FINAL WAMSI NODE 4 SUMMARY REPORT

Node Details

Name of Node:	SUSTAINABLE MARINE ECOSYSTEMS: ESD FOR THE STATE'S MARINE FISHERIES (IMPLEMENTING ECOSYSTEM BASED FISHERIES MANAGEMENT, EBFM)
Node Leader:	Dr Dan Gaughan

1. Node KPIs

Brief Description of "**why**" the research in the Node was undertaken. What were the key questions being addressed and were outlined in the original 2006 WAMSI Business Plan? [A listing of the Projects and Project Leaders and their Project staff, including students will form Annexure 1]

The overall strategic purpose of WAMSI Node 4 was to develop methods and 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 management approach new to Western Australia (WA), which is termed Ecosystem Based Fisheries Management (EBFM)[1]. The implementation of the approach has required supporting research that was, in many cases, very different in nature to traditional fisheries research programs. The research within this Node was designed to cover all requirements to enable the implementation of EBFM for the State's fisheries resources, while at the same time filling some knowledge gaps concerning priority risks along with the identification of hitherto unidentified risks.

A critical aspect of this Node was how to undertake regional-level assessment and planning while avoiding the generation of an impossibly complex set of issues, systems, models and uncertainties. Specifically, the Node needed to address how to reduce complexity to a level that could be used by management. The capacity to manage fishery resources on an ecosystem basis for an entire bioregion was also assessed.

Some critical strategic research gaps relevant to generating information required for applying the EBFM process were identified in the initial government-level scoping of WAMSI and during collaborative development of the Node 4 Science Plan. These were addressed in Projects 4.2 – 4.5, whose management questions were as follows.

- 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 (e.g. climate change, pollution) was having an unacceptable level of impact on these elements?
- How can risk assessment processes improve understanding within each of the bioregions of the possible indirect impacts on trophic interactions (e.g. removal of keystone species) resulting from fishing or other impacts?
- When a risk has been identified, or there is evidence that fishing activities are having a strong

[1] EBFM is defined as the assessment and management of all ecological impacts and socio-economic outcomes related to any commercial, recreational, charter, indigenous fisheries, or "no-take" sector operating within an ecosystem or bioregion. It can cover both individual fisheries and the cumulative impacts using a risk based framework (Fletcher, W.J. 2006 Frameworks for managing marine resources in Australia through ecosystem approaches: do they fit together and can they be useful? *Bulletin of Marine Science* 78:691-704). EBFM is synonymous with Ecosystem Approaches to Fisheries Management.

impact on trophic interactions, what types of experimental studies would be needed to examine these processes and what are the main processes leading to changes in trophic interactions?
- How can risk assessment processes improve understanding within each of the bioregions of the possible indirect impacts on trophic interactions (e.g. removal of keystone species) resulting from fishing or other impacts?
- When a risk has been identified or there is evidence that fishing activities are having a strong impact from trophic interactions, what types of experimental studies would be needed to examine these processes and what are the main processes leading to changes in trophic interactions?
- How do you define what is the optimum social and economic benefit to be derived from the use of the marine resources within a bioregion for use in planning?
- Once the plan has been defined, how do you provide for the ongoing management of change flowing from shifts in social and economic values with respondent changes in resource use?
- What institutional arrangements need to be put in place to best deal with these issues?

2. Research Plan/Science Plan

Describe the high level "**Research Plan/ Science Plan**" for the Node in simple language [Note: the approved Science Plan for each Node will form Annexure 2]

In the past, fisheries management generally focussed on single-species with little explicit reference to other parts of the ecosystem. With a greater understanding of the importance of ecosystem-level interactions, such as trophic and habitat interactions, and social and economic effects, it has become clear that a more holistic approach to the management is necessary. Ecologically Sustainable Development, which was adopted in the 1980s, was the first step towards holistic resource management and was designed to ensure that all ecological, social and economic impacts were taken into account in management plans. However, a method of generating more practical outcomes was deemed necessary to ensure that the cumulative effects of fisheries in a region were taken into account including the management of conflicting objectives and allocations. The regional, multi-fishery EBFM approach takes such effects into account using a risk-based management system.

The aim of Project 4.1 was to develop a means of integrating EBFM into mainstream fisheries management, including the WA government's Integrated Fisheries Management (IFM) initiative, and to source, identify and integrate appropriate supporting research.

The general aim of undertaking Projects 4.2 to 4.5 was to provide additional information to Project 4.1. Collection of data was undertaken to allow the confirmation or reassessment of risk levels, to identify some specific effects (i.e. of climate change) or changes to ecosystems (i.e. due to fishing or other impacts) within the West Coast Bioregion, and to identify cost-efficient and effective methods for data collection. These projects were both field-based (e.g. in situ counts of lobster, scalefish & benthic flora, tracking movements of lobster and ocean currents) and laboratory based (e.g. examination of methods to detect patterns in complex sets of data, development of models to predict effects of potential climate change and estuary condition). Some of the work focussed on collating historical data and examining current monitoring methods; these elements included national/international expert-based workshops. There was also a strong element of qualitative modelling undertaken to generate better understanding of, and new insights into, how ecosystems function, including the human elements (social and economic considerations).

The project included work by a range of professional, undergraduate and post-graduate scientists from a range of universities and other research facilities. The integration of the results from these projects can provide an example of the need for continued data collection and analyses, and the reassessment of risk and management plans.

3. Research Activities

Describe the "**Research Activities**" for the Node in simple language. Please try and summarise the methodologies utilised as part of each Project in the Node [Note: the methods section of the approved Project Plans will form Annexure 3]

The EBFM framework was trialled on the West Coast Bioregion as a case study and used a series of component trees to describe ecological, social, economic and governance assets and issues. The use of a series of component trees is designed to facilitate the capture of all possible issues or assets in an ecosystem. The trees were populated during stakeholder workshops and each component (asset or issue) was subjected to a risk assessment. The use of component trees allowed for the reduction of whole-of-ecosystem complexity by consolidating individual assets (e.g. individual species or benthic habitats) and their risks to a higher level (e.g. suites of species, regional-level habitats). This was undertaken because the separate management of these individual assets (in excess of 600 for the West Coast Bioregion) would not be feasible due to funding, time and efficiency constraints.

A multi-criteria analysis was applied to integrate the different types of risk identified during the production of the component trees. Ecological, social and economic risks as well as scores for the risk to social amenity and Gross Value of Product (GVP) were included in this multi-criteria analysis. In addition, the level of influence of external factors, which were outside of the control of the Department of Fisheries, was taken into account as this affects the overall priority of any one asset or issue to the Department. The inclusion of the external factors in the multi-criteria analysis was important to provide a distinction between EBFM, where fisheries management is the main priority, and EBM where all ecosystem impacts are a priority.

The complementary part of Project 4.1 was the use of qualitative models to integrate inputs from all stakeholders and sectors that would allow the investigation of ecosystem linkages and identify data gaps. Multiple stakeholder workshops were held to gather the appropriate information for inclusion in the qualitative models. An important data gap that was identified involved general economic information (e.g. influence of global economy, international demand, effect of changes in the Australian dollar) regarding export fisheries such as the rock lobster fishery. In addition, recreational fisher behaviour due to management changes was identified as a data gap and was subsequently further investigated in Project 4.5. This technique has also directed research in other areas, such as the data collection of specific indicator species to assess the effects of deepwater (>40m) rock lobster fishing in Western Australia. Also know as loop analysis, qualitative modelling can investigate the behaviour of systems (or interconnected elements within a system) for which the interactions of interest are not well enough known to allow quantitative modelling, a situation prevalent across the majority of ecological systems.

Project 4.2 developed quantitative methods to assess the status of the community structure, biodiversity and key habitats within each of the priority ecosystems within the West Coast Bioregion and, where possible, to discriminate the potential impact of each individual factor within the cumulative impacts of all fishing activities, climate shifts and other factors. The data on types and numbers of fish and benthic flora and fauna were collected using standard (e.g. baited underwater cameras, hand-hauled seine nets) and novel (precisely positionable underwater probes) approaches, in addition to undertaking further complex analyses of previously collected data (e.g. historical fisheries and oceanographic data, sea-floor mapping data collected by the Marine Futures project). In the case of the Swan, Peel-Harvey and Leschenault estuaries, historical data on the composition of fish communities was used along with new data collected using identical sampling methods to ascertain if there has been any major changes in the health of these systems. Iterative analyses on the various marine and estuarine data sets were completed to derive options for generating meaningful indices that could potentially be implemented for future assessment of the health of fish and benthic communities. This project also collated all relevant data sets on environmental variables of possible relevance to fish stocks and ecosystems and examined these with respect to recruitment variability on rock lobster. 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 assessed. Finally, a modelling exercise was undertaken to examine potential range shift of various fish species under the influence of predicted climate change impacts on the coast waters around Western Australia.

The primary aim of Project 4.3 was to develop a greater understanding of trophic interactions within the West Coast Bioregion and the potential for these interactions to be affected by fishing and other factors, such as climate change. This project permitted completion of a major assessment of historical fisheries data to determine, using the internationally accepted modelling approach, if any significant ecosystem-wide trophic impacts had occurred over the past 30 years in Western Australia's marine waters. New data collection included implementation of experiments on rock lobster abundance and foraging behaviour, along with detailed examination of types and quantities of invertebrates in fished and unfished areas for

deep and shallow water rock lobster habitats. An approach to develop a better understanding of the broader potential anthropogenic impacts on ecosystems was undertaken via trialling of sophisticated modelling approaches to the Peel Harvey estuary, identified as the most at-risk ecosystem during the EBFM risk assessment process.

A key risk for trophic integrity was that identified for the west coast demersal scalefish fish resource. A review of information on diets of species in the West Coast Bioregion was used to develop a food web. Pink snapper and skippy (the dominant local trevally species) were two important exploited species in the West Coast Bioregion for which more dietary data were collected as part of this study. This work is ongoing through a PhD study being undertaken at Murdoch University.

Project 4.4 examined a range of issue relating to directly to key exploited species. This project examined some techniques that worked directly on fish (genetics and otolith chemistry data) to ascertain the spatial relationships (i.e. "stock structure") of the exploited species dhufish, pink snapper and baldchin groper in the West Coast Bioregion. In addition, deployment of satellite-tracked drifters to improve our understanding of coastal currents and oceanographic models that employ this knowledge to predict drift patterns of fish eggs and larvae were utilized to help better understand the spatial links between fish populations in the different management zones of the West Coast Bioregion. This project also examined different types of bycatch risk assessment and the potential for on-board cameras to improve cost-effectiveness of monitoring of bycatch in some commercial fisheries. Finally, methods to estimate recreational catch were examined at an international workshop of experts to help guide future surveys.

Project 4.5 undertook a range of social and economic studies to help increase our understanding of some of the underlying factors that must be considered when managing fisheries and aquatic ecosystems. Due to the dearth of data on social and economic aspects of management of the scalefish fisheries in Western Australia, the socially important west coast demersal scalefish fishery was chosen as a case study of the commercial, charter and recreational sectors of this resource. These studies involved examination of historic data along with interviews of current fishers to generate up-to-date data. The first step was to conduct a detailed workshop-based study of suitable methods, followed by observational fieldwork and direct interviews with fishing sector members to collect detailed information. Phone-based surveys of recreational fishers were undertaken to ascertain changes in behaviour in response to implementation of new management measures for the west coast demersal scalefish fishery.

4. Research Findings

Describe the "**Research Findings**" for the Node in simple language. Follow the sub-headings:

a. Overall research findings [very high level]
b. Specific research findings/ outputs [specific to the individual projects]
c. Intra-Nodal scientific outcomes [across the projects]
d. Inter-Nodal scientific outcomes [between this and another Node[s]
e. What wasn't addressed by the Node research, but is likely to be important from a scientific perspective?

[Note: the final Project Reports for the Node will form Annexure 4]

Project 4.1 focussed on developing a better system for holistic management of marine ecosystems and developing a clearer understanding of how both management systems and the ecosystems are structured. Ultimately, the challenge is to balance the available management resources against the range of management issues in a manner that maximises return to the community; this challenge is about risk assessment and risk management placed in the context of governance decision systems that can deliver value-for-money natural resource management. The purpose of the case study was to assess whether the EBFM framework can assist in providing natural resource management planning for the optimal management of marine resources at a bioregional level; i.e. a risk-assessment of the ecological assets and management issues for an entire bioregion. It was also the intention to ensure that the planning structures, to meet the legislative responsibilities of the Department of Fisheries, were being undertaken in a holistic manner. The EBFM framework that was developed through this case study was ultimately successful in meeting both of these objectives because a pragmatic, management focused approach was taken.

The second part of Project 4.1 investigated structures of a variety of systems (e.g. estuary ecosystems including governance arrangements, behaviour of recreational fishers, rock lobster fishery trophic paths) using qualitative modelling. This highly intuitive, expert-based modelling approach developed much better understanding of several systems for which data were limited and for which indirect interactions between system components had hitherto not been anticipated or understood. This series of modelling exercises have ongoing benefits to management and sampling design across a variety of areas. As the benefits of the loop analysis approach to investigate system stability became obvious in Project 4.1, they were extended to deal with the issue of recreational fisher behaviour in Project 4.5, and that of attempting to understand the key drivers responsible for the poor condition of the Peel Harvey estuary, being dealt with in Project 4.3. Problems with the structure of estuarine governance were highlighted using qualitative models and potential management strategies were identified to overcome different estuarine issues. The quantitative modelling workshop identified the need for collective decisions from a group of 'experts' as well as having one department/agency responsible for the management of nutrients and the need for the economic benefits of a healthy environment to be considered in government decisions. The results from the qualitative ecosystem models may provide a stimulus for a change in governance to ensure assessment and management are appropriate for the range of impacts occurring and community benefits that may be obtained through healthy ecosystems.

Application of international standard modelling techniques to 30 years of fisheries data indicated that there had been no ecosystem level changes to fish communities, nor any impacts on the foodweb structure of marine ecosystems in Western Australia. This WAMSI-funded work value-added to an existing project funded by the Commonwealth government's Fisheries Research and Development Board (FRDC).

The examination of methods to monitor biodiversity of demersal fish communities and benthic assemblages of flora and some static fauna (i.e. corals, sponges) in marine systems now provides a standard sampling system and analytical methods on which future monitoring for major fishing or climate change impacts might be based. For example, a monitoring program for demersal fish communities was developed, using Baited Remote Underwater stereo-Video (stereo BRUV) surveys at three sites in the West Coast Bioregion (Cape Naturaliste, Rottnest Island, Abrolhos Islands), to help develop a baseline understanding of potential indicator regions. The research concluded that this choice of locations is appropriate; critically, hitherto unavailable baseline data for marine ecosystems will place government in a strong position to determine what further levels of monitoring of potential changes to our marine ecosystems is required. This work has highlighted temperature-related distributions of key fish species, and shown that whole assemblages of demersal finfish can be cost-effectively monitored over time. The same data collection methods were applied in the Node 3 program (based at Ningaloo) so adds an additional region north of the Abrolhos Island as a monitoring location.

In contrast to the marine fish communities, those for the estuaries of the West Coast Bioregion remain at a significantly higher level of risk. The current Peel Harvey fish fauna composition was deemed to be unacceptable, reflecting poor water quality (i.e. excess nutrients). This result suggests that the health of the estuary is intermediate between the very poor hyper-eutrophic condition of the 1980s and the more marine-influenced condition that was attained after the Dawesville Channel was constructed, i.e. the fish community of the Peel-Harvey estuary remains highly impacted by negative impacts on water quality. Very little change was observed in the fish composition of the Leschenault estuary. Indices of estuarine health based on fish communities were developed. Summer and autumn are the best season for future monitoring of the ecological health of the Swan Estuary, using the system of indices developed. 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 using fish assemblages was fairly robust.

The collation of environmental data allowed a detailed examination of potential affects on recruitment of rock lobster. 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, i.e. 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 separate modelling exercise that examined the potential extent of range-shifts of various exploited marine species under currently available climate-change projection scenarios found that a general shift (or contraction) southwards in response to warmer water temperature could be expected in 50 – 60 years.

A key finding of this project was that there was no effect of lobster density on the overall community structure in the habitats that support lobster populations in shallow water. This is an important outcome for the assessment of the ecosystem effects of the rock lobster fishery. For the deeper water habitats, maps and data from the monitoring of lobster densities in a recently-closed reference area of the fishery were generated; these will provide baseline data for the assessment of change in the future. A series of qualitative models were used to represent the food web in this deepwater ecosystem and identified small demersal fish and small crustaceans as indicators of change due to rock lobster extraction and bait input respectively.

Project 4.4 provided a method of assessing risk for bycatch across multiple fisheries. This method allowed the assessment of risk by species and was able to highlight data gaps. The collection of bycatch data was highlighted as an issue because it is not undertaken consistently by all WA fisheries. However, the EBFM process showed that for many bycatch species there is in fact no sustainability concerns.

The foodweb for the demersal ecosystem of the West Coast Bioregion was subject to qualitative modelling, which showed that the trophic relationships of this demersal system were highly complex. For most of the components of the foodweb for the west coast demersal ecosystem there is no information on population sizes of the individual species or stocks. The key outcome was that there is little that can be determined from dietary studies of fish, in terms of ecosystem impacts, if nothing is known about the sizes of their populations or the populations of their prey.

Project 4.5 uncovered a number of important findings, including that charter boats with substantial fishing activity in the West Coast Bioregion can incur substantial declines in revenue when restrictions were placed on the west coast demersal scalefish resource. This decline in revenue forced some operators to leave the fishery, some to switch their main target species or undertake more ecotours and party cruises, while others increased their activity in the surrounding bioregions. Impacts to commercial fishers were the exclusion of some vessels from the fishery due to a move from 'open access' to a limited entry fishery. The commercial vessels that remained operating achieved higher catch rates, increased prices and greater security of income.

The study investigating behavioural response of recreational fishers found that for boat-based fishing the overall number of trips per fisher per year has remained the same since a similar study in 2003, despite the introduction of a two-month seasonal closure. In addition, the overall satisfaction per fishing trip was higher than in 2003 despite the new regulations for recreational boat fishers, even though mean catch per trip was significantly lower.

5. Implications for Management (address the "So What")

a) What "management objectives" were being addressed by the research in this Node?
b) Who are the key management agency "beneficiaries" of the work in this Node?
c) What "management strategies" were being addressed by the research in this Node?
d) What "strategies and actions" are likely to be changed as a result of the research in this Node?
e) Has the research in this Node improved "management effectiveness"?
f) Are the research findings "easily accessible" and in a format that allows for ease of interpretation and "take-up" by management agency staff? How has this "knowledge transfer" been facilitated to ensure the maximum value has been gained from the research?
g) Has the research in this Node improved the overall management of the marine/ coastal environment in WA? How and give examples.
h) What are the longer-term likely impacts of the research for the State?

The application of the EBFM framework to identify and assign risk to all elements of ecological, social and economic relevance for the West Coast Bioregion, and then consolidating these up to a level that is of practical management use, has not only assisted the Department of Fisheries in improving its planning processes for natural resource management, but has in fact constituted a revitalised approach to identifying risks within the portfolio of the Department. Because the EBFM framework was applied in a manner that formally captured all relevant elements of concern (or perceived concern) for the West Coast Bioregion, this allows more efficient use of government resources when addressing natural resource management issues. For example, expenditure on research or policy projects directed towards low-risk elements could (and will) be redirected towards higher risk elements.

To avoid merely generating impossibly complex sets of regional issues, uncertainties and expectations, a hierarchical, risk-based framework was developed. In applying the EBFM framework to the West Coast Bioregion, stakeholder workshops identified over 600 ecological assets, social and economic issues, governance issues and external drivers. This complexity was reduced by consolidating these into 60 regional-level risks, with a multi-criteria analysis used to integrate related ecological, social and economic values and risks into 24 'Agency level' priorities ranging from urgent to very low priorities. This framework has been applied to all six bioregions in WA, with these priorities now used as the basis for the annual budget setting process. Furthermore, WA is revising it's legislation and governance arrangements to facilitate creation of regional level strategies to coordinate the management of all individual fisheries/activities and simplify the Department's engagement in future multi-sector (EBM), regional planning processes.

Other government departments and agencies could benefit from the use of qualitative models to investigate relevant social, ecological, economic and governance systems. The technique is highly intuitive and relatively quick to use in comparison to other data-intensive models so is cost-efficient and easily incorporates stakeholder input. Being able to produce models in real-time during workshops is beneficial to ensure agreement on model structure and to identify new links and variables of importance while in discussion with stakeholders. The assessment of alternative management strategies can be used to focus further investigation on potential strategies for improvement, thereby aiding the prioritisation of future resources. Such prioritisation can be difficult without a method of simplifying issues to their core drivers.

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 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.

The collation of environmental data sets, which were in many cases disjointed and almost impossible to find and access efficiently, now means that fisheries recruitment problems that might be related to environmental variability can be more effectively addressed. The prime example of the benefits of this data set, representing a critical outcome from WAMSI, was its application to the rock lobster recruitment problem. Although the development of this dataset constituted a relatively small investment by WAMSI, the funds nonetheless permitted employment of an expert oceanographer to focus on this one task. As the rock lobster recruitment problem arose over the past few years the outputs from this project had a real-time impact on the ability of the Department of Fisheries to respond. The dataset was used for collaborative exploration of the factors that might be influencing rock lobster recruitment, and provided key background information for a national workshop on this important management problem.

An important finding was that the risk levels identified for estuaries and estuarine species during the risk assessment workshops (Project 4.1) were appropriate. The estuaries of the West Coast Bioregion continue to require careful management or increased management in the case of those deemed to be a severe risk. The results of the detailed qualitative modelling suggest it is unlikely that the management of water quality will substantially improve with the current governance structure. A need for changes to governance of the catchment and estuary was identified. In addition, the need for collective government decisions regarding environmental quality and the reduction of impacts on the total catchment resource use were predicted to increase real estate values and the economic value of the environment.

The study of stock structure and likely dispersal of eggs and larvae for the west coast demersal scalefish resource showed that the spatial management arrangements were appropriate. This was a significant fisheries management concern in 2006 that has now been resolved.

A critical component of the EBFM framework is the recognition of the relevance of social and economic outcomes, and that they need to be a major part of the input to management decisions, and to the extent to which these decisions generate successful outcomes. Having the capacity to include social and economic data and analyses into fisheries management is a valuable outcome of Project 4.5. In general, social and economic analyses were not a standard inclusion in assessments for fisheries management.

However, the identification of the most appropriate methods of analysis along with the growing recognition of the need to include this type of information in assessments for management will further progress the implementation of EBFM in WA. This project has provided baseline data for the charter and commercial sectors with which to build on-going monitoring through regular socio-economic data collection and periodic surveys. Information regarding the impact of management changes on the fishing community is particularly valuable for future management plans, particularly, that the overall satisfaction of recreational fishers was higher despite increased regulations in the WCDSF.

6. Capacity Building

Detail the additional "capacity building" this Node has provided to WA. Considerations include Masters and PhD students, postdocs, technical support staff, research staff, equipment, facilities, building expertise and associated "knock-on" opportunities and income streams.

Talented PHD graduates have filled a number of postdoctoral positions, bringing skills to Western Australia on topics such as qualitative modelling, benthic ecology and fish community ecology. In most cases these young scientists have come from interstate and overseas, so have brought fresh perspectives on ecosystem research that have now become part of our knowledge- and skills-base for marine research in Western Australia. These highly productive postdoctoral scientist have helped shape the outcomes for Node 4 directly, and have also had broader impacts by contributing to a range of positive outcomes for marine and estuarine research that were not directly part of the Node 4 program.

7. Data Management

Summarise the "Data and Information products" that have been generated by this Node.

Node 4 encompassed a wide range of activities including risk assessment of fisheries and ecosystems, governance of estuarine management, behaviors of recreational fishers, developing databases of environmental variables, stock structure of exploited species, and trophic relationships of fish and rock lobsters. Considerable quantities of data were collected for assemblages of fish and composition of benthic communities. The information from all aspects of Node 4 has been published as research reports or scientific papers. See project reports for details.

8. Modelling

Describe [where applicable] the modeling tools that have been created by this Node. What are their strengths and limitations?

This Node made excellent use of established modelling techniques (qualitative modelling, bioregional assessments of trophic impacts). Various innovative multi-variate statistical models were employed to develop potential indicators for marine benthic communities and both estuarine and marine fish communities. Details can be found in the project reports and publications.

9. Societal Benefits

Summarise the societal benefits of the research in the Node [suggest you summarise section 7 [*Benefits*] from the individual Project Reports]. Give a snapshot of where we were at the beginning of 2006 and where we are in mid 2011?

In 2006 the governance systems for fisheries and ecosystem management in Western Australia recognized the need to further implement effective ecological sustainable development, including evolving towards a system that explicitly considered ecosystem management (e.g. dealing with cumulative impacts at the bioregional level), not just a focus on targeted, exploited species. WAMSI provided the means to undertake a highly focussed study to trial the implementation of the EBFM framework, which in turn focussed the whole department of Fisheries to make rapid progress over what was a relatively short period of time to enact a major shift in governance. Node 4 also highlighted the means to identify system assets, then, importantly, linked these assets to social and economic outcomes. Linking the assets and outcomes in this way is critical for EBFM and without linkages the integration of ecological, social and economic aspects of the system cannot be undertaken. Furthermore, this study allowed the recognition of

the role of cumulative impacts of multiple fisheries and external impacts in ecosystem management while explicitly showing the difference in priorities between EBFM and EBM. These benefits have all been undertaken using an internationally endorsed, comprehensive framework based on risk management principles. These high-level results have changed the department of Fisheries governance structure, thereby allowing a better use of available resources, which are provided by public funding.

The process of explicitly articulating how priorities are effectively determined was itself a very useful exercise as this step had previously used an implicit process, which is likely to have been applied inconsistently. A valuable outcome was the explicit recognition that we had been implicitly discounting the those risks that were largely generated by activities under other legislative management systems. Hence, this was not only useful for setting our internal priorities for direct management actions but also for discussions with other agencies, plus government more broadly, about whether the current jurisdictional and management responsibilities are appropriate. This is a major governance and efficiency benefit.

The application and consolidation of the EBFM framework to identify and assign risk to all elements of ecological, social and economic relevance for the West Coast Bioregion has not only assisted in improving the planning processes for natural resource management, but has revitalised the entire approach to identifying and managing the risks across the entire portfolio of the Department. It has further reinforced the formal adoption of risk management principles as the appropriate basis for natural resource management agencies.

Following the successful completion of the EBFM process for the West Coast Bioregion (which effectively took 2 years to complete), the same principles have subsequently been applied to the other bioregions in Western Australia. Now that a clear format has been generated and there are detailed examples from the West Coast to use as a guide, the time taken to undertake these assessments has been substantially shorter (a few months). Updating the risks is now planned to occur on an annual basis as a formal part of the Department's planning cycle.

The potential benefits and impacts of the EBFM approach now adopted by the Department of Fisheries applies not only to other Western Australian government agencies but also to natural resource management jurisdictions in other states as the relevant Commonwealth government departments.

Research in this node has provided a large amount of information that will be valuable for future studies into food webs and ecosystem interactions within the reef and estuarine ecosystems of the West Coast Bioregion. For instance, a valuable outcome was the finding that western rock lobster are not a dominant ecosystem driver in shallow water. This has implications for the management of the rock lobster fishery in that trophic interactions, following the removal of rock lobster from shallow water, are not at a high risk of change. An experiment to better understand deepwater rock lobster interactions was also established through this project, as well as improved mechanisms for determining trophic interactions and food webs. The finding that the trophic status of ecosystems for the bioregions is not being deleteriously affected in a cumulative manner by fishing provides government with confidence that exploitation of these marine resources has been well managed. This underpins the ongoing ability of fisheries to operate without undue concern about poor fishing practises. At the level of individual stocks, or particular fish resources (e.g. demersal scalefish resource), given that nothing is known about the sizes of the populations of prey of key exploited species any concerns about direct trophic impacts for fish communities should focus investment on assessing the status of their prey populations.

Problems with the structure of estuarine governance were highlighted using qualitative models and potential management strategies were identified to overcome different estuarine issues. The results from the qualitative and quantitative ecosystem models, may provide a stimulus for a change in governance to ensure assessment and management are appropriate for the range of impacts occurring so that community benefits may realize the full benefits that can be obtained through healthy ecosystems.

Improved knowledge of the spatial relationships of the socially and economically important west coast demersal scalefish resource provides security of this resource for all Western Australians into the future. The work undertaken has confirmed that the spatial configuration of the management package is appropriate.

The results from the study on behaviour of recreational boat fishers, which showed an overall high degree of acceptance of new management restrictions in the west coast bioregion, highlight the societal benefits

of enacting sustainability measures despite initial reluctance on the part of stakeholders. The benefits are largely for future generations, an outcome that the majority of current fishers apparently agreed. This study showed that the fishing community can deal with a level of lowered personal benefits (individual catch rates) in the overall interests of maintaining future sustainability.

10. Future Research

Further work recommended. Outline what the next stage of the Node research should look like [if it was to continue] and where are the priority regions? Outline your hopes for the future as it relates to the ongoing uptake and maintenance of this work

There is a continuing risk to establishment of healthy fish communities in the Peel-Harvey and Swan-Canning 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 in the Peel-Harvey emphasises that there has most likely been an increase in the amount of macroalgae since the mid-1990s.

Hydrodynamic models and associated dispersal models (for eggs and larvae) for inshore (shelf) waters need more work to account for variability in cross-shelf water movements. Some further research in this area is expected to occur as part of another project focussing on the early life history and spatio-temporal distribution of dhufish eggs and larvae; this is a collaborative study lead by CSIRO and involving fisheries biologists from the Department of Fisheries.

Sign off the Node report in your capacity as Node Leader.

Annexures

Annexure 1: A listing of the Projects and Project Leaders and their Project staff, including students

Annexure 2: The approved *Science Plan* for the Node [2006 or 2007]

Annexure 3: The methods section of the approved *Project Plans*

Annexure 4: The final *Project Reports* for the Node

Annexure 5: Any other relevant information