes have been found in south coast samples in all three species but these have only weak node support (66-69%) and they occur at insufficient numbers to allow statistical inference. All available specimens of the two focus species, *H. erythrogamma* and *P. irregularis* have now been sequenced at COI.

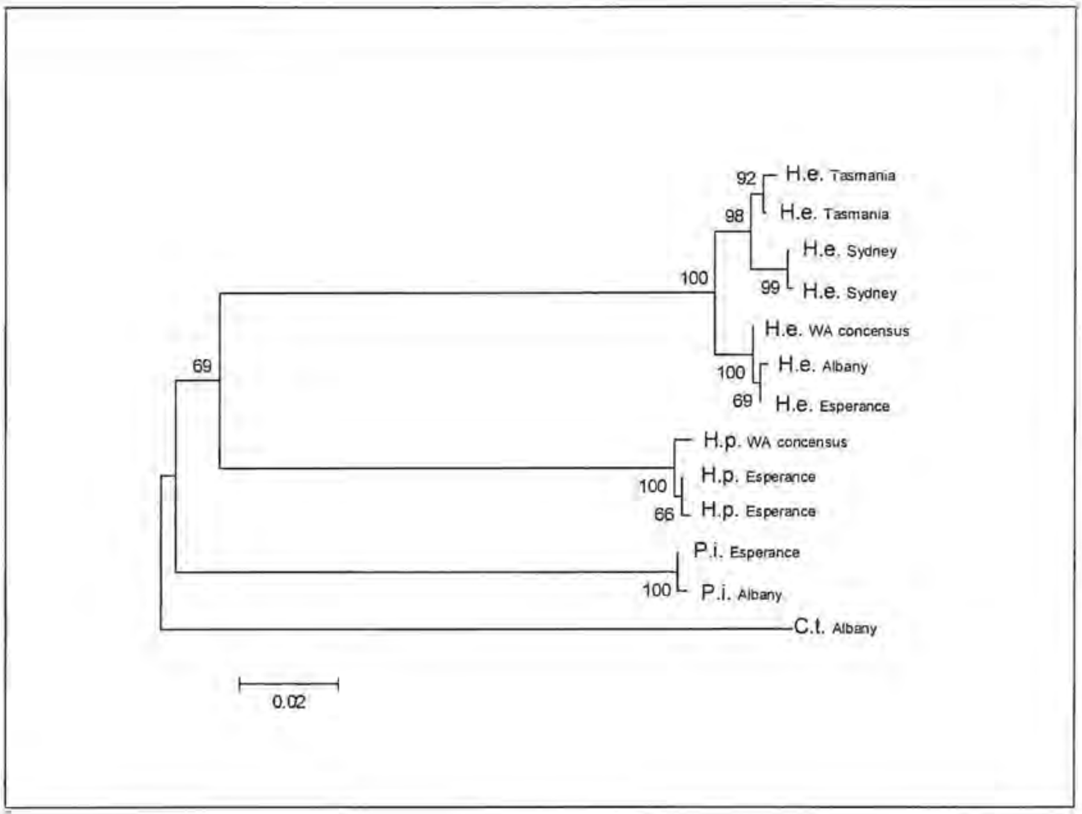


Figure 26. Phylogenetic tree (minimum evolution algorithm with bootstraped node support values) based on mitochondrial COI gene in 4 species of urchin from sampling locations in WA and from the GENBANK database (Tasmania and Sydney). Scale represents percent sequence divergence.

Preliminary sequencing of the intergenic transcribed spacer (ITS) nuclear region and two new mitochondrial genes, ND5 (mitochondrial NADH dehydrogenase 5 gene) and the mitochondrial control region, sometimes found to have sufficient phylogeographic resolution, has begun but as yet no variation has been detected. South coast specimens have not been sequenced. Success with the nuclear regions described below has obviated the use of these two loci and no further sequencing of these regions will be conducted.

Ten additional single copy nuclear genes are now being investigated for single nucleotide polymorphism (SNP) : actin, calmodulin and enolase (Audzijonyte *pers. comm.*) and seven conserved coelomate loci from Jarman et al 2002. [Jarman S Ward RD Elliott NG (2002) Oligonucleotide primers for PCR amplification of Coelomate introns. Marine Biotechnology 4: 347-355]
To date, four nuclear loci display sufficient reliability of amplification and degree of variability to be worthy of full scale sequencing and this is now in progress. These are Adenine Nucleotide Transporter (ANT), ATP Synthetase subunit β (ATPS β), ATP Synthetase subunit α (ATPS α), and TATA Box Binding Protein (TBP).

Collections of netted plankton from two Southern Surveyor cruises have been preserved for later genetic analysis of urchin larvae they might contain.

Milestone 2.3.2: Identification of potential connectivity patterns between Shark Bay and the Capes based on particle track modelling. MS preparation.

Original Forecast Finish Date: 30/06/07

Revised Forecast Finish Date: 31/12/07

This section updated from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Preliminary particle track modelling based on two different approaches were conducted using output from the SHOC hydrodynamic model run in a domain spanning Kalbarri to Augusta. Dispersal of particles over a period ranging from 5 – 100 days was modelled by seeding all cells in the domain with particles initially. Areas of low and high particle concentration could be observed at the end of the dispersal period corresponding to oceanographic features including the Leeuwin system. The alternative approach consisted of plotting the 60 day dispersal trajectories of individual particles released from coastal positions on the west coast.

A deterministic particle tracking model is also now implemented in Matlab for the BLUELink Re-analysis (BRAN) model outputs during 2003, 2004 and 2005. Particle tracking experiments have been carried out to quantify the fate of the Leeuwin Current waters. Particles are continuously (once a month) seeded at a vertical section along 25.5 S where the Leeuwin Current eddies are relatively weak and the current is relatively narrow. Each particle represents a portion of the Leeuwin Current volume transport and is tracked in the 3-dimensional flow fields for up to 2 years. Preliminary results show that a significant portion of the Leeuwin Current particles, representing more than one third of the Leeuwin Current southward volume transport, are advected around Cape Leeuwin and eastward into the Great Australian Bight. The rest of the particles are dispersed by the Leeuwin Current eddies and interaction with the continental shelf. Analysis is underway to better quantify these processes.

Sample animations of particle tracks are accessible at: http://www.per.marine.csiro.au/wamsi/ptrack2.mov

The particle tracking method has now been developed to study alongshore connectivity off the west coast of WA. As part of associated work aimed at understanding fish dispersal on the west coast which is equally applicable to this sub-project on urchin connectivity, we have studied the connectivity between Abrolhos Islands and Rottnest Island to understand the possibility of fish recruitment between the two regions. Particles are seeded near Rat Island daily during February to June to simulate the spawning events of fish larvae and the particles are advected the two-dimensional current averaged from sea surface to 20 meters (top two layers of the BRAN model) for 20 days. Figure 27 shows some examples of the particle distribution (percentage) at 10 days and 20 days after their release averaged over the month during 1995 and 1999. The particles can arrive from Rat Island to

Rottnest Island during a 20-day larval phase, due to the Leeuwin Current transport, however there are significant year-to-year and month-to-month variations of the arrival rates so that the timing of the particle release is rather important.

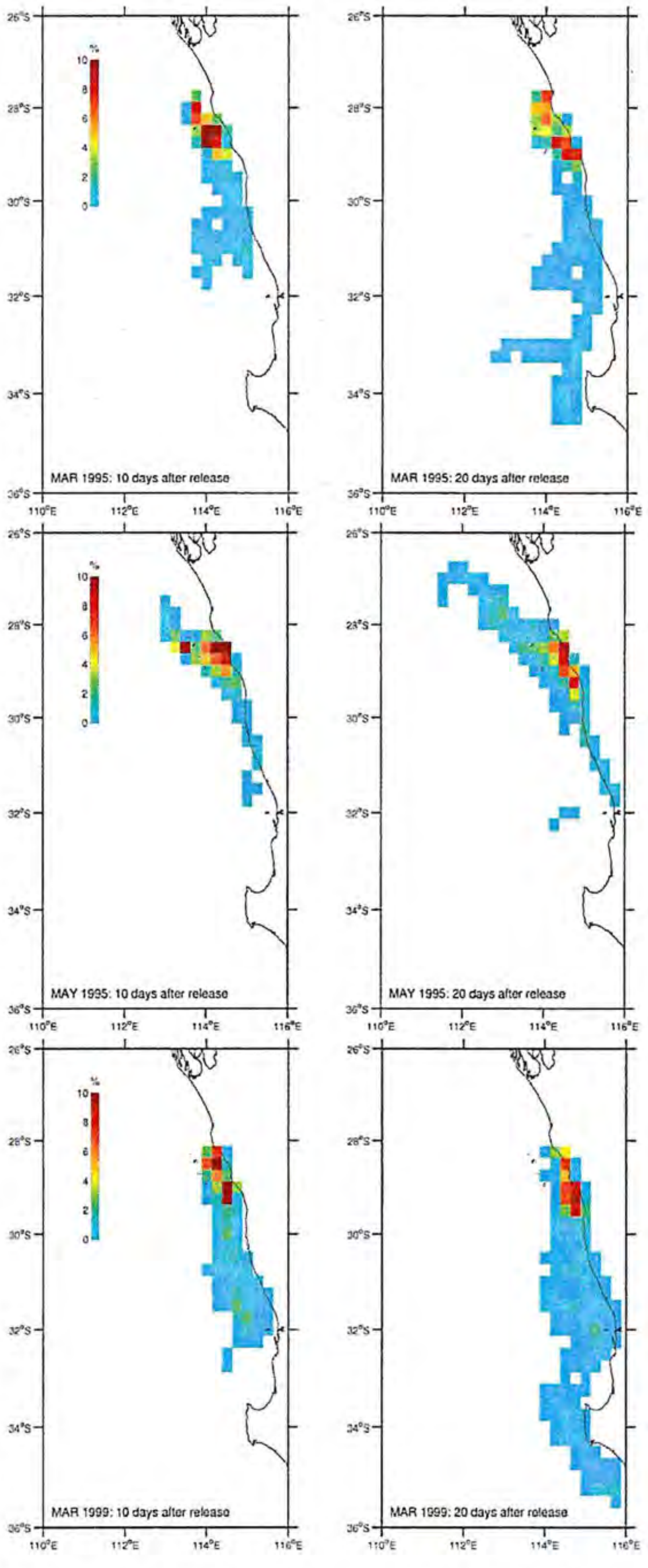
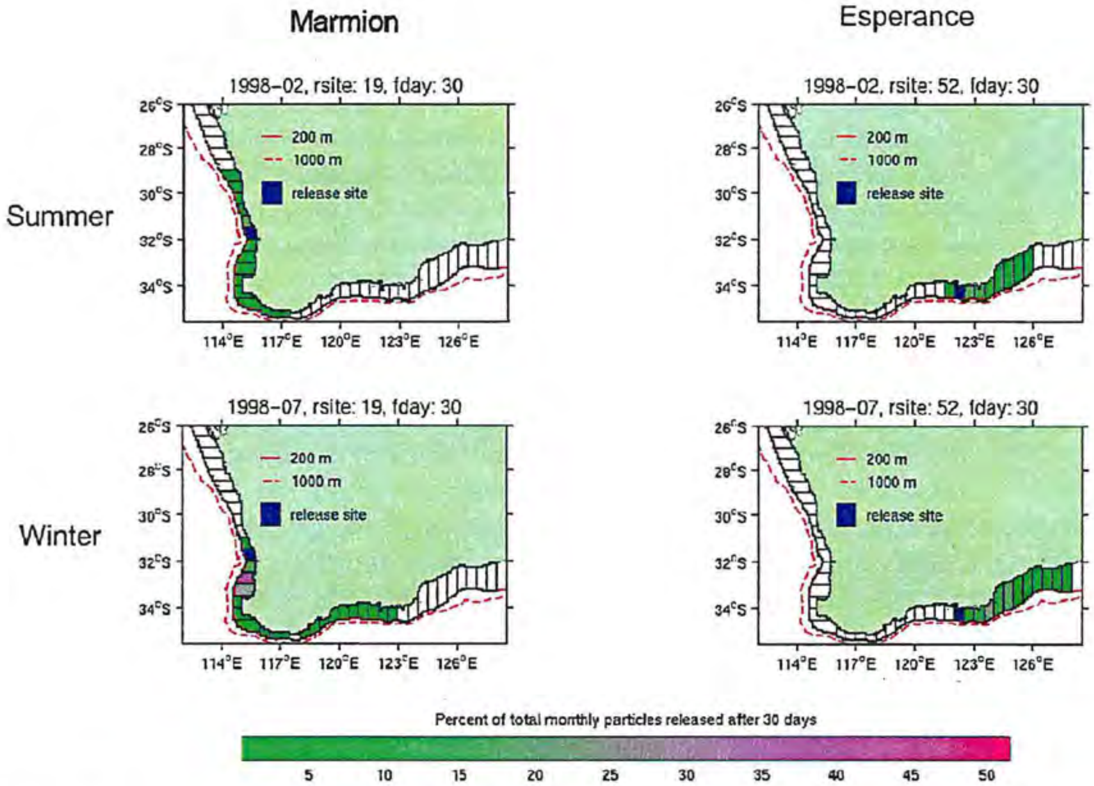


Figure 27.The spatial distribution of the percentage of particle location at 10 days and 20 days after their release at the Rat Island during March and May 2005, and March 1999.

Extension of dispersal modelling to southern WA: Particle tracking has been conducted throughout the range for which urchin samples are being analysed genetically (2.3.1). Because information on larval longevity in urchins is scant, parameters for larval dispersal were chosen to cover a broad range (5, 15 & 30 days) to potentially allow comparisons with connectivity statistics obtained from genetics. Coastal waters to 100m depth were divided into ½ degree cells and particles were seeded in the cells corresponding to each of the four urchin sampling locations: Jurien, Marmion, Albany and Esperance. Particles were tracked for 30 days in two summer and two winter months in six years (1997-2002) of the BRAN time series encompassing the years of the strongest and weakest Leeuwin current flows, 1997 and 1998.

Particle dispersal was generally southward on the west coast and eastward on the south coast, however, substantial northward dispersal was also observed in summer on the west coast when the Leeuwin Current flow is weakest and eddy activity is greatest (e.g. Fig1X Marmion release site, Feb. 1998). Much less counter flow was observed from the south coast sites (e.g. Fig 1X Esperance release site, Feb. 1997)) in summer when nearly all the dispersal was easterly as in winter months. Dispersal distances were greater in winter when Leeuwin Current activity is greatest (e.g. Fig X1, Marmion release site, July 1998). In most years, regions were evident downstream of the release sites with higher concentrations of particles than elsewhere (eg. Fig X1, winter. This is consistent with higher retention or lower flushing rates in these areas allowing the accummulation of larvae. The ecological implications of this result invite further investigation.

Translation of these particle dispersal results into connectivity statistics summarising the relationship among the four urchin sampling sites will allow comparisons with estimates of genetic connectivity currently being obtained. Visualisation of these pairwise connectivity statistics (FigX2) highlights the increased magnitude and directionality of modelled larval dispersal in winter months, with cells of greater probability density occurring below the diagonal.



FigX1. Representative 30 day particle dispersal maps for two of the four urchin sampling sites, illustrating the contrast between summer and winter Leeuwin Current influence on the west and south coasts.

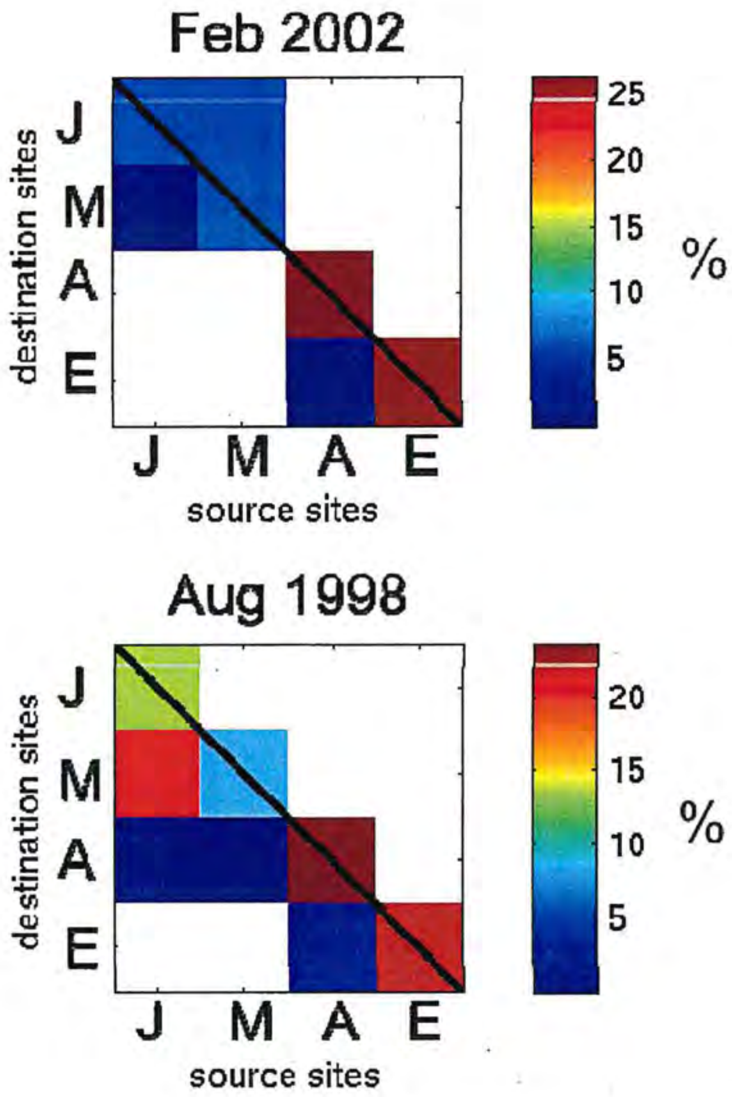


Fig. X2. Representative summer and winter connectivity matrices from particle dispersal modelling at four sites in W.A.: Jurien (J), Marmion (M), Albany (A) & Esperance (E). Each site was used as a source for particles and a destination for counting the percentage of released particles present at the destination cell after 30 days of dispersal.

Milestone 2.3.3: Identification of two urchin species with genetic variability levels that will allow comparative dispersal studies.

Original Forecast Finish Date: 20/12/07

Revised Forecast Finish Date: 30/06/08

This section unchanged from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Sampling of urchins has now been completed from the west and south coasts of WA (Figure 28). Samples are presently being sequenced to identify SNPs at nuclear loci as these show greater likelihood of providing resolution at the geographical scale required than COI, ITS, ND5 and the mitochondrial control region.

The pilot study has identified potentially suitable variability at COI and the four nuclear loci in *H. erythrogamma* and *P. irregularis* and these will form the two key species for this comparative study.

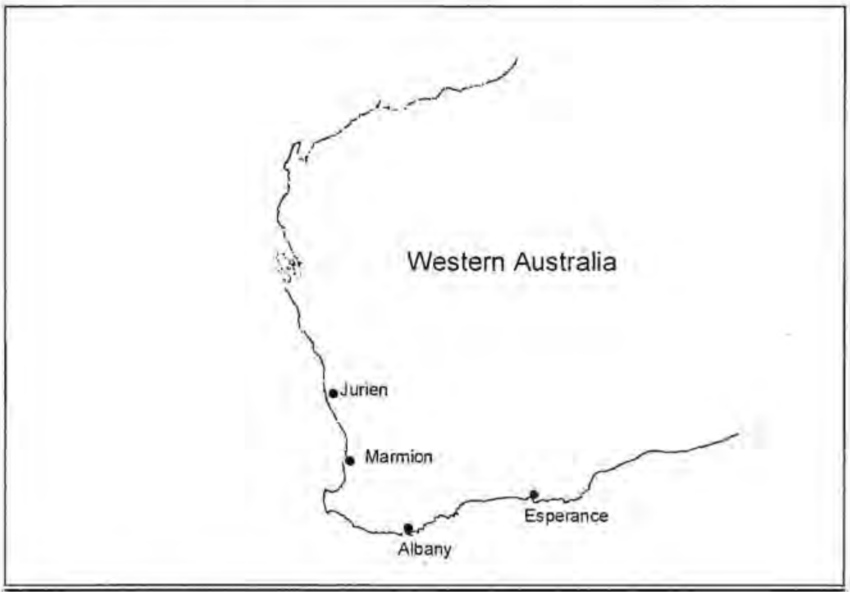


Figure 28.The four main sampling locations used in this study.

Milestone 2.3.4: Completion of genetic sequencing of samples and lodgement of data with GenBank.

Original Forecast Finish Date: 30/06/08

Revised Forecast Finish date 30/09/09.

This section updated from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Sequencing of COI and ANT genes in all available specimens from the four sampling regions has been completed and a preliminary analysis of genetic connectivity in one species *H. erythrogamma* has been conducted (Table X1). Lodgement of these data with GenBank is now possible but effort is currently focussed on completing sequencing at the other loci so that the full genetic analysis can be conducted.

Table X1. Provisional estimates of genetic distance (Nst) from COI (upper matrix) and ANT (lower matrix) in *E. erythrogamma*

	Marmion	Jurien	Albany	Esperance
Marmion		**0.192**	**0.045**	**0.081**
Jurien	0.0029		**0.140**	**0.071**
Rottnest	0.0034	0		**0.137**
Albany	-0.0028	0	0.0004	
Esperence	-0.0006	-0.0003	0.00007	0.0006

Sequencing is still underway at the other nuclear loci and while this was expected to be completed by March 09, unforeseen delays resulting from reduced quality of PCR amplification and DNA have occurred. Efforts to identify the cause(s) included complete replacement of experimental reagents and repetition of the PCR amplification in another laboratory (courtesy of Murdoch University) and these appear to have succeeded. We now expect to be able to complete sequencing at ATPs alpha within weeks. Lodgement of sequences with GenBank and the full multilocus genetic analysis can then be conducted.

Milestone 2.3.5: Population genetic modelling of likely dispersal patterns and generation of null models for comparison with observed genetic structure patterns. Draft MS on observed patterns of genetic structure and what it reveals about potential versus realised dispersal.

Original Forecast Finish Date: 30/06/09

Revised Forecast Finish Date: 30/12/09

This section updated from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

With the hydrodynamic modelling now complete (milestone 2.3.2 above) parameterisation of the population modelling (degree of spatial structure, rates and direction of gene flow and larval migration) awaits completion of the spatial genetic analyses in milestone 2.3.4 above. The proposed comparison of hydrodynamic estimates of connectivity with spatial genetic patterns and modelling will then be made and written up.

2.4 Electronic delivery of data and models to management agencies, building on the development of the Data Interrogation and Visualisation Environment (DIVE) in SRFME.

Summary of Activities Undertaken, Outputs Produced:

There were no specific milestones for DIVE in 2008/09 but the software continues to be developed and improved in response to user requirements. This section provides an overview of DIVE's current capability, lists milestones from previous years, and finally details upgrades made to DIVE during the present reporting period. Importantly, DIVE will soon be able to access data and metadata held under GeoNetwork protocols being adopted by the Australian Ocean Data Centre Joint Facility, and the Australian Integrated Marine Observation System.

DIVE is a data access and visualisation package that has been developed through CSIRO's partnership with the WA Government. DIVE enables both scientists and managers to view the diverse data sets that are generated in WAMSI. The data are multidisciplinary and multidimensional, and range from small numbers of samples collected by divers through to 4d model output occupying gigabytes of computer storage.

Figure 29 shows a typical DIVE screen display, in this case of model output off WA. The narrow left-hand panel provides detail of the data being displayed. The graphics panel is on the right, featuring four different panes. The main pane is a plan view of currents (represented by arrows) overlaid on water temperature (shown by colours). There is a red sample location marker inserted by the user at approximately 32 °S, 114 °E. The graph to the right shows vertical profiles of current speed (black), temperature (red) and salinity (blue) at this location. On the extreme right, there is a vertical depth-slider. The marker on this slider is located at 0 m, indicating the depth at which the plan view is plotted. This marker can be dragged to change the depth of the plan view.

Below the plan view is a time-series, showing the variability of current speed, temperature and salinity at the sample point location, and at the depth indicated by the depth-slider. At the bottom of the panel is an equivalent time-slider, which changes the time of the plan view (and the vertical profiles). The bottom plot on the panel is a cross-section of temperature along the track indicated near the top of the plan view. This track is selected by clicking with the screen cursor.

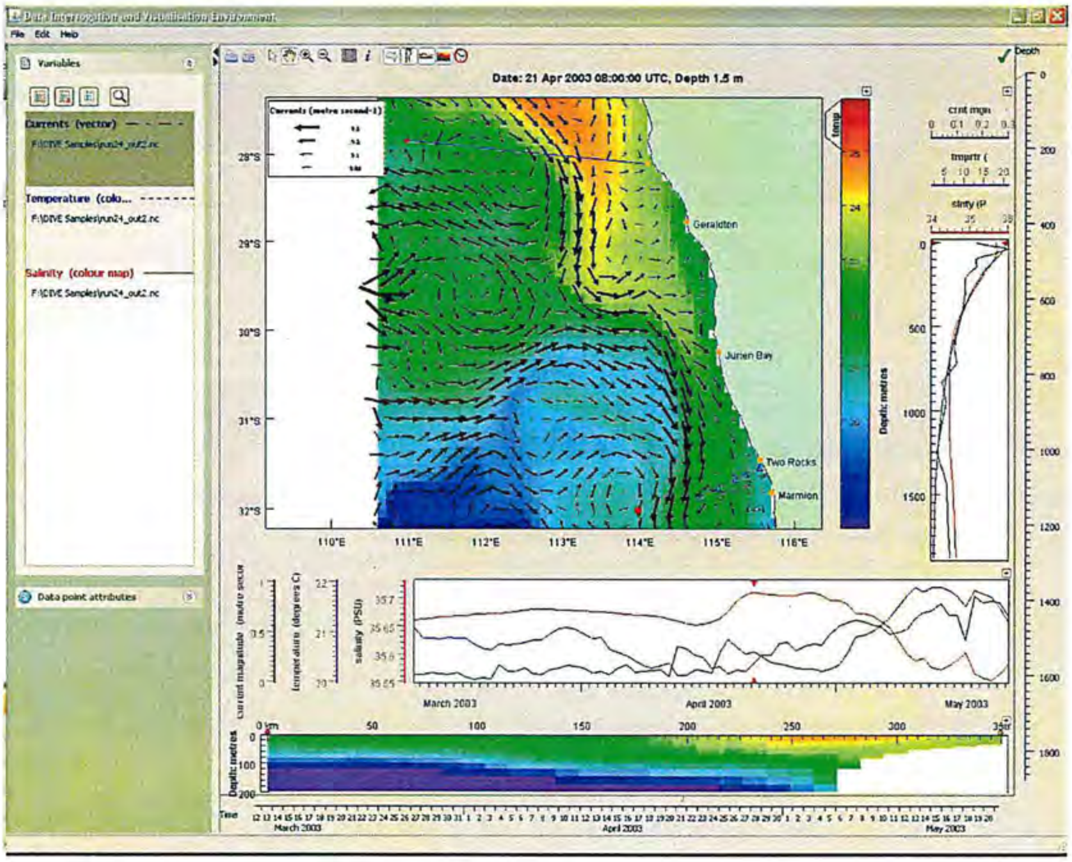


Figure 29. Presentation of layered data with one sample point displayed as time-series and profile in conjunction with a vertical section displayed along an arbitrarily drawn transect.

Individual panels can be expanded by utilising a "lift-out" function to assist with examination of the data. The lift-out option is invoked by clicking on the small square at the top-right of each plot.

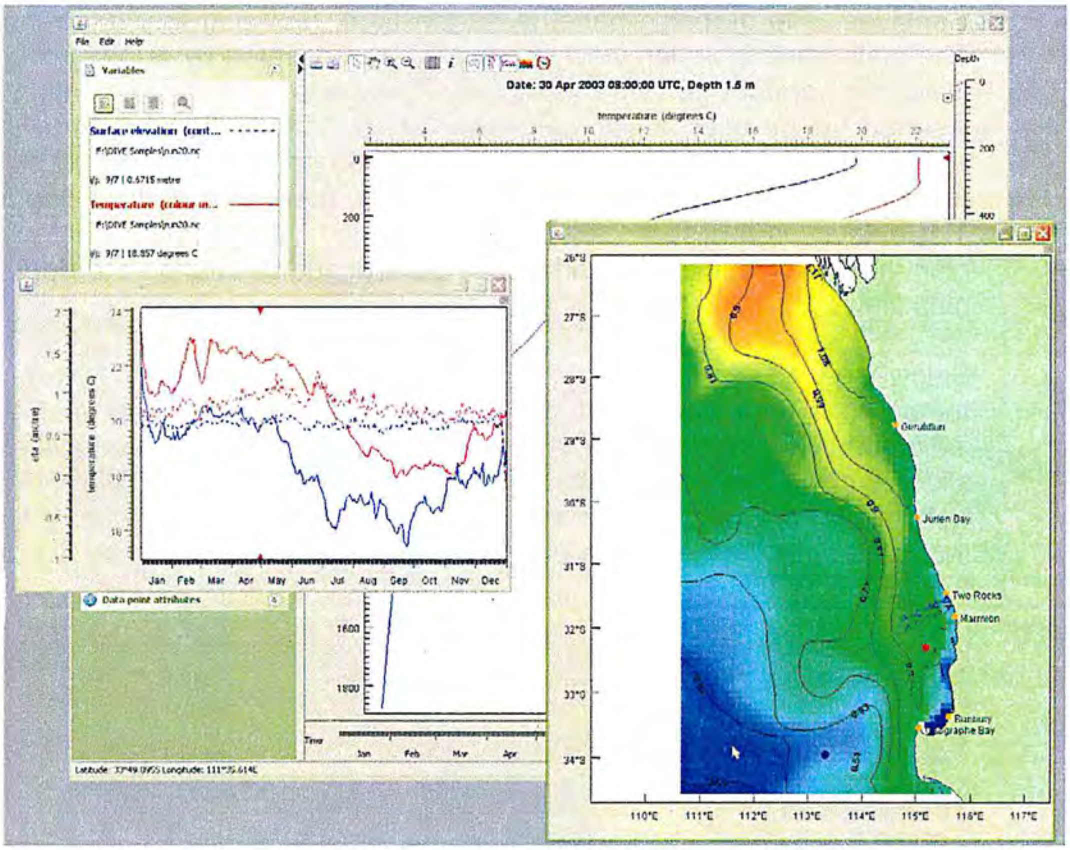


Figure 30. Demonstration of multiple sample points and the 'lift-out' functionality on the time-series and map plot.

DIVE can also plot data for sediments or the atmosphere, when they are available. Figure 30 shows an overlay of water-column and sediment nitrate from a coupled model. The water-column nitrate is shown in red in the graphs, and by the colours on the map view, while sediment nitrate is shown in blue, and by contour lines on the map.

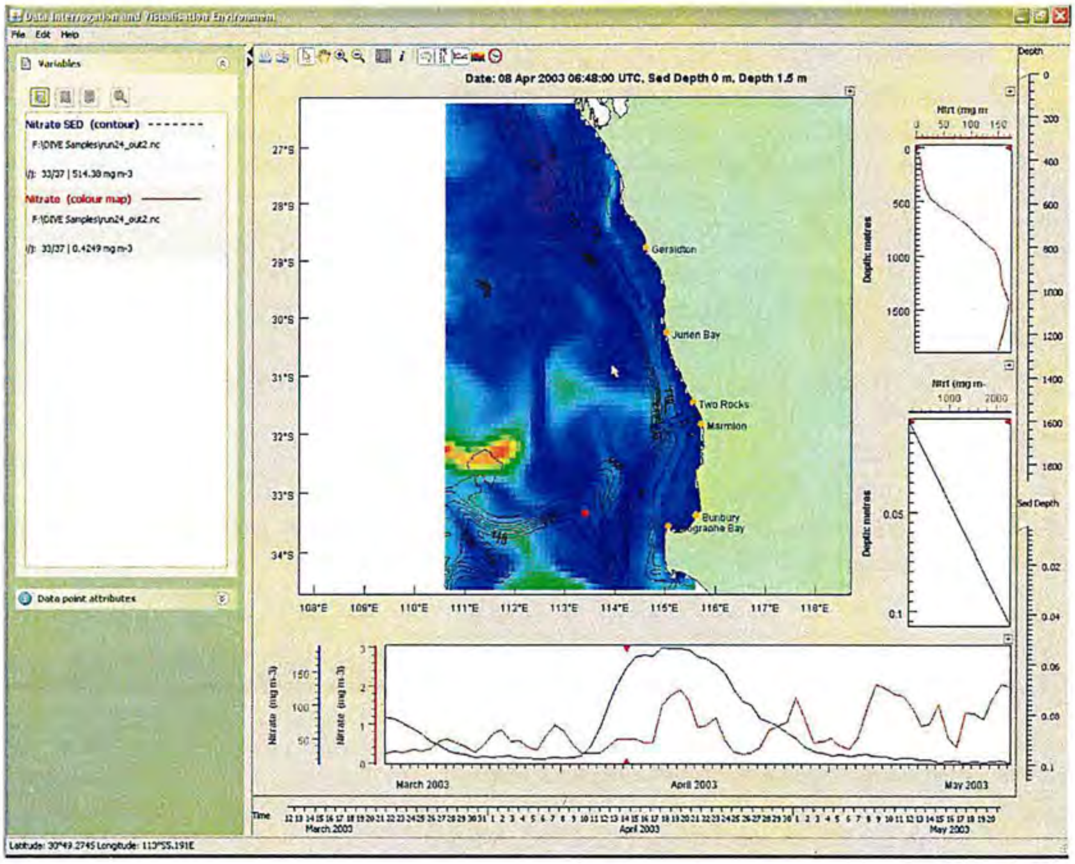


Figure 31. Display of data from different vertical grids, showing separate nitrogen profiles in water and sediment.

Milestone 2.4.1: Extend DIVE to support new datasets

Original Forecast Finish Date: 30/06/07

Revised Forecast Finish Date: 30/06/07

This section unchanged from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

Extensions to DIVE:

- Implemented new 'Look & Feel' for DIVE facilitating ease of navigation [Aug 2006].
- Released DIVE v 2.0 along with User manual to the state agencies [Aug 2006].
- Presented DIVE to the JVMC [Sep 2006]
- Incorporated handling and display of metadata with links to the CSIRO metadatabase Marlin [Dec 2006]
- Due to departmental firewalls, the agencies could not access the WAMSI data through DIVE. An alternative strategy, to store an embedded database with

the DIVE application, was employed to provide access and DIVE v 2.1 was released in December [Dec 2006].

- The Dec 06 strategy was only partially successful. Some WA agencies use mandatory proxy servers and DIVE assumes direct web access. DIVE is being modified to handle environments which use mandatory web proxy servers [May/June 2007].
- Meetings were held at Western Australian Marine Research Laboratories at Hillarys, and the Department of Environment and Conservation (DEC) at Kensington. Staff from many sites of DEC attended, and there is considerable interest from DEC staff in DIVE. This has included a request that DIVE be the data platform for a DEC/AIMS/WAM field study on Rowley Shoals in November 2007. [May 2007]
- Presentation on DIVE made at a meeting of the Western Australian Land Information Systems (WALIS) Marine Group. [May 2007]
- Sample data from DEC provided to CMAR for processing into a format viewable by DIVE. This is complete. [May 2007]

Milestone 2.4.2: Extend DIVE to support new visualisation views subject to user feedback

Original Forecast Finish Date: 30/06/08

Revised Forecast Finish Date: 30/06/08

Text in this section unchanged from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

The functionality of DIVE has been substantially extended. New features include the following:

- Selection and display of arbitrarily directed cross-section plots.
- Improved display of multiple sample points – variable names are better indicated on time series and profile plots.
- Restructuring and extension of DIVE code, particularly the handling of symbols, which underpins ongoing work to display biological point data sets.
- Data sets can be assigned to different vertical sections, so that the same variable can be plotted in both the water column and the sediment.
- Box-model output can be displayed, and new projections are being added on an ongoing bases.
- The display of vector variables has been improved.
- Datasets in different files for the same geographic region can be presented as a single data stream.
- Fixes to allow proper functioning on Mac and Linux platforms.
- Time-series and depth-profile displays have been modified to cope more clearly with multiple variables and multiple points.
- Existing data formats have been extended to accommodate a greater variety of data.

Further, an update system has been developed, that allows notification to users, and on-line updates of DIVE components, without requiring a reinstall. The DIVE manual has also been updated (March 2008).

In addition, the display has been improved by more efficient labelling, and resizable panels. If the displayed variables cover different geographic areas, it is now also possible to zoom to particular datasets by clicking on the variable in the left-hand panel.
The new version of DIVE has been released, following a standard progression through several release candidates which have been provided to selected users for testing.

Modifications in progress include:

- Display of histograms or pie-charts at field data-collection points
- Automated meta-data feed between the local DIVE data repository and MEST (BlueNet Metadata Entry and Search Tool).
- Incorporation of data provided through GIS web services.
- Customised edit layers – ability to create and edit symbols, and to add text to annotate DIVE output.
- Several formats, including pdf, are being added to the export facility of DIVE

DIVE is planned as the visualisation tool for the Rowley Shoals study conducted by DEC, the WA Museum and AIMS. We are liaising with DEC on their data formatting and display needs.

Presentations on DIVE have been given at the first Ningaloo Symposium in July 2007, the WAMSI-iVEC-WASTAC seminar in October 2007, and at the Wealth from Oceans symposium in March 2008 in Hobart.

Milestone 2.4.3: Evaluate priorities for new web based applications to extend model delivery

Original Forecast Finish Date: 30/06/08

Revised Forecast Finish Date: 30/06/08

Text in this section unchanged from previous Biannual Report

Summary of Activities Undertaken, Outputs Produced:

DIVE has advanced considerably in its sophistication, functionality and versatility through 2007/8. It is, and will remain, our priority tool for accessing, visualising and exporting both local and remote data sets. Its web-functionality has been increased, in particular with the on-line notification to users of updates, and with upcoming compatibility with the Bluenet MEST facility. It will become more attractive to ecologists through its ability to handle GIS web-service data and, further, data that are sparse in space and/or time (see below).

All current development of DIVE is undertaken with view to creating a web-based tool providing a sub-set of functionality, should there be demand. As a consequence, the majority of functions can be translated seamlessly into a web-based tool.

To address the requirements of the ecologists associated with WAMSI and, in particular, with DEC, DIVE will shortly incorporate a substantial framework for presentation of temporally and spatially discontinuous data. For example datasets can be presented as bar charts in a variety forms. Communication is also underway to establish the best means to deliver dynamic and static data to stakeholders. With the advent of the Portable Document Format (PDF) and Adobe 'flash' (swf), supporting layers and menu-driven manipulation of such files, DIVE is in the process of being equipped with the export facility to produce layered PDF files. The AVI and 'flash' video format is also being added to DIVE's export facility. These formats will facilitate the static presentation of data online.

Upgrades to DIVE in 2008/9

It is an ongoing challenge to ensure that DIVE recognises the data types and formats commonly used by marine scientists. Development of DIVE has continued in the 2008/9 project year, to improve its versatility, and accessibility to a wider range of users.

In particular:

- The user can now select the time-zone in which the data are displayed: most commonly, this will be UTC, or the local time-zone of the user.

- Data can be viewed in "single steps" through the time series or vertical layers; that is, the time-slide and depth-slide can be clicked through individual time or depth intervals in the data file.
- There have been many interface and consistency improvements:
  - A "busy indicator" shows users when DIVE is active but busy – such as downloading data over the Internet.
  - Improved display of data for multiple datasets and multiple variables, through the use of colour and line styles (e.g. the coloured time-series).
  - Hiding and display of data depending on the selected viewing time.
- Improved animation exporting:
  - more options on time-range to export - for example, only a subset of the data may be exported, and the time can be specified in various units.
  - export of AVI format and 'flash' as well as animated gif.
- Backdrops in GeoTIFF format (a standard geo-referenced file format) such as maps, charts, aerial photography can be displayed (Figure 32).
- The user preference system has been improved. The user-preference system enables a user to establish settings (such as the domain, annotations, backdrop, time-zone...) that will be maintained, rather than having to be reset every time DIVE is opened.
- The lift-out function has been improved.
- DIVE now has the ability to look at folder-based datasets. If data are held in multiple files within a single folder/directory (as is common with output from large model runs), DIVE can interpret the files as a single data source, enabling, for example, faster access and continuous plots (rather than a new plot for each separate file).

- DIVE is able to read ROMS (Regional Ocean Modeling System) output. ROMS is a widely-used, open-source hydrodynamic model which has been implemented in Project 1 – see Milestone 1.1.8.
- Improvements to facilitate improved display of biological and underway datasets including high-resolution glider data. Sparse data sets present significantly more challenge for visualisation than regular data typical of model output. For underway measurement, hovering the cursor over the vessel track will produce detail of the data (e.g. Figure 33).

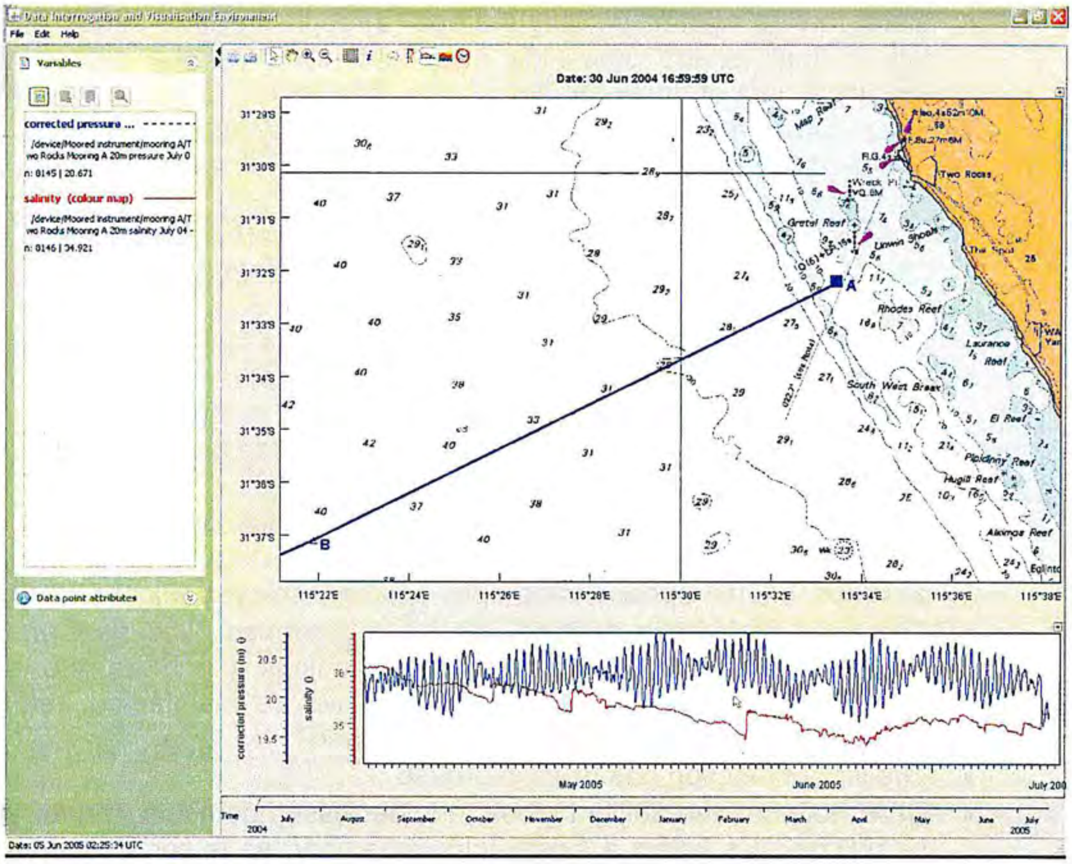


Figure 32. Display of pressure and salinity from mooring at Two Rocks transect station A, with a navigation chart back drop.

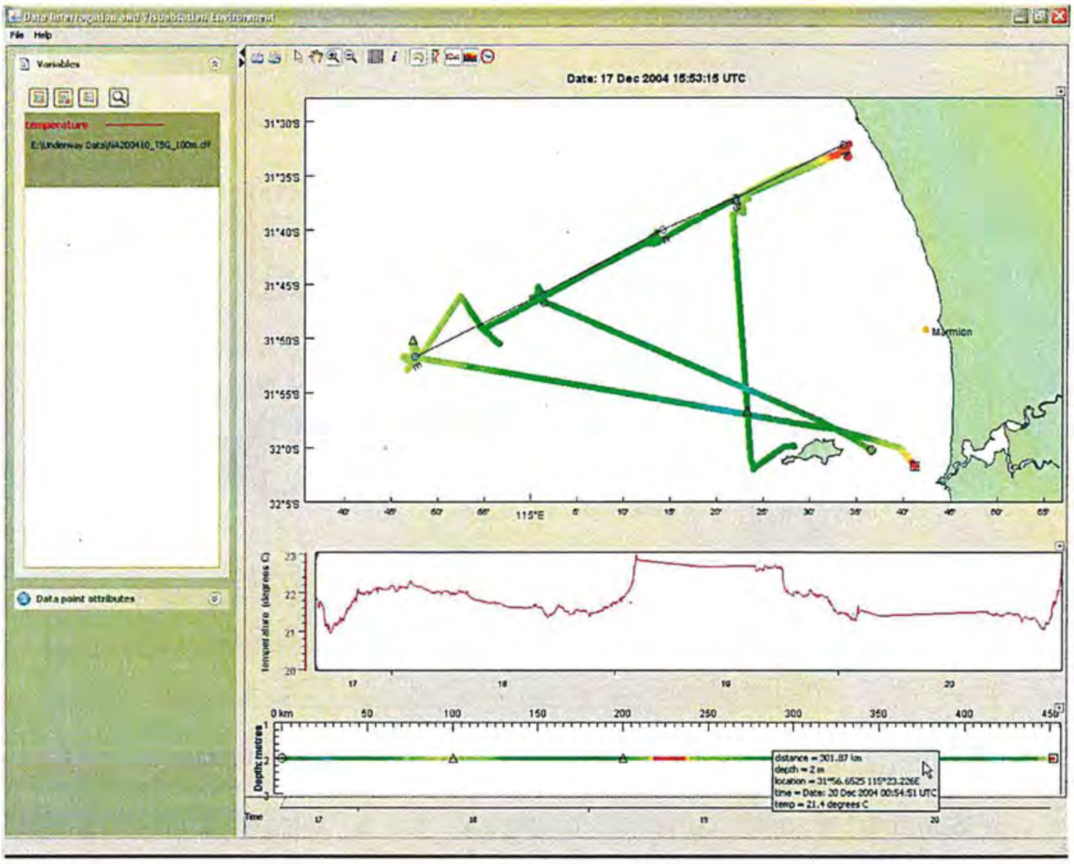


Figure 33. Display of underway data, showing the information panel activated by hovering the cursor

Modifications in progress include:

- Sparse data, as collected by divers, for example, can be shown in DIVE by using bar or pie charts that might represent species abundance at the site (e.g. Figure 34).
- The user will have the ability to create and edit symbols, and to add text to annotate DIVE output.
- An import facility for incorporation of non-continuous, non-contextual data (effectively by copy and paste from a spreadsheet) is in development. (Non-contextual data are insufficiently located, in time or space, in the data file, requiring additional user-input through the import facility.)
- The DIVE manual is being updated – this will be completed by 30 June.

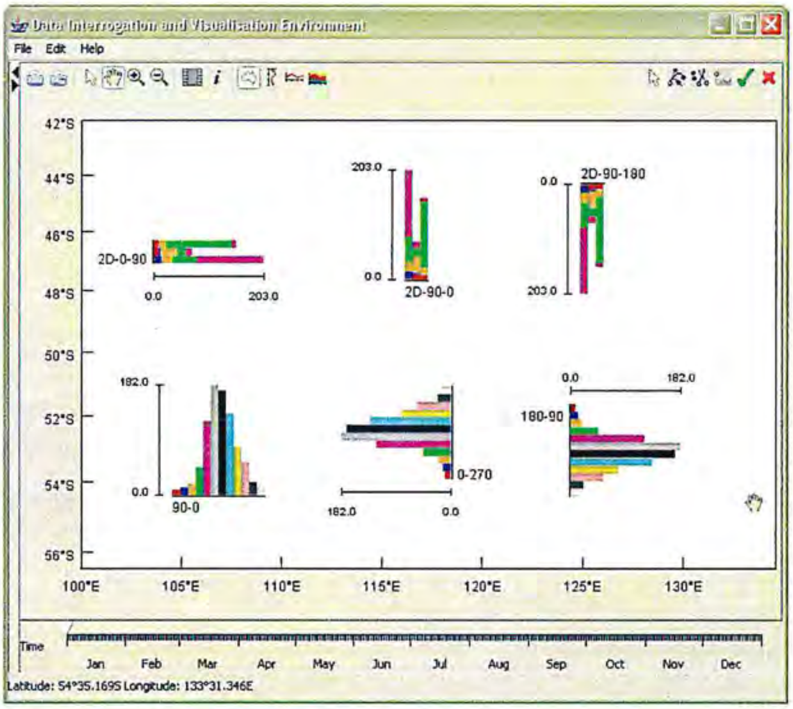


Figure 34. Various bar charts in different orientations

Scoping is also currently underway for a "wizard tool" that will enable biological scientists to create relational database records from arbitrarily formatted data in documents such as Excel spreadsheets. DIVE will be able to display data from the relational database records so created. This wizard tool will utilise the import facility for non-continuous, non-contextual data

The recent plan to extend DIVE to recognise OGC (Open Geospatial Consortium) Catalogue Services standards to access data sets has been dalayed to ensure compatibility with IMOS software presently under consideration and development. This capability will enable DIVE to access data sets archived by the Australian Oceanographic Data Network (AODN), and the Australian Integrated Marine Observation System (IMOS). It is likely to be added in 2009/10.