FINAL WAMSI PROJECT REPORT

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Project Details

Project Number and Title:	WAMSI 4.2: Assessment of Marine Communities and the Impact of Anthropogenic Influences
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Project Start Date:	1 July 2008
Project End Date:	30 June 2011
Due Date for Final Report:	30 June 2011

1. Project Objectives and Achievement Criteria

Confirmation of the project objectives and the delivery of milestones against the Key Performance Indicators:

The overall strategic purpose of WAMSI Node 4 was to develop methods and/or generate the information needed to assist with the management of the marine ecosystems of Western Australia consistent with the principles of Ecologically Sustainable Development (ESD). Implementing these ESD principles in a practical manner for fisheries has involved the development of a new management approach which is termed Ecosystem-Based Fisheries Management (EBFM)
Within the EBFM Node, Project 4.2 addressed the following management questions:

- What changes, if any, were occurring in the biodiversity, community structure or habitats within each priority bioregion?
- Where practical, identify whether fishing or any other factor (eg climate change, pollution) was having an unacceptable level of impact on these elements?

The Project Strategy consisted of developing cost effective, quantitative methods to assess the status of the community structure, biodiversity and key habitats within each of the priority bioregions and, where possible, discriminate the potential impact of each individual factor within the cumulative impacts of all fishing activities, climate shifts and other factors. These metrics should, where practicable and appropriate, be capable of being linked to measures of the condition of smaller scale marine parks and sanctuary areas. Advice on the appropriate number and extent of areas to be monitored should also be provided.

The table below lists all the milestones for each of the subprojects. All these milestones were achieved.

	4.2.1a Bioregional assessments				
1	Appoint postdoctoral researcher (MU)	Jun 2008	MU		
2	Complete 1st and 2nd sampling trips to Peel Harvey (PH) and 1st trip to Leschenault Inlet (LI) Report on completed sampling trips	Dec 2008	MU		
3	Complete 3rd and 4th sampling trips to PH and 2nd trip to LI Report on completed sampling trips	Jun 2009	MU		
4	Complete 5th and 6th sampling trips to PH and 3rd trip to LI Report on completed sampling trips	Dec 2009	MU		
5	Completion of preliminary statistical analysis.	Jun 2010	MU		
6	Completion of statistical analyses. Completion of draft final report. Completion of final report.	Dec 2010	MU		
	4.2.1b Estuarine Health Index				
1	Satisfactory completion of annual university progress report for first year of PhD for Chris Hallett	Dec 2008	MU		
2	Satisfactory completion of annual university progress report for second year of PhD for Chris Hallett	Dec 2009	MU		
3	Satisfactory completion of annual university progress report for third year of PhD for Chris Hallett	Dec 2010	MU		
	4.2.2a Indicator Regions				
1	Appoint 2 x postdoctoral researchers (UWA) and Snr Research Scientist. Steering Committee established Steering Committee confirm indicator regions Synthesis of historical and existing data completed Potential indicators identified for habitat / sessile benthos (SB) Sampling plan for habitats / SB indicators developed	Jun 2008	UWA		
2	Review of potential indicators identified for finfish Initial habitat monitoring program implemented	Dec 2008	UWA		
3	Review of potential indicators identified for mobile invertebrates	Jun 2009	UWA		

	Workshops held for fish / mobile invertebrate indicators and for habitat / SB indicators Workshop report completed					
4	Sampling plans for fish / mobile invertebrates developed Workshop report completed	Dec 2009	UWA			
5	Monitoring programs for finfish and mobile invertebrates commenced	Jun 2010	UWA			
6	Monitoring programs for finfish and mobile invertebrates completed	Dec 2010	UWA			
7	Workshop completed on expansion of program to other areas Consultation and information exchange with Node 4.1	Feb 2011	UWA			
8	Draft and final reports produced	Jun 2011				
	4.2.1b Metro Fish Indicators					
1	Identification of focus areas in metro region	Jun 2008	UWA			
2	Completion of field sampling	Dec 2008	UWA			
3	Completion of video analysis	Jun 2009	UWA			
4	Completion of draft analyses, workshop and revised outputs	Dec 2009	UWA			
	4.2.3 Fisheries Dependent Data and Climate					
1	Researcher hired	Dec 2007	DoF			
2	Relevant climate-related data sets compiled Relevant fisheries data sets compiled Statistical analyses of fisheries dependent data as related to climate completed Draft report completed Final report completed	Jun 2009	DoF			
	4.2.4 Cost effective methods					
1	Post docs and Snr Research Scientist appointed as per 4.2.2 Literature reviews (including report) on alternative sampling designs completed Power analyses on habitat / SB data sets completed Trial sites for SB indicators identified	Jun 2008	UWA			
2	Power analyses on fish data sets completed Comparison of diver vs camera-based techniques for fish and mobile inverts completed	Dec 2008	UWA			
3	Power analyses on remote sensed data / map-derived indicators completed Comparison of diver vs camera-	Jun 2009	UWA			

	based techniques for SB indicators completed Power analyses on mobile invertebrates completed Trial sites for fish and mobile invertebrates chosen Trial for SB indicators completed Interim report on habitat / SB methods completed					
4	Trial sampling program for fish and mobile invertebrates completed Draft and final reports for project completed and provided to 4.2.2	Dec 2009	UWA			

2. Overview

To meet the objectives of the Project, the following Sub Projects were undertaken. Full accounts of these can be found in the Sub Project Reports and Attachments.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data

Key questions

- To what extent can the data that are available from commercial fishing be used to monitor the status of the community structure in each of the bioregions?
- Is it possible to generate a cost effective fishery independent monitoring program of the fish community for areas where commercial fishing supplies insufficient information?

Project Specific Objectives

1. To produce a cost effective fishery independent monitoring program for the fish communities in the Peel-Harvey and Leschenault estuaries, in which data from commercial fishing supply insufficient and no information, respectively. The proposed program is dependent on exploring the trends exhibited over time, as determined from comparisons with the results of studies carried out in previous decades in those two estuaries.
2. Collect samples of fishes from the Peel-Harvey and Leschenault estuaries in each of the eight consecutive seasons between winter 2008 and autumn 2010 and at the same sites as those sampled in previous studies of these two systems. Both estuaries were sampled using a 21.5 m seine net and the Peel-Harvey Estuary was also sampled employing a 102.5 m seine net. The Peel-Harvey Estuary was previously sampled in 1980-81, when macroalgal growth was close to its maximum and, in 1996-97, two to three years after the opening of the artificial Dawesville Channel and thus when tidal exchange had become greatly increased, salinity modified and macroalgal growth reduced. The Leschenault Estuary was previously studied in 1994.
3. Compare the densities, numbers of species and species compositions of fishes recorded in the Peel-Harvey and Leschenault estuaries during present and past studies. Comparisons in the Peel-Harvey Estuary focused on data collected using a 102.5 m seine net as this was employed in all three periods, whereas comparisons in the Leschenault Estuary concentrated on those derived from samples collected using a 21.5 m seine net, which was employed in both periods. Note that a 21.5 m seine net was also used in the Peel-Harvey Estuary in 1996-97 and thus enabled further comparisons to be made with the results of the current study.
4. Determine whether the ichthyofaunal characteristics of the Peel-Harvey Estuary have remained similar to those in the 1990s, following the opening of the Dawesville Channel, or had returned towards those in the macroalgae-dominated period of the 1980s. The possibility that the ichthyofauna may have changed since the mid-1990s is raised by anecdotal reports that macroalgal growth increased in the intervening period.
5. Determine whether any shifts in the characteristics of the fish fauna of the Leschenault Estuary between 1994 and 2008-10 are consistent with anecdotal reports that macroalgal growth has increased during recent years.
6. Determine whether any changes in the ichthyofaunal characteristics of the Peel-Harvey and/or Leschenault Estuary are sufficiently deleterious to change the risk status of these systems and thus require action by managers.
7. Propose a fishery-independent monitoring programme for the Peel-Harvey and Leschenault estuaries that would detect any conspicuous changes in the characteristics of the fish community in those estuaries and highlight any research needs.

4.2.1b The development and validation of an estuarine health index using fish community characteristics

Key question as for 4.2.2a

Project specific objectives

1. Develop an approach for constructing a fish-based, multimetric index for assessing the ecological health of estuaries in south-western Australia, and apply that approach to the large and extensively-modified Swan Estuary.
2. Evaluate the sensitivity and reliability of the resultant index.
3. In light of the findings arising from the second objective, identify key considerations for the future development of a practical, cost-effective and scientifically robust monitoring regime, to enable the index to be used for ongoing assessment of the health of the Swan Estuary and potentially other estuaries in south-western Australia.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment

Key question

- The establishment of long term monitoring sites is essential to enable reporting on the level to which community structure is changing or not through time. To what degree can identified changes in marine communities be detected through the establishment of long term monitoring sites which can be sampled at regular intervals through time to provide a baseline for assessments?

Project specific objectives

1. Determination of indicator regions.
2. Development of monitoring strategies, given an understanding of short term variability.
3. Provision of an assessment of expanding the monitoring system to other areas.

4.2.2b Metropolitan fish indicators

Key question

- What are the patterns of species distribution, abundance and size for many of the finfish found in the metropolitan region?

Project specific objectives

1. Benchmark the biodiversity of fish communities in the Perth Metropolitan area.
2. Provide the basis for an ongoing monitoring program to assess responses.

4.2.3 Establishment of fishery-dependent indicators of climate change

Key question

- To what degree can the use of fishery-dependent data provide a cost-effective way of assessing whether there have been any changes in the distribution and relative abundance of species?

Project specific objectives

1. Develop an understanding of the key environmental trends that are occurring in the marine environment off Western Australia (WA) that may affect fisheries e.g. increasing water temperatures, decrease in storms and westerly winds, more frequent ENSO events.
2. Determine the effect environmental variability is having on biological parameters (e.g. recruitment, size at maturity, growth) of fish stocks.
3. Examine the historical variability of the environmental variables that have been identified as affecting fish stocks e.g. determine the presence of any long-term trends.
4. Use climate modelling to assess the likely trends in the identified environmental variables in the short-term (10-20 years) and long-term (50-100 years).
5. Hypotheses on the effect of these trends on the fisheries can then be developed.

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

Key question

- What cost-effective methods are needed to monitor biodiversity and habitats in an ongoing manner?

Project specific objectives

1. Review outcomes from WAMSI 4.3, 4.2.2 and other projects to assess options for the most appropriate methods for monitoring community structure, biodiversity and benthic habitats within any high priority ecosystem.
2. Evaluate alternative sampling designs including non-random designs based on gradients, maximum heterogeneity, maximum sensitivity, and the use of permanent stations.
3. Trial alternative sampling methods for primary producers and sessile invertebrates, macroinvertebrates, finfish and habitats as indicators for each group identified.

3. Summary

Half page to full page Executive Summary of results from each Sub Project. Must link directly to Objectives of Project.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data

This project has developed a cost effective fishery independent monitoring program for the fish communities of the Peel-Harvey and Leschenault estuaries. This monitoring program, which employed identical sampling methods at the same sites to those sampled during previous studies of these two estuaries, has enabled direct comparisons with the historical studies. Analyses of the data for the Peel-Harvey Estuary demonstrate that the present composition of the fish fauna, like that of the 1990s, is distinguished from that of the 1980s by consistently far greater numbers of Weeping Toadfish (i.e. blowfish), *Torquigener pleurogramma*. In contrast, the consistently greater numbers of the Western Gobbleguts, *Apogon rueppelli*, and the Western Striped Trumpeter, *Pelates octolineatus*, helped distinguish the present fauna and that of the 1980s from the 1990s. Although the ichthyofaunal composition of the Leschenault Estuary in the present study and in the 1990s was very similar in both periods, in terms of the number of individuals and number of species caught, they differed conspicuously in the fact that substantial numbers of two tropical species of Hardyhead (*Craterocephalus mugiloides* and *Atherinomorous vaigensis*) had colonised the estuary in the intervening period, when coastal water temperatures had risen.

The risk status of the Peel-Harvey Estuary remains high while there is no indication that the current risk status of moderate for the Leschenault Estuary requires alteration. While these studies have shown that the fish fauna has changed, the actual causes were not determined in a manner that could dictate what management changes might remedy the situation. A rigorous study of the characteristics of the benthic invertebrate fauna may help to ascertain the state of the health of the benthic environment, which in turn may allow better determination of causal effects of the observed fish community changes.

4.2.1b The development and validation of an estuarine health index using fish community characteristics

This study has succeeded in developing health indices for the Swan Estuary, which are the first such tools to be produced for Western Australian estuaries. A suite of fish community characteristics (metrics), including measures of species composition, diversity and abundance, trophic structure and life history function, were selected via a novel weight of evidence approach, on the basis of their sensitivity to detect inter-annual change in estuarine condition. Seasonally-adjusted reference conditions for each selected metric were established for each region of the Swan Estuary using 30 years' of historical fish assemblage data, and thus represent a best available standard of biotic integrity against which the current and future health of the estuary may be assessed and compared. Scores for each metric were assigned according to the extent of the metric's deviation from its reference condition. Values for the health indices were then calculated from summed metric scores for each main region of the Swan Estuary for each season and year. Whilst the trends exhibited by the mean index scores for shallow waters of the Swan Estuary suggest that the health of those waters has remained relatively constant over the last three decades, shallow water health has increased in recent years, with the mean health index score increasing from *ca* 58 in 2005/06 to 64 in 2008/09. In contrast, the deep water index score has decreased consistently from 56.5 in the late 1970s to 47 in 2008/09, resulting, for the first time in three decades, in the health status of the deeper waters being classified as poor. It is hypothesised that these results reflect a shift of the fish fauna from deeper waters to shallower areas, in response to declining ecological condition and habitat quality of the former waters.

Although index sensitivity to changes in specific ecological stressors could not be demonstrated, the consistent decrease in deep water health index scores from 1978 to 2009 suggests that this index is capable of detecting the widely-perceived, long-term decline in the condition of the deeper waters of the Swan Estuary.

Summer and autumn are the best season for future monitoring of the ecological health of the Swan Estuary using the system of indices developed in this study. Overall, validation of the indices developed during this study demonstrated that their spatial and temporal variability was comparable to that of existing multimetric indices employed in the USA and Europe, and that classification of the health status of the estuary was fairly robust. These indices thus provide managers with an option of using fish communities as a basis for detecting improvements or declines in estuary health and a means for communicating ecosystem health implications to the wider public. Moreover, the approaches developed

during this project may potentially be applied to other estuarine systems throughout south-western Australia, given the collection of suitable baseline data.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment

The project has established long term monitoring sites and developed monitoring strategies that have been found to be sensitive to change in marine communities. These strategies have been found to provide clear reporting on the level to which marine community structure is changing or not through time. The Houtman Albrolhos, Rottnest Island and the Capes were identified as key locations for implementing a long-term monitoring program. Key measurable attributes/values for sessile benthos and finfish assemblages at these indicator regions have been identified and it has been shown that these attributes can be monitored efficiently in the future.

An extensive review of the use of indicators to monitor the health of ecological assets was completed. This large body of work examined the usefulness of various attributes of primary producers, mobile and sessile invertebrates and demersal finfish as indicators that can be cost-effectively monitored to detect changes in ecosystem health. The review facilitated an assessment of potential indicators that could be measured in the West Coast Bioregion as part of a monitoring program.

Using outcomes from the indicators review and Subproject 4.2.4, sampling designs were developed to monitor sessile benthos and finfish assemblages, which have been identified as key ecological assets within the EBFM risk-assessment framework developed in Project 4.1.

A major outcome of this subproject has been the establishment of a monitoring program to detect changes in the benthic ecosystem using a state of the art Automated Underwater Vehicle (AUV). The AUV is operated and maintained by the Australian Centre for Field Robotics (ACFR) at the University of Sydney, and is funded through the Integrated Marine Observation Strategy (IMOS). This powerful tool facilitated data collection at a high-resolution and multiple spatial scales. As the vehicle traverses pre-determined transects, it collects video, bathymetry and a range of physio-chemical data. The vehicle can 'dive' for over 6 hours, which allows a considerable area of seabed to be surveyed and mapped. In 2010, AUV sampling was conducted at Abrolhos, Jurien, and Rottnest as a collaboration between UWA, Dept. Fisheries WA, CSIRO and University of Sydney. At each location, 3-6 replicate subtidal reefs were mapped (100% coverage) at three depths (~15, 25 and 40 m), and comparable surveys were conducted inside and outside marine reserves. In 2011, repeat surveys were conducted at most reefs to bolster the utility of the program. Data analysis is ongoing, but benthic communities at long-term monitoring sites have been benchmarked, and we also observed extensive coral bleaching at the Abrolhos as a result of the 'marine heat wave' of 2011.

Similarly, a monitoring program for finfish was developed, using Baited Remote Underwater stereo-Video (stereo BRUV) surveys at numerous sites within the Indicator Regions. This work has highlighted temperature-related distributions of key fish species, and shown that whole assemblages can be cost-effectively monitored to track changes in demersal finfish assemblages over time.

Finally, in collaboration with Project 4.1, a workshop was held to discuss the contribution of these monitoring programs to natural resource management decision-making, and to continuation of the programs and expansion of the work into other areas.

4.2.2b Metropolitan fish indicators

This study involved a benchmarking survey of the demersal fish assemblages of the Metropolitan area just after the closure of the commercial wetline and gillnet fishery and prior to the seasonal closure of highly-targeted demersal finfish species. The data has provided an opportunity to asses the sensitivity and distribution of likely indicators of changes in the fish assemblage due to the effects of fishing and predicted increase in ocean temperature.

Workshops have been conducted at the Department of Fisheries to discuss and interpret the results of this study. Various species and assemblage metrics were predicted to be good indicators of the effects of fishing and changes in ocean temperatures. This study found that whilst some of these species and metrics provide a good indication of ecosystem impacts, others did not.

This study provides a starting point for future research programs to develop indicators of change in marine communities due to human use and predicted increase in ocean temperatures. The integration of future studies within the Metropolitan area with larger-scale monitoring programs around the south western coast of Australia (Subproject 4.2.2a) will enable these indicators to be further refined and value

add to these existing programs.

4.2.3 Establishment of fishery-dependent indicators of climate change

As this project was completed before the climate modelling in WAMSI Node 2, the main focus on this relatively small WAMSI project was collation of available data and re-examination of previously developed relationships.

A number of oceanographic and meteorological data sets from both historical and current data sources, within and external to the Department of Fisheries, were compiled. These include Southern Oscillation Index, sea level, water temperature and salinity, wind strength and direction, ocean current, cyclones, rainfall, winter storms, cyclones, chlorophyll levels, Indian Ocean Dipole. These data sets are being used to understand the effects of the environment on fisheries.

Some of the key environmental trends that may be affecting fish stocks of Western Australia include:

(a) increasing frequency of ENSO events;
(b) more years with weaker Leeuwin Currents;
(c) increase in water temperature off the lower west coast of WA, particularly in autumn-winter;
(d) increase in salinity which includes some large annual fluctuations;
(e) change in frequency and location of storms (and rainfall) affecting the lower west coast of WA; and
(f) change in frequency of cyclones (and summer rainfall) affecting the north-west of WA.

One area of greatest increase in surface sea temperatures (SST) (0.02^{o}C per year) in the Indian Ocean over the last 50 years has been occurring off the lower west coast of Australia. Water temperature trends at a number of coastal sites since the early 1970s were examined: two rock lobster puerulus monitoring sites in shallow water (<5m); four sites from a monitoring program onboard rock lobster vessels that provide bottom water temperature (<36 m); an environmental monitoring site at Rottnest (0-50m depth). Two global SST datasets are also examined. These data also showed that there was a strong seasonal variation in the historic increases in temperature with most of the increases ($0.02\text{-}0.035^{o}$C per year) only focused on 4-6 months over the austral autumn-winter with little increase ($<0.01^{o}$C per year) apparent in the spring-summer period. These increases are also apparent after taking into account the interannual variation in the strength of the Leeuwin Current. The warming trend results in a change to the seasonal temperature cycle over the decades with a delay in the peak temperature during autumn between the 1950s and 2000s of about 10-20 days. A delay in the timing of the minimum temperature is also apparent at Rottnest from August-September to October.

Fisheries data collected from a number of sources are used to assess the effect of environmental conditions on fisheries which then may be useful in assessing effects of climate change on fisheries. The sources of data include: (a) catch and catch rate data from monthly returns or daily logbooks; (b) research staff going on board commercial vessels to monitor the catch retained and that returned to sea; (c) standardized research survey of stocks onboard commercial or research vessels; and (d) research survey of stocks independent of commercial vessels.

The western rock lobster fishery has long-term time series (about 35-40 years) on a number of biological variables as well as fishery-independent estimates of recruitment, puerulus settlement, which makes it one of best candidates to study climate change effects on a fishery in Australia. This study noted that climate change effects such as increasing water temperatures may cause a decrease in size at maturity, decrease in the size of migrating lobsters, an increase in the abundance of undersize and legal size lobsters in deep water relative to shallow water and a subsequent shift in catch to deep water. The size of the migrating lobsters is significantly related to the water temperature about the time of puerulus settlement (4 years previously). The impact of climate change on the level and spatial distribution of puerulus settlement, catchability of lobsters in traps, numbers of mature females moulting from setose to non-setose, growth rates, timing of moults and hence the timing of the peak catch rates, were also assessed. Climate change model projections are that the warming trend is likely to continue so that these biological trends may continue. Some of these changes (such as the increasing frequency of El Niño events) may have negative implications on the western rock lobster fishery but others such as increasing water temperature may have some positive influence.

The Leeuwin Current not only affects the western rock lobster fishery, but has been shown to be related to changing abundance of a number of key invertebrate and scalefish species harvested by on-shelf commercial fisheries off the WA coast. These relationships were recently reviewed and showed that the addition of more recent data has strengthened the relationship for rock lobster, the only species whose larvae are primarily distributed in the area of the influence of the Leeuwin Current and its offshore eddies.

For other invertebrate species, such as scallops and Shark Bay prawns, the addition of new data has weakened the relationships. For prawns, although the underlying trend remains positive, the additional data strongly suggests that the overall production from the fishery has declined. Preliminary data for some coastal scalefish species (tailor, dhufish) suggest that while the Leeuwin Current strength per se is implicated, other physical variables that are likely to be influenced by the Leeuwin Current may also be important. To help unravel these relationships, the underlying mechanism of the influence of the current, particularly the role of salinity and temperature of shelf waters, and factors controlling the availability of nutrients to on-shelf primary production need to be better understood.

These case studies highlight the value of long-term time series in fisheries and environmental in assessing the effect of climate changes on fisheries. Examples across a number of fisheries indicated that the different types of data obtained for fisheries stock assessments can also be used to understand environmental-fisheries relationships. The variability of these environmental data affecting fish stocks can be examined for historic long-term trends that may have implications for long-term climate change trends in fisheries. Climate change models such as those being developed by WAMSI Node 2 study and the Indian Ocean Climate Initiative can then be examined to assess how these environmental trends may change in the future.

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

The choice of sampling methodology and sampling designs has major implications for the effectiveness of any ecological monitoring program. Poorly designed sampling programs can result in a loss of power to detect change and non-detection of significant environmental impacts. The over-arching aim of the subproject was to determine appropriate methodologies and sampling designs for the continued monitoring of ecological indicators derived from finfish, sessile benthos and mobile invertebrates.

To develop cost-effective and statistically powerful monitoring programs, we conducted a literature review on sampling designs and power analyses. The review highlighted the usefulness of a gradient-based approach to monitoring, the need for predictive models, and the importance of randomisation of replicates within a nested sampling design. The power analyses showed that a moderate sampling effort would be required to detect ecologically relevant change in the populations of dominant large macroalgae, such as kelps, but monitoring programs based on non-fished mobile invertebrates would have little power to detect change and prove cost-ineffective. For fish, power analyses on datasets derived from both Baited Remote Underwater Video (BRUV) and Diver Operated Video (DOV) were conducted, and used to optimise the number of replicates and sites needed to detect significant changes in the structure of fish assemblages.

To assess the most appropriate methodology for sampling sessile benthos and demersal fish assemblages, we conducted a statistical comparison of currently available sampling techniques. For benthic communities, we used three contrasting methodologies to assess coarse macroalgal assemblage structure on subtidal reefs in Western Australia. Two diver-conducted methods, quadrat harvesting and video transects, and a remotely triggered ‘drop camera’ system were used to quantify macroalgal assemblages. The work suggested that subtidal macroalgal monitoring programmes should adopt a two-pronged approach, including both intermittent high-resolution species-level sampling and regular monitoring of coarse-level benthos over large spatial scales. For fish, we compared estimates of common fish assemblage metrics obtained with stereo-BRUV stations and diver swum stereo-video (stereo-DOV) transects across three biogeographic regions. Stereo-BRUV stations were found to sample greater species richness and obtain greater estimates of relative biomass of generalist carnivores, but no differences occurred in the biomass of herbivores sampled by the two techniques. A cost-benefit analysis showed that stereo-BRUV was generally more efficient than stereo-DOV transects.

Finally, a trial sampling program was developed and conducted for sessile benthos and finfish, to facilitate an assessment of the cost-effectiveness of the methodologies and sampling designs. Sampling was conducted at the Indicator Regions proposed by Subproject 4.2.2.a (i.e. Abrolhos, Rottnest, Capes), as well as at additional locations, and the structure of sessile benthos and demersal fish assemblages along a latitudinal gradient was examined. This work was subsequently developed in Subproject 4.2.2.a to develop a system for consideration as a cost-effective monitoring program.

4. Discussion

Implications for Management and/or Advancement of the Field – Describe the key findings as they relate to the objectives and the management questions discussed at the outset of the project.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data

The present composition of the fish fauna of the Peel-Harvey Estuary was distinguished from that of the 1980s by consistently far greater numbers of Weeping Toadfish (i.e. blowfish) and distinguished from that of the 1990s by an increase in the abundance of the Western Gobbleguts and Western Striped Trumpeter, two weed associated species. There is a continuing risk to establishment of healthy fish communities of estuaries until the causal factors for undesirable changes to these communities are understood and mitigated against. For example, the increase in the abundance of weed-associated species emphasises that there has most likely been an increase in the amount of macroalgae since the mid-1990s.

Although the composition of the fish faunas of the Leschenault Estuary in the 1990s and the present study were very similar, they differed conspicuously in the presence of two abundant tropical species of Hardyhead. Whether this should be viewed as a negative, neutral or positive impact was not determined. A study of the benthic invertebrate fauna of the Leschenault Estuary would compliment the present investigation of the composition of the fish fauna and would proved invaluable in elucidating the state of the health of the benthic environment in this estuary. Indeed, in view of the vast changes undergone by the benthic macroinvertebrate fauna of the Peel-Harvey Estuary since the 1980s, examination of the factors that influence this fauna may well assist in better managing this estuary into the future.

The results of the present study provide managers with baseline data for detecting whether the fish faunas of Peel-Harvey and Leschenault estuaries are undergoing more change in the future. While the interlinked issues of catchment management, coastal development, eutrophication, acidification and changed salinity regimes etc (e.g. modelling from Projects 4.1 and 4.3) are those that ultimately drive potentially undesirable changes in habitat quality and community composition in these estuaries, the data series continued in the present project may represent a good starting point to determine if any future remedial actions are having a positive impact. If causal mechanisms that influence fish communities in these estuaries can be identified, such monitoring will allow documentation of the effects of climate change and catchment management.

4.2.1b The development and validation of an estuarine health index using fish community characteristics

To date, resource managers of estuaries in Western Australia have lacked a reliable, rapid and affordable method for (i) quantifying the environmental health of estuaries relative to appropriate reference conditions, (ii) monitoring temporal changes in estuarine health to detect deterioration beyond critical thresholds and (iii) identifying those regions of individual estuaries at greatest risk of environmental decline.

1) This subproject has developed an approach for constructing a fish-based, multimetric index for assessing the ecological health of estuaries in south-western Australia, and applied that approach to the Swan Estuary. Reference conditions against which the previous, current and future health of the Swan Estuary may be assessed and compared, were established for each season using 30 years of fish assemblage data. The resulting quantitative index scores, and corresponding qualitative health status classifications (good, fair, poor, very poor), can be used to compare ecosystem health across estuarine zones, seasons and years.

2) Tests of the reliability of the indices developed during this study demonstrated that their spatial and temporal variability was comparable to that of existing multimetric indices employed in the USA and Europe, and that classification of the health status of the estuary was fairly robust. The sensitivity of these indices to specific stressors could not be determined due to a lack of suitable, robust information on stressors collected at appropriate spatial and temporal scales. However, additional data collected in the course of follow-up work is currently being analysed to demonstrate the sensitivity of the index to algal blooms.

3) Key considerations have been outlined for the future development of a practical, cost-effective and scientifically robust monitoring regime to enable ongoing or periodic assessment of the health of the Swan Estuary and, potentially other estuaries in south-western Australia, if warranted by risk assessments of ecological assets.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment.

This project has delivered a considerable increase in the knowledge of "BRUV related" fish communities and benthic communities. Establishment of indicator region and development of methods to monitor fish assemblages and benthic communities were two components of Project 4.2 that had different goals but which ultimately shared sampling and data-analysis components.

Through provision of focussed funding on methods to assess biodiversity of fish communities and habitats this project has had the additional benefit of pulling together recent data sets from other research programs and add these to the new data collected here. This represented a significant level of value-adding which has greatly improved understanding of the fish and benthic communities along the west coast of Western Australia, and potential options for future monitoring of aspects of these ecological assets.

This project has characterised the gradient of the fish assemblages from the temperate to subtropical regions of southwestern Australia. An innovative technique for detecting change in the temperate or tropical dominance of the fish assemblage along the coast provides a sensitive way to detect how fish assemblages might respond to a changing ocean temperature.

Benthic assemblages were 'benchmarked' at several long-term monitoring sites within the Indicator Regions, using an Autonomous Underwater Vehicle (AUV) in 2010. These surveys generated high-resolution information on the structure of benthic assemblages and the distributions of key sessile organisms, such as *Ecklonia radiata*, *Scytothalia dorycarpa*, sponges and corals. Such benchmarking provides a basis to determine if any major changes occur in the future, which will better platform managers to instigate remedial action. Major changes requiring management action are those that increase the risk level of the biodiversity assets under consideration.

A program to monitor the biodiversity of demersal fish communities was implemented in April and May 2010. This program repeated existing baseline surveys that have been conducted in the Southwest Capes region, Central and Northern areas of the Perth Metropolitan region and around the Abrolhos Islands. Sampling was conducted using baited remote underwater stereo-video to record the diversity, abundance and size-structure of the demersal fish community.

See section 4.2.2 below for further details.

4.2.2b Metropolitan fish indicators

This study sampled the demersal fish assemblages of the Metropolitan management zone just after the closure of the commercial wetline and gillnet fishery and prior to the seasonal closure of the recreational fishery for highly-targeted demersal finfish species. Baseline information on the distribution of likely ecosystem state indicators of the effects of fishing and long-term changes in sea surface temperature were described. Analyses have been completed and the results written up as a research report to the Department of Fisheries and as a scientific paper.

This study used an experimental framework to compare the predicted patterns of likely indicator species to their observed response, using an existing gradient in recreational fishing pressure, to evaluate if they could provide useful and rigorous information for ecosystem based fisheries management. The relative biomass and abundance of highly targeted and generalist carnivore fish species were found to be good indicators of the effects of fishing, based on existing gradients in recreational fishing pressure within the Metropolitan zone.

Neither assemblage size-spectra nor Abundance Biomass Composition curves were found to provide a good indicator of the effects of fishing pressure within the Metropolitan zone.

This study provides a blue print which can be extended for larger scale biodiversity research programs and used to test the generality of these indicators and test other metrics that may be indicative of other ecosystem pressures.

4.2.3 Establishment of fishery-dependent indicators of climate change

The use of fishery-dependent data may be a cost-effective way of assessing whether there have been

any changes in the distribution and relative abundance of species. Such indicators are part of an ongoing data gathering system and the costs are relatively low compared to those of a fishery-independent field program. Fishery-dependent data may therefore be obtained at a higher frequency and allow detection of changes faster than would be possible from the results from the direct sampling of specific sites within entire ecosystems.

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

1) A key objective of this subproject was to assess the performance (i.e. variability and power) of potential ecological indicators derived from finfish, sessile benthos and mobile invertebrates, using existing data. For benthos, we compiled a range of existing datasets to examine variability patterns of whole assemblages and of key invertebrates and macroalgae. The analyses showed that a moderate sampling effort would be required to detect ecologically relevant change in the populations of dominant large macroalgae, such as kelps. Some benthic taxa changed in abundance predictably along a latitude/temperate gradient, and may serve as useful indicators of environmental change. Finally, we showed the power to detect change in mobile invertebrate populations was low, due to their high patchiness and generally low abundances, so that ecological indicators derived from mobile invertebrates alone would not prove cost-effective. For fish, a traditional power analysis was conducted for a number of typical assemblage metrics, which could be used as indicators of climate change or the effects of fishing, using data from baited remote camera surveys conducted by the Marine Futures Program at Cape Naturaliste, Rottnest and the Abrolhos Islands. A theoretical experimental design was created, to test the statistical power of the monitoring program. The results of this analysis were used to determine the number of locations and replicates needed to achieve a cost-effective and reliable sampling design.

2) An important outcome of this project has been an assessment of various methodologies for sampling finfish, sessile benthos and mobile invertebrates, to establish the most appropriate and cost-effective approach for ecological monitoring at the WAMSI indicator regions. For benthic communities, we used three contrasting methodologies to assess coarse macroalgal assemblage structure on subtidal reefs in Western Australia. Two diver-conducted methods, quadrat harvesting along video transects and a 'drop camera' system, were used to quantify macroalgal assemblages. Within each location, assemblage-structure derived from each methodology was consistently moderately different, but no consistent pattern in the macroalgal group causing this dissimilarity was observed between locations.

We discussed the limitations associated with the photographic methods, in particular the inability of such techniques to gather high resolution, species-level data, and the consequent loss of ecological pattern. We suggest that subtidal macroalgal monitoring programmes should adopt a two-pronged approach, including both intermittent high-resolution species-level sampling and regular monitoring of coarse-level benthos over large spatial scales. For fish, we compared estimates of common fish assemblage metrics obtained with stereo-BRUV stations and diver swum stereo-video (stereo-DOV) transects across three biogeographic regions. Stereo-BRUV stations were found to sample greater species richness and obtain greater estimates of relative biomass of generalist carnivores, but no differences occurred in the biomass of herbivores sampled by the two techniques. A cost-benefit analysis showed that stereo-BRUV was generally more efficient than stereo-DOV transects, which has important implications for the design of a long-term monitoring program.

Problems encountered (if any) – Describe any major problems/issues encountered during the study and how they were addressed.

4.2.1b The development and validation of an estuarine health index using fish community characteristics

The first approach employed for selecting appropriate fish metrics sought to identify those metrics that showed the strongest responses to spatial differences in the quality of physical habitat, as quantified using a novel and independent measure of habitat degradation. Habitat quality was thus assessed at 136 nearshore sites throughout the estuary in spring 2007, using rapid visual survey techniques to assign scores for each of six habitat quality metrics. However, the results of graphical screening and various multivariate statistical techniques demonstrated that this approach failed to identify a measure of habitat health that could be linked to a measure if fish community health. Moreover, the compositions of the fish assemblages did not differ significantly among habitat quality categories, either across the whole estuary or within its various regions. It is thus suggested that habitat quality influences the fish communities of the Swan Estuary at a broader scale than that at which it was assessed.

As none of the candidate metrics were found to be sensitive to spatial differences in habitat quality at

local scales there may well be a need to re-evaluate the proposed metrics for both habitat quality and fish assemblages. Due to time constraints, a novel alternative approach was developed to identify the metric subset that most consistently reflected temporal (inter-annual) changes. This approach to metric selection relied on the assumption that the ecological condition of the Swan Estuary has varied over time in response to changes in the suite of stressors acting on the system. This assumption is supported by the fact that there has been considerable inter-annual variation in the severity of environmental perturbations affecting the estuary, including large phytoplankton blooms and hypoxic events, and consequently in their effects on ecological processes and biota including fish.

Given the above assumption, and the associated uncertainty surrounding the nature and magnitude of temporal changes in the ecological condition of the Swan Estuary over the last few decades, the second approach to metric selection employed a combination of multivariate statistical approaches to assess both metric sensitivity to inter-annual changes in ecosystem condition, and the extent of metric redundancy. This approach succeeded in enabling inferences to be drawn from the weight of evidence derived from multiple analyses of fish data sets collected using divergent sampling techniques throughout the estuary between 1976 and 2009.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment
The AUV surveys were part-funded by IMOS, and only the costs associated with ship time and fieldwork were covered through WAMSI. As such, the surveys were extremely cost-effective and generated a wealth of data that would not be possible with more traditional sampling techniques and, ideally, an AUV should be employed to conduct future surveys. However, an issue going forward is the longevity of IMOS support for AUV sampling across the country and whether changes in funding priorities will impact future monitoring efforts. Even so, the long-term monitoring sites established here could still be sampled in the future with other remote sensing techniques (i.e. drop cameras), should AUV work become unfeasible.
There have been no problems or major issues encountered with the fish assemblage monitoring program.

4.2.2b Metropolitan fish indicators
No issues occurred in this project. The objectives of the project remained unchanged. Sampling plans were modified to allow for a through baseline study within the Two Rocks region and to provide a near-shore to off-shore transect. This variation in the sampling plan has meant that a second sampling location to the south-west of Rottnest could not be sampled. However, the Marine Futures data set already provided two seasons of remote video observations from the waters around Rottnest Island which provides valuable complimentary information to the near-shore to off-shore transect completed in the north of the metropolitan area at Two Rocks.

New Research Directions (if any) – Identify new research directions pursued during the course of the project and reasons for modifying original research plans. Describe how the changed research agenda improved the project.

4.2.1b The development and validation of an estuarine health index using fish community characteristics
Responsive and parsimonious subsets of 11 and seven candidate metrics were selected for incorporation into multimetric health indices for the shallows (< 2 m depth) and deep waters (> 2 m depth) of this system. The second, successful approach to metric selection by which this was achieved was devised with the assistance of Professor Bob Clarke. It is a novel approach for selecting metrics in the absence of independent measures of ecological condition, with broad applicability across a range of estuarine systems. A paper describing the development and application of this approach has been submitted for publication in the peer-reviewed journal Ecological Indicators.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment
As a result of the literature review on sampling designs and the power analyses conducted for subproject 4.2.4, it was evident that a monitoring programme based on non-fished mobile invertebrates would have very little power to detect ecological change and would not be an effective use of resources. This is principally because mobile invertebrate species in WA are, on the whole, low in abundance, very patchily distributed, and difficult to sample. Furthermore, while herbivorous invertebrates, such as sea urchins, play important roles in structuring benthic systems elsewhere, their relative importance in driving the distributions of natural resources is far less in WA. As such, monitoring efforts to achieve EBFM for benthic ecosystems were focussed on sessile benthos, such as corals, kelps and sponges.

4.2.2b Metropolitan fish indicators
Initially the project was designed to sample areas in Southern, Central and Northern area of the

Metropolitan region. The objectives of the project remained unchanged. Sampling plans were modified to provide a higher level of replication in the Central (off Rottnest) and Northern (off Two Rocks) areas, by limiting sample effort to these areas and not doing any sampling in the south.

5. Overall Project Accomplishments

Students supported – Record the name of each student involved with the project. Indicate whether PhD or other (give details) and briefly describe their role.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data
Lauren Veale (PhD student)

4.2.1b The development and validation of an estuarine health index using fish community characteristics
Chris Hallet (PhD Student)

PhD theses, Dissertations and Student Placement – Please give complete citation for theses and dissertations (student's name, month and year completed or expected, level of degree, institution). Please provide a copy of the abstract of the thesis or dissertation when complete.

4.2.1b The development and validation of an estuarine health index using fish community characteristics
Christopher Sean Hallett, PhD thesis, Murdoch University (submitted August 2010, conferred March 2011).

Publications - List in standard academic format the citations of literature produced during the reporting period. Include journal articles, book chapters, reports, etc. submitted, in press and printed. Please provide a paper and electronic version copy of each publication resulting from the project. If there is a link to the journal electronically, please also include this.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data
Lauren Veale, L., Coulson, P., Hoeksema, S., Tweedley, J., Hall, N. and Potter, I (2010). The characteristics of the fish and crab assemblages of the Leschenault Estuary. Inter-period comparisons and their management implications. South West Development Commission Report. Murdoch University, Perth.

4.2.1b The development and validation of an estuarine health index using fish community characteristics
Hallett, C.S., Valesini, F.J., Clarke, K.R. (In review). A method for selecting health index metrics in the absence of independent measures of ecological condition. Ecological Indicators.

Valesini, F.J., Hallett, C.S., Cottingham, A., Hesp, S.A., Hoeksema, S.D., Hall, N.G., Linke, T.E., Buckland, A.J. (2011). Development of biotic indices for establishing and monitoring ecosystem health of the Swan-Canning Estuary. Final Report to the Swan River Trust, Department of Water, Department of Fisheries. Murdoch University.

Hallett, C.S. (2010). The development and validation of an estuarine health index using fish community characteristics. PhD thesis, Murdoch University.

Hallett, C.S., Valesini, F.J., Potter, I.C. (2007). Fish community characteristics as indicators of estuarine health: Discussion paper. Swan River Trust, East Perth.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment
Smale, D. A., Wernberg, T., Peck, L. S. and Barnes, D. K. A. (2011) Turning on the heat: ecological response to simulated warming in the sea. PLoS One 6: e16050

Smale, D. A., Langlois, T., Kendrick, G. A., Meeuwig, J. Harvey, E. S. (2011) From fronds to fish: the use of indicators for ecological monitoring in marine benthic ecosystems, with case studies from temperate Western Australia. Reviews in Fish Biology and Fisheries. DOI: 10.1007/s11160-010-9173-7.

Wernberg, T., Russell, B. D., Moore, P. J., Ling, S. D., Smale, D. A., Campbell, A., Coleman, M., Steinberg, P. D., Kendrick, G. A., Connell, S. D. (2011) Impacts of climate change in a global hotspot for temperate marine biodiversity and ocean warming. Journal of Experimental Marine Biology and Ecology. doi:10.1016/j.jembe.2011.02.021

Smale, D. A., Kendrick, G. A., and Wernberg, T. (2011) Subtidal macroalgal richness, diversity and turnover, at multiple spatial scales, along the southwestern Australian coastline. Estuarine, Coastal and Shelf Science 91: 224-231

Langlois, T. J., Van Niel, K. P., Meeuwig, J. J., Pearce, A., Radford, B. & Harvey, E. S. (in review) Consistent abundance distributions of marine fishes in an old, climatically buffered, infertile seascape. Global Ecology and Biogeography.

4.2.2b Metropolitan fish indicators

Langlois, T. J., Harvey, E. S. & Meeuwig, J. J. (in review) Strong direct and inconsistent indirect effects of fishing found using stereo-video: testing indicators from fisheries closures. Ecological Indicators.

4.2.3 Establishment of fishery-dependent indicators of climate change

Caputi, N., Mellville-Smith, R., de Lestang, S., Feng, M., Pearce, A. (in press). The effect of climate change on the western rock lobster fishery. Canadian Journal of Fisheries and Aquatic Sciences.

Caputi, N., de Lestang, S., Feng, M., Pearce, A. (2009). Seasonal variation in the long-term warming trend in water temperature off the Western Australian coast. Marine and Freshwater Research 60:129-139.

Lenanton,R.C., N.Caputi, M.Kangas & M.Craine (2009). The ongoing influence of the Leeuwin Current on economically important fish and invertebrates off temperate Western Australia – has it changed? Journal of the Royal Society of Western Australia 92(2): 111-127.

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

Langlois, T.J., E.S. Harvey, B. Fitzpatrick, J.J. Meeuwig, G. Shedrawi and D.L. Watson (2010) Baited video and diver video transects for sampling of tropical and temperate fish assemblages: A comparison and cost-optimization. Aquatic Biology. 9: 155-168

Watson DL, Harvey ES, Fitzpatrick BM, Langlois TJ and G Shedrawi (2010) Assessing reef fish assemblage structure: how do different stereo-video techniques compare? Marine Biology. 157: 1237-1250.

Smale, D. A., Wernberg, T., Vance, T. (2011) Community development on temperate subtidal reefs: the influences of wave energy and the stochastic recruitment of a dominant kelp. Marine Biology. doi: 10.1007/s00227-011-1689-4

Smale, D. A. (2010) Monitoring marine macroalgae: the influence of spatial scale on the usefulness of biodiversity surrogates. Diversity and Distributions 16: 985-995

Smale, D. A., Kendrick, G. A., and Wernberg, T. (2010) Assemblage turnover and taxonomic sufficiency of subtidal macroalgae at multiple spatial scales. Journal of Experimental Marine Biology and Ecology 384: 76-86.

Smale, D. A., Kendrick, G. A., Waddington, K. I. Van Niel, K. P., Meeuwig, J. J. and Harvey, E. S. (2010) Benthic assemblage composition on subtidal reefs along a latitudinal gradient in Western Australia. Estuarine, Coastal and Shelf Science 86: 83-92.

Presentations - Cite any presentations resulting from the project, including conferences, symposiums, etc.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data

Coulson, P., Hoeksema, S., Potter, I. and Hall, N. (November 2008). WAMSI 4.2.1(a) & (b) Current status of the fish faunas of the Peel-Harvey, Leschenault and Swan Estuaries. WAMSI node 4 review, Western Australia Fisheries and Marine Research Laboratories.

Coulson, P., Hoeksema, S., Valesini, F. (November 2009). WAMSI 4.2.1(a) Current status of the fish faunas of the Peel-Harvey, Leschenault and Swan Estuaries. WAMSI node 4 review, Western Australia Fisheries and Marine Research Laboratories.

Veale, L. (February 2010). Fish assemblages in the Peel-Harvey and Leschenault Estuaries. WAMSI and AMSW-WA marine science in Western Australia: show and tell symposium, Fremantle Maritime Museum.

Veale, L., Coulson, P., Hoeksema, S., Potter, I. and Hall, N. (February 2010). Fish assemblages in the Peel-Harvey and Leschenault Estuaries. WAMSI and AMSW-WA marine science in Western Australia: show and tell symposium, Fremantle Maritime Museum.

Hoeksema, S. (May 2010). Past and present status of the fish fauna of the Peel-Harvey Estuary, Peel Waterways Commission.

Veale, L., Coulson, P., Hoeksema, S., Potter, I. and Hall, N. (May 2010). Australian Marine Science Association Annual student conference. Stradbroke Island, Queensland.

Veale, L., Coulson, P., Hall, N., Potter, I. and Hoeksema, S. (June 2010). WAMSI 4.2.1(a) Current status of the fish faunas of the Peel-Harvey, Leschenault and Swan Estuaries. WAMSI node 4 review, Western Australia Fisheries and Marine Research Laboratories.

Coulson, P., Veale, L., Hoeksema, S., Potter, I. and Hall, N. (September 2010). Crab populations of the Peel-Harvey and Leschenault estuaries (WAMSI node 4.2.1a). Blue swimmer crab review workshop, Western Australia Fisheries and Marine Research Laboratories

Veale, L., Coulson, P., Hoeksema, S., Potter, I. and Hall, N. (December 2010). WAMSI 4.2.1(a) Current status of the fish faunas of the Peel-Harvey, Leschenault and Swan Estuaries. WAMSI node 4 review, Western Australia Fisheries and Marine Research Laboratories.

Veale, L., Coulson, P., Hoeksema, S., Tweedley, J. Potter, I. and Hall, N. (May 2011). The characteristics of the fish assemblages of the Leschenault Estuary. Inter-period comparisons and their management implications. National Estuaries Network Symposium, University of Western Australia.

4.2.1b The development and validation of an estuarine health index using fish community characteristics

Hallett, C.S. and Valesini, F.J. (2011). Progress towards fish-based multimetric indices for assessing and monitoring the ecological health of the Swan-Canning Estuary. National Estuaries Network symposium, Perth).

Hallett, C.S. (2010). Assessing the health of estuaries: an Australian perspective (or “How do we catch up?”). (Plenary presentation; Riversymposium, Perth).

Hallett, C.S. and Valesini, F.J. (2010). A fish-based Estuarine Health Index for the Swan Estuary, WA. (Riversymposium, Perth).

Hallett, C.S. and Valesini, F.J. (2010). Developing a multimetric estuarine health index for the Swan Estuary, Western Australia: An approach for selecting fish community metrics in the absence of independent measures of ecological condition. (Estuarine and Coastal Sciences Association Conference, Figueira de Foz, Portugal).

Hallett, C.S. and Valesini, F.J. (2009). The development of a multimetric index of ecosystem health for the Swan Estuary, Western Australia: Metric selection. (Coastal and Estuarine Research Federation Conference, Portland, Oregon, USA).

Hallett, C.S. and Valesini, F.J. (2009). The development and validation of an estuarine health index using fish community characteristics. (8th Indo Pacific Fish Conference, Fremantle).

Hallett, C.S. (2009). Selection of metrics for incorporation into an Estuarine Health Index. (Swan River Trust Research Program Showcase, Perth).

Hallett, C.S. (2008). Selection of metrics for establishing an index of estuarine health (AMSA 6th Annual

Student Conference, Rottnest Island).

Hallett, C.S. (2007). Fish as Indicators of Estuarine Health (presented at: Centre for Ecosystem Management Seminar Series, Edith Cowan University; AMSA 5th Annual Student Conference, Rottnest Island; National Estuaries Network Public Forum: 'Estuary Science for a Changing Climate', Perth).

4.2.2a Establishment of Indicator regions for long term monitoring and assessment

Langlois, T.J (31/05/2009) Regional models of finfish assemblage structure with changing sea surface temperature. Preliminary analysis of finfish assemblages indicators of the influence increasing sea surface temperatures was presented by Dr Langlois at the 8th Indo Pacific Fish Conference in Fremantle.

Harvey, E.S. and Langlois, T.J., (3/06/2009) Regional models of indicators. Preliminary analysis of finfish assemblages indicators of the influence fishing pressure was presented by Drs Harvey and Langlois at the Australian Society for Fish Biology Workshop in Fremantle.

Harvey, E.S., Langlois, T.J., Smale, D.S. and Kendrick, G. (30/09/2009) proposed research directions for indicators for EBFM WAMSI 4.2.2a. (WAMSI Node Steering committee, Department of Fisheries)

Harvey, E.S., Langlois, T.J., Smale, D.S. and Kendrick, G. (13/12/2009) Options for implementing a monitoring program for WAMSI 4.2.2a. (WAMSI Node Steering committee, Department of Fisheries)

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (17/06/2010) Methods and indicators for long-term monitoring and assessment of fish and benthic biodiversity

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (5/12/2010) Integrating research outcomes from fish and benthic monitoring into the EBFM process

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (13/06/2011) Workshop to discuss the monitoring program for fish and benthic assemblages and expansion of the program

4.2.2b Metropolitan fish indicators

Langlois, T.J. (11/6/2008) Options for implementing a monitoring program for WAMSI 4.2.2b. (WAMSI Node Steering committee, Department of Fisheries)

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (17/06/2010) Methods and indicators for long-term monitoring and assessment of fish and benthic biodiversity

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (5/12/2010) Integrating research outcomes from fish and benthic monitoring into the EBFM process

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (13/06/2011) Workshop to discuss the monitoring program for fish and benthic assemblages and expansion of the program

4.2.3 Establishment of fishery-dependent indicators of climate change
Animal Biology seminar series at University of WA on 23 May 2008
Conservation Council Symposium: WA Biodiversity and climate change forum on 5 June 2008 at University of WA.

South West Catchment Council seminar 'Predicted changes in local coastal and marine ecosystems at Mandurah on 23 July 2008

WAMSI Node 2 symposium at CSIRO Floreat 9 September 2008

Fisheries Volunteers State Conference at WA Fisheries and Marine Research Laboratories on 13 September 2008

Rock lobster Industry Advisory Committee coastal tour at Geraldton and Fremantle on 28 and 30 October 2008

WAMSI Node 4 symposium at WA Fisheries and Marine Research Laboratories on 26 November 2008
Marine Parks and Reserves Authority on 11 December 2008

Seaweek Educators Expo at WA Fisheries and Marine Research Laboratories on 6 March 2009
Symposium on 'A changing climate: Western Australia in focus' on 27 March 2009 at University of WA.
Fishing Industry Women's Association of WA on 18 May 2009

WAMSI Node 4 symposium at WA Fisheries and Marine Research Laboratories on 2 November 2009
Western Australian Climate Change Adaptation Symposium organised by National Climate Change Adaptation Research Facility (NCCARF) at Murdoch University on 8 December 2009.

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

Smale, D., Kendrick, G. Waddington, K., Van Niel, K. Meeuwig, J. and Harvey E (2009)
Broad-scale marine benthic community structure on subtidal reefs along a latitudinal gradient in Western Australia. Presentation at AMSA meeting, Adelaide.

Harvey, E.S., Langlois, T.J., Smale, D.S. and Kendrick, G. (30/09/2009) proposed research directions for indicators for EBFM WAMSI 4.2.2a. (WAMSI Node Steering committee, Department of Fisheries)

Harvey, E.S., Langlois, T.J., Smale, D.S. and Kendrick, G. (13/12/2009) Options for implementing a monitoring program for WAMSI 4.2.2a. (WAMSI Node Steering committee, Department of Fisheries)

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (17/06/2010) Methods and indicators for long-term monitoring and assessment of fish and benthic biodiversity

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (5/12/2010) Integrating research outcomes from fish and benthic monitoring into the EBFM process

Langlois, T.J., Smale, D.S., Kendrick, G. and Harvey, E.S. (13/06/2011) Workshop to discuss the monitoring program for fish and benthic assemblages and expansion of the program

Other Communications Achievements - Interviews, press releases, etc.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data

- Leschenault Estuary examined'. Bunbury Mail, January 2009
- 'Fish data for the future'. Countryman, January 2009
- ABC News segment, February 2010
- 'Estuary under research spotlight', Harvey Reporter, August 2010

4.2.1b The development and validation of an estuarine health index using fish community characteristics

- ABC News : 02 March 2011 07:14PM
  Compere: Karina Carvalho
  Checking on the health of aquatic species in the Swan River has now become more scientific. A new system has been devised to make proper comparisons over time. Chris Hallett, scientist, Murdoch University, says there is anecdotal evidence the system is under pressure. Kerry Trayler, Swan River Trust, says the study will run for one year.
  Interviewees: Chris Hallett, scientist, Murdoch University, Kerry Trayler, Swan River Trust
  Item ID: S00042739467 ASR: AUD 9,494 Duration: 1 mins 46 secs
  Audience: Male 16+: 45,000, Female 16+: 53,000, All People: 102,000
- Van Zeller, M. (2008). Fishing the Swan for science. Western Fisheries magazine article.

4.2.2b Metropolitan fish indicators

- During a media interview on ABC Stateline, the importance of putting in place monitoring to evaluate the effect of management changes, such as the recent changes to commercial and recreational fishing, was identified, with reference to WAMSI. This media interview was aired in Perth on the 12th of December and in Melbourne on the 13th of December. A copy of this interview has been given to the WAMSI communications officer.

4.2.3 Establishment of fishery-dependent indicators of climate change

- Interview with Channel 9 News
- Western Fisheries magazine
- Media briefings/interviews West Australian, regional and community newspapers
- Media briefings/interviews with ABC radio including Country Hour and regional stations

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

- None

6. Overall Project Benefits Please note: Benefits go beyond Results and Accomplishments to provide information on direct physical, environmental, economic or social gains realised as a result of a research project or outreach activity.

Discovery and Application of New Products and Processes (if applicable) - Describe any actual or anticipated products or processes discovered or developed in the project.

4.2.1b The development and validation of an estuarine health index using fish community characteristics

This subproject has developed the first fish-based, multimetric index for quantifying the ecological health of estuaries in Western Australia. It is envisaged that this index will be used by natural resource managers to assess, monitor and report on the health of the Swan Estuary and potentially other systems.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment

Initial results suggest this regional model, using sampling areas spread along the coast to cover a gradient of temperature, will be sensitive to detecting subtle trends in the fish assemblage associated with trends in the temperate or tropical dominance of the fish assemblage. This regional multi-species model will provide a reliable indicator of temperature related changes in the fish assemblage.

The development of the LTMP for benthic assemblages has focussed on the application of Autonomous Underwater Vehicle (AUV) technology for sustained ecological observations. Extensive AUV surveys have been conducted at 3 key locations in successive years , in conjunction with an IMOS-funded national programme. Preliminary analyses have demonstrated the cost-effectiveness of the methodology and high statistical power to detect change. Benthic assemblages at 18 reference sites have been 'benchmarked' to facilitate an ongoing examination of temporal variability in habitat quality and extent, and seabed biodiversity.

4.2.2b Metropolitan fish indicators

The BRUVS is providing a baseline for assessing changes or differences in the biodiversity of BRUVS-associated assemblages of fish. It has yet to be ascertained how biodiversity may be related to fishing pressure. The relative biomass of highly targeted and generalist carnivore fish species were found to be good indicators of the effects of fishing, based on existing gradients in recreational fishing pressure within the Metropolitan zone, but the actual effect on biodiversity has yet to be clarified.

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

We suggest that subtidal macroalgal monitoring programmes should adopt a two-pronged approach, including both intermittent high-resolution species-level sampling and regular monitoring of coarse-level benthos over large spatial scales. A cost-benefit analysis showed that stereo-BRUV was generally more efficient than stereo-DOV transects for assessing biodiversity of fish assemblages so would be the preferred option for the design of a long-term monitoring program.

Tools, Technologies and Information for Improved Ecosystem Management - Describe how project results are being (or will be) translated into sustainable use and management of coastal and ocean ecosystems. Tools might include benthic habitat maps or environmental sensitivity indicators. Technologies might include remote and bio-sensing, genetic markers, and culture systems. Information might include technical assistance, training and educational materials.

4.2.1a Development of bioregional level assessments of the status of community structure based

on fishery dependent and/or fishery independent data
The current composition of the fish communities in the Peel-Harvey and Leschenault estuaries and how it has changed over the last three decades provides a basis for natural resource managers to determine, in the future, whether the fish communities in these estuaries has continued to change. This will be demonstrated to estuary managers.

4.2.1b The development and validation of an estuarine health index using fish community characteristics
This project developed the first fish-based multimetric indices for assessing the health of a Western Australian estuary. A follow-up project is currently underway to complete the validation of the index and address some remaining questions regarding the effects of sampling timing and intensity on index reliability. At the end of this project, the design of an annual monitoring regime will be detailed. This will include a non-technical account of index implementation from sampling of the fish community through to index presentation and interpretation, and will incorporate information on standard operating procedures for each of the major stages involved, a description of the rationale, procedures and software for calculating fish metric and index scores. This will be demonstrated to estuary managers.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment
In particular for fish assemblages, the data collected during the WAMSI monitoring program has been combined with existing baseline and other time series on finfish assemblages. Although, different temporal trends in the changing temperate or tropical dominance of the fish assemblage were observed for each of the three regions the between location variation for each was found to be small. The consistent trends between locations within regions suggest that the regional model of assemblage turnover will be sensitive to detecting overall regional trends. This study demonstrates a cost-efficient method of detecting changes in the temperate or tropical dominance of the fish assemblage across regions. This will be demonstrated to marine ecosystem managers, with future implementation dependent on identified risks and priorities from the EBM risk assessment process.

4.2.2b Metropolitan fish indicators
This project developed a rigorous baseline on the demersal reef fish assemblages in the Perth Metropolitan region. Baseline data now exists on the composition of the fish assemblage as well as data on the numbers of species, numbers of individuals recorded, the relative abundances of key target and non target fishes and their mean length, length frequency and biomass. This will be demonstrated to marine ecosystem managers, with future implementation dependent on identified risks and priorities from the EBFM risk assessment process. Focussed stock assessments are expected to deal with management issues relevant to highly-targeted species.

4.2.3 Establishment of fishery-dependent indicators of climate change
Full accessible data bases of environmental measure have been established. These provide a basis for developing or testing relationships with biological variables.

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

We suggest that subtidal macroalgal monitoring programmes should adopt a two-pronged approach, including both intermittent high-resolution species-level sampling and regular monitoring of coarse-level benthos over large spatial scales. For fish, a cost-benefit analysis showed that stereo-BRUV was generally more efficient than stereo-DOV transects, which has important implications for the design of a long-term monitoring program. This utility of this approach will be demonstrated to marine ecosystem managers, with future implementation dependent on identified risks and priorities from the EBM risk assessment process.

Forecasting for Natural Resource Management Decisions - Describe how results already are being used - or are expected to be used after project completion - by natural resource management to make decisions based on project forecasts. Forecasts may be due to field and laboratory studies and models. Examples include hypoxia forecast models, algal bloom alerts, forecasts of fishery harvest, and prediction of impacts from ecosystem stressors such as pollutants or invasive species.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data
The sampling of fish biodiversity in the Peel-Harvey estuary indicates that the fish fauna continues to vary

over time and that this is likely related to estuary health.
That is, the data provide managers with data on the current composition of the fish faunas of the Peel-Harvey Estuary. This also applies to the Leschenault Estuary except in this case the only major change is the increased abundance of two tropical species which may reflect a climate change impact. Managers will thus have baseline data for detecting whether the fish faunas of these systems are undergoing further change in the future.

4.2.1b The development and validation of an estuarine health index using fish community characteristics
It is envisaged that the Swan River Trust will be able to use the indices developed in this study to assess and report on biotic ecosystem health as part of a future report card system for the Swan-Canning Estuary. The indices we have developed enable assessment of the health of each individual Ecological Management Zone designated for the management of this system (i.e. Lower Swan-Canning Estuary, Canning Estuary and Lower Canning River, Middle Swan Estuary and Upper Swan Estuary), and may thus be used to inform managers of the relative health of these zones. This will allow managers to better target management efforts towards those zones in greatest need of ecological restoration.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment
A number of ecological assets have been identified for the EBFM framework established by WAMSI 4.1. These assets include 'Ecosystem Structure and Biodiversity' and 'Benthic Habitat Categories' within nearshore and inshore zones (especially at the Abrolhos and Capes). Furthermore, captured finfish in nearshore and inshore zones are also ecological assets. Each of these assets has been assigned a 'risk rating' in order to prioritise management actions and achieve a holistic 'ecosystem-based' view of the West Coast Bioregion. However, the status of, and risks to, these assets must be regularly reassessed to achieve effective EBFM. The monitoring programs described here provide a cost-effective approach to the continuous assessment of these assets, which will inform managers and other stakeholders of the health of the benthic ecosystem at the Indicator Regions.

4.2.2b Metropolitan fish indicators
This program has identified a variety of fish assemblage metrics which provide useful information on the status and condition of the fish assemblage. However, the status of, and risks to, these indicators must be regularly reassessed to address the risks to assets identified as part of the EBFM risk assessment process. The monitoring programs described here provide a cost-effective approach to the continuous assessment of these assets, which will inform managers and other stakeholders of the condition of the fish assemblages within the Metropolitan Region.

4.2.3 Establishment of fishery-dependent indicators of climate change
The possible climate change trends identified for some fisheries can have significant effects on the stock assessment and management of the fisheries. The changes in some of the biological parameters of the rock lobster stocks have been included in the population dynamic model of the fishery which generally have a stationarity assumption of parameters. Long-term changes in the abundance of fish stocks, particularly declines, requires an appropriate adjustment of fishing effort or catch quota, for the stocks to be managed sustainably. In addition, changes in the spatial distribution of fish stocks pose some interesting policy dilemmas to evaluate when there are fixed management boundaries. Does fisheries management maintain the current zone structure and recognize that there could be some long-term 'winners' and 'losers' in that situation or does it adjust the management to maintain some historical equity in the system?

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods
An important outcome of this subproject has been the completion of trial sampling programs, to help design long-term studies to investigate of fish and benthic invertebrate communities and assess the impact of anthropogenic influences. These sampling programs have allowed us to trial different sampling designs and estimate the required levels of replication and therefore the cost of future studies. This will ensure that future studies are cost-effective while still being sensitive enough to detect change in fish and benthic communities. These sampling programs will provide and early warning system for WA and enable us to anticipate larger changes in marine communities due to human use and predicted increase in ocean temperatures. With this knowledge, managers will be able to adapt our use of the marine environment to ensure the sustainability of the marine environment and economic resources. Sampling programs for fish have been trialled across the three Indicator Locations, the data from which will be combined with existing data to facilitate analysis of patterns of community change along the temperate coastline of WA. Sampling of benthic invertebrates and macroalgae has been conducted at a number of locations along the coastline, to determine patterns of community change at multiple spatial scales.

Impacts - Impacts are higher order, usually long-term results of a project's activities that have significant scientific, economic or social benefits. Impacts may involve behavioural, policy or economic changes. Describe impacts (anticipated or realized. These impacts may involve behavioural, policy or economic changes. Seminal contributions to science are considered impacts especially if the research findings lead to major progress in a particular field, implementation of new technologies or have a substantive bearing on an economic or societal issue.

The significant impacts of this project are
(1) the benchmarking of baseline data on the community assemblages of demersal fish and benthic habitats in a manner suitable for consideration by managers when assessing or re-assessing risk level to these important ecological assets,
(2) further repeat assessments of estuary fish assemblages highlight that they may continuing to be degraded so continue to represent a serious ecological risk.

The benefits of these are that managers will now be better placed strategically to deal with the above risks and will be better informed as to the nature of the risks. In combination with Project 4.1, which focussed on trialling and implementing an EBFM risk assessment approach to ecosystem management, this project has highlighted that some of the underlying causes for variability in estuarine and marine ecosystems are not related to extraction of fish but rather to other causes, natural (latitudinal gradients in temperature) or anthropogenic (estuary modification), so are best addressed via fishery independent sampling. In contrast, the bioregional level assessment of trophic impacts afforded by bioregional –level time series of fishery dependent data (see Project 4.4.2) cannot necessarily provide the resolution for relatively small spatial and temporal scales. These projects highlight that ecosystem managers need to be aware of the combined strength of employing fishery–independent and fishery-dependent data, and the choice of these needs to be cognisant of the ecological risk(s) being addressed.

7. Project Metadata and Data Generated

These must be available at an open access repository/data centre/iVEC.

4.2.1a Development of bioregional level assessments of the status of community structure based on fishery dependent and/or fishery independent data
Fish species abundance and length data.
Temperature, salinity and dissolved oxygen data.
Metadata
Sampling site code, fish species code, sampling method code.
Two files have been loaded onto IVEC
Final_Peel-Harvey_2008-2010_Raw_fish_data.xls
Final_Leschenault_2008-2010_Raw_fish_data.xls

4.2.1b The development and validation of an estuarine health index using fish community characteristics
- Collated data sets of fish metric and index scores for all samples collected 1976-2009.
- Fish metric calculation software developed.

Files loaded to IVEC
1) 'Establishing reference and scoring_gill Metrics.xls'
2) 'Establishing reference and scoring_seine Metrics.xls'

The gill net and seine net files contain, respectively, for each offshore and nearshore historical fish sample collected between 1976 and 2009,
(i) the raw values calculated for each of the selected fish metrics comprising the offshore and nearshore health indices;
(ii) the corresponding metric scores (i.e. scored in comparison to the appropriate reference conditions I derived for each metric); and
(iii) the final health index scores for each historical sample.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment
2010 WA AUV survey data (currently stored on the freely-accessible IMOS database, managed through

ACFR, contact :
2011 WA AUV survey data (currently stored on the freely-accessible IMOS database, managed through ACFR, contact

Files loaded to IVEC
1) 'WAMSI 4.2.2a Metadata for LTMP fish sampling, Abrolhos, Metro, Rottnest, Capes.xls'
2) 'WAMSI 4.2.2a MaxN and Length data for LTMP fish sampling, Abrolhos, Metro, Rottnest, Capes.xls'

4.2.2b Metropolitan fish indicators
Data in the form of excel spreadsheets containing the counts, names and lengths of individual fish has been loaded on IVEC. Similarly, the imagery (in the form of avis) from each of the stereo BRUV deployments in have been loaded onto IVEC.

Files loaded to IVEC
1) 'Metadata WAMSI_4.2.2b'.xls - June 2009 WAMSI 4.2.4 Metadata Central Metro and Rottnest fish sampling.xls

4.2.3 Establishment of fishery-dependent indicators of climate change
No new data was collected as part of this project, however the data accessed as part of this projected is listed in the DOF report section 2.2. Alan Pearce provided some metadata collected by DOF to Luke Edwards

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods
Benthic assemblage - Dataset on the biomass of macroalgal species collected from 14 different locations along the Western Australian coastline (collated from previous projects).

Files loaded to IVEC
Fish assemblage – 'Metadata WAMSI_4.2.4.xls'

URL Links to data

4.2.1b - http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=566d6d02-1b69-4e9a-974a-ea1615ba8212

4.2.2a - benthic - http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=54bee7ff-a4c2-48c9-be27-da7197a37216
4.2.2b - http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=f8a33169-9228-4620-813d-59346ffa4952

4.2.3 - http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=37544f5b-b36c-4c61-9d45-c44e5b0e6a5e (parent record - summary)
- http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=f2aad140-c633-4493-91e2-08fc476619e0 (child record - SOI)
- http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=93e70dab-2838-4117-91ff-f9cc1dc05ad8 (child record - Western Rock Lobster Monthly sampling)
- http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=0024b456-4636-42cd-b097-388f6d39a835 (child record - Continuous temperature loggers at puerulus collector sites (Western Rock Lobster)
- http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=b3f720e7-b5ef-4eef-82a5-c1167158a7bd (child record - Coastal temperature/salinity from puerulus collector sites - Western Rock Lobster)

4.2.4 - http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=e9fb0599-a077-46e7-9a49-d41432cd2e85 (Parent record - summary)
- http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=15fc642c-0a63-4bf1-b83b-44d870824741 (Abrolhos)
- http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=01f81b37-50b3-40ff-894b-e9a02b5cb2ce (Capes)
- http://waodn.ivec.org/geonetwork/srv/en/metadata.show?uuid=faac8a7b-be35-480b-bf0b-d0841164dc29 (Ningaloo)

8. Linkages to Associated Projects – can be WAMSI and non-WAMSI

4.2.1b The development and validation of an estuarine health index using fish community characteristics

This work was part of a broader project, entitled "Development of Biotic Indices for Establishing and Monitoring Ecosystem Health of the Swan-Canning Estuary", which was funded by the Swan River Trust, Department of Water and Department of Fisheries.

4.2.2a Establishment of Indicator regions for long term monitoring and assessment

1. The AUV surveys form part of a national project, funded by IMOS and led by ACFR at USyd, to establish benthic monitoring sites around Australia. The WA component of this project has been completed as part of this WAMSI subproject.
2. AUV surveys were conducted in the newly-established rock lobster reserve at Leeman in 2011, to facilitate an analysis of lobster-habitat relationships. These surveys form part of a larger project at Department of Fisheries.
3. This project built upon an existing 6 year data set from the Houtman Abrolhos collected by UWA and DoF with NACC funding. The WAMSI data will be added to in 2011 by a further set of monitoring.
4. Stereo BRUV surveys have been conducted in collaboration between UWA and DoF in the newly-established rock lobster reserve at Leeman in 2011, to facilitate an analysis of potential changes in demersal fish assemblages associated with the cessation of rock lobster fishing.

4.2.2b Metropolitan fish indicators

The sampling plan from this project has been integrated into the WAMSI Node 4.2.2a Indicator Regions Long Term Monitoring Plan, and sites were re-sampled as part of the 2010 sampling program.

4.2.3 Establishment of fishery-dependent indicators of climate change

This study has focused on historic trends in environmental trends and how they may be affecting fisheries trends. Outputs from WAMSI Node 2 and IOCI will provide an opportunity to assess the effects of future climate change effects on fisheries in WA based on the relationships established in this study.
This project also led to submission of a successful FRDC grant on a related topic,
RDC 2010/535 Management implications of climate change effect on fisheries in Western Australia
PI: Nick Caputi
Co-investigators: Ming Feng (CSIRO)
Lindsay Joll (Fisheries WA)
Rod Lenanton (Fisheries WA)
Brett Molony (Fisheries WA)
Alan Pearce (Fisheries WA)
Liejun Zhong (CSIRO)

4.2.4 Cost effective ongoing, general biodiversity and habitat monitoring methods

In collaboration with DoF, a FRDC-funded project has been conducted to examine the use of mobile invertebrates that recruit onto existing puerulus collectors as cost-effective monitoring tools. This project resulted in a 1st Class Hons thesis (Shelley Foster – UWA) and a paper, currently in preparation. Investigations into the use of mobile invertebrates as indicators of ecosystem health and environmental change are ongoing.

9. Other Comments and General Discussion

10. Annexures

- Sub-project reports presented
- Additional attachments

4.2.1b The development and validation of an estuarine health index using fish community characteristics

Christopher Sean Hallett PhD Thesis.pdf
Abstract_final_C Hallett.doc